THE REPAIR MINDSET

HOW TO FIX OFF-GRID SOLAR POWER IN KENYA

DECLAN MURRAY

THE REPAIR MINDSET

How to Fix Off-Grid Solar Power in Kenya

Declan Murray

BRISTOL
UNIVERSITY
PRESS

First published in Great Britain in 2026 by

Bristol University Press
University of Bristol
1–9 Old Park Hill
Bristol
BS2 8BB
UK
t: +44 (0)117 374 6645
e: bup-info@bristol.ac.uk

Details of international sales and distribution partners are available at bristoluniversitypress.co.uk

DOI: 10.51952/9781529250893

British Library Cataloguing in Publication Data
A catalogue record for this book is available from the British Library

ISBN 978-1-5292-5087-9 paperback
ISBN 978-1-5292-5088-6 ePub
ISBN 978-1-5292-5089-3 OA PDF

Cover design: Liam Roberts Design
Front cover image: iStock/filo
Bristol University Press uses environmentally responsible print partners.
Printed and bound in Great Britain by CPI Group (UK) Ltd, Croydon, CR0 4YY

Bristol University Press' authorized representative in the European Union is:
Easy Access System Europe, Mustamäe tee 50, 10621 Tallinn, Estonia,
Email: gpsr.requests@easproject.com

To the *mafundi* of Kenya

Contents

List of Figures

List of Abbreviations

ABM	Associated Battery Manufacturers
AECF	Africa Enterprise Challenge Fund
Ah	amp-hour
AI	artificial intelligence
am	*ante meridiem*, before noon
AMREF	African Medical and Research Foundation
BBC	British Broadcasting Corporation
BoP	bottom (or base) of the pyramid
ca.	*circa*, about, approximately
CBD	Central Business District
CD	compact disc
CEO	chief executive officer
CNN	Cable News Network
CRT	cathode ray tube
CSR	corporate social responsibility
DFID	Department for International Development
DIY	do-it-yourself
DVD	digital versatile disc
EAA	Energy Alternatives Africa
EABC	East African Business Council
EAC	East African Community
EnDev	Energizing Development
EoL	end-of-life
EPI	Extended Programme on Immunization
ERC	Energy Regulatory Commission
ESMAP	Energy Sector Management Assistance Program
et al	*et alia*, and others
EU	European Union
FMCG	fast-moving consumer good
FOIA	Freedom of Information Act
GHG	greenhouse gas
GIZ	*Gesellschaft für Internationale Zusammenarbeit*
GOGLA	Global Off-Grid Lighting Association

GTZ	*Gesellschaft für Technische Zusammenarbeit*
IC	integrated circuit
IEA	International Energy Agency
IEC	International Electrotechnical Commission
IFC	International Finance Corporation
IOM	International Organization for Migration
IoT	Internet of Things
IRENA	International Renewable Energy Agency
IRIS	Impact Reporting and Investment Standards
ISM	Import Standardization Mark
ITDG	Intermediate Technology Development Group
KCYP	Kibera Community Youth Project
KEBS	Kenya Bureau of Standards
KEPSA	Kenya Private Sector Alliance
KEREA	Kenya Renewable Energy Association
KIRDI	Kenya Industrial Research and Development Institute
KTDA	Kenya Tea Development Agency
kWh	kilowatt hour
KWS	Kenya Wildlife Service
LCD	liquid crystal display
LED	light-emitting diode
MENA	Middle East and North Africa
MFI	microfinance institution
MP	Member of Parliament
NASA	National Aeronautics and Space Administration
NGO	non-governmental organization
OECD	Organization for Economic Co-operation and Development
PAYG	pay-as-you-go
PCB	printed circuit board
pm	*post meridiem*, after noon
PSP	pico-solar product
PV	photovoltaic
PVMTI	Photovoltaic Market Transformation Initiative
SACCOs	savings and credit co-operatives
SDGs	Sustainable Development Goals
SHS	solar home system
sic	so, thus, in this manner
SMS	short message service
SNV	*Stichting Nederlandse Vrijwilligers*
SVTC	Silicon Valley Toxics Coalition
TV	television
UN	United Nations

UNDP	United Nations Development Programme
UNHCR	United Nations High Commissioner for Refugees
US	United States of America
USAID	United States Agency for International Development
USB	universal serial bus
VAT	value-added tax
W	watt(s)
WEEE	waste electrical and electronic equipment
WHO	World Health Organization

Glossary

baiskeli	bicycle
chai	tea
chuma	metal
(ma)fundi	skilled technician(s) or artisan(s)
(ma)gari	vehicle(s)
-haribika	to be destroyed/ruined
jua	sun
jua kali	hot sun/informal sector
-kataa	to refuse
kidogo	small
Kikamba	Kamba language
kikapu	a basket made of pandanus leaves
kufundisha	to teach
kufunza	to learn
kukata	to cut (can also mean to come loose or disconnect)
kuwa	to be
maandazi	a deep-fried bread, similar to a doughnut
(ma)kumbusho	memory(ies)
matumbo	beef tripe
mbao	wood
mzungu	white person/foreigner
nguo	clothes
omena	Silver Cyprinid fish
pesa	money
piki piki	motorbike
redio	radio
shamba	field or farm
stima	electricity
taa	light, lamp, lantern
-tengeneza	to create, make, fix or repair
-tosha	enough, sufficient

ufundi	skill
-vunjika	to be broken
wa	of, from
-zaliwa	to be born

About the Author

Declan Murray is Research Associate in the Department of Social Anthropology at the University of Manchester. He has previously worked as a consultant in the off-grid solar industry.

Acknowledgements

This book has been a long time in the making. It would not have been made without the support of lots of people. I would like to acknowledge them here.

Back in 2014, Chris Baker-Brian, co-founder of BBOXX, took a punt on me which led me to Kenya for the first time. Those months on the shores of Lake Victoria shaped much shaped much of the next decade of my life.

My PhD supervisors at the University of Edinburgh, Jamie Cross and Jamie Furniss, also took a punt on me. Jamie Cross was the one that secured the funding for the research and when I only discovered the advert for the position *after* the deadline, he graciously offered me a 24-hour extension to pull together an application. If he had not, then my life would look very different today.

During the PhD journey that followed, and shaped the bulk of this book, I was lucky enough to make some of the best friends: Henry, Ismay, Maurice, Mike and Tom. I see them less these days, but they continue to inspire me. I am grateful to the Economic and Social Research Council (ESRC) and Solar Aid for having funded the research; to the African Centre for Technology Studies (ACTS) in Nairobi for sponsoring my research visa and to everyone who participated in the fieldwork in whatever form that took. I must, however, single out Wilson and Hesbon for letting me pull up a stool in their repair clinic: *erokamano.* I am also indebted to my examiners: Blanca Callén, Julia Corwin and Tom Molony for their supportive reading of my thesis.

Although my Swahili-learning journey is ongoing, it will always be shaped by my early teachers: Steve Kaye at Edinburgh and Abdulmajid Igombo at the former Research Institute for Swahili Studies in Eastern Africa (RISSEA) in Mombasa – *asanteni*.

More recently I am grateful to Kate Hampshire and the Department of Anthropology at Durham University for inviting me back to academia so warmly in 2022. Catherine Alexander and Felix Ringel were the ones who pushed me to pursue the book project and told me that I was capable of it.

I am grateful to Emily Watt, Anna Richardson and Angela Gage at Bristol University Press who have been incredibly helpful and endlessly patient through the editing and publication process. I am grateful, too, to the

anonymous reviewers who offered encouraging and challenging comments on the proposal for this book and on the manuscript.

It would be remiss of me, as a repair and maintenance scholar, not to acknowledge the too often invisible work of university administration and facilities staff who actually keep those institutions running. They should be recognized more.

And a final thanks to my parents, who I owe everything. They have always been behind me and gave me the greatest gift: a belief that I could try anything, go anywhere, be anyone.

Introduction: A Broken World

Bii came to the Malo Malo Repair Clinic looking for a solar television (TV) he had brought in previously. It was not ready. Come back tomorrow, he was told. And so tomorrow, he came back. Give me two more weeks, he was told. Once again, Bii obliged. Now, having successfully bought himself some time, Wilson, the main repairman at Malo Malo immediately got to work looking underneath the front counter of the clinic where flat screen TVs were layered like a black and silver sedimentary rock of the future. Once he located Bii's 22 inch TV, Wilson looked out a different, Samsung, screen from the same stash under the counter. Next Wilson put the Samsung screen into the casing of Bii's BBOXX solar TV. But when he turned it on the screen was still showing white. Wilson said it would need a new motherboard. And so, holding a hot air gun in his left hand and tweezers in his right Wilson soldered an old motherboard (taken from the same pile of parts) onto the back of Bii's TV. By the time Bii's TV was fixed, its stand had got lost in the clinic somewhere, and it had also acquired a new power cable. The only original remaining part then was the black, BBOXX-branded, plastic casing. But, Bii said, as he stood outside slapping the dust off the original cardboard box for his TV, 'so long as it works, it works'.

This is the Repair Mindset. Bii, and Wilson, prioritize functionality over form. Wilson uses materials at hand that he has saved over from previous repair jobs, and he draws on his years of experience of repairing electronic and electrical devices to identify and fix the problem with Bii's TV through a process of trial and error. In this book I suggest that we can think of concerted efforts to improve the human condition, sometimes referred to as 'Development', as attempts to fix the world, as repair. I suggest that there are lessons in the micro-level repairs performed by people like Wilson, that can help us better deliver on the macro-level repairs sought by International Development. I argue in favour of the Repair Mindset.

The solar assemblage

Electrification has long been at the heart of the world-improving project of International Development. Improving standards of living, health, education

and economic output as International Development is wont to do (1: Peet and Hartwick, 1999; 3: Sen, 1999) can all be aided by the presence of electricity (Kanagawa and Nakata, 2008). The electrification project has proven particularly challenging in rural areas however, where settlements can be more dispersed, energy demand lower and income levels generally lower as well (Chaurey et al, 2004). This in addition to political challenges of governance, corruption and local socio-political dynamics which also obstruct electricity provision (Pless and Fell, 2017). In the face of slow grid expansion and unreliable electricity grids, *off*-grid solutions to electrification have emerged. Improvements in battery chemistries and ever-falling prices of solar panels have made solar photovoltaic technology a popular and economically viable option for un-electrified rural areas (Singh, 1991).[1] This is particularly true for sub-Saharan Africa where solar irradiance (light energy from the sun) is over 2,000 kilowatt hours per metre squared (kWh/m^2) per year and most of the population is rural (World Bank, 2024a; World Bank, 2024b).[2] The material shift in form from grid to off-grid solutions has been mirrored with a shift in language from 'electrification' to 'energy access'. In 2015 the United Nations Development Programme (UNDP) launched a new agenda for International Development – a set of 17 targets called the Sustainable Development Goals (SDGs). SDG 7 aims to: 'Ensure access to affordable, reliable, sustainable and modern energy for all' (21: United Nations, 2015a). Where 'electricity' implied a mains electricity grid, 'energy' includes alternative sources and forms of electricity, such as off-grid systems and extends to other fuel sources used for domestic cooking. In addition to community-level mini- or micro-grids powered by solar panels, these off-grid solar options include products targeting individual households.

Off-grid solar solutions at the household-level are referred to according to their size as: solar lanterns, pico-solar products (PSPs) and solar home systems (SHSs) (238: Hansen et al, 2015; xvi: Dalberg Advisors and Lighting Global, 2018). Materially, the differences across these categories are minimal. The panels (which are at times integrated in to the same unit as the light and battery) are made from crystalline silicon and can be anything up to 350 watts (W) in size. The casings are generally of smooth, bright-coloured plastic with rounded edges. The most variation is in the battery. Lithium ion, lithium fero-phosphate and lead acid are the most common types, with capacities of up to 10 amp-hours (Ah). Operationally, the objects are the same, too: light lands on the solar panel where it is converted into electrical energy, which is stored in the battery and later released to activate one or more light-emitting diode (LED) or to charge another battery in a phone or radio, or, in Bii's case, to run a TV. The three types of object – lantern, PSP and SHS – are manufactured, distributed and sold alongside each other by the same companies and organizations. Reflecting these broad similarities, this book uses the single term 'off-grid solar product' to refer to the range

of models under discussion.[3] Users in Kenya, where this book is set, more commonly refer to off-grid solar products as *taa*s (lamp/lantern) or d.lights – one of the most established and best-selling brands. This is because for many Kenyans the off-grid solar product is not solar at all. For them 'solar' refers to a solar panel (which has been available in the country for much longer) that is attached to a lead acid battery as part of what are sometimes called component-based systems (xvi: Dalberg Advisors and Lighting Global, 2018). The term off-grid solar product is still chosen here to avoid confusion with other uses of the word taa, such as torch, and to be able to discuss d.light as one brand among many (like BBOXX – the makers of Bii's TV). Off-grid solar is also the term used by the industry to describe the sector.

In 2010 while director of the British Museum, art historian Neil MacGregor chose an off-grid solar product as the '100th object' in an exhibition called: *A History of the World in 100 Objects* (MacGregor, 2011). MacGregor described it thus:

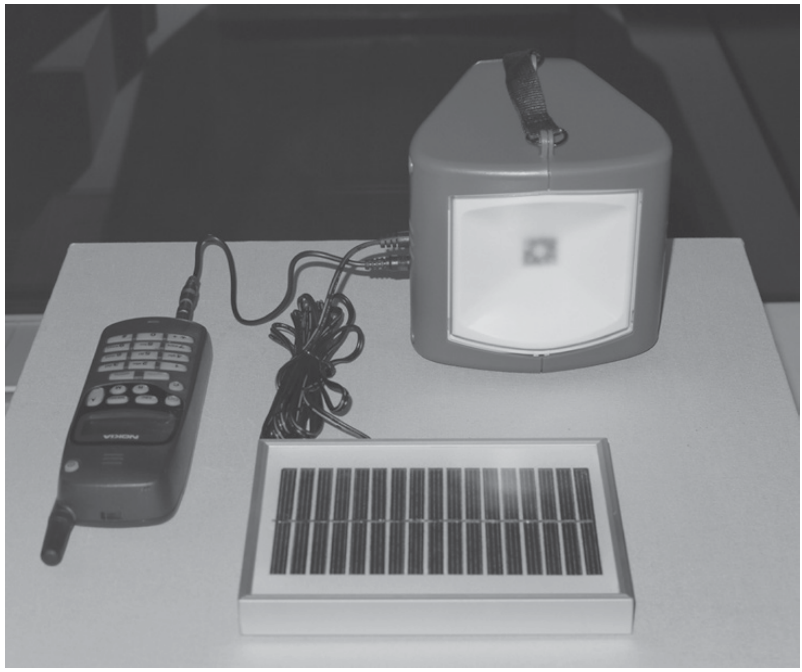
> [The product] is in fact a little kit, consisting of a plastic light containing a rechargeable six-volt battery and a separate, small photovoltaic panel. The lamp has a handle and is about the size of a large mug, and the solar panel looks like a smallish silver photo frame – the sort you see on a desk or a bedside table. (p 432)

MacGregor's description of the d.light Nova S200 (Figure 0.1) draws attention to the multiple parts the object is made of.

Although stripped of its brand and market context for the purposes of the exhibition (Cross, 2013) the Nova S200 is actually one of hundreds of different models of solar products that are being marketed, sold and distributed to the 750 million people worldwide who live without ready access to electricity (56: IEA, 2024). In addition to providing light the Nova S200 can charge a mobile phone. Similar but smaller models only offer lighting (solar lanterns) while other, larger kits (solar home systems) can charge accessories like radios and TVs in addition to the mobile phone (Figure 0.2).

The marketing, sale and distribution of off-grid solar products has been led by non-governmental organizations (NGOs) and private companies, often from outside the region. This industry has caught the attention of media outlets and financial investors outside of the region as well. After a radio series to accompany MacGregor's exhibition (xiii: MacGregor, 2011) the British Broadcasting Corporation (BBC) has since run several stories and reports on the off-grid solar industry that the 100th object, the Nova S200, came from (Heap, 2013; Jackson, T. 2015; Nuwer, 2017; BBC, 2018). Along with other prominent media outlets such as Cable News Network (CNN; Prisco, 2016), *The Economist* (The Economist, 2016) and the *New York Times* (Okonjo-Iweala, 2015), the BBC coverage tells

Figure 0.1: The 100th object, the Nova S200



Source: Photo of a solar powered lamp by user:geni, November 2010. https://commons.wikimedia.org/wiki/File:AhotwSolar-powered_lamp_and_charger.JPG. Available under Creative Commons License GFDL CC-BY-SA.

Figure 0.2: A typical solar home system

Source: Bboxx, 2025

an optimistic story of the potential of the global off-grid solar industry to bring 'power to the people' (BBC, 2018). The academic, grey and industry literature is similarly positive in assessments of the impacts these products can have on health (Obeng et al, 2008), education (Kanagawa and Nagata, 2008), gender (Cabraal et al, 2005) and economic (SolarAid, 2015a) indicators. The narratives in these press, industry and academic publications help raise awareness of the industry and bring in financial support and investment from individuals and institutions alike. In the two years to 2018, off-grid solar companies raised $500 million (1: Dalberg Advisors and Lighting Global, 2018). But this surrounding investment of excitement and finance is not captured in a material description of the object, like that given by MacGregor. Instead, as anthropologist Jamie Cross, reminds us:

> Since the 1980s, social studies of science and technology have urged us to see an object like this as more than an assemblage of microelectronic components, and to engage with the complex array of knowledge practices, social relationships and meanings that enable the Nova S200 to convert sunlight into electrical energy and achieve its range of purported effects. (369: Cross, 2013)

In other words, we are invited to bring the culture surrounding these products together with the parts and materials into a socio-material solar assemblage. Cross sets out the socio-material relationships that the off-grid solar product is entangled with in a blog post titled 'The Solar Assemblage' (Cross, 2012). This book builds on the concept by extending our understanding from the assemblage's formation, which Cross describes, to its breakdown.

The idea of the assemblage was first articulated by French philosophers Gilles Deleuze and Félix Guatarri in *A Thousand Plateaus: Capitalism and Schizophrenia*. Frustratingly for some (DeLanda, 2016), Deleuze and Guatarri were not explicit or necessarily consistent in how they defined an *agencement* (as it is known in French). So I follow the definition of assemblage laid out by another philosopher, Thomas Nail. In the article 'What Is an Assemblage?' Nail formalizes three components in the structure of an assemblage: relations, concrete elements and agents (24: Nail, 2017). The agents, according to Nail, are the collective third-person subjects (we, one, everyone) that arrange and give meaning to the relations and concrete elements. For the solar assemblage the agents are the roles such as users, designers, manufacturers, financiers, retailers, lobbyists, regulators, fundraisers, journalists, researchers and so on. The concrete elements are the embodiment of the assemblage. In this case the concrete elements are the off-grid solar products, the people (rather than their roles), the

companies and the market institutions. The relations, or 'abstract machine' to use Deleuze and Guatarri's term, connect the concrete elements with the agents by giving them a proper noun. In this book, the abstract machine is the off-grid solar industry. The assemblage is useful not just for its focus on relationality but for its shifting, emerging nature. An assemblage is 'an entity produced by the recursive application of the part-to-whole relation' (70: DeLanda, 2016). It is defined only by its relations and not by any essence to its subsisting parts (22: Nail, 2017). Its features are contingent, not eternal. That is to say that the off-grid solar industry is constantly changing and it is co-constituted by the interactions of the different aspects of the assemblage. Without the concrete elements (products, companies, people) then there are no agents (users, manufacturers, investors) and without the agents there are no relations and so on and so forth. The solar assemblage is actually a series of nested, overlapping assemblages. It is not a discrete system but is connected to assemblages of Development, consumer electronics, materials and more.

In the next section I explain why the assemblage is useful for studying the off-grid solar industry, particularly in moments of breakdown. I then introduce the 'follow the thing' methodology through which the research was conducted. I close the introduction with a chapter-by-chapter overview of the rest of the book that follows the off-grid solar product through the solar assemblage from homes to independent repair clinics and on to company offices, workshops and warehouses.

Broken products and broken provision

The off-grid solar product is an example of a 'development device' (Collier et al, 2017). In the form of goods such as toilet bags (Redfield, 2012), water filters (Redfield, 2016) and rapid diagnostic tests for malaria (Street, 2017), development devices are presented as modern, dynamic and innovative solutions to problems of sanitation, water and health that more centralized or capital-intensive interventions have failed to resolve. The size of development devices facilitates an understanding of them as discrete entities. They are described and marketed as 'standalone', 'decentralized', even 'democratized' *solutions*. It is a language that implies an essence or independence of the object. Being small and portable has also made development devices amenable to market-based approaches for their delivery, allowing them to be distributed and sold like other consumer goods. Rather than seeing development devices as parts of assemblages their advocates grant them a stability and power to exist and perform as objects in isolation. While this may be true in a material sense: the off-grid solar product does not require the underground or over ground cables that characterize a grid system, the products' journey to their 'remote',

'isolated' areas of use relies upon various other connections. The off-grid solar product may be 'off-' in relation to the mains electricity grid, but it is very much 'on-' the market that makes, transports, promotes and sells the products. Remote, mobile-enabled payment systems that can be managed at a distance further the illusion of these goods as free from the bureaucratic ties that infrastructure has historically implied. Development devices are designed to work in low- or off-grid settings: typically areas without connections to mains electricity or water services and often at a distance from tarmacked roads. The off-grid solar industry uses this discourse of previous failure and absence to create the appearance of an empty zone into which it can insert itself without need to integrate with pre-existing local economies and networks. In doing so, actors within the industry are able to establish a particular understanding of what the problem is (slow grid expansion) and so what the solution must be (off-grid solar products). In spite of these discursive efforts by development actors, however, the empty zone does not exist. People living in rural regions of the Global South have access to forms of energy before the arrival of off-grid solar products. Diesel generators, kerosene lanterns or charcoal are widely available. The connectivity to global supply chains that the presence of these 'traditional' energy sources proves is generally also neglected by the development community; it is inconvenient to their narrative of need. Assemblage thinking helps keep visible the immaterial connections that are integral to the delivery of electricity. In both off- and on-grid forms, electricity, like any infrastructure, requires continual upkeep, maintenance and attendance to those relations to keep the electrons flowing. Electrification does not end the moment a house is connected to a grid or the solar panel is installed: that plethora of relationships has to keep working.

An advocate of development devices may think that if well-designed and well-made it will work anywhere. But once development devices reach the off-grid area of their intended use they encounter 'local, customized, intimate and flexible use' (3: Star and Ruhleder, 1996) which transforms them in ways the manufacturer or distributor never imagine. Sociologists studying IT infrastructures have found that as decentralized technologies are used more and more, across ever wider geographical distances, the need for alternative forms of control emerges, such as common standards and categories (3: Star and Ruhleder, 1996). In attempts to counter these local transformations, the off-grid solar industry has responded with product quality standards and social impact metrics that frame appropriate usage. While this standardization of products and market categories seeks to establish control and consistency, foster market growth and facilitate business, local realities often complicate the picture. The merging of global markets with local conditions of poverty is 'both complex and fragile' and 'thus always under construction, never

guaranteed' (106: Roy, 2012). It is at the intersection of a global market and local reality that this book sits.

One thing that is guaranteed in the life of a product-as-infrastructure is that it will break down. The inevitability of breakdown has been repeatedly emphasized by scholars of infrastructure (see Larkin, 2013) but has not been much explored in the nascent collection of work focused on development devices (Cross et al, 2017 is an exception). This breakdown, like the relations themselves, can also be less visible in off-grid settings where power cuts are not uniform across a neighbourhood or community as they would be in a grid system. Assemblage thinking is helpful in examining off-grid power cuts; moments and processes where relationships within the assemblage shift, strain and break down. Much like the broad range of actors and services understood to make and maintain electrification (Bennett, 2005) responsibility for disconnection is also distributed across and through the assemblage. In addition to taking the assemblage approach to look at blackouts, or breakdowns, off-the-grid, this book takes it a step further to explore how the solar assemblage *responds* to breakdown: is it fixed? How? And if not, what happens?

It has been argued of infrastructures in Nigeria that breakdown is so ubiquitous that repair emerges as 'as a cultural mode of existence for technology' (235: Larkin, 2008). It is a corollary that has garnered increasing amounts of attention in recent years as researchers recognize that breakdown is not an exceptional state but, for many technologies in many parts of the world, a regular occurrence that people contend with almost daily. Taking breakdown as a starting point, repair studies, a growing body of scholarship across anthropology, sociology and science and technology studies, claims that 'approaching infrastructure from the standpoint of repair highlights actors, sites, and moments that have been absented or silenced by stories of design and origination' (Jackson, 2015).

This book brings the approach of 'broken world thinking' advocated by prominent repair scholar Steve Jackson (2013) to bear on development devices. Broken world thinking involves starting not from the design nor the dissemination of technology but from breakdown. Product design and dissemination through the market are addressed in the book (in Chapter 2) but predominantly in relation to their ability to shape breakdown and the later responses to it.

The kinds of promises that are made by off-grid solar companies 'have been made over and over, with different technologies but the same groups in power' (192: Ames, 2019). Narratives of innovation and technological utopianism that often accompany 'new' products or initiatives often obscure corporate greed, unequal distribution and wasted resources (195: Ames, 2019). Rooted in a linear economy where products are made, then sold, then disposed, undermines the green claims made on solar power. This

material damage is compounded by the neo-colonial dynamics underlying International Development (see Escobar, 1995). The provision of off-grid solar products propagates many of the same dynamics around where expertise is located and who holds authority. Its language of spreading light to a dark continent is particularly problematic (Ntapanta, 2023). Moments of breakdown, or material disruption, not only force us to examine the broken object 'but also the social situation that its ordinary use configures' (4: Strebel, Bovet and Strebel, 2019). The breakdowns explored in this book then are both material (surrounding the solar product) and political (surrounding its provision). Working with assemblage thinking helps keep these two strands together.

There have been a small number of publications exploring the actual case at hand: the end-of-life, disposal and waste management of off-grid solar products (Pepinster, 2012; Batteiger, 2015; Turing, 2015; Verhoef, 2016; Cervantes-Barrón, 2016). This book then is not the first piece of academic research to look at this topic. What sets this book apart is not only its depth; it is the first book-length study of the topic, nor its geographical focus; it is the first to focus on Kenya alone, nor its attention to the actual breakdown of products; rather than just responses to breakdown. In addition to helping to solve the 'problem' of the waste that off-grid solar products can become, this book explores what our understanding and approach to the problem tells us about the thinking and philosophy involved in contemporary development practice. The case study of waste within the off-grid solar industry is attached to broader questions about how Development is practised and experienced when delivered through market-based approaches.

Next, I discuss the methods by which the research was conducted.

Following a broken thing

Understanding the infrastructural object of the off-grid solar product as an assemblage required a methodology that could somehow capture the various relationships, actors and locations that constitute the assemblage. I needed a methodology that could interrogate the past, the present, points of sale, sites of use and places post-consumption. In other words, the methodology needed to be both multi-method and multi-sited. The methodology I adopted is known as following the thing.

In 2004, cultural geographer Ian Cook wrote a paper called 'Follow the Thing: Papaya' (Cook, 2004). In it Cook offers a series of vignettes of different parts of the global papaya supply chain from farmers in Jamaica to consumers in the UK. His purpose was to make visible connections between distant and disparate groups in order to ask questions of the narrow stories of global commodities we are often presented. Although the papaya is a thing, Cook's research exposes its wider assemblage of

marketing, manufacture, labour and livelihood. Since 2004 others have followed Cook's approach of applying a multi-sited ethnography (Marcus, 1995) to make visible assemblages of other things such as t-shirts (Rivoli, 2014), hot pepper sauce (Cook and Harrison, 2007) and flip-flops (Knowles, 2014). However, these things have largely been followed from production in the Global South to consumption in the Global North, and discussion of what comes after consumption has been rare. Another geographer, Nicky Gregson, writes that:

> 'follow the thing' research needs to also attend to flows 'down' the value chain, from developed to less-developed worlds, and to things that are either coming apart or being disassembled. … Paying attention to the back-end of the value chain shows that things are but temporary configurations of material. At best partially stable, things are argued to be endlessly being assembled, always becoming something else somewhere else. (846: Gregson et al, 2010)

Alison Hulme (geographer and follower of things) also calls on researchers to follow 'what happens when things fall apart' (159: Hulme, 2017). Hulme advocates for particular attention to 'the gaps', 'collateral damage' and 'micro-catastrophes' at each part of the chain (159: Hulme, 2017). Such attention is precisely what is given in this book. Where though does this following happen?

The off-grid solar products that are the subject of this book are conceived and designed in Europe or North America (the North) before manufacture in China and Malaysia and on to be consumed in South Asia and sub-Saharan Africa (the South). The metals and minerals they contain come from Central and Southern Africa and South America while some of the parts and materials of products later move to Europe, India and China for recycling. However, due to considerations of time, finances, language and access, the following, and so the multiple sites, in the research for this book have been largely within one country: Kenya. Although some research by way of participant and non-participant observation was carried out in Dubai and Hong Kong during and after industry gatherings in those cities. Kenya has received the most attention from the off-grid solar industry thus far with most companies and organizations having regional offices in the country, and, with the highest sales figures, it is the biggest market for off-grid solar products in sub-Saharan Africa (17: Dalberg Advisors and Lighting Global, 2018). Off-grid solar products are known to be in over 50 per cent of Kenyan households which are off-grid or have unreliable grid connections (17: Dalberg Advisors and Lighting Global, 2018). The size and age of the market in Kenya meant there would be more likelihood in the research of coming across products that had broken down and users,

repairmen, retailers and other individuals who had witnessed, experienced or taken part in breakdown. There is also an established tradition within development studies, largely inherited from anthropology, to concentrate one's research in one location, for example Escobar (1995) in Colombia, Mosse (2005) in India and Ferguson (1994) in Lesotho. This book then is offered as ethnography of development in that vein. It offers empirical evidence of how development operates at the local level which then allows for discussion of development in an abstract sense. Most of my following took place between 2014 and 2018.

The first method I employed was a longitudinal telephone survey, conducted with three research assistants. This made it possible to collect data from a wider area (9 counties) and sample size (262 people with at least 730 products[4]) than would have been possible to cover in-person myself. The survey extended back in time to include products purchased as early as 2013. The survey was conducted in partnership with SolarAid – a UK-based charity – using their in-house research team. The respondents, were all customers of SunnyMoney – a social enterprise that is owned by SolarAid and operates in several African countries. The respondents, called first in May 2015 and again a year later, were asked about their experiences with any electronic and electrical appliances at home (including their solar products): had they ever had any difficulties with them? If so, what had they done and what would they do should a problem occur in the future? The survey was useful then in accessing understandings of breakdown as well as responses and reactions to breakdown. The survey data predominantly features in Chapters 3 to 6. Respondents had no prior warning of *when* these calls might occur so the sample reflects those who answered their phone. The sample size was determined by how many people three research assistants could speak to in a two-week period, working full-time.

At the end of the follow-up survey in 2016, I complemented the phone calls with visits to a small number of users at their homes in Bungoma County on the border with Uganda. This is similar to Malinowski, a pioneer of the ethnographic method, who, although an advocate of survey work as 'an excellent skeleton' in the early stages of an ethnography, stressed that it 'must be supplemented by the observation of the manner in which a given custom is carried out' (17: Malinowski, 1964). Ethnographers need, Malinowski maintained, to watch people's behaviours and be attuned to exceptions to that behaviour or those customs. In addition to users, I also observed company technicians and independent repairmen at work. And, true to the ethnographic tradition, I carried out participant observation of industry managers, investors and policy makers at industry conferences and other events where I was a researcher. I also carried out participant observation in one repair shop where I acted as an apprentice for three months. Observations helped me to see the assemblage in-action. In

interviews or surveys, while actors may speak of others, just one actor is being engaged with at any one time. In observation, however, I could watch how repairmen interacted with the solar products and how they engaged with users. I could observe how technicians related to company processes and market institutions through their work. Observation also has empirical value in watching and learning how things get fixed as well as how and where things are disposed of. At times this offered visual information to compare and contrast with how the same individuals spoke about these processes or, in the company settings, how their, often senior, managers explained processes to me in interviews.

The third method I used was semi-structured interviews. I accessed interviewees through cold-calling (in-person, over the phone or by email), through snowballing (from previous interviewees, existing contacts or observations) as well as networking (at relevant events and conferences). The industry in Kenya was relatively small and so easily navigable at the time. Some respondents had previously worked for other companies and organizations (as I had myself) while interviewees and I often realized we already had mutual contacts in one of the other companies or organizations. On one occasion as I waited in an office reception before an interview I was passed by someone I knew leaving a meeting with the interviewee only to pass another mutual contact when I myself left the office an hour later. While generally successful in arranging interviews, I sometimes faced problems. Interviewees in government departments or agencies were particularly unresponsive or difficult to arrange – I arrived at empty offices and voicemail services on numerous occasions. And I sometimes had difficulty finding homes (of users) and challenges with changing phone numbers. Most interviews lasted around 40 minutes (although some home visits lasted a little longer). I prepared by creating a list of questions and topics in advance (66: Crang and Cook, 2007). However, I tended to only refer back to this during the interview if a certain line of questioning reached an end or there was a lull in the conversation. Most were recorded with an audio recorder unless an interviewee did not wish to be recorded (two occasions) or the setting was not appropriate (for instance, home visits where our conversation moved around and we interacted frequently with our surroundings, which regularly included young children and free-roaming chickens). The order that the interviews were conducted in was largely determined by the availability of respondents.

Further reflections on method are found throughout the book signalled by three asterisks (***) in a paragraph break. These paragraphs stem from the view that the method, the data it produces and the researcher themselves are inseparable. By interspersing them through the book, the reader is invited to reflect, as I have done, on the close relationship between method, data and researcher while limiting interruption to the narrative.

Outline of the book

Part I sets out the nature of the off-grid solar industry in Kenya today and also outlines the conceptual understanding of breakdown which the analysis in Part II builds on.

The first chapter revisits some of the earliest recorded photovoltaic (PV) installations in Kenya and speaks with the users, designers and technicians of old, no longer shiny systems. Retracing a chronology of PV in Kenya from the early 1980s to now, the chapter shows that the technology has got cheaper, smaller and reached more people. Where earlier projects were run by outside charities or NGOs, today's installations, still led by outsiders, are delivered by social enterprises committed to the diffusion of technology through the market. The chapter argues that these trends have kept users outside of the technology and so reduced the need for, ability to, and interest in, repair. A focus on growth and market development has also neglected the material legacy and remnants of the technology over the last 40 years.

Starting at an industry conference in Dubai, Chapter 2 outlines the contemporary global off-grid solar market. The chapter describes two influential market devices: quality standards and impact metrics, that distinguish a certified market from a non-certified one. The second half of the chapter moves back to Kenya: first to capital Nairobi to see how the devices are used by certified market actors to push for favourable tax, import and energy policies, and then to Bomet, the main field site for this research. Here, the main companies that are examined in the book are introduced and how their products are sold, distributed and financed. Despite the work done, through market devices, to differentiate them, the two certified and non-certified markets are much closer at this local level. The chapter argues that the effort invested in creating the market (through the standards and metrics) sidelines product repair and waste management.

Chapter 3 introduces the various types of breakdown that can occur within the solar assemblage. These can be breakdowns in design, manufacture, impact, use, water damage, dust, dirt, fire, theft or a business decision. The chapter works with breakdown to show that functionality is not a determining factor in whether or not something is disposed. Breakdown moves a product in to a gap between consumption and disposal. It can be returned from this gap by repair or it can be moved on by acts of disposal. The chapter concludes that where breakdown is, who the product is with and what type of breakdown has occurred, all shape the possible responses to it.

Part II forms the basis of the empirical contribution. Over three chapters the broken down solar product is followed across three sites: the home, the independent repair clinic and the company premises.[5] Chapter 4 visits the home, where the most common response to breakdown is to wait: the certified market is creating passive users who await further instruction

rather than pursue their own repair or take it to the repair clinic. Where repairs *are* made the chapter suggests that these are more often of oneself or one's routine (a repair of practice) than any material alteration (a repair of product). In terms of disposal, although products, and parts of products, are sometimes put down the toilet, into the ground, burnt in a fire or sold as scrap at home, the chapter describes how the majority of the products and their parts are held on to in case of some future possible use.

Chapter 5 moves to repair clinics where material repairs are more common but there are also limits here. Next to other household electronics the small, simple solar product does not promise much profit for repairmen,[6] nor are the necessary spare parts available and so they increasingly direct users towards company warranty processes instead. Broken down products and parts, are found waiting in the clinic as well. Uncollected products (and parts) either form the basis of the repairman's stock to facilitate future repairs or they are eventually disposed of by being sold on (to metal collectors) or fed in to the municipal waste stream. In cases of the latter, objects are burnt at the side of the road or taken to landfill, if not first siphoned off by passers-by and playing children.

Chapter 6 goes inside the company premises where repairs are once again found to be limited. Motivated by a concern for brand image and a minimum and consistent level of quality, companies (and their partners) replace rather than repair products. Despite an emphasis on training and process, observations reveal that informality persists, however, and technicians work to repair out-of-warranty products or earn a side income. Products and parts returned to company offices, warehouses and workshops also wait. If not siphoned by security staff or employees of the waste company collecting them, the chapter also explains how products and parts can end up in one of Nairobi's landfill sites. Others are sent to manufacturing facilities in China to aid future product improvements or stored until collection by a recycling company.

The major contribution of Part II is that when repairs *are* done, similarities are found across the three locations. Through a process of trial-and-error people draw on previous experiences, cannibalize other objects and prioritize functionality over any aesthetic aim or benchmark. It is suggested that these commonalities are comparable to the idea of *bricolage* as articulated by Claude Lévi-Strauss (1994). At each repair location (and in any act of bricolage) however, there is, as has been described of mobile phone repairmen in Uganda 'that [which] cannot be tidied away' (55: Houston, 2017). And so Chapters 4, 5 and 6 also describe the 'material legacies and externalities' (55: Houston, 2017) found and produced in those respective locations.

The book concludes with a call for greater attention to repair within International Development. Health, sanitation and cooking, where goods and technologies distributed through markets have also come to prominence

in the fixing of problems of poverty (and climate change) are possible areas where this might be useful. The development project at its heart recognizes the current state of the world as unacceptable, as broken. Too often, however, responses to that breakdown (through projects and increasingly products) do not work from what exists, as the *bricoleur* would do, but draw on new resources aiming for a permanent fix to the broken-ness. Learning from repair studies and 'broken-world thinking' (Jackson, 2013) perhaps a more successful approach to development might be to accept the inevitability of breakdown and work on continual repair rather than futile attempts to out-design or out-innovate the broken world.

PART I

Making and Breaking Products

1

Old Tech Made New

A development technology

The first installation of solar panels in Kenya is thought to have taken place at some point in the late 1970s. Panels are believed to have been used to power telephone masts in rural areas (75: Byrne, 2009). Over the 40 years since, the solar assemblage has continually changed in form and grown in size. In terms of locations the technology has moved from being solely found in institutional settings to come to focus on individual households. Materially, systems have shifted from being built and assembled in-country to full manufacture in China. Application-wise the technology was used first for refrigeration then for running televisions then came a concentration on lighting before moving back up again in recent years to powering radios, mobile phones and televisions. Since 2018 there have also been renewed efforts towards what is known as 'productive use' – particularly in terms of powering water pumps and refrigeration (GOGLA, 2024). Delivery models have also moved: from being dominated by one-off projects towards being led by a vibrant market of specialist companies. And at the level of human resources early projects were driven by environmentalists committed to training Kenyans as technicians while their successors have committed more to a commercial approach where Kenyans largely perform the roles of sales agents.

One continuity of the solar assemblage underlying, and at times driving, these changes is the technology's continued proximity to International Development and by extension colonialism. Solar photovoltaic (PV) technology in Kenya has been financially supported by international sources (from the Global North), advocated and spread by foreigners (often White and male) in the pursuit of other goals (particularly in health and the environment) on top of its contribution towards rural electrification. Such directionality and the dynamics of race, gender and power that it involves are, of course, not unique to solar but are found throughout development practice and beyond. Existing histories of solar PV in Kenya, however, do not reflect adequately upon them.

The most thorough accounts of PV development in Kenya are found in *From Space to Earth* by John Perlin (2002) and sections of Robert Byrne's doctoral thesis *Learning Drivers: Rural Electrification Regime Building in Kenya and Tanzania* (2009). Perlin, a trained physicist and vocal advocate for solar power, traverses the globe in his history of breakthroughs and firsts for solar power. It is an empirically rich text that tells the story of 'people who innovated, went against the grain, bucked authority, and risked it all' to turn PV from a 'scientific curiosity into a booming business' (xiv: Perlin, 2002). Perlin does not, however, dwell on the overwhelming identity of those people as White men. Byrne, meanwhile, in a regionally and temporally more specific study seeks to answer why PV adoption is markedly different in Kenya and Tanzania. Approaching the question through the framework of 'strategic niche management' Byrne discusses the importance of social networks and institutions in the development of the technology and does make more of the role of pioneering Kenyans. But, like Perlin, Byrne makes no explicit comment on the race or gender dynamics of those networks and institutions.

Perlin's and Byrne's narratives also trace a successful trajectory, as is common in histories of technology (Edgerton, 2008). Their forward narratives of diffusion, development and progress diverts attention from that which breaks down, does not work or is left behind. A timeline marked by new innovations and introductions is always shadowed by a timeline of less visible but more frequent moments of breakdown, decommissioning and disposal. What makes the history in this chapter distinct from the work of Byrne and Perlin then is two things: one is its attempt to reflect on the gendered and racial origins of the technology, drawing out the consequences of these origins for the technology, its use and its users today. The other is its attention to the material legacy of previous projects, programmes and businesses.

The pioneering individuals behind the spread of PV in Kenya from the 1980s to now were able to be such by virtue of their race, gender, nationality and youth. As White outsiders these were individuals who had easier access to resources and organizations than their Kenyan colleagues, friends and employees. They were also able to reach higher levels of study – in several cases pursuing master's degrees in relevant subjects. These early dynamics of male, outsider dominance have continued until today where gender roles are such that it is largely men, especially outsiders, who implement solar technology and Kenyans, especially Kenyan women, who benefit from it. I myself am a White man in my 30s, and I came to research the off-grid solar industry after having worked for a solar home system (SHS) provider in Kenya and Uganda. In these respects, I am very much part of, and have benefited from, the structures embedded through the history described in this chapter.

Perlin's focus on technical legacies, each new iteration or application building on the last and Byrne's focus on social ones, how communities of individuals and organizations came to build a niche market, neglect the materiality of the technology's dissemination. Although often learning from previous efforts, each stage of PV's development in Kenya has neglected the material leftovers of what came before. Hardware has not been collected, re-used or re-purposed but, in addition to the programme structure and financing models, it has been wholesale replaced. This chapter seeks to counter this neglect.

I draw attention to people left out (Kenyans, especially women) and things left over (waste materials). My contribution here to the overall argument of the book is to show that how the technology is designed and distributed and by whom shapes how it breaks down and what happens when it does so. Like development's inherited colonial origins (Kothari, 2005), the solar assemblage has inherited racial dimensions that shape whose expertise is valued and the roles that different groups are to play within the assemblage. Being an external technology delivered by White outsiders frames Kenyans as users of it, not its designers or repairers. Seen as an outside technology because it has been brought from outside by outsiders has also left Kenyan users with little understanding or knowledge of what to do with the technology when it breaks down. Despite the fact that some of the early pioneers were themselves *bricoleurs*; working from constrained personal budgets they used off-cuts of old panels and made other components from scratch, the dissemination of solar technology in Kenya has tended towards more of an *ingénieur*'s model. The ingénieur for Lévi-Strauss always tries to go beyond any limits they encounter (19: Lévi-Strauss, 1994); in the case of off-grid solar this has led to the wholesale introduction of materials, expertise, financial services, benefits and marketing to solve the question of energy access, rather than building upon existing or leftover skills and materials.

In November 2016 I took a month-long trip to early and historically significant sites of solar PV installations. I used Perlin's authoritative history (2002) and Byrne's doctoral thesis (2009) as starting points from which to navigate. I moved to health centres, schools, businesses, banks and private homes across Eastern and Central Kenya tracking down panels, refrigerators, batteries and other components; and then speaking to the users and technicians of these older systems and projects.

The chapter recounts this trip and traces the shifting shape of the assemblage chronologically. It begins with the experiments of the 1980s where local skills were valued and the space-age technology was brought to rural households. Next comes the project-focused 1990s when attention turned away from the social towards the technical with efforts to ensure quality through targeted manufacture. The 2000s were product-centred as the efficiency of components and scale manufacture in China made solar

both portable and affordable. Since 2008 the focus has been on serving the poorest at the 'bottom of the pyramid' through companies and business models focused specifically on what is called 'last mile distribution' to reach rural households.[1] I close by suggesting that solar PV in Kenya has largely been implemented through what can be characterized as an ingénieur's approach where the technology, expertise and finance is brought in from outside and engagement with pre-existing resources, as bricolage might do, has been limited.

American equipment, expertise and finance

Byrne (2009) has shown contrary to earlier studies (Lorenzo, 1997; Nygaard, 2009) that the development of the private PV market in Kenya has benefited a lot from donor funding, most of it American. In the early 1980s the American influence on the solar assemblage, however, extended beyond finance to the equipment and expertise involved in projects, too. This influence came with consequences. Donor funding meant that PV's applications were defined by American implementers and so were often tied to development goals such as improving the quality of healthcare provision. High equipment costs meant this was delivered at an institutional level. Bringing equipment and expertise from the outside generally put Kenyans in the position of users. Being left out of the project design and implementation also left them *outside* the solar system. Users were not tasked with or trained in matters of installation, maintenance or repair. Not feeling nor having ownership over the solar systems was also disabling when it later came to the question of disposal of no longer functional equipment – users did not know what to do. Together these aspects contributed, as has been documented in development studies, to 'whiteness and the west' being regarded as 'symbols of authority, expertise and knowledge' (10: Kothari, 2006). The association of PV with White Americans contributed to a perception of them as symbols of modernity and progress (16: Kothari, 2006). This, in turn, made solar technology a target of theft – a theme that runs through to the present day. That the first American engineers were men is also significant, as will become clear later. But first, an anecdote.

Steve moved to Ikutha in 1992, when his mum was posted to the area by Kenya Wildlife Service (KWS). While only six years old at the time, Steve remembers going for check-ups at the Ikutha Health Centre where he is now the director. He also remembers the solar panels. Although bemused at why I was interested in something so old (the system was installed in 1983), Steve walked me, nonetheless, from his office to where the panels used to be. Passing under two wind-ripped, sun-faded United States Agency for International Development (USAID) shelters we re-emerged in to the sun and Steve pointed to a white square in the ground. Steve said this concrete

slab was part of the fence that surrounded the array. When the system stopped working (ca. 1999), all of its parts remained in place, for a time, he told me. But then some of the panels were stolen, at which point the others were moved inside for safe-keeping. Steve took me to the drug store to show me where these remaining panels were being kept. Some parts of the system had not been moved, however; the control box, light fittings, switches and wires were all still in place. Steve pointed these out to me as we moved from building to building, retracing the movements of the system centrepiece – the refrigerator – from its original position in the laboratory towards the store where it was resting in 2016.

I asked Steve why all this stuff (the panels, the fittings, the refrigerator) was still there. He said it was because it belonged to the Ministry of Health – he or his team could not do anything with it. Although the Health Centre was connected to the grid in 2011, Steve estimated they had power cuts about two or three times a week sometimes lasting for up to 12 hours and so still had a need for solar-powered refrigeration. For this reason, the Ministry of Health had returned in 2015 to install a new solar-powered refrigerator in the same building where the old one had been (now the Ante-Natal Check-up unit). However, the visitors from the Ministry did not take the old refrigerator with them, nor did they offer Steve and his team any direction on what to do with it. Ownership and responsibility are themes that are re-visited in Chapters 4 and 6 as they influence user and company responses to breakdown.

Leaving Steve to get on with his day's work: taking chilled vaccines (from the new, again USAID-funded, fridge) to Mukuanima, a remote market centre on the edge of the Tsavo East National Park, I headed down the road towards the police station to see if anyone there remembered, or had a record of, the panel theft that Steve had told me about. Theft remains a concern for contemporary users of solar PV. It is a theme that will be revisited in Chapter 3 as a cause of system breakdown.

The installation at the Ikutha Medical Centre was part of a World Health Organization (WHO) project called the Expanded Programme on Immunization (EPI) which was trying to increase vaccination of children worldwide. The equipment I saw in Ikutha and Kibwezi, the second of two Kenyan sites in the programme (Roberts and Ratajczak, 1989), 48 km downhill from Ikutha, was installed by employees of the United States' National Aeronautics and Space Administration (NASA). NASA had been an early adopter of PV in the 1960s, recognizing it as the safest, most reliable (if expensive) source of power for satellites and space probes (50: Perlin, 2002). Space was, in many ways, the off-grid region of the industrialized world. Africa, however, particularly south of the Sahara, remained for the most part off-grid. And so having gained experience of the technology in space NASA engineers were called on to advise for projects on Earth like

EPI. Although NASA provided the expertise for the EPI installations, the actual materials of the refrigerator systems were supplied by an American company called Solarex. The finances for the project, meanwhile, came from yet another American body, the USAID. In order to photograph the original EPI refrigerator, Steve and I had to move several USAID branded boxes of food supplements: 'We get so much from USAID' he said as we moved the boxes to one side.

The examples of Ikutha and Kibwezi are not anomalies in either their American connections or development applications. Most early PV installations were oriented towards community-level facilities like health centres or water pumps – both government and charity-run. The clinic in Kibwezi was run by a charity called the African Medical and Research Foundation (AMREF). If not directly connected to their work (that is AMREF's need for vaccine refrigeration in Kibwezi) non-governmental organizations (NGOs) and Christian missions were, due to high costs, the only feasible clients for solar in the late 1970s and early 1980s. These wealthier groups would buy systems to power their offices or living quarters (131: Perlin, 2002). Safari camps and upmarket hotels were another customer segment of the time.

The examples of the WHO–EPI installations introduce two legacies that are traced through this history: a technological one (of people and applications) and a material one (of things and equipment). The technological legacy of the earliest PV installations in Kenya being used to power NGO offices or community institutions like health centres was a connection to the realm of International Development. That the NASA engineers who worked on the WHO–EPI projects were White men, set another precedent that would continue for decades afterwards. Being a White male myself, I likely benefited from this precedent, too. My outsider identity, and its connotations of authority and expertise (Kothari, 2006), undoubtedly helped me gain access to the management of the Ikutha and Kibwezi health facilities. Indeed, when I walked in to the office at Kibwezi the staff there first thought I was from USAID(!).

That projects were led by outside companies, bringing outside expertise and outside technology, cast Kenyans as beneficiaries or users rather than installers, technicians or engineers, and so shaped their experience of and with the technology. In Ikutha this could have contributed to the theft of the panels. In Kibwezi, a former watchman at the Health Centre remembered how a White man came periodically from Nairobi to service the system, or would have to be called if there was any problem with it. Such arrangements bred unfamiliarity with the technology and left Kenyans impotent in the face of repair. The lack of ownership also left them uncertain regarding disposal. Because the solar system (and equipment) was the property of the Ministry of Health, Steve and his team could not remove the panels or refrigerator,

only periodically move them from building to building. This disposal-by-storage has been described in other contexts as 'accommodating' (Gregson, 2011) and is a common practice identified in homes, repair clinics and on company premises, too. It is returned to in later chapters. Kenyans were not only left out of the design and implementation of the technology then but often had to deal with its material legacy, too – leftover panels and fridges.

Harry Burris and the household market

Another institution which benefited from the early forays into solar PV was the school. A project in the mid-1980s, again funded by USAID, saw solar systems installed in four secondary schools in what is today Meru, Tharaka-Nithi and Embu counties to the east of Mount Kenya. The project was led by a young environmentalist called Harry Burris, known invariably to his Kenyan colleagues as Burris. Burris first arrived in Kenya as a Peace Corps volunteer teaching Physics.[2] After his service, in the early 1980s, he moved to a town called Kithimani in the eastern region where his Kenyan wife, Stella, came from. Another American, Dan Schellenberg, was living in the area at the time. Schellenberg described his first encounter with Burris to me in an email:

> I was driving along … when I saw this white guy with tire tread sandals, a plastic woven hat and a *kikapu* [basket made of leaves] walking along the side of the road. It was my custom to pick up all foreigners no matter what, so I stopped and offered him a lift. He was hot, sweaty, smelled like he had had no bath for days, and needed a drink. We stopped at a 'hotel' in Matuu for said drink, and he asked me what I was doing in Yatta. … As soon as I mentioned the word 'missionary' he put his cup of *chai* [tea] down and said: 'Yeah but do you know what you are doing?' Ok asshole, I thought, drink your tea and I'll drop you off at the next town or wherever. Me speaking Kikamba for 30 years and this loser American asking me that! 'Well,' he said, 'not to pry but have you ever read Harold and Elizabeth Odum's book: *Energy for Man and Natu* I had not, and he informed me that I therefore did NOT know what I was doing. He hauled out a yellowed, dog-eared bunch of papers and handed them to me. 'Here, read this.' That beat-up old book changed my life and re-directed my planning and projects for the rest of my years in Yatta, and, in fact, the rest of my life since. So yes, I knew Harry Burris.

When I visited Kithimani in 2016 I met others who remembered Burris. Burris' former landlord, Pascal, told me Burris was rarely seen by locals. He spent most of his time in a solar-powered workshop he set up on the edge

of town. In 1983, on one of his trips to Nairobi to collect panel off-cuts and other components, Burris met another American who was in Kenya teaching science as a Peace Corps volunteer, Mark Hankins. Hankins recalls mentioning his host school's search for a diesel generator to which Burris suggested the possibility of a solar system (82: Byrne, 2009). The idea soon developed into a project, to install solar systems in four local schools, for which Hankins and Burris successfully elicited Peace Corps approval and funding from USAID. The headteachers of the schools were not motivated, as Burris was, by the environmental agenda set forth by Howard and Elisabeth Odum (1981) but rather by the thought of saving money.

Burris and Hankins used the project as an opportunity to train a group of seven local technicians. In 2016 I met Silas, one of the seven, in Chuka, the town nearest to Karamugi Secondary School where Hankins had taught and where the first of the four solar systems was installed.[3] One day Silas and I took a trip down to Karamugi to find out what had become of that first system. We spoke at length to the school clerk, Gitari, who had arrived at the school in 1986, one year after he said the solar was installed. After working well for six years Gitari said the system was supplemented with a generator and, in 2006, a grid connection. At which point the remaining equipment was sold as scrap except for three panels and batteries, which were kept for practical demonstrations in Physics classes.

After the schools project, demand for solar rapidly increased: the headteachers purchased systems for their own homes and the technicians and their families bought systems too. Around 1984/5, Burris, Stella and Daniel (another of the seven initial technicians) moved to Embu, a larger town 44 km south of Chuka, and registered a company under the name Solar Shamba (Solar Farm) to better service the growing demand in the area.[4] While their work would continue to include schools and other institutions, the main innovation of Solar Shamba was to install systems for households. Towards the end of my time in Chuka, Silas and I visited a customer at her home among tea fields on the edge of Mount Kenya National Park. Mrs Gakuru invited us in and pointed happily to the system control unit still mounted on the wall, complete with Solar Shamba sticky label. Electricity reached this part of the country in April 2016, seven months before my visit; however, they still use the Solar Shamba system during blackouts.

In 1987, Burris moved to Tanzania where he continued to work in solar with Securicor until his death.[5] And, having finished his Peace Corps service, Hankins returned to the US. Daniel, however, stayed. He told me he could not leave because:

> many of the people knew me as the head of the, the company, even most of them didn't know Burris, they didn't have contacts for Burris so they were contacting me. If they had problem they contacted me, if

> they had other new systems they contacted me, so I could put myself in trouble if I could have left to home, so I said, 'By the way where am I going? I should continue with the job.'

In the months following Burris' departure, not having access to the Solar Shamba bank account, Daniel set up his own company to finish the installations of pending customers and such like. He called his company American Solar Technologies – a nod to the mentorship he had received from Burris and also to make the association with 'the West' and its connotations of quality, modernity and technology. Although, as Daniel alludes to in the earlier quote, company names (including BP, Total and Solarex) were not what people knew, business spread more through word-of-mouth and system visibility that is panels on roofs than by any company name or logo.

By 1987 then there were hints of an indigenous solar industry, one targeting households rather than institutions. The environment had been brought in to the solar assemblage for the first time. The idea of 'appropriate technology' had created a role for Kenyans, or at least Kenyan men, with some being trained as technicians. In cases of breakdown this meant the skills were there to repair and service systems, many of which remain in place over 30 years after their installation, and some of which are still in use. Other bits live on as teaching aids.

Quality concerns

The growth of a household market in Kenya however soon faced challenges. When more and more brands came in to the market and more and more people turned to make, or add to, their livelihoods from selling and installing solar equipment, problems arose in the quality of equipment itself and the quality of system-sizing and installation. The American outsider was losing a grip on the market to poor quality and mis-labelled panels from China – a new arrival to the solar assemblage. The batteries available in the market and already in some Kenyans' homes (mainly vehicle batteries) were also not well-suited to the unique charging patterns of a solar panel. Nor did all users and installers include charge controllers in their bespoke system designs which put the function and longevity of their systems at risk. In this section I show how organizational, regulatory and material responses to these challenges in the 1990s established a particular understanding of quality as being something inherent to the material equipment in a solar system and not, as it had been previously understood, in terms of technical training and skills. While the design of solar-specific batteries, with in-built charge controllers, aimed to reduce breakdown, it also reduced the user's knowledge of how the technology functions, keeping them outside of the technology and so limiting possibilities for repair. Other precedents were set including

market research into panel quality and the forming of an organization to raise awareness and protect the market.

In 1991, having graduated with an MSc in Renewable Energy Engineering, Hankins returned to Kenya and formed a new company with Daniel, Energy Alternatives Africa (EAA). In the following years, EAA's work remained closely aligned to development, responding to tenders and calls of NGOs and other development actors. EAA also retained a focus on training. In March 1992, together with the Kenya Environmental Non-Governmental Organizations (KENGO), EAA organized a workshop in Nairobi that trained a second generation of technicians. Although EAA worked across several different countries, its office was in Nairobi; Kenya was establishing itself as the regional hub for business, technology and development work (131: Perlin, 2002).

The continued global price drops for silicon (and so silicon-based solar panels) helped solar module brands like Alpha Nguvu and ARCO move in to Kenya, in addition to the BP panels that Solar Shamba had used. However, this proliferation in the solar market came at a cost: systems were mis-sized, parts were missed out, panels were mislabelled, poor quality panels came in to the market and existing lead acid batteries were ill-suited to the less consistent charging profiles that come from a solar module than a diesel generator or grid connection (lower or slower charging on cloudy days for instance). Although there were some specialist solar companies such as Kenital and Telesales emerging in the 1990s, general electronic and electrical retailers in Nairobi's Central Business District (CBD) sold equipment to untrained technicians or directly to users. For users the solar panel was often a new way to charge an existing battery-based system that they had previously charged from the grid or a diesel generator (see 148: Jacobson, 2007). So users and technicians would not match the size of new solar panels to the size of existing batteries or appliances at home. Cost-conscious rural Kenyans also often forewent the solar charge controller, a vital piece of equipment that protects the health and so the lifespan of the batteries (207: Miller, 2009).[6] A research article published in 1997 suggested the private sector approach was showing its limitations and, 'in the absence of equipment standards and codes of practice' system performance was low (8: Lorenzo, 1997).

With the rise in Chinese manufacturing at the time, especially in electronic and electrical goods, unbranded panels came to prove particularly problematic for the Kenyan market. These Chinese-made panels were typically lower cost but also lower quality, and came without any human resource or company recourse to offer technical support. Concerned by this Hankins partnered with American academics Arne Jacobson and Dan Kammen to run surveys of the modules available on the market and their performance with the help of two Kenyan technicians of the second generation: Henry Watitwa and Maina Mumbi (Duke et al, 1999; Jacobson et al, 2000). This community, concerned

with the social and material problems of installation quality and panel quality, soon coalesced into a new NGO called the Solar Energy Network (later shortened to SolarNet). Set up in 1996 to protect the nascent solar market, SolarNet retained both international and development links: the network's archive contains meeting minutes, project proposals and emails with the German Corporation for Technical Cooperation (*Gesellschaft für Technische Zusammenarbeit*, GTZ), the United Nations Development Programme (UNDP) and the UK Department for International Development (DFID). Although these documents are kept by White Kenyan Mike Harries (a former treasurer of the network) on his farm south-west of Thika, in its later years African Kenyans also held positions of responsibility within the organization.

SolarNet also signalled a shift from development involvement in solar projects themselves (installations and training) towards a more supportive role (awareness and capacity-building). In addition to educational calendars and market days (open-air exhibitions for solar companies) SolarNet worked with the Kenya Bureau of Standards (KEBS) on efforts to keep the fraudulent modules identified in Hankins et al's surveys out of the market. The NGO also ran a database of registered technicians around the country and later assisted Henry Watitwa with the launch of the Kenya Solar Technicians Association (KESTA) that wanted to formalize this further by certifying technicians in order to address the issue of incorrect installation.

In addition to the attempts to begin regulation of technicians and of solar panels, steps were made towards improving battery performance, ever the Achilles heel of a solar system (see Chapter 3). Prime examples of this are the *Jua Tosha* (enough sun) and the BatPack initiatives, both run by EAA and launched in 1997 (Byrne, 2009). The Jua Tosha, funded by the World Bank's Energy Sector Management Assistance Program (ESMAP[7]), was a specially designed battery for the deep-discharging that is specific to solar power. 'Deep cycle' batteries, with stronger and heavier lead plates, are able to charge at low currents and are better able to withstand the stress and corrosion of repeated deep discharges, that may occur in rainy season or on cloudy days than regular vehicle batteries. BatPack, supported by The Ashden Trust – a charity that funds sustainable development projects – was a battery and charge regulator in one.[8] It was the first step in what would become a gradual tightening up, and closing in, of the product upon itself. The market, or user failure, to buy the right battery and a charge controller was to be corrected by bringing both elements into a single object itself.

As the household market expanded concerns about the quality of solar equipment and installations grew. Issues with panels, batteries and charge controllers were addressed in various ways but always in Kenya which, by the end of the 1990s, having been the chosen site for research and implementation projects alike, was firmly established as the solar centre of Eastern Africa, if not the continent as a whole. Projects to promote

design innovations demonstrate that quality concerns were no longer being addressed through the training of technicians as Burris might have had it. Instead the problem was to be solved by bundling parts of the solar system together in to one object which, although reducing some forms of breakdown, made repair difficult and reduced the average user's understanding of the technology. The organizational response of SolarNet to gather together concerned parties and lobby for regulation, meanwhile, did increase the role for Kenyans: several held committee positions at the network. However, its ties to the International Development community through organizations like GTZ meant that the outside influence remained. Similarly, in the emerging field of research around the market, Kenyans remained in supportive or assistant roles under lead researchers who were generally White American men. Hankins remained involved in solar running a different company called African Solar Designs from Nairobi, but it was the next generation of outsiders, also men, also in their 20s, who would tighten the assemblage yet further and bring together the quality-certified panel and the solar-specific battery into one product – the solar lantern.

The emergence of the solar lantern

The second generation of outsiders were, like Hankins and Burris, believers in appropriate technology and the environment. Also like their predecessors they had been inspired to act after volunteer teaching placements in the region and in the early stages especially they would invest their own money in their photovoltaic experiments. They shared a commitment to using local materials and re-using materials too, although as with Burris this may have been to keep costs down as much as minimize resource use for environmental reasons. And like their predecessors, they had little engagement with the Kenyan state but instead were connected to the International Development community of NGOs, charitable foundations and similar. Their most obvious difference from Burris and Hankins was that they were British, not American and so brought funding from DFID rather than USAID. The two heirs also brought media attention in to the ever-growing assemblage attracting the attention of international journalists. In this section I show how two more individual outsiders initially experimenting with bricolage provision of solar came to be involved in commercial assembly operations before ultimately conceding product manufacture to China.

With questions of quality largely addressed, or at least in view, a second challenge of the 1990s was cost. Continuing in the vein of the solar-specific batteries pioneered by the ESMAP and Ashden Trust projects earlier in the decade, in 1997, DFID funded a project to design and manufacture a solar lantern for Africa (White and Fearnon, 2010). A self-contained solar lantern would further limit the risks of mis-selling and mis-sizing as well as meet

the price challenge as a smaller, and so cheaper, product. The development charity: Intermediate Technology Development Group (ITDG, now Practical Action) were tasked with designing an economical solar lantern that could be assembled in Africa using locally available materials and locally feasible production methods. The result was the Glowstar – an upright orange plastic-cased product that was carried from the top, like a kerosene lantern, but with a tube light bulb rather than a wick.

Once the Glowstar's design was set, DFID put out the tender, worth £1,000,000, for a company to make the lantern. The tender was won by Sollatek in Mombasa; again, Kenya was at the centre of a development project involving solar. Watching from the ITDG library near Coventry, UK, a British undergraduate student, called Leo Blyth, followed the project closely while writing his bachelor's dissertation. I met Blyth, who now works as an off-grid industry specialist at the World Bank Group, at the World Bank offices in Nairobi in December 2016. It was when Sollatek, a UK-owned company, won the tender, however, that things started to go wrong according to Blyth. Sollatek immediately moved manufacture of the Glowstar to China. The promised gains for Kenyan industry through local assembly were immediately lost to the dictates of mass production – it was cheaper to manufacture in China than in Kenya. But Blyth is even more despairing of what happened next:

> First application of that [the Glowstar], the company fits it with an internal circuit so that it can be charged from the mains as a back-up lantern for the urban rich, the middle-class and the next innovation was so when it senses that the power that's charging it is cut off, it comes on automatically as an emergency lantern, literally for people on the grid, who were living in fancy houses with the grid, that's what happened to a million pounds of our work to try and get out to the poorest.

Blyth first went to Kenya in 1996 to teach Physics for three months in Taita Taveta, in the south-east of the country, before starting his undergraduate degree in Third World Development Studies. Two days before leaving the UK, Blyth received a simple solar kit (a small panel with two wires with crocodile clips on the back) through the post that he had ordered after reading an article about 'DIY Solar' in a publication called *Positive News*. Unfortunately, that first panel through the post had arrived broken. Blyth took it anyway and although he could not demonstrate solar to the villagers in Taita Taveta, he was able to introduce them to the idea. A key influence on Blyth during this time was Ken Darrow and Mike Saxenian's *Appropriate Technology Sourcebook* (Darrow and Saxenian, 1993). In our interview over lunch Blyth referred to it as 'a stunning book … it's like a bible'. For Darrow

and Saxenian, 'appropriate technology' is a political project as well as an environmental one, to them it should involve the creation of jobs and skills in order to redistribute income and power (6: Darrow and Saxenian, 1993). Upon graduation in 2000 Blyth moved to Kenya full time to continue his work. One of his early experiments involved locally sourcing discarded film canisters to house three button batteries with a jack in the lid running to a small solar panel. By assembling something from existing, available parts Blyth was exhibiting bricoleur tendencies.

In 2001, the same DIY Solar kit caught the eye of John Keane, another British man, who was similarly committed to the dual causes of environmental sustainability and local development. Keane had just returned from a seven-month stint volunteering in a village in the Iringa region of Tanzania, an experience he told me in our interview was 'a bit like a Peace Corps type thing', where he had been struck by the frequency with which people went through batteries for their radios and the number of old batteries lying around. Over Skype in December 2016, Keane told me that it was in thinking of other ways to power the farmers' radios that he had come across DIY Solar. And so on returning to the UK, Keane, like Blyth, ordered a sample kit and, like Hankins, enrolled himself on a Renewable Energy course (with the Open University). Once he had saved enough money, as Burris had done in the 1980s, Keane would return to the village in Tanzania, and, using the knowledge from his university course, train people in DIY solar.

Keane moved back to Tanzania at the end of 2003. En route, he stopped by Nairobi to meet Leo Blyth. Over the next few months they ran various projects together in partnership with NGOs across the region. Training communities to build (and repair) their own solar systems, Blyth and Keane, like their predecessors, were introducing solar PV to a third generation of Kenyans. Keane worked a lot with the Kibera Community Youth Project (KCYP), in the Nairobi slum of the same name. Recognizing that entertainment objects were in demand (the first explicit recognition of such by the outside implementers) the KCYP production line focused on powering mobiles and radios rather than providing light. Another first that occurred around this time was that the concept garnered attention outside of the environmental, technical and development communities, when Keane's work was picked up first by the BBC (Hicks, 2004) and then later by CNN. This media attention brought new financial interest that Keane directed towards a Kenyan, Fred Migai, who he and Blyth had trained a few years earlier. Migai was able to set up a solar panel assembly line in downtown Nairobi as a result.

It was about this time that Keane and Blyth went their separate ways. Keane told me, 'after a little while basically it was clear that I needed to go and try and figure out this route myself and Leo wanted to start Solapak'.

Inspired by some Chinese-made solar products that he had come across in Uganda, Blyth set up Solapak in 2004. The Solapak lantern was one of the first products in Kenya to use LEDs.[9] Blyth established an assembly line in Karen, a wealthy suburb outside of Nairobi, and hired local young people to build the lantern. However, much like the Glowstar coming to cater as a back-up for grid-connected households, the Solapak lantern came to target upmarket safari lodges, as the very first systems had done in the 1980s. Things were drifting from Blyth's initial focus, inspired by Darrow and Saxenian, to get affordable power to local people with technology that could be 'be understood, controlled and maintained by villagers' without needing 'a high level of specific training' (7: Darrow and Saxenian, 1993). Meanwhile, Keane was hired by SolarAid in 2007 to set up a factory manufacturing solar lanterns in Nakuru (a town to the north-west of Nairobi). The factory was managed by Migai.

Blyth and Keane, like Hankins and Burris, had followed their interests in appropriate technology and the environment to train a new generation of Kenyans basic solar skills (in both assembly and repair). However, by the end of the decade their early 2000s bricolage, involving the local (re-)use of scrap resources, had given way to manufacturing in China. The move to China also reduced chances of repair through the reduced likelihood of locally available parts or skills. A new addition to the assemblage around this time was the media. The work of Keane and Blyth had attracted attention not just from environment-specific organs (like *Positive News*, where 'DIY Solar' had featured) but mainstream outlets such as the BBC and CNN. As with project funding, such coverage was helped by the access and profile the two had as White British men.

The last mile at the bottom of the pyramid

Even with costs coming down, solar lanterns were still missing the poorest, often serving safari lodges and as back-up lights for on-grid households instead. In response to this emerged a new World Bank programme called Lighting Africa.[10] Its focus was on catalysing a market for off-grid lighting, creating demand. The programme did not involve funding for businesses. Funding could now come from private sources (a new actor in the assemblage). Against the backdrop of two newer concepts within International Development: 'last mile distribution' and the 'bottom of the pyramid' (BoP), a new type of solar business emerged focused uniquely on distribution, their sole business to sell (rather than manufacture) solar products. In a market approach such as this the solar product becomes more a 'fast-moving consumer good' (FMCG) rather than a technical object that may need maintenance or repair. This section of the chapter covers the period from 2008 to 2018 when, although the focus was on what the

product enables (improved health, education and livelihoods) rather than what it does in itself, the falling price in lithium-based batteries and ever-brighter LEDs also saw products' technical performance increase.

In 2008, Blyth saw an advert in the newspaper: 'Lighting the Base of the Pyramid (LBOP)'. It was a new project from the World Bank's International Finance Corporation (IFC) focused on catalysing a market for off-grid lighting. Just as it had been for the ESMAP projects, PVMTI and the DFID lantern, Kenya was yet again one of the pilot countries. Intrigued, Blyth invited the programme founder, Russell Sturm (a White American man), to come and visit the Solapak operation. Taken by Sturm's commitment to scale and dissatisfied with serving luxury safari camps rather than those more in need, Blyth shut down Solapak not long after Sturm's visit and joined the World Bank as a consultant in 2009. By which time LBOP had become Lighting Africa.

Lighting Africa ran a design competition, developed a certification scheme to verify the quality of products, organized conferences and put on a series of roadshows in rural market centres to spread awareness of the growing number of solar lanterns that were available (World Bank, 2012). The programme paved the way for a new kind of business that did not necessarily manufacture solar equipment or products but concentrated solely on distributing them over the last mile. In such a climate there was increasingly less place for an organization like SolarNet with its focus on local training and capacity-building – the network closed around 2009. One of the most prominent and early success stories of the new era was SunnyMoney, a social enterprise owned by SolarAid, where Keane was still working. In 2014, I spent a day observing one of their sales representatives, Paul, at two primary schools in Western Kenya. 'When we usually enter a place, because of the car, everyone knows the solar is coming,' Paul told me as we rolled in to Etenje, a small market centre in Kakamega County. We were in The Solar Roller, a bright yellow mini-bus with the slogan: 'Here Comes The Sun' emblazoned down the side in jaunty black writing, on our way to Etenje Primary School to deliver some solar products. From 10 am headteachers started arriving, mainly on motorbike taxis, from approximately 50 surrounding schools to collect products that they had ordered over the phone with Paul's colleagues in Nairobi. Two hours later at 12 pm, Paul's phone was still ringing and some plastic bags of products were still remaining: more headteachers were on their way but we had to leave for St Anne's Girls. On we rolled.

The 12 km from Etenje to the nearest tarmac road are an example of 'the last mile'. It is the 'mile' that Burris walked in his tyre-tread sandals. The 'last mile' describes the distance from market centres to dispersed rural communities. It is problematized in the off-grid solar industry as being difficult to reach and is characterized by rough roads, impassable in bad weather. But while it might be the last mile for companies, like SunnyMoney,

for users it is not – teachers first travel back to their schools (which for some was over an hour's motorbike ride away) and then have to arrange the final delivery to the home of the parent who bought the light.

The last mile did not just change how solar was sold though but also what it does. The school is no longer just the place where solar is to be used (a place to be lit up) but a place to sell, the same money-saving pitch that had attracted the first headteachers remains but added to it are promised improvements in educational performance, health benefits and gender equality. While there has been a long association between solar power and health, rather than act in a supporting role (through refrigerating vaccines) the solar lantern in itself was now improving health outcomes. Lighting Africa roadshows and specialist distributors like SunnyMoney used marketing messages to claim that through the replacement of kerosene lanterns, solar lanterns were reducing eye and lung irritations from kerosene smoke.

Although it is called *Lighting* Africa it is phone charging and television powering that have really driven the market in the last few years (79: Dalberg Advisors and Lighting Global, 2018). Recognizing the value of the TV as Jacobson had done several years earlier (Jacobson, 2007), an interviewee at the Family Bank Foundation told me how that demand for the solar systems they were distributing peaked around the time of the World Cup, while SHS manufacturer BBOXX found their customers used much more power from their systems than usual to watch a football match between Kenya and Zambia on their solar-powered TVs (Herring, 2017).

The products were different now though. The move to lithium-based batteries, predominantly lithium-ion to begin with, rather than the lead-based ones used previously, helped further lower the cost of products. And the dawn of mobile money – the ability to pay for products remotely through a mobile phone – also made last mile business cheaper and easier as customers were able to pay in daily, weekly or monthly instalments, which reduced upfront costs. This is particularly true for Kenya where the M-Pesa (*pesa* is Swahili for money) mobile money service enjoyed reach unparalleled in other African countries (9: GSMA, 2017). Once again Kenya was at the centre of a technological step-change regarding solar. Connected to the Global System of Mobile Communications (GSM), these 'GSM-enabled' products are monitored from Nairobi or even abroad. If a payment is missed then power can be cut, also remotely, so the product stops working, until payments are resumed. With the help of telephony, solar companies can now cover the last mile without the need for Burris' sandals or Paul's minibus.

The last mile approach has also changed *who* is part of the solar assemblage. Although most of the companies that have emerged under the Lighting Africa programme, are led by men (who are often still White) the programme has also introduced a gender angle that has been missing from the history until

now. Women are employed by some of the distributor companies as trusted sales agents with one, Solar Sister, doing so exclusively.

New companies, new business models, new investors, new payment systems, new benefits and a newfound place for women suggest there has been lots of novelty and innovation in the Lighting Africa era. However, when situated in the history of this chapter, it is possible to identify several continuing trends. Historical parallels help break the spell of the present (Ames, 2019). The association of health and solar, for instance, has been there since the early days. What is new is the defining of solar against kerosene, something only made possible by reducing the focus, at least initially, to lighting. Similarly, the arrival of lithium batteries is part of a longer trend of improvements and falling prices in the global consumer electronics market that has had an incidental benefit for solar technology. And while the sales agent model is also new it is in line with the trend of Kenyans holding junior roles to outside managers. The new, brand-conscious companies are also still headed by young, White, male outsiders who were motivated to enter the market by a mixture of 'on-the-ground' experience and academic interest. Their race and nationality with its historical advantages has allowed them easier access to sources of funding and investment. Although the gender focus is new it concerns the beneficiaries of solar and less the gender of those designing and delivering the technology which remains male dominated. What is novel is perhaps a disregard for bricolage. All the work by the Lighting Africa programme and its associates through quality standards, business support, consumer awareness and access to finance represents a wholesale introduction from outside – it reflects more the approach of the ingénieur.

The engineer's approach

In Kenya, solar PV has consistently been promoted by outsiders. The motivations of whom have traced the prevalent trends in International Development of the time: appropriate technology, poverty alleviation and market development. The benefits of solar PV have been increasingly emphasized and increasingly expansive, from saving money to saving the planet, saving lives and improving grades. The move from the 'small is beautiful' approach (Schumacher, 1993) of some of its first proponents to contemporary ambitions of providing universal energy access through a market that can reach scale has seen local engagement give way to uniform imposition, from bricolage to an engineered blueprint.

In this closing section of the chapter I suggest that the ingénieur's approach has created an overly material understanding of the solar product which has consequences for its breakdown, repair and disposal. The material closing in of the solar product: first with the inclusion of the charge controller

with the battery, then the pairing of the LED within the same unit has seen the surrounding immaterial concerns such as system sizing and installation removed. The broader move from solar projects to solar products has changed the user's experience of the technology and also the jobs available with users needing less understanding of how PV works and technical positions being replaced by sales ones. Users are cast in a user role and the technology and any repair or service requirement is neglected in favour of robust products.

Although many of the institutions and innovations of the post-Lighting Africa era position the solar product as standalone, it is still dependent on various other parts of the assemblage. It is deeply connected, for instance, to the wider global electronics industry from which Blyth, Keane and Burris all sourced their parts in Nairobi. Falling prices in the global electronics industry facilitated the growth of the off-grid solar industry. The products may be discrete in a technical sense, but they are part of broader business, social and historical networks. These connections look set to increase as the industry moves to include more appliances with solar home system packages and turn (once again) to applications of water pumping and other 'productive uses' such as milling and irrigation.

At an industry gathering in Hong Kong in 2018 these 'new' applications were prominent in panel discussions and in the accompanying exhibition hall. During an evening reception the founder of Greenlight Planet (one of the most successful companies of the Lighting Africa generation), Patrick Walsh, told attendees his personal story of how he moved to Hong Kong (rather than Kenya) in 2008 to try and manufacture a solar lantern that he had designed back in the US. He said:

> And, having just graduated from college, to be honest I was mostly clueless, and I probably had no business whatsoever manufacturing anything. I had never been involved in manufacturing, … And I guess I was expecting that I could just come to Hong Kong and walk up and down the street and knock on factory doors to see who could make this thing.

In his address Walsh spoke of how the industry has evolved since that time; he and his company maturing in line with an industry that is attracting ever greater attention and investment. Walsh specifically acknowledged the role of donor funding from USAID, DFID, the Shell Foundation and others as well as the policy-oriented efforts of the World Bank in helping the industry grow. At the same time that Walsh stressed his belief in a 'free market', he also acknowledged the off-grid solar market as being uniquely connected to International Development.

What can now be called the off-grid solar industry in Kenya remains heavily directed by outside actors. Leaders in the contemporary market such

as d.light also have White men at the helm with comparable stories to tell of how they started out as enterprising individuals. The history of PV in Kenya is littered with youthful mavericks who have tinkered with different forms of technology (homemade charge controllers and solar-specific batteries) and more recently experimented with different forms of delivering that technology (local assembly versus import). Inspired by their experiences of living off-grid, or with people who did, these influential individuals matched their practical experience with an academic grounding studying for undergraduate and postgraduate degrees in energy or development studies. They all either wrote a text on the topic (Hankins, 1995; Keane, 2014) or were deeply inspired by one (Odum and Odum, 1981 for Burris; Darrow and Saxenian, 1993 for Blyth). The academic connection has continued with many of the Lighting Africa generation of companies growing out of institutions such as Stanford, Cambridge and Imperial College London. This latest generation of pioneers are equally influenced by contemporary global discourses but today these are less about appropriate technology and more about connectivity, the Internet of Things (IoT) and smart technology.

Another more recent pre-occupation is the brand. Unlike in previous decades when the brand was the individual (typically the Kenyan installer) or the thin copper lines and dark blue rectangle of a solar panel that would attract customers to shops and thieves to houses, companies such as Walsh's Greenlight Planet today push their brand (name, colour and form) in a competitive market rather than push the technology more broadly as their predecessors had done. The identity of these brands as coming from outside is still present; however, with packaging stressing that products are: 'Designed in USA' or 'Engineered in UK'. Notable exceptions to this are companies such as Solinc and M-Kopa that stress their Kenyan identity. But beneath the Kenyan colours of the M-Kopa brand their practices and products follow the 'outsider' line in keeping users outside of the products and not connecting to local electronic retail or local electronic repair networks. That aside, the very concept of a brand is an outside concept. In Kenya for many goods, especially in rural areas, the distinction between products is more binary: between Chinese and original. Informed by experiences with other consumer and household electronics, users in Kenya rarely distinguish between the Lighting Africa associated brands (that is d.light, Greenlight Planet, M-Kopa and others), instead they work on that more binary distinction between 'Chinese' (a by-word for poor quality) and 'original' – referring to quality products. The lack of brand significance is an example of the different planes that the international actors are working on from the local.

The material and geographic shift from locally assembled systems to products imported from China and Hong Kong, although resolving questions of product consistency, low costs and manufacturing at scale, has still maintained the colonial power dynamic of the industry. Assemblage thinking

helps us see beyond the product and into these networks, relationships and historical precedents that have made that product possible, and crucially the times when those surrounding relationships might prevent the product from functioning. Events such as Burris being arrested in connection with the attempted coup against President Moi and when Fred Migai's Fomax warehouse was broken in to around the time of a fraught election in Kenya – both offer non-material examples of when the assemblage can break down. It is not just the literal breakage of the panel Knight sent to Blyth through the post that stops solar technology from working then. Disconnects and political differences in the assemblage also play a role. These are discussed collectively in Chapter 3 under the umbrella of breakdown.

I suggest that the outside shaping of off-grid solar in Kenya is an example of pursuing development through ingénieur's thinking. The ingénieur does not look at what already exists but focuses on what should exist. By adopting this forward-looking stance and creating a whole new solution or response to a challenge rather than building from existing and accessible ideas, skills and resources as bricoleur thinking would dictate, the ingénieur forgets or is blind to that which was already there and that which is left behind from previous inventions. It is a perspective that corresponds to the colonial outlook where Africa (or the Global South) appears as a figure of absence in the Western mind, a negative space (Mbembe, 2001) upon which plans and projects can be applied. The development of PV over the almost 40 years covered here has left physical traces around Kenya. That most of the systems were in place when I went to visit them in 2016 is no surprise. Similar to conversations with users of today's products there is often uncertainty over responsibility for systems and their repair or disposal so they end up just waiting in place. The use of old equipment as educational aids or toys is also something that occurs today. These long periods of waiting accompanied with occasional repurposing allow products and systems to disintegrate with different parts ending up in different places. These practices, and their consequences, are explored in Chapter 4, but first I look in more detail at the contemporary market; how it has been built and what that construction means for breakdown, repair and disposal.

2

Market Devices: Quality Standards and Impact Metrics

Two trade centres, two markets

In 2012 the Lighting Africa model was expanded to Asia through a programme logically called Lighting Asia. Together they became part of a Lighting Global family of programmes which has since expanded to include Lighting Pacific and Lighting Middle East and North Africa (MENA). In the move from Lighting Africa to Lighting Global, a new organization was founded: the Global Off-Grid Lighting Association (GOGLA). GOGLA was established as an independent, not-for-profit industry association to oversee the legacy of the World Bank's initial efforts towards catalysing a market. Based in the Netherlands, GOGLA works to increase company access to finance, lobby national governments to shape policy and globally harmonize quality standards. It consults with its members (mostly manufacturers, distributors and investors) through thematic working groups covering topics such as: business development, impact, policy, sustainability and technology.

GOGLA's work has also involved taking over the organization of a series of conferences that Lighting Africa had begun in Accra, Ghana in 2008. When opening the fourth edition of the International Off-Grid Lighting Conference at the Dubai World Trade Centre, Harry Verhaar, the president of GOGLA, said, 'we need to bring those people into the global equation'. Verhaar was referring to the 1.2 billion people then living without regular or reliable access to electricity (23: OECD and IEA, 2015).[1] His global equation was the off-grid lighting market. Fostered since the late-2000s by the IFC, the co-organizer of the Dubai event, under its Lighting Global programme, it is a market that, as Chapter 1 demonstrated, is rooted in International Development: Verhaar's opening address was followed by a video message from Nobel-prize winning development practitioner Muhammad Yunus, who was succeeded by the then UK Minister for International Development, Grant Shapps MP. Yunus talked of how dealing with individual households

is quicker to implement than at a community level, while Shapps spoke of a race between companies from village to village. The script they were each reading from was of a market-based approach to development, of universal energy access provided by commercial competition. In addition to profits the off-grid solar industry claims contributions to job creation, income generation, environmental benefit, health improvement and educational attainment. These claims were proudly displayed in PowerPoint presentations on the stage at the GOGLA-IFC conference and on marketing materials and boards in the booths of the accompanying exhibition. I was in Dubai to speak at the conference. I presented in a session on Environmental and Social Sustainability Across the Value Chain (GOGLA and IFC, 2015), which I had helped organize through the Sustainability Working Group at GOGLA.

If you take the metro five stops east from the World Trade Centre, you cross Dubai Creek and arrive at Baniyas Square in the heart of the Deira district of the emirate. Here multi-lane boulevards become bustling alleyways, and hotels sat back from the road are replaced by cafes that spill out on to the road. Historically the commercial centre of Dubai, one area of Deira is known as Satellite Market, so named for its original speciality – the satellite dish for domestic television. Satellite Market has since diversified to become the electrical and electronic trading centre of Dubai. The area is now full of shops and indoor markets selling car radios, office fans, LCD screens and more; from component level to complete products. Satellite Market also sells solar lanterns and home systems.

During a tour of Nairobi's equivalent neighbourhood around River Road and Luthuli Avenue in the Central Business District (CBD) a few weeks earlier, I had been struck by retailers telling me that they sourced products from Dubai, especially knowing I would travel there for the conference. And so after the conference closed I moved from a four-star hotel in Al Jaffiliya (near the World Trade Centre) to a less-lauded establishment in Deira to learn more about a market that was absent from the conference hall. Over the next five days I visited a dozen retailers selling solar products. The retailers I spoke to were not aware that there had been a relevant conference taking place along the road. They were more concerned with telling me about the function (hours of light and brightness settings) of these products than their impact (reduced eye and lung problems by replacing kerosene). In Deira, products just light homes and charge phones. This function focus perhaps stems from the close connections the retailers there have with the wider (and older) electronics market. This broader, more established, electronics market has never experienced the same efforts to catalyse or create a demand that was discussed at the conference and exhibition. The benefits of TVs and radios already being evident for those that can afford the appliances, or have the means to power them (a grid connection or a generator). Despite dealing with the same technology and targeting the same ultimate user,

'those people' that Verhaar mentioned, Satellite Market felt much further than ten minutes from the World Trade Centre.

A uniting feature of most of the products on display at the conference was their shared certification by the Lighting Global programme. None of the products I saw in Deira had this. One of the first activities of Lighting Africa (as was) was to set up a quality certification scheme. Companies which are willing to pay can put a sample of their products through a testing process in order to meet the Lighting Global quality standard. While it is only the products themselves that are tested and carry the certification mark, the centrality of the mark to the market at large, in negotiations with investors and funders, discussions with national governments, national industry bodies and national trade associations, as well as in sales training and marketing pitches, makes it possible to speak of certified actors and a certified market. Certified actors are those companies, organizations, investors and individuals who use the certification (test and mark) to advance their own interests: be they political, commercial or altruistic. Certified actors describe themselves as 'certified' in order to differentiate from those outside of the conference walls. The approach found in Satellite Market is referred to as the *non*-certified market. The *non-* is not intended as a value judgement that gives those I spoke to in Deira, their networks and transactions, less legitimacy but simply to indicate that they do not carry, nor are they interested in, certification.

This chapter, and the book at large, are weighted towards the certified market. With no collective identity in an industry association, no controlled supply chains and rarely publicly available contact details (or physical premises) it is harder to access non-certified actors. This is particularly true as a White European – the non-certified market is dominated by African and Indian traders. It was clear from my short stay in Deira that it would have been difficult to gain further access to those spaces especially where they are not as accustomed to academic researchers and research. The certified market, on the other hand, as emphasized in the previous chapter, is populated by White Europeans like myself as well as White Americans. And the certified market's other interest (alongside quality) is impact. To measure impact, one requires researchers and so my presence as an academic in their offices, shops and email inboxes was less unusual than it was on the roadsides, and in the cafés and budget hotels of Deira.

The chapter begins by discussing the concept of market devices and their role in the creation of the two markets. In the second section I look in more detail at the Lighting Global quality standards, how quality is understood and what the standards include and exclude. In the third section I introduce the GOGLA impact metrics, another device that is used to build and maintain the certified market. I then move to Kenya to look at how the certified market uses these two devices to create legitimacy by lobbying local and regional governing bodies to also adopt them, thus bringing new actors

in to the assemblage. In the penultimate section I set out the various sales channels through which products (certified and non-certified) make their way to sites of use in rural Kenya, based on the case of Bomet, a small town in the south Rift Valley. Here at points of sale and in sites of use the divisions between certified and non-certified are increasingly blurred. I close the chapter with a suggestion of what this self-designed, self-defined, certified market means for the breakdown of solar products, for their repair and ultimately their disposal.

Market-making devices

The Lighting Global quality standards and the GOGLA impact metrics which differentiate the certified from the non-certified market are market devices. A market device is a term from economic sociology used to refer to 'the material and discursive assemblages that intervene in the construction of markets' (2: Muniesa et al, 2007). Market devices qualify market objects, in this case the solar products, and so make economic transactions possible. They are both material and performative. That is to say that they do something and they also represent something. The quality standards, for instance, measure the quality of products in a material sense yet they also act as a boundary between the certified and non-certified markets. Market devices can work at an instrumental or operational level or they can work at an analytical or observational level. The impact metrics, for example, are an analysis of the market's effects, but they are also operationalized to allocate funding or secure investment. This section of the chapter describes how the standards and metrics, as market devices, do material and performative work to construct the certified (and non-certified) market. But crucially I take the concept beyond market construction to show how the devices also shape the afterlives of solar products at times and in spaces outside of the market.

For market devices to intervene and perform in the market, they require 'highly consequential investments in economic knowledge and analytical techniques' (10: Muniesa et al, 2007). And so, in studying market devices, 'close attention' must be paid 'to the different types of knowledge required to produce and stabilize [the devices]' (5: Muniesa et al, 2007). The knowledge and techniques behind and in the quality standards and impact metrics are discussed later. First, a discussion is needed of the role of market devices in ongoing market construction.

Although IFC and GOGLA are not the only development actors active in the solar assemblage, their early and central involvement in the market formation have made them the dominant ones. Prominent peers such as the German Corporation for International Cooperation (*Gesellschaft für Internationale Zusammenarbeit*, GIZ) and the Foundation of Dutch Volunteers (*Stichting Nederlandse Vrijwilligers*, SNV), for instance, broadly work within the

IFC and GOGLA established framework, especially on consumer awareness and sales training. In Kenya the two development organizations jointly run the Energizing Development, or EnDev, programme. During a conversation with John who works on EnDev from SNV's side, he assured me that 'we have to be neutral when it comes to products'; although that neutrality was only with regards to certified products, they can and are impartial against non-certified products. And when I attended a GIZ training session in Eldoret in the Rift Valley we were given presentations by Sollatek and Greenlight Planet – both certified actors – but no non-certified actors had been invited to attend.

In addition to other development actors, a large target audience for the impact metrics and quality standards are investors and government departments. Using sales data reported by members, GOGLA and Lighting Global are able to quantify the certified market and so establish a space that less familiar international investors are increasingly willing to enter. Although increasingly recognizant of the non-certified segment, the lack of data on non-certified sales makes it less measurable and so sales statistics based on certified companies are used to further differentiate the two markets. The devices also reassure those in the worlds of social enterprise (SunnyMoney) and corporate social responsibility (Shell Foundation) that the products they buy or support are of a certain quality. Then there are grants, awards and competitions run by organizations such as the Ashden Trust, the Africa Enterprise Challenge Fund (AECF) and the Zayed Energy Prize that have also been the preserve of certified companies and organizations. Those featured in the media coverage (Okonjo-Iweala, 2015; Prisco, 2016; The Economist, 2016) are also exclusively certified actors.

These two market devices and the bifurcated market they create are important for the chapters that follow because they shape how breakdown is understood (Chapter 3) and how it is responded to (Chapters 4–6). The market devices define quality on a material basis and impact on an immaterial one. The quality standards require quality parts to be used but give less regard for their assembly alongside each other or for their interaction with human, animal and environmental actants in the assemblage. The quality standards do not consider product performance in moments or processes of repair. Meanwhile, the impact metrics track and account for the positive, non-material benefits of certified products but do not highlight the material risks they present when disposed of. The impact metrics do not adequately account for the material longevity of products and their potential negative environmental impact if not appropriately disposed. The two devices bring in to the solar assemblage specific understandings of quality and impact that, when enshrined in a label or on a website and tied to pre-existing authorities such as the International Electrotechnical Commission (IEC) and the Impact Investing and Investment Standards

(IRIS), leave them less open to questioning and critique, turning attention instead to their enforcement and implementation. The market devices are a micro-example of the global process whereby Enlightenment rationalism 'has been made to look obvious far beyond the ground where it originated' (43: Chakrabarty, 2008). The devices take on an authority that obfuscates their political and cultural origins allowing them to be presented as neutral and incontestable. The devices propagate a limited understanding of breakdown, limit the opportunities for repair and absolve certified actors of responsibility for waste management.

The next two sections of this chapter explain how the quality standards and impact metrics make the off-grid solar products in a certain way. The two sections show how the two devices were created, how and where they are manifested (in documents and in practice) and their consequences for breakdown, repair and disposal. The chapter turns first to the quality standards.

Device #1: quality standards

First introduced in 2009 the Lighting Africa (now Lighting Global) quality standards are the defining feature of the IFC programme. The standards are a series of indicators which exist 'to protect buyers and consumers and effectively regulate the marketplace' (Lighting Global, 2024). They also serve to give investors' confidence in the market. To gain certification, at the time of writing (Version 7.1 for Pico-PV, Version 2.3 for SHS kits), pico-solar products (PSPs) or solar home systems (SHSs) must meet a minimum benchmark in six areas (2: Lighting Global, 2017a):

- Truth in Advertising
- Lumen Maintenance
- Health and Safety
- Battery
- Durability and Quality
- Warranty

Product test results are valid for two years, during which time products can be tested in-market and at the end of which products must be *re*-tested for renewal of the certification (1: Lighting Global, 2018b). The selection of products and the frequency of 'Market Check Testing' during the two-year validity period is at the discretion of Lighting Global (1: Lighting Global, 2018a). Here I split the six test measures into two groups:

1. Internal, product performance (covering Lumen Maintenance, Health and Safety, Battery, and Quality and Durability).
2. External, product surroundings (Truth in Advertising and Warranty).

I argue that while the standards put the responsibility on manufacturers to make products that perform consistently, to offer a warranty and to tell the truth to consumers, those responsibilities are limited in time and in scope. First, the internal elements of the product's performance are tested only in the time that it is functional; its performance in other stages of its life such as repair, recycling or disposal are not included. Second, the external elements of advertising and warranty do not assess whether or not a warranty is actually serviced and how.

Although a critique could be made of the way the standards were developed, are calculated or tested, this section of the chapter is instead focused on what they do not include. The standards' focus on the material quality of the product neglects non-material factors that can affect performance. Focusing on the performance of the constituent parts (lumen brightness, number of battery cycles, physical resistance of plastic) ignores their collective assembly and the wider assemblage where products interact with humans and animals giving rise to problems and breakdowns. The quality standards protect individual elements of the product and the product itself from particular breakdowns but, as Chapter 3 will demonstrate, there are other types of breakdown that have little to do with the material integrity or functionality of the product. Nor do the standards address how the constituent materials connect to each other. This has consequences both for the ability to repair a product and for the quality of waste materials the product becomes later. If materials are mixed or stuck together then their re-sale or recycling becomes more time and so cost-intensive or simply impossible. There are, of course, reasons for the exclusion of these elements. It is not the exclusion that is critiqued per se but what it reveals of the understanding of certified actors: a heavily material view of product performance that simultaneously neglects materiality beyond use.

Internal product performance

Of the six measures within the standards *Lumen Maintenance* is perhaps the one most visible to the user. The light output of products after 2,000 hours of operation needs to be '≥85% of initial light output' (2: Lighting Global, 2017a). Although an important measure, there is an irony in this being the sole mention of maintenance in the standards. It is not maintenance with hands or by human intervention but a maintained level of performance inherent and in-built to the LEDs within the product. The measure does not include, for example, the ability to replace the LED – another form of maintenance.

To pass the *Health and Safety* measure batteries are not allowed to contain more than trace amounts of dangerous metals mercury or cadmium, as defined in the European Union (EU) Battery Directive (2: Lighting Global,

2017a). The measure also says that if an AC–DC charger is included with the product that it must be approved by another consumer electronics safety certification. The accepted marks are 'UL, CE TÜV Rheinland, CCC, or similar' (5: Lighting Global, 2017a; see Lighting Global, 2016a for more detail on these adjacent certifications). The concern here for both human and environmental health is commendable, yet limited: there is no control for cobalt or lead, two other hazardous metals (Demayo et al, 1982; Brock and Stopford, 2003) in batteries or the presence of cadmium and mercury – two other harmful metals (Godt et al, 2006; WHO, 2024) – in panels and LCD TV screens.

History suggests (see Chapter 1) and interviews also attested that batteries are central to the performance of the solar product but are also often their weakest part. Perhaps recognizing this, there is a measure in the standards that applies to the *Battery* specifically in addition to its inclusion within the Health and Safety measure. The battery-specific measure stipulates that the battery in products '[m]ust be durable and adequately protected' (1: Lighting Global, 2017a). However, similar to the lumen measure, there is no recognition of the position, accessibility or replaceability of the battery.

The fourth area that focuses on the internal performance of the product is *Durability and Quality*, which requires products to have '[a]ppropriate protection to prevent early failure' (1: Lighting Global, 2017a). Rather than referring to the electrical protection of a charge controller as in the Battery measure, here 'protection' is understood in a more physical sense. It covers Physical Ingress Protection (for dirt and dust), Water Protection (for rain and moisture), a Drop Test (from 1m), soldering quality (as defined by IEC), switch durability and Strain Relief Durability (of cables). Durability and quality matter and these areas cover the key causes of failure that users spoke of in my survey. 10 per cent mentioned a fall or water damage as having caused them problems with their product. The measure, however, is based on a material understanding of durability. The measure does not allow for durability that draws on other elements of the solar assemblage, namely human hands, skill and spare parts to replace the LEDs, battery, switch or cables that could keep products running longer.

External, product surroundings

Although not compulsory companies sometimes mark the Lighting Global certification on their packaging and at times in advertising materials. What the standard does specify, under the *Truth-in-Advertising* measure, is that any information companies do provide to the user through labelling is '[a]ccurate' (1: Lighting Global, 2017a). This could include information such as brand name and model, light output and run time, or the use of auxiliary appliances. This information never seemed to be that important

to users I encountered. Others have found a similar lack of importance for labels on packaging materials (Harrington and Wambugu, 2021). Instead of receiving information through packaging, which could even be left at the point of sale, users were more likely to remember the information given to them from a sales agent or retailer.

The second measure that applies to the product surroundings, the external more social aspects of the assemblage, is that of *Warranty*. To pass, PSPs must have a consumer-facing warranty 'with at least one year of coverage' (1: Lighting Global, 2017a). For SHSs this must be two years for the main system (that is, the battery and lights) and one year for 'most included appliances' (TVs and radios, for example; 4: Lighting Global, 2018d). The measure acknowledges, despite the protections and material qualities specified previously, a product's ability to break down (if not its propensity to do so). However, the standard does not concern itself with the quality of that warranty: companies only have to offer a warranty, they do not necessarily have to honour it. Nor is there any verification of their presence or ability to do so. Further, while the measure states the warranty information must be written 'in a regionally appropriate language', there is more to the consumer's comprehension than whether the language is locally understood, there is a question about whether the very practice of a manufacturer warranty is locally understood or locally practised.

The standards, as a market device, both reflect and shape the nature of the products that make up the certified market. Performance is only measured of functionality not non-functionality (repair or recyclability). Components are tested but not how they are assembled, and so could be disassembled. The standards define quality in a material way that neglects other aspects of the assemblage where quality could be important such as the quality of information or the quality of relationships. Quality is also limited to one lifetime of the product and not the possibility of second or third lifetimes through the continual replacement of parts. For SHSs there is an extra measure called 'Consumer Information' which at least acknowledges the concept of replacement, if still allowing manufacturers to make a 'clear consumer-facing statement that the batteries and other components are *not* replaceable' (emphasis added – 4: Lighting Global, 2018d). The tying of testing methods to existing IEC practices and safe limits to EU legislation gives the Lighting Global standards a sense of broader legitimacy, connecting the certified market to wider, older regimes of governance thus widening the assemblage. The standards simultaneously impose geopolitical boundaries to the market too; the fees involved to secure certification limit access for Kenyan owned and run companies. One manager of a Kenyan solar company told me 'it's a long process and an expensive one' with another telling me it 'is very expensive for us'.

The next section explores what these quality products do (as a whole) as opposed to what their component parts can do independently.

Device #2: impact metrics

In January 2016, a couple of months after the conference in Dubai, a set of metrics to measure the social impact of the off-grid solar industry were approved by IRIS. IRIS is a global initiative which aims to increase the scale and effectiveness of impact investment through better measuring impact. The impact metrics for the off-grid solar industry are a second market device that both creates and protects the certified market. In 2013 GOGLA convened a Working Group, as they had done for the quality standards, to 'produce a harmonised industry standard for reporting on social impact' (5: GOGLA, 2016). The first version was released in June 2015. The target audience for this market device is regulators and investors, the metrics exist 'to attract investment, working capital, and regulatory support for the off-grid lighting industry that will help the sector to scale' (5: GOGLA, 2016).

Although early versions referred only to PSPs the metrics have since been expanded to include SHSs. The current metrics, Version 2.0 (released in January 2016 and aligned with IRIS), cover six areas (4: GOGLA, 2016):

- Lives impacted
- Livelihoods supported
- Status quo lighting sources no longer in use
- Change in available lighting service
- Money saved
- Greenhouse gas emissions offset

This section of the chapter groups these six metrics into three groups:

1. Energy access (Lives impacted, Change in available lighting service).
2. Economic impact (Livelihoods supported, Money saved).
3. Environmental impact (Status quo lighting sources no longer in use, Greenhouse gas emissions offset).

I argue that the metrics, as with the standards, are limited in scope and time. The metrics only track *positive* impacts and only those that occur when the product is functional. In tying the measure of energy access to the source of energy (the sun), rather than the material product that makes that energy usable (the solar product) the impact metrics are able to overlook the greater recyclability of kerosene lanterns (glass and steel) against the potentially more damaging solar product (containing toxic metals and plastic). In limiting economic impacts to the first lifetime of a product (assumed to be 1.5 times the warranty period; 6: GOGLA, 2016) the metrics do not account for possible positive impacts available through repair or refurbishment that could give a product a second lifetime. Finally, in limiting environmental

impact to emissions offset, the environmental impact of the material product at the end of its lives is not accounted for, when products may be disposed of in local environments.

A critique could be made of the metrics themselves, their calculation and their measurement. A lot of the metrics, for instance, are based on problematic assumptions such as products being used at home, rather than at work or school; or all members of the household having equal access to the product. However, like with the critique of the standards the focus here is not on how the impact metrics are calculated but more on what they do not measure, the impacts they do not promote. If the quality standards are too material in their focus on inherent material properties and performance of discrete components, then the impact metrics are too *im*material in their focus on intangibles such as light, money and gases, at the expense of the very tangible, very physical, impact of waste batteries and plastics in the ground.

Energy access

The impact metrics define energy access as having *more* light for *longer*, and it being generated from *modern*, *renewable* sources. To measure this, the metric is split into assessing an 'improved' source and an improved output (17–19: GOGLA, 2016). To qualify as being an improved source the metric assumes solar products are being used in households where there a 'worse' energy source was being used beforehand. According to the survey this was true in 75 per cent of cases. 'Worse' sources are sometimes referred to by certified actors as 'traditional' and include kerosene, candles or non-rechargeable battery-powered torches and lanterns. The metric assumes a one-for-one replacement of that 'worse source' and that it is no longer in use. But in some of my home visits, I was told and saw that 'worse sources' came back in to use especially when the solar products had had problems. Similarly, in the survey a third of those spoken to said they had continued to use the 'worse' source alongside their solar product. While solar does provide more light for longer and is renewable, the simplified narrative of like-for-like replacement and the traditional-modern energy source binary may appeal to investors and policy makers, but it is not reflected in practice.

Economic impact

The economic impact group covers two metrics: *Livelihoods supported* and *Savings on energy-related expenditure*. The livelihoods metric is split in to two categories: those who use the products for their business (that is ,to charge phones or to light a kiosk) and those employed in the distribution chain. The limiting of the employment category is telling in itself: that jobs at the management, design, engineering or finance stages of the supply

chain are not considered. For most of the certified actors these jobs are at headquarters, often outside of Kenya. Further, this means the metric does not include those working outside of the certified market: either in servicing products or selling them alongside other electronics. Admittedly, the Impact Working Group are reviewing the inclusion of the distribution chain part and so it may be removed from future versions of the metrics (16: GOGLA, 2016). Another limit to the livelihoods measure, however, is that it does not account for jobs *lost* through the growth and scaling of the market: this could be people involved in the kerosene supply chain for example (see 158–9: Davies, 2014).

The *Savings on energy-related expenditure* metric is calculated as the amount of money a household saves on lighting and phone charging after the purchase of a solar product, for the lifetime of that product. Possible savings on other related expenditure such as radio batteries are not included. The main issue with this metric, however, is its basis on a product lifetime of 150 per cent of the warranty period. In ignoring the possibility of repair and extending product lives beyond that time period the metric does not account for possible further savings in pursuing a repair rather than re-purchase.

Environmental impact

The environmental impact includes measuring status quo lighting sources that are no longer in use and greenhouse gas emissions offset. In addition to my own empirical examples, other scholars have found evidence of energy stacking where multiple different sources are used in tandem (Hiemstra-van-der-Horst and Hovorka, 2008; Brew-Hammond, 2010). This further undermines the usefulness of a metric that risks simplifying the complexities of household energy politics.

The second measure of environmental impact: offset greenhouse gas (GHG) emissions, is not currently in use (22: GOGLA, 2016). This is perhaps because, as the working group itself concedes, it is: '[i]ntrinsically difficult to pin down a precise estimate for life-cycle impacts because of the dynamic and connected nature of global economies' (23: GOGLA, 2016).

While GHGs are important there is more to the current global environmental crisis than emissions, such as electronic waste, for instance. It is of little surprise that the environmental impacts are the least measured as they are in many ways assumed, and assumed to be positive.

In the introduction and background to the document that outlines the current metrics it mentions that 'many of the *benefits* from off-grid lighting are difficult to track directly' (5: GOGLA, 2016; emphasis added). These other areas that the authors know solar affects but they do not yet know how to measure effectively are: health; education; the productive use of energy; and household income, are foci for the future development of the metrics

(45: GOGLA, 2016). While some of the other impacts I suggested in this section (livelihoods through repair or environmental impact of hardware) would also be difficult to track and would also rely on a range of assumptions to the ones already in use, they would give a more holistic perspective on the impact of these products.

The indication of the future direction of the metrics confirms that they will continue to measure positive impacts, confirming itself not as neutral assessment of the impact but rather as a normative one that aims to support the industry. The Working Group explains in one document how the metrics allow adopters to 'speak with a unified language of *positive* change' (emphasis added – 5: GOGLA, 2016). Future metrics will not incorporate negative impacts such as the interaction of lithium with ground water or the contact between soil and plastic. Nor do future versions of the metrics look likely to include positive afterlife impacts that could be had on repair and waste livelihoods, or the economic savings to customers through the refurbishing or re-selling of products that increases energy access.

If standards shape the boundaries of the product, then metrics shape the boundaries of the market. The metrics strengthen the role of impact investors within the solar assemblage and also legitimize a particular type of quantitative knowledge regarding users' experiences of products. By removing differences of product and context, impact metrics facilitate comparison across countries and companies. Similar to the quality standards connections to benchmarks and tests of the IEC, linking the impact metrics to the official IRIS catalogue gives the GOGLA measures credibility to a wider audience. This credibility is crucial in then using the market devices to create a favourable policy environment across different countries. This operationalizing of the market devices is discussed in the next section.

Lobbying for local policy

On the second day of the Dubai conference I attended a panel called: 'Achieving National Level Policy Change: The Case of Kerosene Subsidies, VAT and Tariffs, and Quality Assurance'. At the end of the session I approached one of the panellists, a Standards Officer at the Kenya Bureau of Standards (KEBS). Before I could even ask the officer, Alex Mboa invited me to come and visit him at his office in Nairobi where we could discuss more. And so, after my ten days in Dubai I returned to Kenya (in November 2015) and made my way to Mboa's office in the south of the city. The KEBS Head Office is just off of Mombasa Road, conveniently, and strategically, situated between the retail hub of the CBD and the industrial warehouses that line the road out to the city's airport and ultimately the coast. During our meeting Mboa told me how Lighting Global had brought a draft set of standards to the bureau and were asking for national standards to be put

in place in order to give Lighting Global's aspirational quality standards a legal basis.

This section of the chapter, like the session in Dubai, discusses quality standards, taxation and government policy. I argue that the quality standards and impact metrics are used by the certified actors as market devices to advocate for favourable policies in the countries where they work. Embedding the limited market devices into national regimes of governance, like the linking of their calculation to international bodies, gives them a credibility and legitimacy in which discussion becomes more a question of how effectively they are implemented rather than discussing, as the previous sections of this chapter did, what the devices might exclude or who and what they may favour. Advocacy efforts serve to favour certified actors only and not the non-certified actors. The focus of these policy efforts has been on aligning national standards with the Lighting Global ones, lobbying for VAT exemptions on certified product imports and on greater recognition of off-grid options in national energy policies; all of which aim to increase sales. Taking each of these three areas in turn I show how the certified market neglects responsibility for other affected policy areas such as in-country manufacture, product repair and waste management. Enlisting national actors in to the solar assemblage, also further reduces the agency of domestic players to determine their own corporate practices (Michael, 2003) and could be seen as part of a macro-level imposition by the outsider.

Making global standards national

North of Popo Road and over the railway from the KEBS headquarters is the Upper Hill district of Nairobi. The district is home to the World Bank's Kenya headquarters and the national Energy Regulatory Commission (ERC). This geographical proximity to the World Bank was echoed in an interview with Nickson Bukachi, a Technical Officer for Renewable Energy at the ERC. Just under a year after my meeting with Mboa, Bukachi told me about a meeting he had had with the World Bank the week before our interview. In the meeting Bukachi said that the World Bank really wanted to know what the ERC was doing in relation to providers of smaller systems because: 'without regulation, them [the World Bank] giving finances now becomes a challenge'. This requirement of regulations as a pre-requisite for financial support is an explicit demonstration of the outside influence of the certified actors. The ERC exists to regulate, and collects data on, energy products and industries in Kenya. Most of its work within solar was to set up a standard for technicians installing the battery-based systems mentioned in Chapter 1, the component-based ones prominent in Satellite Market. The current three-tier classification of systems 'did not capture the small, small systems' Bukachi said; these are 'systems that do not require any installation'.

The aim of the domestic regulations had been to address the more historical concerns of bespoke (component-based) solar home systems being over-sold or under-sized (see Chapter 1), not the pre-defined plug-and-play variety espoused by certified actors. Nickson, however, was reluctant for the ERC to regulate the smaller systems as well.

The push from the World Bank away from licensing technicians to certifying products perhaps reveals the belief and conviction held by the certified actors in the ability of these products to operate as objects independent of their interaction with humans rather than as part of the solar assemblage.

Tax: exemptions and definitions

Moving further north from Upper Hill, on the other side of Uhuru Park, is the head office of the Kenya Private Sector Alliance (KEPSA). Despite indicators from KEBS and ERC to the contrary, I was trying to find evidence of a domestic off-grid solar agenda and wondered if KEPSA might offer some. As we sat across from each other in a large board room in September 2016, Laureen Wesonga, a policy analyst at the alliance, told me that the Kenya Renewable Energy Association (KEREA) had recently approached KEPSA asking for support to revise a piece of regional legislation. In June 2016 the East African Community (EAC) – a regional body that aims to increase integration across Burundi, Kenya, Rwanda, South Sudan, Tanzania and Uganda (EAC, 2017) – separated electricity generation equipment from appliances in the application of VAT (EAC, 2016). The EAC decided that assembled solar products (the electricity generation part) were to remain 'zero-rated' (given a tax rate of 0 per cent) but imported additional parts or accessories (such as TVs within SHS kits) would be subject to taxation (EAC, 2016). KEREA was asking KEPSA if they could push for the reversal of this amendment with the East African Business Council (EABC) – a regional platform that aims to create a more conducive business environment through 'targeted policy reforms' (EABC, 2018). While KEREA and KEPSA are both national bodies, the campaign to remove VAT duty on accessories for solar systems was initiated by GOGLA. The month before my meeting with Wesonga the association had written a letter to the leaders of the EAC on the issue calling for accessories and spare parts to be 'explicitly *included* in the list of import tariff exempted goods' (emphasis added – 1: GOGLA et al, 2016). Although the letter mentions 'spare parts' the only examples listed in the letter are 'accessories such as fans, fridges, radios, or TVs' (1: GOGLA et al, 2016). No mention is made of replacement batteries, modules or LEDs. The certified market favours growth through the sale of more appliances over extending the lifetime or preventing the breakdown of those appliances. The campaign is an example of a certified actor (GOGLA) using the market

devices (only certified products would be zero-rated) to gain favourable conditions in the country and region.

Policy

Less than a kilometre east of KEPSA are the offices of the Ministry of Energy and Petroleum. In September 2016 the Minister for Energy and Petroleum, Charles Keter, opened a different conference, that of the International Renewable Energy Agency (IRENA[2]) with words of Kenya's commitment to renewable energy. I was sceptical, however, given that just the previous month the government had announced that Kenya would be exporting its first barrels of oil by June 2017 (Namunane, 2016). Watching the minister on stage at a well-known Nairobi hotel I could hear Wesonga's voice in my head: 'it's one thing for a government to tell you "we are keen on renewable energy" but it's another, what is it they are doing to promote that renewable energy you know? The devil is in the detail.'

I had heard similar from Willis Makokha, the head of the Renewable Energy Division at the Kenya Industrial Research and Development Institute (KIRDI), who told me that small solar was not a focus for the government. Of course, there is a hint in the name of the Ministry itself that priority is not towards renewables. Although the plan would later stall (Okoth, 2017), in June 2018 Kenya exported its first barrels of crude oil (Kiplang'at, 2018). The Kenyan government's historical role in the off-grid solar industry is debated: some argue it has been limited (Hankins, 2000; Ondraczek, 2013) while others (Byrne, 2009; Bawakyillenuo, 2012) put more emphasis on its contribution. Most scholars, though, recognize the role of foreign, non-government actors as having been more influential. As highlighted in the previous chapter in earlier decades these actors were individuals (Burris, Hankins, Keane and Blyth). In more recent times the outside influence has come in the form of institutions and companies, although still from the UK (DFID) and the US (IFC). DFID's Energy Africa campaign, for instance, which was actually launched at the conference in Dubai, lobbies national governments across Africa to agree to adopting Lighting Global standards, removing import duty on solar products and incorporating off-grid options in to government rural electrification policy (DFID, 2015).

The close relationships between domestic and international institutions: Mboa having been invited to the GOGLA-IFC conference in Dubai and Bukachi having met with the World Bank, highlight the influence that the international certified actors have over domestic agenda-setting and so decision-making. The focus on import policies and, to a lesser extent, energy policies, reveals that that agenda is geared towards market growth with little concern for the market's material footprint and later concerns such as product repair or waste management.

Selling the standards and the impact

Despite the efforts to keep them out of Kenya through the aligning of local policies to supra-national standards, non-certified products are still present in the country. In this section I argue that although sales processes are shaped by the quality standards and impact metrics, it is from the point of retail onwards that the certified and non-certified markets begin to merge and at times become indistinguishable.

In January 2016 I moved to Bomet, a town in the south of the Rift Valley, 220 km west of Nairobi. Over the course of the three months I stayed there I saw both the suave M-Kopa shop (a certified manufacturer and distributor) with its Apple Shop aesthetic (Figure 2.1) and the independent electronic store selling certified and non-certified products side by side (Figure 2.2). I also encountered mobile sales agents selling certified products and independent hawkers marketing non-certified ones. There were roadside tables selling certified products and second-hand products and many of the banks, microfinance institutions (MFIs) and savings and credit co-operatives (SACCOs) in the town were also engaged, or had previously been, in partnerships with certified actors to distribute products to their members and customers.

Figure 2.1: The inside of the M-Kopa shop in Bomet, which opened in early 2016 near the town's old stadium

Source: Author's image, March 2016

Figure 2.2: Olesoi Electronics, an independent electronics store on the main road through Bomet, opposite the bus station

Source: Author's image, March 2016

Previously no more than a transit trading centre between the capital, Nairobi and Lake Victoria to the west, Bomet has grown noticeably since 2010 when a new constitution introduced a system of devolved government in Kenya, creating Bomet County with Bomet town as the site of its County Assembly (168: National Council for Law Reporting, 2010). Sitting between the tea-growing hills to the north and the cattle-grazing plains to the south, centred on its bus station, and navigated by its four petrol stations, Bomet remains, like most towns in Kenya, more of a commercial than a residential centre. Bomet was chosen as a site for this research partly for its location in a highly populated region of the country, and so a focus area for the certified market, but also because Lighting Africa had hosted a training session there in 2013 with a focus on the maintenance of products (Lighting Africa, 2013).

In March 2016, I walked systematically around the town recording all the places and ways one could access solar products, which models were available and at what price. In total there were 40 different points of sale. These were made up of 30 shops (selling from a roofed structure); five bank, co-operative or microfinance institution schemes; two temporary stalls (plastic tables by the roadside); two roaming sales agents (with rucksacks); and one roaming hawker (also with rucksack) who dealt exclusively in solar products. There was also an occasional lorry-load of second-hand electronics that was

displayed on heavily crowded tables again by the roadside. The lorry that brought these second-hand electronics appeared twice in the three months I was in the town, each time for two or three days. I do not know where these electronics were sourced from, but I imagine they were collected from homes, repair clinics and various people involved in the waste management system around the country who can recover such items when discarded by others (see Chapters 3–6).

There were 56 different models of solar product available through these points of sale, representing 37 different brands: 12 certified, 25 non-certified. The brands available in Bomet informed which companies I sought to interview and observe in Nairobi. Although the share of sales points does not necessarily reflect the share of sales volumes, that there were more non-certified products available shows that in Bomet, like industry estimates for sub-Saharan Africa as a whole (12: Bloomberg New Energy Finance and Lighting Global, 2016), non-certified products represented a larger and growing share of the overall off-grid market against the certified ones. Similarly, that I found solar in 30 shops, only one of which belonged to a solar manufacturer (what is known as 'direct sales') does not necessarily mean that that is where most sales occur. Lighting Global, for instance, finds that sales agents and direct sales are the most common sales channels used with independent retail shops, bank/MFI partnerships, bulk distribution (say, in disaster or humanitarian relief) and corporate social responsibility (CSR) schemes (for plantation worker families, for instance) representing smaller proportions of sales (23: Bloomberg New Energy Finance and Lighting Global, 2016). These other channels did not feature in Bomet and so are not examined here. However, products purchased through these channels *are* included where I encountered them in their journeys through homes (Chapter 4), repair clinics (Chapter 5) and company premises (Chapter 6).

Beyond Bomet, in those villages where Shapps called for the race between companies the sales mix is different. Shop fronts in smaller market centres are less glossy and certified retailers are less common (particularly in terms of direct sales), even sellers of electrical goods display a less focused offering selling solar products alongside food supplies. Toroche Enterprises in Siongiroi, a small trading centre 26 km south-west of Bomet, is one example. In villages like Siongiroi the non-certified market can be seen as most clearly riding off the success of the certified one – Toroche Enterprises uses the painting of a d.light S2 to advertise its sale of solar lights, not just the d.light S2. In many parts of Kenya d.light has come to be used as shorthand for small solar lantern in a similar way that Hoover did for the vacuum cleaner. Regardless of whether the product they have or are selling is a d.light or a different brand users, retailers and repairmen alike all referred to off-grid solar products as d.lights or 'ma-d.lights' – a plural form borrowed from Swahili.

I did not spend much time in Siongiroi or other similar market centres around the county. But in passing through them en route to users' homes it became clear that most people travel to Bomet to purchase electronics where there is greater choice, better quality and lower prices.

At the retail level the certified market is most obviously distinguished by its branding. Certified companies brand their products, premises, staff, vehicles and other paraphernalia (such as umbrellas and baseball caps) in order to distinguish themselves from their certified competitors but also from the non-certified products which are often not branded at all. Yet it is in sales training and consumer awareness campaigns that the market devices that underlie that aesthetic distinction are found. Certified actors run trainings for independent retailers and sales agents that focus exclusively on certified brands. These trainings stress the quality of certified products and emphasize the impacts the products can have. Consumer awareness events such as market days are used to further support the certified market using similar language of quality and impact. As part of the sales pitch consumers are taught how to use products, in order to shape usage and minimize breakdown from the manufacturer's perspective. Warranty is also mentioned in sales processes but repair and disposal are rarely raised.

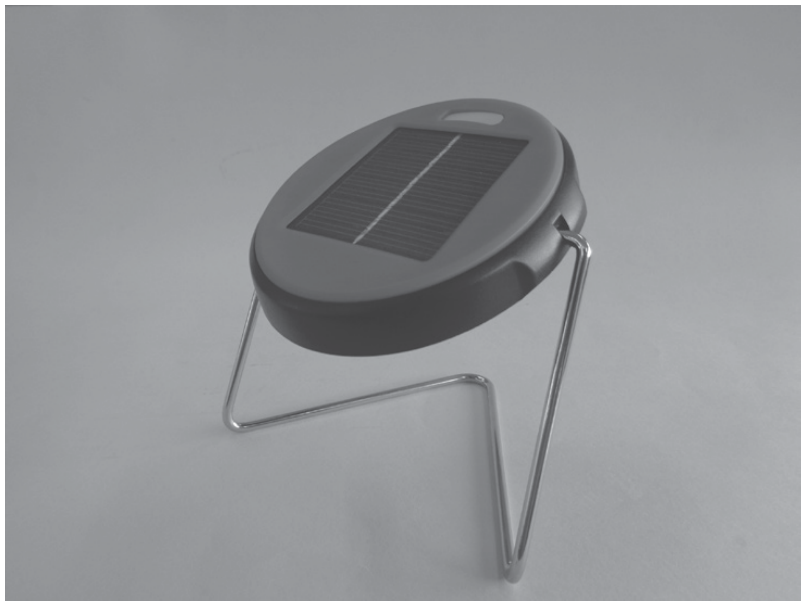
One unintended consequence of the branding efforts of certified actors is that without the resources, networks or possibly the interest in replicating the marketing and advertising strategies of certified manufacturers and distributors or becoming certified themselves, non-certified manufacturers increasingly mimic the form, colour and packaging of the most successful products in a bid to increase their sales. The similarities in product and package design allow the non-certified products to benefit from the awareness and policy campaigns of Lighting Global, GOGLA and others without actually being present at the sales training events or on the lorries at market days. The d.light S2 being one of the earlier and most successful models has been a particular target of this (see Figure 2.3).

Despite the internationalized efforts by the certified community and the increasing adoption of those international market devices within domestic regimes of governance, in smaller market centres the two markets are less discernible. The visual distinctions of shop fronts and sales channels come even more undone when one moves to the homes where certified and non-certified products are used alongside each other and in repair settings where certified parts might be used to fix non-certified products and vice versa.

Merging markets

There are two off-grid solar markets operating in Kenya today: certified and non-certified. The two markets are distinguished by their relationship to two key market devices: the Lighting Global quality standards and the GOGLA

Figure 2.3: An unbranded product that looks exactly like the best-selling d.light S2



Source: Author's image, September 2015

impact metrics. The devices appear implicitly in a promotional video from certified company d.light design as described by Cross:

> d.light design CEO Sam Goldman stands at a bench next to component parts, plastic cases and tools.[3] In the first half of the film, he picks up a Nova S200 prototype and describes its physical, material attributes, its battery length, its brightness and its charging time. In the second half of the film, he lists the range of potential benefits that this light could have for users, emphasizing that it can help people to study and work at night, cleanly and safely. (376: Cross, 2013)

The 'material attributes' of the first half of the film are captured in the quality standards, while the 'potential benefits' discussed in second half of the film are the basis of the impact metrics. Together they facilitate access to certain spaces, organizations and sources of funding and investment.

The typology of certified-non-certified is useful for keeping the quality standards to the fore in later analysis and also acts as a reminder of one community keeping out another based on a documentation process. The chapter has shown how the certified market, the focus of the rest of the book, focuses on the material qualities of the product at the neglect of its

interactions with other human, animal and environmental actors all of which, as the next chapter will show, can cause or be involved in breakdowns in the assemblage. This concluding section first describes the consequences of the divide between the two markets for the themes of the book: breakdown, repair and disposal. It closes by indicating how that division may change in the future.

The distinction between these two markets is important in the later chapters because whether a product is certified or not carries different consequences for its breakdown, repair and disposal. The certified market through its quality standards understands quality as a material measure. It seeks to delay (for we can never eliminate) breakdown through material means – by making better-performing products. In the non-certified market however less conscientious practice and lesser concern for quality means breakdowns often occur sooner. Although the certified market, through its more specialized approach and intensive presence in Kenya, has the greater potential to facilitate repair it is the non-certified market that is better placed to integrate with existing local repair networks, in part due to its close connection to the general consumer electronics market – where those repair practices are already well-established. In terms of what comes after repair the certified market is also better placed to establish responsible waste management for its products, yet it is its non-certified counterparts which, through less tightly controlled supply chains, could more readily move in to existing waste economies.

The underlying driver of the extensive work done by certified actors is to increase product sales. But 'alternative chains of circulation' (50: Bhattacharya, 2018) such as those found in the non-certified market can undermine those sales and so consumption. Repair and reuse sit in conflict with standardization and predictability upon which the certified market depends. The focus on new product sales also neglects what happens when products break down. While the quality standards mean that certified products generally last longer than the non-certified ones (Lighting Global, 2018c), they are not invincible, they too will break down. And as all the benefits tracked by the impact metrics are tied to the functionality of the product, when the product breaks down these benefits and claims are undone. So if breakdown is present on both sides of the divide, then what happens in response?

The certified market through closer connections between user and manufacturer and ongoing relationships post-sale through pay-as-you-go (PAYG) models may offer opportunities for repair. However, the focus on creating a market, improving the regulatory environment and increasing consumer demand limits this. The non-certified market, on the other hand, offers a greater opportunity for entry from local repair. Although there is no provision for repair by non-certified manufacturers there is equally no barrier to their integration to existing repair networks. In places like Siongiroi

and Bomet, generations of other electronics found on the same shelves of retailers in Bomet or of the wholesalers I visited in Deira have been serviced and repaired in independent repair clinics (see Chapter 5).

Finally, in terms of disposal the same trade-off is identified: the greater presence of certified actors makes product take-back (the first step of any waste management or recycling process) possible and branding makes identifying producers possible and so holding them to account. Although there is increasing recognition among certified actors of the need for adequate waste management the market devices in their current guise largely absolve certified actors of any responsibility. None of the traders I spoke to in Satellite Market were bothered by waste either and the looser, discrete and transactional links and longer chains of their non-certified market make it harder to hold those involved to account over the waste their products become. However, that same openness could make for easier integration into existing waste streams and markets with waste workers able to collect, buy up and sell on constituent materials.

The relationship between the two markets is changing, however. In Dubai the non-certified market was referred to in terms of counterfeits and copycats (4: GOGLA and IFC, 2015), yet just over two years later at the next gathering of the certified industry in Hong Kong the language had shifted to become affiliate and non-affiliate – less confrontational, more inviting terminology perhaps. The change in language could also be a reflection of, as admitted in certified market reports from the time (12: Bloomberg New Energy Finance and Lighting Global, 2016; 1: Dalberg Advisors and Lighting Global, 2018), the sizeable, majority market share of non-certified products in many markets. The term 'affiliate' also reflects a greater community of adherence, recognizing conformity to additional market devices beyond the quality standards such as the impact metrics. The location of the 2018 conference, right next to China, could also symbolize the merging of the two markets, demonstrating greater acknowledgement of the non-certified by the certified community. Such changes are not necessarily surprising, however. Industries 'are constantly re-negotiated, re-framed and re-mobilized in response to their environment' (167: Granovetter and McGuire, 1998). And in these processes of re-calibrating market devices are re-made too. Unlike more rigid *rules*, the ways in which market devices are 'tinkered with, adjusted and calibrated' affect the way people and things are 'translated into calculative and calculable beings' (5: Muniesa et al, 2007).

Another change in the certified market has been the growing attention given to the waste produced by the industry. Despite GOGLA and the IFC having held a workshop on the topic in 2013 (GOGLA and IFC, 2013) and the Sustainability Working Group at GOGLA having published an Industry Opinion on Lifecycle and Recycling in 2014 (GOGLA, 2014), Muhammad Yunus' opening acknowledgement in Dubai that 'one of the thing that

I have been talking about that I don't feel very comfortable because er that's a battery which is not very friendly to the environment. So we need to er, replace that battery. We need environment-friendly battery' passed largely under the radar. A separate session dedicated to 'Environmental and Social Sustainability Across the Value Chain', meanwhile, was attended by fewer than ten people. Yet, two years later in Hong Kong, the equivalent session filled its assigned room with nearer to 50 people. Meanwhile, industry elders DFID and USAID have funded initial research in to end-of-life topics. In 2016 DFID commissioned a report to look at the issue (Magalini et al, 2016). And in 2018 USAID launched a $1.8 million grant programme to finance innovation in the area (USAID, 2018). US and European investors are increasingly asking companies what their waste policy is and manufacturers are under pressure from third-party distributors to offer a solution, too, while they themselves face rising stockpiles of faulty products in their offices, workshops and warehouses (see Chapter 6). Although there is no current move to incorporate these growing concerns into either market device: the impact metrics or quality standards, there is an indication that waste and recycling could yet become another differentiating feature between the two markets with certified actors seeking to distinguish themselves from the non-certified crowd by putting in place responsible waste management systems for their products. Thus far Lighting Global discussions of end-of-life concerns have been kept to a series of working papers on topics covering Battery Toxicity, Hazardous Substances and Repair (Lighting Global, 2012; Lighting Global, 2013; Lighting Global, 2016b; Lighting Global, 2017b).

What is already clear is that 'whether they might just help (in a minimalist, instrumental version) or force (in a maximalist, determinist version), devices do things. [Market devices] articulate actions: they act or they make others act' (2: Muniesa et al, 2007).

The next chapter looks at how the market devices influence actions and processes of breakdown.

3

Breakdowns in the Assemblage

Functional products, broken relationships

At the end of the conference in Dubai, a colleague and I saw the solar waste we had each spoken about on panels a few days earlier.[1] As exhibitors packed up products and parts of products, that which they did not take away was either gifted to friends, colleagues or researchers – my colleague was given one – or left behind on the floor of the exhibition hall. These display and demonstration products, or parts of them, are generally functional but, once used in pitches or meetings from the stands and sofas of the conference hall, for the certified actors, they can no longer be sold or sometimes even used again at future events. The products which were left behind were most likely disposed of into Dubai's waste streams, if not first siphoned off by the workers tasked with clearing the hall (to use themselves, gift to a friend or family member, or try to sell). Despite, for the most part, still being functional and rarely materially damaged, by leaving them behind the certified actors are indicating that to them the products are waste. Yet what was waste to the exhibitors becomes something else to the exhibition hall workers or those who work in Dubai's wider waste economy – a new relationship is formed. Such relationships, and how they are broken and forged, are the focus of this chapter.

The certified market's overly material understanding of the solar product, manifested in the quality standards (see Chapter 2), makes certified actors blind to these surrounding relationships and the role they can play in whether or not a product can be used. Neglecting, or not recognizing, the surrounding social relationships of the wider solar assemblage, around the material product, means the certified actor can only understand product performance in terms of materiality and not in terms of various actor-actor relations. This material understanding leads certified actors to view product functionality in binary terms: broken (below the standards) or not broken (at or above the standards). The material focus also serves to absolve manufacturers of responsibility for out-of-use (waste) products that are

materially intact. And it trains attention on the reasons and causes for products to go out of use squarely on the user phase of a product journey, again absolving other actors and other stages of responsibility. Users, meanwhile, have a less discrete understanding of product performance, talking instead of products lighting for *less* time or having to charge for *more* time. These divergent understandings of product functionality are important for later chapters concerning responses to out-of-use products.

I first introduce the concept of 'breakdown' as a useful term to capture the material *and* social dynamics that determine whether or not, and how, a product is used. Then, drawing on data from a survey of users; conversations with repairmen; and interviews with company representatives, I outline the various types of breakdowns encountered during my fieldwork. These are breakdowns associated with: product and business design; manufacture and transit; installation and payment systems; theft and usage; force and impact; dirt and dust; and water and heat. I will conclude that breakdowns in the solar assemblage are productive, generative events that shape the possible responses available to it. How, where, when and why a breakdown occurs determines the nature of the new relationship that can be formed.

Capturing disagreement

The lifespan of the display products that my colleague and I saw littered behind after the conference was nearer to the three days of the conference than the three to five years advertised by manufacturers. Such (functional) display products are not typically what comes to mind when one thinks of waste electronics. Instead, the terms 'e-waste' or 'end-of-life' electrical and electronic equipment, that are used by waste management professionals, in a Global South context more typically conjure images of consolidated urban dumps of computer screens and circuit-boards, of child labour and polluting practices of 'informal' recycling (see Puckett et al, 2005). This visual distinction prompts a need for an alternative term that can capture both the functional display products of Dubai as well as those in Kenya that, not functioning, may appear more typically as waste. In this section, I propose 'breakdown' as that alternative term.

While there is an ethical argument for adopting the terms used by those closest to the solar products in order to foreground the knowledge and experiences of users, retailers, manufacturers, product designers and repair technicians, my fieldwork revealed that all these different groups of actors actually have divergent understandings of when a product cannot be used and why. Therefore, in order to capture these disagreements around times and moments when solar products are no longer in use, it is more helpful for this discussion to take an external term. Although 'breakdown' was used by one interviewee, it did not come up in a survey of product users or during

observations with users or company technicians. Alternatively, there is a practical argument in favour of using already accepted terminology of waste management professionals or scholars in discard studies. However, I will now demonstrate why these are also unsuitable for my purposes.

Aside from misleading visual connotations of piles of bashed up products smouldering in an urban dumpsite, the analytical value of 'end-of-life' (EoL) electronics is also limited. The term is too singular for the various things that can cause an object's life to end – a battery fault or a conference closing – end*s* of life. Nor does the term give any indication as to how long that life has been: three days or three years. The term is similarly ill-equipped to account for products that may have had more than one life (through repair, resale or gifting): end-of-*one*-life. Thinking in terms of product lifespans or -times (as manufacturers and distributors do) also offers little indication of *where* that waste product might be, in whose possession and in what condition. Adapting the EoL concept to account for these dynamics, however, would require agreement over the cause of that life-ending, when it ended and indeed whether its life has ended. None of which are guaranteed given that, as the old axiom goes, 'one man's trash is another man's treasure'.

That something can be simultaneously waste to one person and not waste to another, and that those perspectives can shift according to context in space and time is broadly established in discard studies (a blossoming field which stretches across anthropology, geography, philosophy and sociology). Despite continuing disagreements over what waste is (see Gille, 2007), there is broad agreement on what it is not. Academia and waste management practitioners share a general consensus that waste cannot be defined according to any physical attribute but must instead account for the human–material relationships surrounding an object. Both the European Union (EU) and United Nations (UN) place the relationship between an electronic product and its 'owner' at the centre of their definitions of electronic waste (e-waste) which, in generating and transferring electric currents, discarded solar products, qualify as (9: The European Parliament and the Council of the European Union, 2008; 43: The European Parliament and the Council of the European Union , 2012; United Nations University, 2014). Assemblage thinking (Ong and Collier, 2008) helps keep such relationships and differing perspectives in view when analysing waste.

Waste, or discard, scholars also dispute waste as a consistent category (4: Goldstein, 2012). Instead, waste is understood as a dynamic category that things can move in and out of: 'trash is created by sorting' (5: Strasser, 1999). Shifts and transfers between socially imposed categories underpins Michael Thompson's 'Rubbish Theory' – which explains how rubbish as a category is integral to how we ascribe and remove value from objects (Thompson, 2017). Sociologist Kevin Hetherington points to a similar dynamism writing

that 'waste suggests too final a singular act of closure, one that does not actually occur in practice' (159: Hetherington, 2004). Hetherington stresses the potential of rubbish to return from the state of being 'rubbish' to being something else. In addition to not only being found at 'the end' (not just in dumps) waste itself might not be the end for an object.

Despite a lingering tendency in capitalist societies and industrial economic processes to the contrary, seeing waste as an inevitable end point or by-product (4: Goldstein, 2012), the equation of end-of-life with waste, has been challenged in waste scholarship (Cross and Murray, 2018). That products can be disposed of before use, at times before sale even, means existing approaches to e-waste, that concentrate on waste post-consumption are missing volumes, flows and sites from their studies. This insight falls within a broader critique from discard studies of the focus on consumer behaviour where waste volumes are minimal versus the discards produced in manufacture, at sites of resource extraction or through industrial processes where volumes are magnitudes higher (see Lepawsky, 2018; Liboiron and Lepawsky, 2022). The downstream focus on post-consumption practices has also been criticized for diverting attention away from product design (see Cross and Murray, 2018). Dominant approaches to e-waste also miss the waste of conference demonstration products.

E-waste and end-of-life then are not helpful terms because they suggest a material definition, a finality and a permanence that my single example from the conference floor in Dubai problematizes. But what of terms from the field? A whole series of words were used by people I spoke to, to refer to products that could not be used or were no longer being used. These were: fault, failure, issue, problem, worn, fatigue, weak, damage, return and breakages. 'Fault' was used by company representatives in interviews to refer to a non-functioning product as a result of a manufacturing failure, and so is too limited for this discussion. Certified actors also speak of 'product failures' to cover the same materially deficient or performance deficient products, but again this implies the locus of the breakdown can only be in the material object and not in the wider solar assemblage. 'Problem' or 'issue' are not suitable for understanding what happens when solar products become waste because they, too, are used to locate the cause or reason for the product's out-of-use status in or on the product itself rather than allowing for the possibility of the cause or reason being located elsewhere in the assemblage. Other terms like 'worn', 'fatigue' or 'damage' are again too materially-minded to be used in this analysis. Talking of 'returned products' is too tied to the company language of after-sales and warranty processes, which do not cover all products taken out of or denied use. 'Breakage' is not used because this is an act, or action, which suggests too singular or momentary a phenomenon for the examples I will provide here. Looking beyond the product to the solar assemblage allows us to see that products do not instantly fall in or out

of use but instead their use is mediated between actors and materials over time. Breakdown better accounts for this unfolding process.

Breakdown has been used variously in repair studies. Danielle Rosner and Morgan Ames (2014), for instance, use it in their comparative study of the One Laptop Per Child programme in Paraguay and a Fixit Clinic in the US; arguing that breakdown is produced through use and is collaboratively defined, often in the act of repair. Jérôme Denis and David Pontille (2017), meanwhile, challenge the traditional view of breakdown as a 'univocal event' and use the diversity of maintenance practices around cars to argue that it is better seen as a 'relational phenomenon' (16: Denis and Pontille, 2017). Cynthia Colmellere (2015) through her ethnography in a pharmaceutical plant recognizes breakdowns as being both social and material and also as being moments of opportunity as much as of conflict. Although Steve Jackson and Laewoo Kang (2014) use the term in their write-up of a collaboration with artists in New York, they do not specify what they mean by the word. Jackson and Kang frequently refer to 'technological breakdown', which might still mislead readers for whom technology is solely a material entity.

Thus, having broken down existing terms and discussed their limits, here and for the rest of the book, I will use 'breakdown' to capture the various disagreements, disconnections and discards that appear when examining solar products which are out-of-use. Breakdown suggests less permanence than waste; it can be undone or restored: a cleaner at the conference hall can pick up a leftover product and extend its use. Breakdown can occur at any point, not just the end and not just in dumpsites: it can manifest, for example, at the end of an industry conference. Breakdowns occur in disconnects between actors within the assemblage, when different perspectives and positions lead to different conclusions and actions. These breakdowns can be between the conference delegate and the anthropologist; the user and the designer or countless other combinations including with inanimate and non-human actors. What breaks is relationships.

Breakdowns in relationships

Breakdown is inevitable. What is unknown in advance is where, when, why, in whose hands and in what form that breakdown will present. Some breakdowns are external to the material product, that is when a product (or parts of one) are taken out of use or denied it regardless of their functionality, such as the display products in Dubai. While others are the result of physical changes on or within the product that affect the product's functionality, that is when a cable splits or a casing cracks. Understanding breakdown in terms of relations within the assemblage allows us to see that it is relations that define waste not material states. This section explains how breakdown is understood in the context of the solar assemblage and how the term in

turn helps us understand both the various *types* of breakdowns and various *responses* to breakdown that arise.

One broken down product can look very different from other broken down products. Some may show little visible sign of physical change, while others, hidden in cupboards or boxes, for instance, may not be visible at all. Broken down products are also found in very different places and at very different times. Breakdowns can present in the warehouse, in the office, on the road, at home, in the shop, in the rubbish dump, or at the repair clinic. They can present before sale, during sale, after sale, in use or after use. Breakdowns can also be triggered by very different actors: manufacturers, distributors, trucks, logistics workers, sales agents, finance partners, motorbikes, users, repairmen, children (mainly boys), thieves, cows, rats, insects, rain, wind, dirt, dust, fire or even the Sun(!).

The range of breakdowns described in this chapter (some more materially dramatic than others) fits with Rosner and Ames' definition of breakdown not as a singular phenomenon but as a continuum (Rosner and Ames, 2014). Rather than think of breakdown as a binary state: fault versus no fault, a continuum encourages thinking in terms of more to less broken down, as 'ordinary and normal, full of activity and exchange' (3: Martínez, 2019). Thinking of breakdown as a continuum, of severity and of time, gives space for understanding how breakdown is negotiated. Breakdown is a process that can start early, at moments of design when products are scripted with the performance qualities and social and environmental impacts discussed in Chapter 2, precluding certain actions and legitimating others. It is often only later in the process of breakdown, however, that those politics are revealed and the disconnect becomes so untenable that the assemblage no longer functions to produce light or charge. Regardless of design scripts, any battery will ultimately run out of charge and so we might think of products existing through a continuous process of breakdown.

The breakdown process and its range of possible scenarios (in time, place and severity) makes it difficult at times to isolate a single cause of a breakdown, especially when different actors, according to their position, view and so report it, differently. Establishing a cause is important because understandings of it shape the possibilities available once a breakdown appears. Generally, repairmen and company representatives identify users as the cause of breakdown, through ignorant or deliberate misuse. Users, meanwhile, tend to blame the product itself or their children. These discrepancies are mirrored in the different views that actors hold on whether or when something is waste or not – and so on how they respond to breakdown.

The relational understanding of breakdown also helps draw attention to its social dynamics, particularly regarding gender and generation. It is often children that are involved in or are blamed for breakdowns. There is a gender dimension to breakdown of solar products as well: men and boys

cause more breakdowns than women and girls who are more careful when using products. A project promoting laptop-based learning in Paraguay found similar gender norms played out with boys allowed 'to be more rambunctious than girls' (323: Rosner and Ames, 2014) and so responsible for more breakdowns than their female peers. By turning attention to relationships around the product and not just looking at the material product itself these dimensions can be recognized.

Beyond capturing the multiple types and kinds of breakdown and their social dynamics that can occur, a relational understanding of breakdown also helps capture the multiple levels and scales on which it can occur. The scale of breakdown can be much bigger when a company collapses than when a single product falls from a user's roof for instance. When thinking of breakdown this way we can see large quantities of stock being written off by a company alongside the breakdown of a single product at home.

There is a degree of difference in the types of breakdowns that affect the three product categories subsumed in what I am calling the 'off-grid solar product': solar home systems (SHSs), pico-solar products (PSPs) and solar lanterns. Issues such as leaving a product out in the rain, placing it near a flame or it falling under the feet of an animal pertain more to the solar lantern than the other two product types. Theft, meanwhile, is unlikely to occur of a whole SHS but more likely just the panel, whereas in the case of a solar lantern the panel is integrated into the unit and so the whole product may be stolen. These differences, however, are another useful feature of the relational understanding of breakdown whereby it allows for comparison and generalization across the categories despite their material differences. Breakdown helps compare disconnects within the assemblage even when they may manifest themselves in different ways.

Types of breakdowns

Breakdowns become visible when a product (or parts of one) cannot be used as an actor wants them to. This section describes ten types of breakdown, those relating to design, manufacture, transit, installation, force and impact, dirt and dust, water and heat, under/over-usage, theft and business decisions. Although addressed discretely here many of these types of breakdown overlap.

Martin, a designer at Greenlight Planet, told me that despite the company's best design efforts and 'all kinds of pulling and damaging test on it [sic]' in the design process, once their SunKing product is in the field (the hands or house of the user) the rubber inserts that keep the stand firm in the main light body, can still fall out. Martin was conceding, in other words, that breakdown is hard to avoid. The pushings, which sit in two small holes either side of the main light-body, break, come loose, or get stuck due to the repeated removal and re-attachment of the metal stand. However, because the pushing is not

a common feature across product designs from other manufacturers, it does not need to feature in the quality testing process; there is no requirement to test either the strength of the rubber the pushing is made from, or what happens with the repeated removal and re-attachment of the stand. For Martin though the issue was less in his design and more because 'people may treat the lamp er, with more violence sometimes'. Design then, even when designers like Martin are aware of the characteristics of later usage, can begin the process of breakdown that will manifest itself later on. It is also in design that products are designed to be portable, easy to install or use in multiple places. Yet this feature also leads to them being susceptible to theft and falls, both types of breakdown that are discussed later on.

After design comes manufacture. Manufacture(r) breakdowns covers those products which do not meet the performance expected (as certified in the quality standards) due to something that occurs during the manufacturing process. Like those originating in the design process, manufacturer breakdowns are also not normally discovered until the product is already in the hands of the user. This is because companies run Quality Assurance (QA) testing on periodic samples of products coming out of production which will catch most of the issues. Although manufacture(r) faults can affect any part of the solar product, the most common point of failure is the battery. Gijs, Chief Operating Officer for Africa at Barefoot Power, told me, as did several other interviewees, that the battery is the most vulnerable component of the solar product or system: 'of course, and I'm sure you're aware of this, the weakest point in the system generally speaking is the battery, it's not the controller, it's not the LEDs, it's not the solar panel, it's the battery'.

Indeed, when watching SunnyMoney's sales operation, Victor, a sales representative there, told me of one instance in Kitale (in the west of the country) the previous year when a 'manufacturer defect' in the batteries of the products they were distributing had affected around 5,000 products. The replacement of which 'gave us a headache' Victor said, not to mention the damage it did to consumer trust, solar's reputation and the reputation of SunnyMoney.

Other products might not even make it in to use to discover these manufacturing issues with batteries, or any other component for that matter. This is because some products experience a breakdown during transit**.** I witnessed one example of transit-related breakdown when I visited the warehouse of d.light on Mombasa Road. Wilson, the workshop manager there, was giving me a tour when I noticed a box with a label on top that read: 'G4S ACCIDENT'. I asked Wilson what these rather squashed-looking boxes were for, what the accident referred to. He explained that a couple of months earlier a G4S vehicle (d.light's logistics partner) was involved in a road accident while driving stock out west. The driver and colleague in the vehicle died at the scene. The stock they were carrying was damaged

in the crash. Wilson told me that the managing director of d.light took the financial blow for this damaged stock; it was not, as would normally be the case, billed to G4S. I do not know how much of the damage to the outer boxes from the fall would have transferred to products inside but because d.light could not guarantee the boxes salvaged from the crash met the quality standards, it could no longer be sold, and so would never be used. In transit-related breakdown, actors are encountered – here, the logistics partner – that could easily be overlooked if one looked only at breakdowns presenting in moments and sites of use. It is not, however, only in the pre-sale phase of a product's life that transit is important. In 2014 I worked for a solar company in Kenya and Uganda and on multiple occasions I saw our company motorbikes topple over when loaded with products on the back. Rough roads, not-always-fully-serviced motorbikes and unlicensed drivers mean motorbike slips and falls are a relatively common occurrence on the journey from point-of-sale to place of use.

Even after navigating the dangers of the road network there is still a chance of breakdown when a product is installed in its place of use. Although these solar products require little in the way of physical installation and nothing in terms of system sizing as was the case in the past – matching panel wattage to battery voltage (see Chapter 1 for more) – users still require instruction on how to use their new solar lantern, or, in the case of solar home systems, where to place the battery, panel and cables around the home. Jaki, who previously oversaw the Kenya Tea Development Agency (KTDA)'s partnership with Barefoot Power, for instance, told me, 'a lot of people will say that their solar lighting products aren't working but it's because they nailed them in wrong'.

Jaki suggested this was because the tea farmers would 'see a product, see how simple it is to install and decide to install for themselves' but then puncture a cable in the process of nailing it in to a wooden beam in their house. Installation is not always just a one-off event though. Huashan, the founder of Omnivoltaic (another certified manufacturer), referred to the placing of the panel as a 'daily installation'. Many users, fearing theft, high winds or playing children, only put their products or panels out to charge when they can stay nearby. This recurrent 'installation' was the cause of breakdown for several interviewees as it could lead to cables becoming loose or products, or parts of products, being dropped.

Loose cables and dropped products also fall under the group of breakdowns caused by force and impact. Force can be applied to a solar product in two ways: accidentally, as in the transit examples outlined earlier, or routinely, perhaps through pulling a panel off the roof by its cable in the 'daily installation'. Accidental force is usually a fall from a roof or chair, or someone or even some*thing* stepping on to the product, or part of it. This accidental category includes incidents when a panel is blown off a roof as

Figure 3.1: An unbranded pull-up lantern and an ST. Light charging on a stool outside Martin's house near Bomet

Source: Author's image, March 2016

was described to me when I visited one home just outside of Bomet. Or when a child knocks or stands on a product as happened to Panai, a survey respondent, in Narok County. While for John, also a survey respondent, in Nandi County it was a cow that stood on one of the seven d.lights he had bought from SunnyMoney. It is not always cows or children that are to blame, however: Eric, from the Equity Bank Foundation, for instance spoke of cables being eaten by rats during the foundation's partnership with Orb Energy.

One part of the Lighting Global quality standards requires that products should withstand a drop test from a height of 1 m on to concrete on six sides of the product (3: Lighting Global, 2017a). While this would protect from falls off stool and chairs on which users often charge products and are normally below 1 m in height (Figure 3.1), roofs, hedges and water tanks where I was also shown products are charged (Figure 3.2) are higher than this.

Admittedly, some of these would be falling on to dirt, grass or carpet rather than concrete and so are perhaps protected in that sense. Meanwhile, the strain relief test of cables, also in the 'Quality and Durability' measure of the standards, will presumably help mitigate against rats' teeth.

In addition to these accidental impacts, routine (or regular) force can also cause breakdown. Describing his idea of the 'daily installation' for instance,

Figure 3.2: A d.light S2 charging on a water tank outside Christie's house near Bomet

Source: Author's image, March 2016

Huashan told me that people 'yank, they try to yank the product off the roof'. In our interview over Skype, Huashan also said that 'people simply use too much force to insert the USB'. This was echoed by other interviewees who describe users pushing cables in too hard or in to the wrong place and so damaging the cable itself, the port in to which it is supposed to fit or both. Unlike accidental force, breakdowns as a result of routine force are often less immediate. Instead they might occur from repetitive use. Continual switching on and off of the switch for instance, might, over time, lead to that switch getting stuck – a reminder of breakdown as a process. Issues with the switch were the second-most commonly reported issue in the survey: 17 of the 262 users spoken to had had a problem with the switch on their product. While the quality standards specify the need for a mechanism such as the switch and connectors to be 'functional after 1000 cycles' (3: Lighting Global, 2017a) they do not cover the 'yanking' or 'force' that Huashan told me about.

The standards do, however, address issues of dirt and dust through its 'ingress protection measures' (2: Lighting Global, 2017a). When I spoke to product designers, or to employees about their product design, ingress protection was a frequently prominent consideration. During a day observing the repair operation at SunnyMoney (who distribute Greenlight Planet products),

George, the SunnyMoney technician, and I assessed multiple products returned from customers that were missing the rubber flaps that cover the charging ports to connect both the panel and the mobile phone. The flaps are there to stop dirt and dust entering the product where it can interfere with connections on the circuit board but after repeatedly being bent forwards and backwards or being held back for a long period of time, this can break off. Similar to Martin's rubber 'pushings' because these flaps are not universal to other brands in the market they do not need to be tested for certification.

Unprotected ports are also a risk for allowing water inside a product. Products can also get wet from rain or having been dropped, or knocked, into milk, the toilet, a pot in the kitchen or a lake.[2] Of these possible cases of liquid-damage, rain is the most common. A few voices from the survey illustrate this:

> It was rained on and got spoiled.
>
> One was rained on and refused to light. It's very dim.
>
> It was left outside and got rained on.

This list could be continued: 12 of the 262 users spoken to spoke of rain having damaged their products. Water, like dust and dirt, is bad news for a product's internal circuitry. When I spent a day with George at SunnyMoney in Nairobi, we came across a product that had a piece of rope attached to it. From this George proceeded to narrate a story about how this user must be a fisherman and they must have dropped it in the lake one time while out fishing. This ability to tell a story about a user and what they have done to/with their product appears again in Chapter 6 looking at independent repair processes.

One element that is not covered in the quality standards is heat-related breakdowns. This could be heat from a cooking fire, heat from the sun or heat that was internal to the product (usually the circuit board). In company offices, workshops and warehouses I regularly saw products where parts of the casing, strap or stand had melted. When spending the day with Henry of Trony (a certified manufacturer), he also spoke of heat and users' fears that if they put their products on the thatched roof of their houses it could catch fire. There is an irony here in that housefires are one risk associated with kerosene lanterns, against which the certified market defines itself. That users see the Sun as a threat despite it being the source of the power for these products is evidence of a further disconnect between actors. The Sun is, of course, central to the solar assemblage, yet it can play different roles according to one's perspective. These mismatches in the assemblage are what lead to breakdowns.

One reason why the risk of heat-caused breakdown does not appear in the quality standards could be because for certified actors they fall more under

the category of use, or in their parlance: mis-use, than anything concerning the performance of the materials themselves – which can be tested in a laboratory. That is to say it is not a problem that the panel cannot withstand the heat of a charcoal stove, the problem is the user should not place a product close to a charcoal stove. Representatives of various companies told me similar stories: 'they just put on, on the ground, where you find like there is shadows from the trees or from the other vegetation around. So at the end of the day the product is not charging properly.'

Or 'they don't clean the panel so after some time there is like dust which accumulate on top of the panel'. Or 'where you insert the, the, the cable for the, to the battery maybe they've inserted it in the wrong way so they, it's been out in the sun, so they return it and say it's not charging but the thing was you really needed to have connected it properly'.

There are a few breakdowns occurring here. These company voices are partly describing how users do not use the products correctly. But the same descriptions also highlights a breakdown in understanding between the user and designer or manufacturer: the user not necessarily understanding fully what they have bought and the designer not fully providing what the user wants or needs.

If products, or parts of products, are deliberately damaged or stolen then a breakdown can occur because such actions can lead to under-charging, which can, in turn, damage the battery and other internal components. One study in Papua New Guinea found 'an unusually high frequency of theft and vandalism of SHS' (1540: Sovacool et al, 2011). However, in my fieldwork it was not often mentioned by company representatives and I was only told of a few examples by users. In the 12 months after Noah and Francis (both of Bungoma County) participated in the first round of the survey, for example, they each had had one of the panels of their SunKing products stolen. And when I visited Samuel also in Bungoma County after the second round of the survey, he told me how a departing security guard had stolen the panel of a d.light S20 that belonged to the school where he taught.

More commonly reported than actual theft was the fear of theft. A technician at Greenlight Planet, for instance, told me that fear of theft is part of the culture in rural areas. This fear leads to users not charging products regularly so they can be kept inside and out of sight or putting them out but in shaded locations or on the ground, again to limit visibility. Although potentially decreasing the risk of theft, these strategies increase the chances of some of the other breakdowns described earlier: the product being knocked or stepped on by children and livestock; or it falling down or a cable becoming loose during repeated installation and de-installation. There is an irony in the role of theft in contributing to breakdown as users often remark that the sign of light that a solar product can bring enhances the security of the household (Bisaga, 2016).

Although theft is an old phenomenon in the solar assemblage (see Chapter 1), the newer PAYG models have introduced a whole new set of possible breakdowns. During days with Greenlight Planet and d.light technicians much of the troubleshooting I observed and assisted with was concerned with the control units of SHSs through which payments are mediated. I was told that users do not always enter payment codes into the control unit keypads correctly and that some try to bypass the payment system altogether. Other challenges for the functioning of these PAYG products are to ensure they are communicating properly with Nairobi and that they have adequate mobile signal to do so, for they work through Global System for Mobile Communication (GSM) networks. Users of PAYG systems, meanwhile, regularly complain about credits (for a certain amount of charging time) not being uploaded or being lost. Similarly, the numbers on keypads can rub off through usage and labels on products containing important customer account or product reference numbers can peel away and fade through time, further complicating matters.

Aside from this sequence of breakdowns that can occur through the design, delivery and distribution of products there are business decisions which can contribute to breakdowns elsewhere and at times on a dramatically different scale. The exhibition display products described earlier are an example, though a minor one. Two other examples where business decisions cause a breakdown are one, the introduction of a new product line meaning the previous one is discontinued and two, in 'writing off' stock that is not selling. During our interview over lunch, for instance, David, an employee of the Faulu microfinance institution which used to distribute solar products to its members, told me of one time around 2011 when 'the market completely rejected the products, I think, we sold less than 30 or so. We bought products worth 1 million shillings, we didn't even return 30,000 [shillings] was on higher side, so we wrote off the entire stock.'

I asked David what they then did with this materially un-touched but financially unviable stock: 'It's still at EcoSmart [a specialist solar distributor that spun out from Faulu] it must be in the stores somewhere. It was never thrown away, it's still there somewhere, at least it was when I left.'

The financial and human resources required to sell it would be a waste for them so rather than waste that, they wasted the material products. When I visited the EcoSmart store in September 2017 just over a year after meeting David and six years after the incident he described, I did not see the stock he had been referring to. Stephen, who showed me round the workshop (a large cupboard of a room), had only started with EcoSmart in a finance and administration role in 2013 and so did not know what had become of the written-off stock. When being given the tour of the d.light warehouse, however, I was shown a whole section of stock of a previous product generation that, although functional, would not and, according to a business

decision, could not be sold. Although on a lower scale (100s rather than 1,000s of units) than in the warehouse, prototypes and marketing products in shops and offices of solar companies are another example of breakdown where functional products never reach use and so hold the potentiality of becoming waste.

There are other macro, market-level breakdowns that the standards, and their focus on material quality and durability, do not prevent from occurring. The continued entry of non-certified products into the country, for example, could be viewed as a breakdown by many in the certified market where continual efforts to set up and communicate a dichotomy between the certified and the non-certified market also breaks down at some points of sale and especially in sites of use. Or that several companies have already closed down: Tough Stuff, SunnyMoney and One Degree Solar have each stopped operating in Kenya, leaving behind a material legacy (as discussed in Chapter 1) of products, the company closure breaking down the relationship with their customers too.

The next, and final, section discusses how breakdowns are formative: the type of breakdown, when and where it presents do a lot to shape the possibilities for what can come afterwards and so whether or not the broken down product is repaired or disposed.

Breakdown as formative

I introduced the term 'breakdown' to capture processes through which solar products stop or are prevented from functioning. Unlike the terminal or permanent connotations of words like waste and failure, breakdown suggests the possibility of being undone. It is more intermediary, more transient. When thought of as a continuum, the term helps capture a more dispersed and diverse set of phenomena than are typically associated with ideas of e-waste or end-of-life electronics. The term also turns attention away from the material product and towards its surrounding relationships, the assemblage. Breakdown allows the focus to move from what is built *in* to the products (materially) and more towards what is built *around* them (the assemblage). Yet it does so in a neutral way, without ascribing blame or priority to any side over another.

Company representatives work to address some of the types of breakdown already discussed. Interviewees spoke of their efforts to reduce problems arising from manufacture, installation and use. The quality standards, meanwhile, target those breakdowns associated with force and impact, dust and dirt, and moisture through the drop test, ingress protection and strain relief measures within the 'Quality and Durability' component. But the companies and the standards do less to reduce breakdowns through transit, theft or business decisions. This is perhaps because recognizing these types of

breakdown requires a recognition of the relationships in the solar assemblage including actors like the underpaid, casual labourer rushing to complete their work before lunch or the precarious motorbike rider looking to maximize their returns on a single journey. The social aspects of the solar assemblage reach out into structural issues that are arguably harder to manage than tweaking manufacturing processes. I do not find any evidence of planned obsolescence in the industry – that is, I did not encounter manufacturers deliberately, and artificially, limiting the lifespan of products so as to increase sales. Instead I see manufacturer efforts to limit repair (and so, indirectly, limit lifespans) as a bid to maintain their understanding of quality performance.

There are an immense variety of types of breakdown. If it is bad for a solar product to be inside where it can get dusty, bad to be outside where it can get wet and bad to move it and un-plug it, then threats of breakdown are everywhere. The ubiquity of breakdown should be taken as a reminder that breakdown is inevitable and, more than that, unexceptional. At some point, all solar products break down. Although I have focused here on examples of early breakdown (before the intended or advertised lifespan is over) general usage (even according to manufacturer-defined limits) also leads to breakdown. Even if the testing laboratory setting could be replicated, a battery will eventually reach the end of chemical reactions it can perform and stop holding or releasing charge. There is also the accumulation of dust and oxidation on circuit boards and charging ports that demonstrate the 'slow temporal horizon of breakdown-through-being' (52: Houston, 2017). This kind of breakdown overwhelmingly occurs in rural homes, the main site of use, which are visited in the next chapter. But first, I will revisit my definition of breakdown before explaining how processes of breakdown are formative and influence later relationships within the assemblage.

At one end of the continuum there are the products that Faulu wrote off or those unopened in the d.light warehouse that would probably function perfectly well, and at the other there is John's d.light squashed by a cow. The breakdown continuum will be important when looking at user and independent repair practices (Chapters 4 and 5) where a more graduated understanding of functionality exists versus the company setting (Chapter 6) where products are working or not, a reflection of their commitment to the standards: themselves a binary measure. The definition of breakdown developed here also allows for a more differentiated understanding of the product where parts can break off, be lost and fall away. This is important for the following chapters where discards can appear as parts and bits rather than whole products.

In an influential discussion of disposal, Hetherington (2004) describes a gap between consumption and disposal, a sort of holding ground from which rubbish can sometimes return. This idea is compatible with breakdown. Breakdown creates a gap in the assemblage, between two previously related

actors. A product (or part of one) waits in the gap until a new action forms a new relationship. This possibility to undo breakdown, for rubbish to return, in Hetherington's words (Hetherington, 2004), is already recognized by repair scholars who describe processes of breakdown as 'creative' (457: Jackson and Kang, 2014). Breakdowns are not just processes through which a relationship ends or a wire comes loose, rather they can be, and often are, productive. Rather than think of a breakdown as the end it can equally be thought of as a beginning, ushering in a new phase for a given product in the potential for a new or altered set of relationships. I suggest that is breakdown that initiates transfers into Thompson's 'rubbish' category (Thompson, 2017), even though what sits in that category, that gap, is not always actually rubbish (as in waste) – that decision is yet to be made.

The gap exists on several levels. It exists as the space where the product actually sits and waits. It also exists in actors' decision-making as users say they will do one thing and when the time comes they do another, or company representatives say a process works in this way yet in practice it works that way. The gap is the space between breakdown and response.[3] It is spatial and temporal and it helps break linear understandings of the relationship between consumption and disposal. Francisco Martinez hints at it when describing the 'terrain of interstitiality' where repair occurs (7: Martínez, 2019). Fabian Echegaray and Francesca Hansstein (2017) call it the 'intention-behaviour gap', while Garrath Wilson and colleagues talk of it as 'hibernation' (Wilson et al, 2017). The concept is also compatible with Bhattacharya's analysis of a junkyard in Delhi, India. Bhattacharya characterizes the junkyard as a liminal space in which waste things sit until some labour or action gives them 'a fresh lease of life' (48: Bhattacharya, 2018). In the subsequent chapters I show how in Kenya this liminal space is more pervasive, however, than the peripheral junkyard of Bhattacharya's study, identifying gaps in multiple locations and forms. In Kenya, the liminal space can be in a warehouse, a shop, along a road, in a house, a toilet, a bush: it, like breakdown, is everywhere. Breakdown moves products into the gap. Responses to that breakdown, such as repair, move the product back from the gap and in to action again. Other responses can move it on and into new places performing new roles. There is no consistent figure as to how long or wide the gap is, broken down products leave or move on from it at different times for different actors. It may be temporary or it may be forever, and it may yet return to the gap again and again any number of times.

The ability of rubbish to return, for the breakdown to be undone, is dependent on the nature of that breakdown. Breakdown 'is thus contingent to situated decisions, grounded in specific contexts and structures' (3: Martínez, 2019). The surrounding relationships and the way, time, place and in whose possession the product experiences breakdown shapes responses to it. It is through the process of breakdown that manufacturers,

distributors, users and repairmen each form particular understandings of each other and the products. Users blame the product when after a few months the light dims. Independent repairmen blame users for causing problems and not always telling them the whole story. Meanwhile, companies blame users for mis-using products when they try and charge 'too many' phones. Breakdown, like waste, is contested, yet unlike that mass noun, breakdown captures this very contest in its own meaning. The disagreements over what causes breakdown extend into what responses are taken. In the company setting it is unlikely that the written-off product will make its way in to use in a home or elsewhere; from the gap, it will be disposed. But at the other end of the continuum, other things can happen. Depending on the damage Panai's child caused to her S2 there are actions she can take to return to it to use. Part II of the book attends to these futures, moving across three of the main locations where breakdowns present: the home, the independent repair clinic and the company premises. Given that most breakdowns present at home it is there that I move first.

PART II

Responding to Breakdown

4

Repairing at Home

Routine repair

Repair occurs at home in two ways: through changing *how* the product is used: repairs of practice; and affecting physical changes to the product: material repairs. Repairs of practice are those actions where the alteration is made not upon the product itself but in the surrounding manner of its use: when a panel is stolen a user may take their product to charge from the electricity grid. Material repairs are those actions where a physical alteration is made to the product: a user may use a small splinter of wood to prevent the switch from getting stuck under the casing of the product. Of these two types of repair, repairs of practice are the most common at home. This is partly because repairs of practice are often an interim or temporary solution. Users adopt such until the moment when the product moves further along the breakdown continuum, and they can no longer support its reduced functionality. Or, they enact the repair of practice while they wait, before the product moves on to another location like the independent repair clinic (Chapter 5) or the company repair process (Chapter 6). Although the material work of repair might happen more in those onward locations, the clinic and the company premises, the home remains a central part of the process affecting the work that happens in those places. Independent repairmen and company technicians imagine how a breakdown occurred at home, and any prior responses to it, in the process of pursuing their own repairs. Both types of repair do, however, share some characteristics with each other and with those observed at the clinic and company. Material repairs and those of practice both involve trial and error and the use of resources 'at hand'. As a result, in both cases functionality is prioritized over aesthetics and, often temporary, their outcomes are inconsistent. These elements all point to repair as a form of bricolage. The same form of improvisations have been identified in the Soviet Union (see Gerasimova and Tchoukina, 2009).

Unlike other studies of repair which use a language of innovation and adaptation to describe non-professional repair, the examples provided in

this chapter do not support a form of *créolisation* (Edgerton, 2008), *jugaad* (Radjou et al, 2012), anarchism (Sterling, 2016) or joy-inducing discovery (McLellan, 2013) but instead they were presented to me as more of an unexceptional, pragmatic response to breakdown. Although there have been calls for researchers to recognize repair that does not involve the physical tools commonly associated with it (like spanners and screwdrivers: Spelman, 2003) and some have studied the 'routine, mundane work' of object maintenance (251: Gregson et al, 2009) there is scant coverage in the academic literature of, and so no terminology to describe, people's daily work on themselves to make an object work. The use of the phrase 'repair of practice' allows this chapter to explore how people adapt themselves and their use of an object in response to breakdown rather than alter or replace the object.

While users recognize their material repairs as such: 'I fixed it' or 'I repaired it myself', so pragmatic are users' repairs of practice that they do not actually describe what they are doing as repair, indeed they do not give it any name. Users accept breakdowns at the less severe end of the continuum (a dimmer light or stolen panel), altering their routines almost automatically to accommodate the reduced or changed functionality of the product. This lack of a word to describe their actions supports the argument of this chapter that the acts are rather mundane and not, as some existing repair studies suggest, part of a broader intellectual or social project (McLellan, 2013; Rosner and Ames, 2014). Similar then to the term 'breakdown' used in Chapter 3, the terms 'material repair' and 'repair of practice' are more analytic than emic. Also, like breakdown, the terms, within the framework of assemblage thinking, show the socio-material relationships that make possible the solar product and that help indicate these relationships can shift.

★★★

In part due to this same mundanity and pragmatism, it was difficult in the survey to clarify at times if people were talking of self-repair (at home) or taking (to a professional) for repair. Responses in the Excel sheet such as 'I will look for someone to repair, or fix it' could mean either that the respondent was interchanging repair and fixing as verbs – they would look for someone else to get their product functioning again. *Or* the same response could mean that the user would first look for someone to repair it and failing that they would fix it themselves. Even a seemingly less ambiguous response like 'I repaired it' could mean it was taken to a repairman for repair or that the respondent had repaired it themselves at home. These doubts are only increased with the case of respondents who themselves or their family members or friends were *mafundi* (skilled technician or artisan). It was not practical to re-call each respondent to clarify their meaning nor

to ask my three research assistants if they remembered, or indeed had ever understood, what exactly the respondent was referring to. The overlap of categories made deciding what data to draw from in writing this chapter a challenge at times. But this is ironically consistent with how companies view unauthorized repair – where customer and third party repairs are treated in the same way (see Chapter 6 for more).

★★★

I begin this chapter with a discussion of the imagined user, a category successfully created through the history, market devices and practices of certified actors. In the second section I look at gender stereotypes that are held up in conversations and observations at home. Men and boys are understood to be more reckless in their use of products but also more likely to attempt to fix them when broken down than women and girls. In the subsequent two sections I look at the two types of repair identified at home: repairs of practice and material repairs. Repairs of practice such as sharing panels or charging products from an electricity grid are shown to be the most common response to breakdown at home and often a precursor to later responses. Material repairs such as taping up a cable or using some wire or rope to tie a case together are less common and mainly for more severe breakdowns. The prevalence of repairs of practice over material repairs is the result of repairs at home being pragmatic. I then turn to look at other responses to breakdown; these include playing, teaching, selling, burning, putting down the toilet, burying or throwing away. I conclude the chapter by arguing that starting from waste, rather than what makes something become waste, misses both the gap and the range of things that can happen to a broken down solar product and the range of places it can move to from the gap; things and places that 'waste' is not typically associated with.

Imagined users, imagined uses

Driving back to his company's head office after having spent the day with him down at the warehouse, Julius, a technician at Greenlight Planet, proudly showed me a new marketing leaflet. On one side it listed the technical capacity of the product (a nod to the quality standards) and on the offer it showed a child studying by Greenlight Planet light (an illustration of the product's impact). The leaflet Julius showed me was illustrative of the broader picture of the off-grid solar industry in Kenya. Studious children, mud walls and thatched roofs are common sights in such materials. Together with the market devices described in Chapter 2 they serve to present the user and the use of products in certain ways, in a certain light. Users are conscientious students, cooking mothers or happy families found in living

rooms or kitchens at night. Of course, the selective use of images to sell goods is not unique to the off-grid solar industry. Nor is it only within energy access that the market is playing a role in International Development (Prahalad, 2006). Their significance here is that they further contribute to market construction and shape how use is understood.

Although predominantly designed for domestic use, as depicted on Julius' leaflet, products might also find themselves in use at school, in a shop, or from a roadside stall (either balanced on an up-turned bucket, resting on a big stone or hanging from a wooden kiosk structure). Products are also used as bike lights or for night fishing. Marketing materials have, however, concentrated on the home and on its use there (as do the Impact metrics discussed in Chapter 2). Leaflets and presentations at industry conferences do not carry images of people carrying products to the toilet, such as Anthony at d.light told me was common. Nor do they feature those for whom solar is a back-up for the grid in power cuts, like the Glowstar had been in the early 2000s (see Chapter 1). Even the presentation of the home, however, is different from that I observed during fieldwork: in marketing images panels are on roofs not the ground, or stools (both common practices).

This variance in places of use leads to a variety of users. Images like on Julius' leaflet feature children and women prominently. They do not, however, include animals or insects that also interact with products (see Chapter 3). Rather than seeing the user as an individual, it is more helpful to think of the user as a role. The user-role can be performed by different actors and often in addition to other roles. They could, for instance, also be a sales agent, an electrical/electronic retailer, a repairman or a solar company employee. Other family members, visitors, researchers and thieves all might also use the product during its lifetime. The company category of 'user': both that portrayed in marketing materials and that spoken of by technicians in company offices, workshops and warehouses, does, however, show some understanding of this diversity. There is, for instance, awareness of access to products and their distribution within households across generations (Jacobson, 2007) and especially across genders (Pachauri and Rao, 2013).

The image of the user comes with a certain understanding and definition of what use is or should be (like placing the panel on the roof not the ground). This chapter is about how that representation shapes the events and actions that occur at home in response to product breakdown. This does not include repair. Repair is not the role of the user and the home is not allowed to be a site of repair. Historically kept outside of the products (Chapter 1) and more recently framed as beneficiaries by the market devices (Chapter 2), the chapter shows that despite the best efforts of certified actors (donors, funders, non-governmental organizations [NGOs] and companies) to the contrary, the user *is* a repairer and the home a site of repair.

Men and boys

One element of the imagined user that largely remained unchallenged in interviews and visits to users' homes were gender stereotypes. In company offices and workshops when discussing 'tampered' products or assessing products received back from 'the field' managers and technicians exclusively referred to users as men. This was especially true when material alterations had been made to the product in front of us. This fits with most major studies of repair in which the central characters are all men (Harper, 1987; Gregson, 2011; Houston, 2013). Beyond repair much has been written about the connections between gender and technology more broadly, specifically between men and machines (see Mellström, 2004) and digital tech and masculinity (Ames, 2019). This work has shown how technology becomes the preserve of men and so integral to cultural and social identities of masculinity. However, women use technology, too, and the examples in this chapter, both material repairs and those of practice, involve and include women as much as men. Repair by both genders occurred in the Soviet Union, although the divisions of where and what was repaired still fell along gendered lines (Gerasimova and Tchoukina, 2009).

Kenya is largely a patriarchal society (at least in the public sphere): business and politics are dominated by men and it is men who are more often seen in bars, cafes and on roadsides (see Simiyu, 2018). This male dominance is only in enhanced in the domains of energy and technology: all interviewees at solar companies were men and all repairmen and technicians I observed were male, too. This is reflective of similar imbalances at international conferences such as those attended in Dubai and Hong Kong. Where women were better represented it tended to be in sessions on policy, finance and impact rather than technology.

These gender differences have been located in other studies of off-grid solar. In the case of a PLAN International project in Guatemala, for instance, it was found that despite training, users were not able to repair basic issues correctly because the training had not been given to the principal users – women (Nieuwenhout et al, 2001). There were examples in my fieldwork where women, without any apparent form of training pursued repair – particularly repairs of practice. This supports existing research which has suggested that when working with a broader definition of repair, one in non-typical spaces of repair and with non-typical repair tools, we can reveal other repair activities. Various scholars have identified an affinity of women with repair by connecting it to ideas of care (Callén and Criado, 2016; Spelman, 2003). And while women were not associated with repair in my fieldwork the association of them with care was common in both interviews and home visits. Steve, one of the survey respondents, for instance, told me how his daughter looked after her SunKing Eco product very well and

guarded it from the 'carelessness' of her two brothers, whose own product had broken down.

More specific than men in general breaking and fixing things there was also a generational angle that emerged in fieldwork. Boys were particularly spoken of, as Steve did, as the source of and solution to breakdown. During one home visit in Bungoma County I asked Kenneth, another survey respondent, why he had not taken a broken down solar product to the One Acre Fund (the social enterprise from whom his wife had bought it) who have a large and permanent presence in Bungoma town for repair or replacement. 'Boys sometimes are creative … he wants to create something unique,' he replied. So while some talk of children as causing problems, other survey respondents spoke of children, exclusively males, as the solution, the repairer. Sometimes a response to breakdown is to give the broken down product to a child. It would be difficult to say whether boys are more inquisitive and so knowledgeable or whether it is more accurate to say that boys in Kenya are allowed to be more inquisitive and so *become* knowledgeable regarding the restoring of functionality to the same products that they may well have broken in the first place.

★★★

Through most of my fieldwork being a man was of great use to me. I am confident I would not have gained as much access to the repair clinics and workshops and warehouses explored in Chapters 5 and 6, was I a woman of a similar age (mid-20s). Indications of this were the frequency of conversations, sometimes lengthy ones, about whether or not I had a girlfriend, was married or was looking for a Kenyan wife. At the repair clinic in particular, jokes were made at times at the expense of young women who came.

However, there were also occasions when my gender became problematic. One of these was after a home visit with Purity, a lady in her early 20s. Purity had brought an M-Kopa radio to the clinic for repair and, as was my strategy, I then arranged to visit Purity at home to learn more about the biography of this particular product, its breakdown and its repair. However, after I had visited her at her family home I received a series of calls and text messages hoping to meet with me again. Although this enthusiasm was common with respondents of all genders and ages, it was made clear that future meetings with Purity were to be of a romantic nature. A second instance was when I went to visit Dorcus at home in Bungoma. Following this visit I received distressed calls from Dorcus whose neighbours, assuming she now 'had a *mzungu'* (White person/man) were asking her for money and favours. A third occasion when my gender created a problem was in a rumour, although little circulated, that I had been staying with a single woman in Kapkwen, a small centre up the road (west) of Bomet. This

emerged from an evening visit I made to a home there at the beginning of my fieldwork when I was looking for a homestay to better inform this very chapter about the dynamics, activities and actions at home. I only became aware of this on a return visit to Bomet in 2017, over a year after having last been in the town.

***

Repair of practice

When Pamela's SunKing Mobile stopped charging at her home in Migori County, near the border with Tanzania, she did not call SunnyMoney (the company from which she had bought the light) but instead, after taking a closer look at the product herself, she realized that if she *held* the cable that runs from the panel to the product in place at a certain angle or *balanced* it in that position, in a place where no one would touch it, it would charge. At this point Pamela's product was still in warranty but rather than seek outside assistance Pamela got her product working again, at home, herself. Pamela's repair was not a material alteration; she did not add or remove anything. It was a repair of practice: she altered the way she uses the product. Rather than inserting the charging cable with little thought, now she does so with care. Pamela was only able to effect this repair of practice through trial-and-error, it is only in some positions and not others that the product still charges. Other repairs of practice are sharing panels across products, charging products through the grid, connecting it to a car battery, only using it in daylight hours (in cases where the battery does not hold charge) and no longer using the product for lighting *and* phone charging but rather for one of the two. This section presents these different examples and shows that in the face of the types of breakdown described in Chapter 3 the most common repair conducted at home is not a material one but rather it is a repair of practice. Drawing on local resources, some as local as their own bodies, prior experience and through a process of trial-and-error shows that repairs of practice are a form of bricolage.

Rather than balance cables like Pamela did (or Martin, another survey respondent in Bungoma County on the border with Uganda), other users in the survey spoke of sharing panels across products. One user in Bungoma, for instance, said that when one of her two SunKing Pro 2 panels stopped working, just over a year after having bought the products, she began using the remaining (functioning) panel to charge both Pro 2s. Similarly, when I was at Timothy's house in Brigedia, also in Bungoma County, he led me in to his bedroom and pulled out a box of panels from under his bed where they are kept safe from his children and thieves. 'In the beginning people were stealing them,' he told me. And so rather than place the panel on the

roof as directed by SunnyMoney sales staff, Timothy would put the panel on a stool by the front door to his house, where it was less visible to passers-by. However, his children would then knock the panels off the stool and so, in Timothy's view, cause the breakdown. He prefers to leave the one remaining functional panel leaning against the wall of the house, but only when *he* is at home. They are kept in the bedroom as there they are 'more safe' as his children cannot enter unless he gives them permission. The link in the solar assemblage that once connected each of these panels to one specific product was broken, instead Timothy now used one panel to charge *any* product. Timothy drew on the resources he had at hand, the box of panels under his bed. I encountered several other instances of panel-sharing during fieldwork. This sort of cross-fertilization of different products is a habit also found in the repair clinic and company settings.

When faced with panel problems other users leave the solar element altogether and charge their solar product from the grid. The solar lantern becomes a grid lantern. In 2016, when I walked around Bomet surveying all the retailers who sold solar in the town I often saw solar lights charging via grid extension cables on the table behind the shopkeeper. Some of these products lay in these phone, clothes and electrical shops because their panel was broken or had already been stolen. Others were there in order to evade theft; users bring their lights to town to charge during the day while they work, returning home with them in the evening. Grid-charging as a repair of practice then demonstrates the existence of pre-emptive responses to breakdown. The previous chapter (Chapter 3) showed that a breakdown is not necessary for a product to potentially become waste. Here we see that a breakdown is also not necessary for a repair to be enacted. The solar part of the solar product (that is the panel) is *not* always what the person in the varied user role values it for. Rather than be tied to the form of the product *and panel* the user values the product for the function it offers: light. How that light is produced is less important. Repairs of practice then show the preference for function over form.

At some point in 2015, the SunKing Pro 2 that Hellen, in Bungoma, had bought in 2014 stopped charging phones. Speaking in 2016, Hellen said that she continued to use the product for lighting. Like Pamela, she altered her use of the product to accommodate the change. Hellen repaired herself with the fact that she would need to return to the shops that offer phone-charging, no longer able to do so from her solar product. Like Timothy, she blamed her children and their curiosity for this diminished functionality. Hellen said that she would only consider contacting SunnyMoney if it got worse, that is to say if the product also stopped lighting. This acceptance supports the idea of breakdown as a continuum (Rosner and Ames, 2014), not a linear or binary state. Responses to breakdown (repairs) like causes of it, are similarly varied. If Hellen's Pro 2 moves along the continuum and breaks

down further then her repair of practice (accepting reduced functionality) will not be enough and she will go further (contact the manufacturer). Repair is not a final state but is often a temporary solution.

Users do not only adopt one repair. Nor do they apply the same fix to all products. When I visited Kenneth at home in Sango, Bungoma County, in 2016, for instance, together with his son Brian, they explained to me how their two SunKing Pro 2 products are charged in two different ways. Sat in their living room Brian showed me how one of the Pro 2s, bought from the One Acre Fund (a social enterprise which provides finance to smallholder farms to help them buy inputs and other goods), runs off of an old car battery which is stowed away behind a cabinet. Brian's younger brother had set this up, attaching the product itself to a wooden ceiling beam over our head. Meanwhile, the other Pro 2 (bought from SunnyMoney) is stored on top of the cabinet (alongside a SunKing Eco and an array of kerosene lanterns). It is taken every two or three days to the family-owned shop a kilometre away to charge from the grid. The battery-charged one is an example of a more material intervention, the second type of home repair that is discussed in the next section. The point here, however, is that like the role of the user and the multiple people and places it represents, repairs are also varied.

Despite the fact that the original problem has not been repaired: for the grid-chargers, the panel has not been fixed or a replacement found, for Pamela, the loose connection has not been restored, the functionality of the products in these examples is returned and so the utility of the product is repaired. Rather than materially altering their product at the point of breakdown, many users instead alter their practices to use the product in a certain way that enables some level of functionality even if a reduced one. Why accept a lower level of functionality? Why adjust yourself and not the product? The repair of practice keeps some functionality. It is important to remember that the user does not have the quality standards or impact metrics in mind, their understanding of performance is not held to the same benchmarks. The imagined user, created by certified actors, is effective in making users just that, users, not repairers. But in practice, urgency requires a solution is found (Graham and Thrift, 2007). And so despite the lack of access to tools, spare parts or understanding of what causes the problem, the user is able to draw on other resources: themselves, the mains electricity grid or other products to make their broken down products work to a degree, for a time. The function of the product is prioritized over its form. This and the inconsistencies it implies mean that a repair of practice is a form of bricolage.

If we understand repair as requiring tools and knowledge then these adjustments to practice may not appear as repair. However, repair does not have to involve tools or materials but is more fundamentally about re-making relationships (Spelman, 2003) and that can be both returning things to a previous functioning or putting them towards a new purpose. Recognizing

the solar product not as a standalone object but as embedded in an assemblage of actors and ideas reveals repairs of practice that a focus on the physical product might miss. Highlighting these non-material responses to breakdown and taking a broader understanding of repair, shows how some users resist the role certified actors would have them play. The users themselves show an implicit recognition of the solar assemblage too. Hellen's ability to separate of functions: lighting and phone charging shows the product is made up of various elements rather than being a single whole. Meanwhile Kenneth's interaction with the grid and Timothy's use of other products and systems are evidence of the possibilities for re-assembling relationships within the assemblage.

Although they occur less often, more 'typical' forms of repair do also happen at home. I turn now to these more material repairs.

Material repair

Despite the companies' best efforts users *do* connect their lamps to other power sources, be they panels from other products (even other brands!), lead acid car batteries and the mains electricity grid. In one of the first critical engagements with the off-grid solar product in the social sciences Cross (2013) argues that the values of the market and market actors are inscribed into the very design of the product. The body casing of the Nova S200 product at the centre of Cross' analysis was 'locked' and could only be recharged with the panel that was sold with it (379: Cross, 2013). The imagined category outlined at the beginning of this chapter: user as user, is made not just through the market devices that measure quality and impact or the marketing materials that convey those devices but is also built in to the product itself. The use of proprietary elements such as Torx screws, unique battery sizes and untypical connectors are physical manifestations of the certified actors' attempts to discourage, as Cross writes, any opening, tinkering or mending. And it is again largely effective. While local improvisation is widespread it is often constrained by product design (Heeks, 2002). Not only are material repairs rarely found at home, but those that do occur are mainly superficial. The main three material repairs that emerged in fieldwork are re-taping cables or re-connecting wires; inserting a piece of wood, paper or card next to the switch to stop it from jamming; or using some thin rope or bent metal to hold a damaged outer casing together. Although now *on* the product rather than upon the user or the manner of use (as in repairs of practice), these material repairs remain external to it. This section takes these three most frequently observed and reported repairs in turn showing similar themes emerging: the use of resources 'at hand', a minimal interest in form or aesthetic and inconsistency in success or outcome.

In the survey, the most commonly reported material repair concerned the cable or wire (when internal to the product) that connects the solar panel to the circuit board. Hilary, in Nandi County, said that one of the wires had become 'cut' in his d.light S2. This translation from the Swahili verb *kukata*, 'to cut', was used often in the repair clinic where I was an apprentice too (see Chapter 5). It was there that I learnt this did not always mean 'cut' in English sense but would be better translated as disconnected or become loose. Hilary reattached the 'cut' wire, although he admitted over the phone that the light was no longer as bright as it used to be. Another respondent in Trans-Nzoia County had a similar problem as had David in Nandi County, both also with a d.light S2. In response, his son who works as a repairman had fixed it. Again, the user should not be interpreted as a singular or individual category, in this instance it includes the wider family. Beatrice in Migori also repaired the cable on her SunKing Mobile, after which the product was working well again. Not all repairs are successful, however. Ezra, for instance, in Narok County failed to repair a wire within her d.light S20 and so proceeded to another response: taking it to the fundi – the repairman that is the focus of Chapter 6. While this inconsistency of success of repairs at home (and to varying standards) could be used to bolster the image of the user as ill-educated or incapable, it is actually characteristic of repair itself, that, unlike manufacture, is never the same (Harper, 1987).

The switch was a popular issue in the survey (17 people complained of problems with it, more than the 10 complaints about the panel). Repairs of practice would involve holding it down for a long time (like Daniel, Bomet County) or doing some 'manual work' to get it to turn off (Jonathan, Bomet County). However, it was during my apprenticeship in one independent repair clinic that I saw how some users materially respond to problems with the switch. When Christie, a schoolteacher, brought her d.light S2 to the clinic, she had already been using a small splinter of wood in her switch for some weeks (Figure 4.1). The splinter stops the white switch from getting stuck under the red casing. Christie had materially intervened with her product in order to continue using it. What prompted her to bring it to the clinic was not the switch issue but a feeling that the light itself was dimming. Christie's home repair shows both use of resources at hand (bits of wood) and also variation in repair: the switch she was able to deal with herself, for the dimming light she sought the support of the professional repairman, the fundi.

In Chapter 3, I describe various causes of breakdown, of which impacts from falls off roofs, racks, stools and motorbikes were prominent. One result of such falls is that product casings can become cracked or damaged; this prompts some users to enact a material repair, others accept a repair of practice. Another visitor to the clinic where I was an apprentice, also with a d.light S2, was a man named Willy, who works at the County Government

Figure 4.1: Christie's d.light brought in to Malo Malo, with wooden splinter next to switch

Source: Author's image, March 2016

compound just across the road from the clinic. One day he came in with his product for repair. As was my practice I arranged to visit him at home and he kindly agreed. When I got there he showed me a second S2 that had a piece of metal bent round it (Figure 4.2). This, he told me, was because the screws in that product had become loose and so the metal held the product together. Similar to Christie, one repair he was able to do himself at home (addressing the loose screws), the second (the product was not charging) he could not and so took it to town. In addition to being another example of using resources 'at hand': Willy told me that he had found the piece of metal outside his house, Willy's case shows that aesthetic appearance or form is less important than function.

Despite then an imagined user to the contrary there are some successful attempts at repair. This has also been found in other studies. One paper examining a solar home system project in Zambia, for instance, found a number of users by-passed the charge controller indicating they knew 'how parts of the system works, and how to obtain additional benefits' (1065: Gustavsson and Ellegård, 2004) from it. But in general, as George, from Tropikal Brands, the main distributor of Philips solar products in Kenya, told me, especially for the bigger systems (what he defined as being anything

Figure 4.2: Willy's d.light S2s, one (to left) with metal wrapped round it

Source: Author's image, March 2016

over 20 watts) you find that 'there are very few who try to repair themselves'. This matches with the survey where when asked about their practices with other household electronics (TV, radio and mobile phone) the bigger the product the more likely respondents were to have either already taken an appliance for repair or the more likely they said they would do so in the future. Users rarely spoke of taking small objects such as torches for repair.

Pragmatic repair

I did not see any children studying by solar light as shown on the leaflet that Julius showed me. However, in visiting several other homes, where these products are designed to be used and indeed where the majority of their use occurs, like Christie's (the schoolteacher) or Willy's (the county government employee), I saw and was shown a range of uses that reach beyond the user role that the certified actor, through its market devices, seeks to portray. None of the homes I visited, for instance, had the thatched roofs sometimes seen in marketing materials and PowerPoint presentations at international conferences. The portrayal of thatched huts is telling of the narrative certified actors want to tell their Western audiences (individual supporters and institutional investors) about poor, rural Africans. Yet the

roofing material of houses has less impact on product performance than another aspect of the rural Kenyan home that was never mentioned in interviews, commented on in conferences or seen in marketing materials: the darkness inside. Overhanging roofs and small windows for protection from the heat and rain made a lot of homes I visited very dark inside, even in the middle of the day. Using lights in the daytime is another contributing factor to the over-use category discussed in the previous chapter but was never mentioned by company representatives in interviews. The point, as set out at the beginning of this chapter, is that use is more varied than that imagined by certified actors. It is more varied in who, in where and also when.

It is not just our understanding of use and user that needs to be widened but also of what it is that constitutes repair. If we take repair to be that conducted with tools and enacted on materials then we cannot see much (see Spelman, 2003). In redefining repair to include non-material alterations we see a direct interaction between user and product involving hands and eyes as tools and knowledge acquired through experience with other household products. This iterative learning and embodied process of repair is similar to that observed in the repair clinic and discussed in Chapter 5. But the part resolutions and temporary solutions that such an approach allows would be unacceptable in the company setting where quality standards and impact metrics still reign (see Chapter 6).

In entering those darkened homes (thatched or otherwise), and interrogating the certified image of the market, this chapter has shown that the certified image is effective regarding repair, in all its forms. Users do little repair, and where they do it is modest (of their routine) or superficial (of the product). Most repairs at home are repairs of practice: they accommodate a new way of living with the product. Where material repairs are attempted, they remain largely external (on the cable, switch or casing). The chapter featured more examples of repairs of practice because it is more common. A broken product that was usable was not a concern to users who could work around peripheral or external problems. This lack of repair could support the company image of the user as lacking in knowledge that I was told about in interviews. The low success-rate of home repairs could be evidence of the user's forceful nature or their impatience as characterized by company representatives. Or, one could conclude that the imagined user, the stereotype, is effective. The ascription of the user's role as not including repair, by and large works.

Users do not do much material repair because they do not have access to the inside of the product, the necessary spare parts or knowledge. Business design through warranties, product design through difficult to reach screws, as well as marketing, and the historical development of the technology, keep users out of the products. Their role in the assemblage is to use, not fix. This confining of users to a particular role has been found elsewhere, too (see

Heeks, 2002). In an investigation of household consumption behaviour in north-east England it was found that 'we are framed, through instruction manuals, as operatives of these things, not as their engineers'. Our role 'is to push the buttons in the right sequence, to call the service engineer if appropriate' it is not to open it up, experiment or bring bits together to make hybrids (140: Gregson, 2011). In addition to instruction manuals, marketing materials and sales pitches also help to frame customers as users, external to the product. The limited nature and range of repair happening at home in Kenya is not because solar users are not good at tinkering (although some are, particularly sons and boys) but they are not *allowed* to be. This denial was recognized in a couple of interviews. Willis at KIRDI showed sympathy with users' struggles, telling me that, 'things break down, something very small, even the battery for example it's, it's worn down after two years or so, and these people don't know where to get another battery to replace it'.

Simon, the founder of EcoSmart, told me that although it was quite easy to change the battery in EcoSmart products 'the problem is where do they get the battery in the rural areas?'

The users I spoke to and those I visited were not, however, deliberately tampering with products or consciously acting against instruction. Nor do many of the repair motivations discussed in the literature appear to apply to the case of solar repairs at home. Users implement repairs of practice (a change in *how* they use the product) or material repairs (a change *upon* the product) for pragmatic reasons. They do what they can because the restoration is too urgent to wait for other avenues (4: Graham and Thrift, 2007). Their actions are motivated by a need for the continued functioning of the household, to recapture the benefits they had been sold. The work of individuals like Kyle Wiens (founder and CEO of iFixit – an American-based website that hosts repair guides produced by a community of activists) is a prime example of where repair is supported by and pursued in the name of, an ideology: to divert electronic waste from landfill and to reclaim the right to repair from corporate manufacturers. But Wiens has himself written of his original interest in repair not being political but instead practical (40: McLellan, 2013). The history of African societies is full of examples of people making adjustments 'to craft self-help solutions to everyday challenges' (7: Mavhunga, 2014) and 'to selectively tap into resources from outside' (7: Mavhunga, 2014). Others identify a similar 'state of constant improvisation and experimentation' (333: Trovalla and Trovalla, 2015) in the face of the uncertainty of daily living in Nigeria. The point is the solar product is not the user's first electronic device nor when it breaks down is it their first experience of electronic breakdown. This connection to other electronic devices (or electrical appliances) is another thing that the imagined user category forgets. Users have more experience and knowledge of electronic breakdowns than the imagined user category implies.

Self-help and self-fixes do not always come off, however. In the survey, Hilary said he had previously tried (and failed) to fix an issue with a mobile phone. At this point users can again turn to their experience with other electronics and seek outside help. Despite the certified actors' best product and business designs, many users will respond in this way. The drawing on previous experience, even if not to actually perform a repair, could be evidence of bricolage thinking if not bricolage practice. The term helping capture both approaches to repair as well as repair actions. The repairs described in this chapter often then precede repairs in electrical and electronic repair clinics or at the company premises, as Chapters 5 and 6 will explore. But as those chapters show, even when the product has moved beyond the home physically, how the home and its inhabitant are imagined continues to shape how repairs are conducted, if at all. When material repairs do occur before a product arrives in the clinic (Chapter 5) or the company (Chapter 6), the imagined users and homes are also carried to these other locations. The visible signs and traces left in or on the material product from a material repair then can fuse with imagined ideas of user, use and cause of breakdown to influence the repair process in these other settings as well.

Repair, however is just one response to breakdown. Some users do not respond. They might also simply accept the breakdown. Several people in the survey, for instance, spoke of how their product had just stopped working. But rather than identify a particular cause or moment, or complain about the product's functionality, they seemed to interpret the finishing of a product as somehow inevitable or natural. This could be one driver then in not pursuing other actions, at least not immediately. Other users still rather than repair (or after having repaired) broken down products put them to new uses or move them to new places to live new lives. It is these new lives that are examined next.

Rural, domestic e-waste

To examine the afterlives of solar (Cross and Murray, 2018), and to further understand the gap, I draw now from a different body of literature which discusses household consumption in the UK (Bulkeley and Gregson, 2009). This is because much of the research on e-waste in the Global South to date has concentrated on urban centres and approached the topic through lenses of informal practices or transboundary governance (see Millington and Lawhon, 2019 for a well-structured literature review). Studies of waste in the Global South have also been treated as somehow unique and specific, leading some to suggest that 'waste studies can usefully benefit from thinking across north-south binaries' (1045: Millington and Lawhon, 2019). By bringing my data into conversation with work from the UK,

I am also able to pursue a postcolonial agenda and challenge empirical and intellectual dichotomies between the North and South (see Comaroff and Comaroff, 2012). I am also able to better understand *domestic* relationships with waste and particular in rural areas. That is to say, waste which is yet to reach the open-air public dumps that much e-waste scholarship in the Global South has been distracted by. In the rest of this chapter I show how 'everyday waste practices' particularly in 'their more mundane forms' (1045, 1051: Millington and Lawhon, 2019) actually have many similarities between North and South settings.

While the volumes of products disposed of at home are smaller, in the rural, domestic setting the effects of disposal could well be more immediate. Much e-waste research has been environmentally motivated, concerned with the effects of 'improper disposal' on human and environmental health. Yet, if, as the next sections discuss, users dispose of their solar products at home they could be contaminating water or land supplies sooner than at urban sites of consolidated waste which have long been under the scrutiny of activist and academic attention (see SVTC, 2004; Greenpeace, 2005).

Waiting in 'the store'

Waiting is another common aspect of African life. In the face of repeated cycles of technological promise and collapse, breakdown and repair that characterize many experiences of infrastructure in Africa, '[e]ach repair enforces another waiting period' (235: Larkin, 2008), the experience of which is exacerbated by its contrast with the speed of ever faster technologies. Waiting gets worse as technology gets faster. Even if the wait itself does not necessarily get any longer. The idea of waiting recurred again and again in my fieldwork in Kenya, too. In addition to 'waiting for e-mail messages to open, machines to be repaired, or electricity to be restored' (236: Larkin, 2008), users of solar products and the solar products themselves, wait before disposal. With some awareness of risks to the environment through local disposal (in the ground, bush, toilet or fire), users' disposal at home, as with repair, is limited. Instead of disposal users hold on to their broken down products as mementoes or symbols of their social status, as teaching aids or as toys. Some hope the products will begin working again at some point, or that the company that sold the products to them will return with advice and others still plan to one day take them for repair. They hold on to them out of an 'expectation of repair' (68: Ntapanta, 2025). Unlike the pragmatism behind repair, other responses to breakdown are driven by uncertainty. Users are not sure what the 'right' thing to do is, nor are they sure what the future might bring and so, in the meantime, products sit in the gap waiting. This section discusses what is the most common response to breakdown at home: holding on.

Timothy Lusamamba bought three products (a SunKing Eco and two SunKing Pro 2s) from SunnyMoney in 2014 when the company came to the school where he was headteacher in the east of Bungoma County. During a conversation with one of my research assistants in 2015, Timothy told us that he had previously thrown away an old solar product (not bought from SunnyMoney) when it was no longer working. Yet when asked about what he will do in future he said he will seek repair, either from the company or from an independent repair person. The gap between Timothy's actions (throwing away the solar product) and his intentions (pursue a repair) appeared repeatedly in conversations with users at home about how they deal with broken down solar products.

When I began the survey through which I came into contact with Timothy, I expected to encounter what has been called the 'materials-flows assumptions' (189: Rathje and Murphy, 2001). The 'materials-flows assumptions' states that whatever is sold then flows in to waste streams after its expected lifespan is over, once its use to the consumer is complete: that is to say that if X million solar products had been sold in Kenya in 2011, with an expected lifespan of five years, then there should be an estimated X million such products in the waste streams five years later in 2016. The first major study to test the 'materials-flows assumption' was the 'Garbage Project'. Researchers spent a week recording all 'major appliances' brought to the Los Reales landfill in Tucson, Arizona, in the US. But very few appliances were recorded. It turned out large appliances, and furniture, would be scavenged from the streets of Tucson before the garbage collectors arrived to take them to Los Reales (190: Rathje and Murphy, 2001).

A subsequent study, the 'Reuse Project' sought to look in to this discrepancy more closely (191: Rathje and Murphy, 2001). The 'Reuse Project' went, as I did, to the place before the dump, the household, to ask residents whether they had recently disposed of any major appliance or piece of furniture. The results of the survey are proportionally similar to my own. 34 per cent had been sold or given to strangers or stores, 30 per cent were still around the house somewhere, 29 per cent had been sold, given or loaned to relatives and friends and just 6.2 per cent had been thrown away (189: Rathje and Murphy, 2001). In the survey of solar users the percentages were different but the relative trend the same: 65 pe cent had kept a broken solar product around the house, 11 per cent had returned or replaced them with the company, 4 per cent had given them away to family and neighbours and 4 per cent had thrown them away. In the US and in Kenya more happens to used electronics it seems than throwing them away.

Users spoke of products being kept in the house, or that it was in the 'store', the 'cupboard' or less specifically that it was just 'there'. This is the gap. And unless another action is taken many said these products had already or would eventually become lost. The reason that the materials-flows assumption does

not hold is that products move into this gap. But why? One answer emerged at the end of the survey when users were asked: 'Is there anything else you would like to share?' While lots of respondents used the opportunity to complement SunnyMoney on the products or asked where and how they could buy more or bigger products, some users asked for advice on how best to dispose of their broken product:

> Can I ask if it is dangerous if it stays in the house?
>
> We should be told how to discard the lights if they get spoilt.
>
> Are they harmful if one decides to burn them?

These, and other questions, are reminiscent of respondents in the midlands and north-east of England who expressed uncertainty and anxiety over what can or should be put in the bin 'because of vaguely felt but barely understood concerns over environmental effects' (687: Gregson et al, 2007). The uncertainty that drives users to hold on to products in the home is also a motivating factor for other actions though, as is demonstrated in the next section. Potentially confusing this shared motivation driving action and inaction makes sense when realizing that users do several different things. Users' responses to breakdown are not one-off and finite decisions. 'Ridding events' are not identified as discrete moments in the passage from one value regime to another but instead they occur 'as part of a seamless flow of appropriation and divestment, storing, keeping and holding' (20: Gregson, 2011) that actually defines a lot of domestic life. Although reaching the discrete percentages offered earlier required coding the responses of the survey and so separating out events, responses were often more complicated than that. Some users spoke of doing several things while others had forgotten or did not know where the product was, this inability to recall the action suggesting that ridding was not a key moment, but part of the daily rhythm of living with things in the home.

The majority of users do not repair at home (as discussed earlier) and many do not move their products on into independent (Chapter 5) or authorized repair processes (Chapter 6). For most users the first response to breakdown is to wait and hold products in the gap. Users wait because they have been told at the point of sale not to intervene or they do not have the knowledge or the parts to do anything else. While some products fall deep in to this gap to be lost, other things can happen. The next section describes these other actions.

Other actions

These other actions include: storing, giving, selling, taking, dismantling, burning, burying and dumping (which can also involve siphoning on the

way to the dump or scavenging from the dump later). This section discusses some of these other forms of disposal.

Michael, a survey respondent in Mulot, 24 km down the road from Bomet said he did not know what would happen should any of the three d.light S2s he had bought fail in the future but suggested that his children will probably take it, play with it and eventually it will get lost. Fearing the same, Steve in Bungoma County was keeping his (already broken) SunKing Eco in a drawer. He told me that otherwise 'my boys can take it, it can be stolen'. The use of broken products as playthings is ironic as one challenge for the certified actors when dealing with national governments in Africa is a conception of off-grid solar products as toys. This is presumably partly due to their size (typically small), colour (often bright) and their capacity (quite low). During our interview, Country Officer for Lighting Kenya, Nana Asamoah-Manu said: 'I remember at the Ministry level, one of the PSs [Principal Secretaries] was so sceptical, not because of us, but because he felt "why should the World Bank and IFC waste their time on these things that are basically toys and they don't really work?"'

Government figures in India have expressed similar attitudes (Cross, 2017). There is a second irony in the sale of these solar products to aid study yet children benefit from them when broken, too. Some children are given the broken solar product to take apart to figure out and learn how they work.

Children benefit in other ways from broken down solar products too. Teacher Samuel, for instance, whom I visited at home told me he would hold on to the wires from his broken products for 'practicals' in the classroom. This was also seen at Karamugi school, one of the original four in which Mark Hankins and Harry Burris installed systems in the 1980s (see Chapter 1). When I visited in 2016 I was told that some of the old panels of the now-defunct system are used for demonstrations in Physics lessons. This re-invention of solar equipment shows a different kind of educational value than that marketed by the certified actors (see Chapter 2). While the products might aid evening, or early morning study, as the marketing materials espouse, solar products are also used as learning aids in and of themselves.

Schools also feature when users discuss local scrap merchants – another destination for solar waste. When I visited Steve at home in Bungoma County I asked him whether there were any scrap dealers or collectors in the area. He told me there were very many: 'they use our schools' he said. Scrap collectors periodically visit schools to buy scrap metal (mainly old cooking pots) or swap it with students for stationery (biros and books). Steve explained that they would typically come one to three times per term. 'The students will steal from parents, teachers say: "No, this one is good. Take it back."' This sentiment was echoed by another survey respondent, Bernard, in Elgeyo Marakwet County, who explained that such school visits had

previously been the case in his area, too, but the practice had since been banned because children would take objects from home and deliberately spoil them so that they could sell or swap with the scrap dealers. Steve told me that 'sometimes they even come as far as houses'. Regardless of where the collection was done, at schools or from homes, more respondents were scathing of the little amount of money they would receive and whether or not these scrap collectors would even be interested in solar products (with minimal metal content, often just a stand or panel frame). 'What can 5 shillings buy?' Dorcus asked me, when I visited her at home. '[It] can't even buy a ¼ of a cup of sugar,' she said.

With little incentive then to sell their broken down solar product users move to other actions still, like burning. And again here children were central to the process. Amos, for instance, in Bomet County said (in 2015) that he will burn his d.light S2 at some point fearing that if his children play with it, it might be dangerous. However, when this option was put to the whole survey sample a year later in 2016 some did speak of the dangers of burning: that it would bring disease, pollute the air and could be deadly for cows.

Instead of burning some users would use the same reasons: protecting children or protecting the environment as justification for putting their broken solar products down the toilet. When discussion over soda in Samuel's front-room turned to disposal of solar lanterns, he said that 'If they [solar lights] are broken they can injure them [children]' so he would put the glass (referring to the solar module) in the pit latrine. I was fascinated by this immediate transformation. When working Samuel and Amos had no qualms letting their children use the solar lights, indeed they are the ideal user of such, but then, instantaneously after breakdown has become too much, the same products become threatening or dangerous. This transformation reminded me of a description of Dayak funeral rites in Borneo where the bodies of the dead 'can no longer be touched without danger' they have become 'an object of horror and dread' (200: Hertz, 1961). The breakdown, like death for the Dayak people, can transform users' perceptions of a solar product from something good enough to invest money in (often for reasons of health or education) to something threatening. Opinion on latrine disposal was also split, however, with some suggesting that nothing would happen and that this was a safe method of disposal but the majority warning of explosions, chemical reactions and radiation.

Although Dorcus was one of those who planned to put her product, a SunKing Pro 2, in the latrine she did worry that the toilet would fill up as a result. And so she would bury the battery, she said. Others cited their uncertainty as a reason to bury their solar products. Because they do not know what is in it or what might be harmful then they will bury it. However, once again opinions were mixed with some expressing concern for soil pollution,

many unsure of what would happen and a few believing that as long as it was buried deep enough then there could be no further risk.

The final action that emerged from the survey was to throw away the broken down product. Few gave reasons for this decision, it was 'just' or 'simply' the case when there was no other option left. Nor did all users specify how or where they would throw the products away. If not just in a nearby bush on their land we can assume these products would also end up being burnt, buried or put down the toilet as these are common and typical methods of disposal for household waste in rural Kenya (Kipkoech, 2014).

First and second burials

The most frequently reported response to breakdown is to hold on to the products at home. Some users do this with the intention of performing another action at a later time. For others the holding is the end, at least for the moment they have no plan to do anything else with it. The holding is characterized by putting the product, or part of it, under a bed, in a drawer or on top of a cupboard. These moves mark what Hetherington, drawing on the work of Robert Hertz, calls the first burial (Hetherington, 2004). Other forms of the first burial are to keep the product as a *kumbusho* (memory) to hang on the wall. When I visited Timothy at home he told me he keeps his non-functioning solar panels for 'remembrance'.

After the first burial comes the gap where products wait. At some unspecified point after that come the other actions discussed earlier that constitute either a new life: using products as toys or educational aids and selling them for scrap, *or* the second burial: burning them, putting them down the toilet or burying them. The choice of when to move a product from first to second burial or move it elsewhere from the gap is an uncertain one. In the follow-up survey when asking users what they thought might happen should a solar product be burnt, buried, thrown down the toilet or left in the house, a large number of respondents simply told us 'I don't know'.

★★★

Through the survey or after a visit, perhaps prompted by our discussions and my visit users would call or text me asking for advice on what to do, or who to contact in the event of a breakdown. They would often ask me what should be done, where they should go et cetera. In the framing of the imagined user this not-knowing is because they are not educated but the same ignorance could be framed as uncertainty: they are unsure what to do. For many users the survey was the first time they had heard from a solar representative in months, possibly even years, and so they would ask questions of us. Because he had not heard from SunnyMoney for a while

when I visited him at home in 2016 Samuel told me that: 'I thought maybe the company had closed.' The survey call reminded him to try again with SunnyMoney about the problem he had. This then is an example of when my research was an actual intervention in the processes this book describes. One must assume that others adopting the telephone survey method, such as Acumen, will be facing similar concerns from customers. This is certainly an ethical challenge to be considered when choosing one's methods. It was not, however, one I had thought of pre-emptively. In response I told users to contact SunnyMoney directly and reminded them of the contact phone number if they did not have it: the research assistants and I had made the survey calls from our personal mobile phones.

★★★

In the absence of guidance from solar providers and retailers a lot of user disposal practices, like their repairs, are informed by experiences with other electronic products. This serves as a further reminder to consider and examine these solar products in the context of household consumption rather than approaching them through the lens of e-waste. It is only by concentrating on the act of wasting rather than the stuff of waste that this variety of practices and the dual burial can be seen. As practices they would be hard to retrace when waste is already consolidated in urban dumps where the attention of e-waste research has focused. Consciously taking a different focus in looking at rural, domestic e-waste the range of actions described in this chapter has demonstrated that very few solar products are making, or look likely to make, their way *as waste* to the urban centres. Admittedly, they may end up there by other means through the prism of independent or authorized repair processes which is where the next two chapters move.

5

Professional Repair

An old profession

When I asked electronic and electrical repairmen how they first became involved, or got interested in repair they often referred to their childhood. I asked one repairman, called Hesbon, how he had learnt electronics:

> *Mimi, hii ni kipawa, nilizaliwa nazo tu*, [For me, this is a talent, I was just born with it] yeah. When I was Class One I started *ku*repair watches, I started with watches when I was in Standard One. Standard Two watches. Standard Three *nianze kutengenza redio*, so *ni kitu nilikuwa nayo* [I started to fix radios, so it's something I have always had], yes.

This locating of one's affinity to repair in experiences as a child is well-established in the repair studies literature (McLellan, 2013; Jackson and Kang, 2014). Artists, hobbyists and professional repairers often talk about childhoods spent disassembling toys and home appliances. It is not just within personal histories of repair that people point to the past, however. Despite the modern flavour that contemporary objects of repair: mobile phones (Houston, 2013), cars (Dant, 2010) or photocopiers (Orr, 1996) might suggest, some argue that repair is 'ancient … even timeless' (226: Jackson, 2013).

When I interviewed Willis, the Head of the Renewable Energy Division at the Kenya Industrial Research and Development Institute (KIRDI), he told me that the tradition of electronic repair is well-established in Kenya:

> it's quite old and mainly it, you find artisans, technicians, dealing with what is called repair work of systems and they repair up to component level. And so when you talk about skill actually, skill is there, skill exists. If you walk around the streets of Nairobi you will find shops all over, breaking TVs apart, putting in new components, and getting the TV working and so that's happening.

It is significant that Willis uses the word 'skill'. In Kenya, those who earn their living through repair are known as *mafundi*, or *fundi* (singular). The word *ufundi* means 'skill'. It is one of a family of words concerned with teaching (*kufundisha*) and learning (*kufunza*). The fundi is a skilled individual who works with their hands to make something function. This could be a new thing: like a flashing LED sign board for a shop or an old thing: like a CRT television for a café. They might work with wood (fundi *wa mbao*) or they might work with metal (fundi *wa chuma*). The profession, that is ubiquitous across communities in Kenya, is united then not by the material it works with, nor what it produces, nor still the tools used. Instead, it is the manual nature of their work, and perhaps most crucially how that skill has been acquired that identifies an individual as a fundi. Although there are numerous types of fundi such as: *wa gari* (vehicles), *wa stima* (electricity), *wa baiskeli* (bicycles) and *wa piki piki* (motorbikes), the type of fundi that is the focus here is the fundi *wa TV na redio* (who work with electronic devices and electrical appliances more generally).[1]

Other terms are sometimes used in the literature and in interviews. In Kenneth King's foundational studies of the informal sector in Kenya, for instance, he refers to the mafundi as 'artisans' (King, 1975; 1977; 1996). Company interviewees spoke to me of: 'technicians', the 'technical guy' or a 'sort of repair guy'. Here, however, I stick with the word 'fundi', the term that mafundi use to describe themselves, and the term that is used by their customers. This also avoids confusion with 'technician' which is used in Chapter 6 to describe technically oriented employees of solar companies. Answering Jackson's calls for researchers to 'expand our cast of characters, including but certainly not limited to the breakers, fixers, and maintainers' (234: Jackson, 2013), this chapter introduces the fundi to repair studies. The fundi is also introduced as another character in the solar assemblage. I argue that the fundi's work, like the origins of their expertise in childhood, is similar to the work of the menders, fixers, mechanics, tinkerers, hackers and repairers already present in the repair studies literature. Still working with the concept of bricolage allows us to see the similarities across contexts. They are all, like the user at home, bricoleurs. Although doing a lot more repairs, a lot more of which are *material* repairs, than observed or reported at home, the fundi proceeds in much the same way as the user, through trial and error. The fundi's work consists of drawing on previous experience, using parts from other objects and prioritizing functionality over consistency or aesthetics. And also like the user at home the fundi's repair is limited by factors beyond and outwith their control such as business design, product design or manufacture. However, what makes the fundi distinct from the user and those fixers already present in repair studies literature is their motivation. Rather than repairing for pragmatic reasons (as users do), for joy, political protest or environmental beliefs (as the literature suggests others do), the

mafundi in Kenya work to fix objects so as to provide for their families. Theirs is an economic motivation to make money.

I begin by introducing the two mafundi I worked most closely with: Wilson and Hesbon. I show how their ethnicity (Luo) and gender (male) are integral to their work. In the second section I turn to the daily work of professional repair: the space, tools and reputation. For the third section I detail 16 solar repairs worked on during a three-month apprenticeship in one particular repair shop. I argue that while repair might be innate to human existence, it is the *way* repair is done that we share across contexts, not *why* it is done. The later parts of the chapter turn to the waste generated in the professional repair setting. Here I stress that, like at home, most 'waste' is held on to in the clinic. Mafundi do not know which part of which old appliance might provide them with the spare part to fix a future product when it is brought in and so in the face of that uncertainty, they hold on to such bits and pieces, or sediments, just in case.

Luo-men and learning

When I first arrived in Bomet in January 2016 I set about finding a fundi who might accommodate me as a participant–observer, or apprentice. I wandered the streets and asked various passers-by and local shopkeepers where I might find a fundi who can fix electronics. I was directed to various places around town. I was taken to one in a hut out the back of the bus station, where I saw a soldering iron being heated in a burning kerosene cooking stove. And I was pointed to another down an alleyway that led in to a courtyard with a hairdresser's, a clothes shop and a fundi. One, however, stood out. Not only because it was on the main road, signposted and had a crowd of people outside it but because, craning to see inside, I saw a box on its back shelf from my former employer: BBOXX – an SHS manufacturer and distributor. I was surprised to see the box of a BBOXX TV here because, at the time, BBOXX were only selling in the Nyanza region of Kenya, 130 km further west. In later visits to the other six repair clinics in the town, I would discover that they, too, had solar products on their shelves, walls, floors and benches, but they had not jumped out at me as the BBOXX one had on that first visit.

I asked the mafundi at the clinic with the BBOXX box, two men named Wilson and Hesbon, if I could spend some time with them over the coming weeks, watching (and to an extent learning) their work. They agreed and so I spent the following three months at the *Malo Malo TV na redio clinic* (see Figure 5.1) observing and participating in the work of a fundi.

This section introduces three broader aspects of the fundi category that shape that work: ethnicity, education and gender. Mafundi in Kenya are historically from the Luo ethnic group. This shared identity and the fact they

Figure 5.1: Malo Malo from the bank up to the main road

Source: Author's image, March 2016

often work away from home were explained to me in terms of economic advantage. Meanwhile, the centrality of the apprenticeship (often through a family connection) as the path to becoming a fundi means repairs in the clinic emerge from acquired, practical experience. Third, the clinic as a masculine environment feeds into understandings still dominant in contemporary rural Kenya; that a man should financially provide for his wife and family.

Both originally from Nyanza (the region in the west of Kenya where BBOXX operated), Wilson and Hesbon are Luo, the fourth largest ethnic group in the country (423: KNBS, 2019) – a group I would learn are disproportionately represented in the fundi category. During the course of my fieldwork I often heard that the Luo were famed for being fundis: taxi drivers in Nairobi told me that the Luo were 'good with their hands' and in Bomet locals (from the Kipsigis ethnic group) said that the Luo are 'the best fundis'. Not just in electronics but across other fundi 'disciplines' such as carpentry, mechanics and metalwork. When I asked Wilson if this was just coincidence he told me:

> you know this country we have many tribes. But every, every tribes have got their knowledge, their experience eh? … So you know in Luoland [Nyanza], a long, long time ago they have to learn something, they have to, all of them are Luo they start to learn something one by

> one. They, a long time ago, if you take something to a Luo person, a Luo man or somebody from Luoland even this, this wine [*picking up the glass bottle of my soft drink*], he want to know which is this thing? What is it? Eh? Ah how do, how do they manage to build this bottle like this? And what is inside it?

Wilson continued, telling me that if you give *some* people something they 'don't care, he can use it and put it there and he can, and he go home'. But a Luo man will want to know how that thing works in order to either make, fix or improve one for himself.

Mafundi are not exclusively Luo, however. Indeed, only half of the 12 mafundi who operate in Bomet are Luo. Crucially though, of the other six, only three are local to Bomet. The others came from Kericho and Kisii, larger towns to the north and west. I spent full days shadowing each of these other mafundi in Bomet's six other clinics during a return visit to the town in August and September 2017. Like Wilson and Hesbon, they, too, were working away from home. When Wilson and I sat down for an interview in 2017 he told me:

> if you are near your friends and neighbours or family you have to help them without payment. So what you can do, that's why you see a lot of people go far, far, away from their villages so if you can help somebody to do something he have to pay you something also.

Unlike 'Barefoot Engineers' in central Rajasthan, India, who are sent *back* to their home villages after their training with the intention that they remain there (Allen, 2011), mafundi generally (and deliberately) work *away* from home. Working away from home is a financially motivated decision; you have to do it in order to get paid. This does not mean, however, that mafundi work alone or are isolated. Rather, the opposite is true. Mafundi form new networks in the place where they operate. When I asked Hesbon in an interview why he did not have his own clinic, rather than share with Wilson, he told me that you cannot do it alone. These networks are formed on ethnic lines. Every lunchtime during my three months at Malo Malo, for instance, we would eat with Luo mafundi *wa nguo* (clothes) and *wa piki piki* (motorbikes and generators) who worked nearby and often in cafés where they serve *omena* (silver cyprinid) – a type of fish that is native to the Nyanza region that Wilson, and others, refer to as 'Luoland'. Other Luo mafundi (*wa TV na redio*) would also drop by at various points during the working day to consult Wilson and Hesbon about a particular repair that was troubling them or, more often, to share tips on the day's football betting. This friendship group also involved several savings groups where each pays a small amount in to a joint account daily that a member can then draw on

if they want to make an investment in their home, business or need to pay larger 'one-off' sums like school fees for their children.

The ethnic network is also important for training and opportunities. Hesbon, for instance, initially travelled from his home town of Nyakach (in Luoland) to Eldoret (out of Luoland), further up the Rift Valley from Bomet to be trained by an uncle of his. He later moved to Bomet to be near his brother who was practising as a mechanic (fundi *wa magari)* at the time. And it was because of the Luo connection that Hesbon and Wilson found each other in Bomet around 2008–09. Wilson had come to Bomet a few years earlier in 2005, again on the recommendation of 'a brother' having done his initial training under the tutelage of a friend back home in Luoland.

Although many mafundi would refer to their childhood as being the origin of their repairing skills, many complement this early curiosity, ethnic belief and apprenticeship with some formal training. The combination of learning-by-doing with more formal study is not dissimilar to the paths taken by Hankins, Keane and Blyth in Chapter 1 who each sought academic degrees to go with their on-the-ground experiences. When Wilson's father died, the family finances were affected and so Wilson's mother paid for him to study electronics at a polytechnic, which would be cheaper than the fees, uniform and books needed for the final year of secondary school. I was initially surprised that a fundi would have gone to college. Having been told by Wilson, Hesbon and others that they were *jua kali* (lit: 'hot sun', referring to work that historically took place outside) and so part of the informal sector, I assumed that those within it would not have received formal training. One appraisal of the need for certificates and diplomas was given to me by Mike, a motorbike fundi who worked on the ground outside Malo Malo and kept his toolbox in the clinic overnight. Mike told me that formal certification helps mafundi secure contract work from institutions like the County Government, for instance, who need such documents in order to award tenders.

One thing that is constant across the fundi category is gender; they are all men. Although some have argued repair is feminine (Spelman, 2003; Jackson, 2013; Callén and Criado 2016) and the previous chapter demonstrated the greater care shown by women and girls towards solar products at home, the clinic, like classic studies of repair in New York (Harper, 1987) and in the UK (Dant, 2010), is a male-only space. In a survey users also spoke of the *fundi* as men and where acknowledged in interviews the repair person was a he, too. Wilson and Hesbon's friendship group was all men as well; many of whom were also working away from their wives.

The bricolage business

Malo Malo sits between a café and a hardware shop. The clinic is separated from its neighbours by some thin wooden boarding. This minimal boundary

is good for calling through to the hardware shop when in need of parts or to assist a customer who is being sent there but less good for keeping out smoke from the café's charcoal-fired kitchen of. Looking in from the road, a stack of sound systems and woofers line the left-hand wall. The back wall is covered with wooden shelves sagging under the weight of TVs, DVD players and radios. On the right-hand wall a single bulb directs light on to the workbench below. Higher and at right angles to the workbench is the counter over which most interactions are had and on which most repairs are made using the much brighter light of the sun from outside. I spent most of my apprenticeship sat on a small stool at the workbench inside or on a high stool in front of the counter.

Every day at Malo Malo began by sweeping out the floor of the clinic. Similarly, the desk and workbench would be sorted at least once during the day as well. Cleaning the object was one of the first and final steps involved in any repair. Indeed, on occasion cleaning the product (or parts of it) *was* the repair (such as wiping with kerosene to remove residues on the circuit board that reduce conductivity). Wilson and Hesbon also regularly wiped their hands together or on a rag to clean them. Although there was dust, insects, fumes, glue and kerosene to contend with at Malo Malo, effort was made to keen the place relatively clean.

Wilson was proud of his standing as well as his workspace – he told me proudly in our interview: 'Most of them, most of the people in this country love, love us because of our works.' Despite this claim of adoration, I did encounter negative views of the fundi during fieldwork. Interviewees in Nairobi spoke derogatorily of the ability of mafundi to fix solar products. One company manager for instance described to me how 'the local chief in the village, right, the guy who knows how to put two wires together he, he then acts as a sort of repair guy right? And he starts doing stuff.'

The European manager's use of the word 'chief' reveals a lack of understanding of rural living in contemporary Kenya where traditional social structures involving chiefs are rare or of little relevance to people's lives today. But, more than this, the skills this 'repair guy' has are belittled. This belittling peaks when the manager explained how any attempt to re-wire the circuit board of one of his company's products will 'just short-circuit it!' Breaking into laughter, he told me 'they [the repair guys and users] don't know that but they will, they will try it, they try to repair, they fail'.

Users also spoke suspiciously of mafundi. Telling the research assistants and me, in the survey, that mafundi would lose products, that they would not be able to fix solar things or that they, a neighbour, friend or family member had had an unsuccessful experience with a fundi in the past. Ironically, past experience (say getting a mobile phone or radio fixed) was also quoted as being how a respondent knew that a particular fundi could repair solar

products as well, having seem them do so when at the clinic with another of their electronics.

At Malo Malo users would often come repeatedly to check up on the status of their repair, not knowing and not being told, that no further action had been taken on it since they last checked. Most repairs happen as customers wait. If a customer did not wait, then others who did would move ahead of them in the queue of jobs to be done. While I could empathize with customers' frustrations at the time they had to wait for a repair to be done, often returning several times over several days or even weeks to remind Wilson and Hesbon, I did not observe any deliberately misleading or malicious work at the clinic. I mostly observed conscientious efforts to fix things. Wilson and Hesbon pushed for higher profits by telling customers that they have paid a certain amount for a new component which is higher than the actual price or indeed when a used component has been put in the product, but I do not believe such financial wrangling constitutes 'banditry' or means Wilson and Hesbon can be called 'buck-happy repairmen' (130: Packard, 1961). Instead, in Bomet, as in communities in the mid-century US, most repairmen are: 'competent, conscientious, and dedicated' (131: Packard, 1961).

Wilson and Hesbon were, however, disparaging of other mafundi, particularly those in more remote areas of the county. I was told that these, who could be referred to as village fundi, had less skill, knowledge and experience than those able to operate from the town. One particular village fundi, Baba Nani, would come to Malo Malo at least once a week to consult Wilson and Hesbon on a repair, at times even sub-contracting them to do the repair for him. Part of this came from a pride in their own work: Wilson described Hesbon to me in an interview as 'a perfect fundi' while Hesbon himself said that he was the best in Bomet for fixing TVs.

It may also be pride that explains the mafundi's response to failure. When repairs failed at Malo Malo it was not seen as a judgement upon Wilson or Hesbon's skill or expertise but rather the object itself is said to simply be 'broken' (*imevunjika*) or destroyed (*imeharibika*). Mafundi speak of products 'becoming' (*imekuwa*) or 'refusing' (*imekataa*). It is not they that have been defeated but more that the product has not co-operated.

Sixteen solar repairs

I worked alongside, underneath, behind and often in-the-way-of Wilson and Hesbon, six days a week from 8 am until 6, 7 or sometimes 8 pm. I watched as people came in with their radios, TVs, sound systems, mobile phones, hairdryers, fans and other household electronics. I followed the negotiations over what the problem was, its cause, its solution, its cost, the time it would take to repair and watched the repair happen. As I did so,

Wilson and Hesbon would tell me to pass this, open that, solder something here, connect something there, hold that bit, get rid of that one and so on. It was a learning much like Daniel had had at the hands of Harry Burris (see Chapter 1) and, excluding my ethnicity, typical of a Kenyan fundi.

When a solar lantern or home system was brought in for repair I introduced myself to the customer and asked them for their phone number so as to arrange either a home visit or an interview at a later date. During my apprenticeship at Malo Malo 16 solar products were brought in. Mercy, Esther, Bii, Willy, Janet, Simon, Martin, Purity, Leonard, Lang'at, Stanley, Christie, Chepuchuk, Samuel, Eliud and another Lang'at brought in their broken solar lanterns and home lighting systems. Each of the 16 customers who came agreed to give me their phone numbers, although ultimately I was only able to visit eight of them at home. This section presents elements of these cases of solar repair to show that Wilson, Hesbon and other mafundi I worked with and was told about, operate as bricoleurs, and so their work, like that of users at home, is a form of bricolage. Mafundi take parts and components from old products and appliances that have been left by previous customers to return other objects to readiness. As for the user at home, the fundi's objective is to restore some level of functionality. Aesthetic or visual aspects of the product are not important. This and the limits of product and business design decisions of others, made elsewhere, means the form that functionality takes is variable. It is variable for two reasons. First, because, as shown in Chapter 3: '[a]ll broken technologies are broken in their own way' (228: Jackson, 2013). This necessitates the trial-and-error approach that the fundi follows and means no two repairs are exactly alike. And second, the close, personal involvement of the fundi in the process means that any repair is informed by the acquired experiences of that particular fundi and often their own bodies.

The main contrast with repairs at home is that at the clinic most repairs are material repairs. However, there are occasions when mafundi like Wilson and Hesbon return a product untouched, perhaps accompanied with advice to a user as to how they might affect their own repair of practice: such as fully charging the product or balancing a cable in a certain way that allows the product to function as desired.

Customers who came to the clinic had bought and received their solar products through various means; some from shops in Bomet, some from bigger regional centres like Kericho while others were given them by family members working as far afield as Somalia. Purity was sent to Bomet with a work colleague's radio from their M-Kopa SHS with the instructions to 'take it to a fundi'. Arriving in town, she asked a motorbike taxi rider where she could find a fundi who can fix TVs and radios as I had done on my arrival to the town. She was directed to our clinic. After quickly opening up the radio, putting his tongue to the circuit board and testing the battery

in a phone repaired earlier that morning, Hesbon told Purity that it needed a new IC (integrated circuit). The problem? It is not easy to get a new IC right now. Hesbon told Purity that if she came back with the spare, that is, a similar model of radio, he would fix it. And with that Purity left with her unrepaired radio.

Purity told me the story from her perspective in her living room about a month later. She said that later that day a friend had told her that this company, M-Kopa, had a shop in town and so she should go there. When Purity visited the shop she was told that the owner of the product (her colleague) needed to come in and do so with the serial number of his SHS (which is on the main battery unit and not on the radio) at which point they would swap the broken radio for a new one – this kind of replacement-as-repair is discussed in Chapter 6.

What Hesbon had planned to do was a more intricate material repair. He would have taken the specific IC from an existing radio and moved it in to Purity's colleague's radio. I was surprised he sent Purity away as there were a couple of M-Kopa radios lying around in the clinic at the time. The use of components from existing 'stock' and testing parts with other products in the clinic to fix new ones is common to repairs in the clinic. The practice is often referred to as 'cannibalizing'. Similar reusing of components has been observed in Barcelona and Madrid (Callén and Criado, 2016). It is also a key feature of bricolage, as Lévi-Strauss writes of the bricoleur:

> His first practical step is retrospective. He has to turn back to an already existent set made up of tools and materials, to consider or reconsider what it contains … He interrogates all the heterogenous objects of which his treasury is composed to discover what each of them could 'signify' and so contribute to the definition of a set which has yet to materialize. (18: Lévi-Strauss, 1994)

In practice, the consideration, reconsideration and interrogation that Lévi-Strauss describes happens almost instantaneously, at least it appears that way to the customer or the trainee-cum-researcher. Hesbon made the evaluation and diagnosis very quickly. Purity's was not the only case where a lack of parts in the treasury prevented a repair. The volume of solar products brought to the clinic is low, compared to other objects. For instance, on the day Purity came with the solar radio, seven speakers had been brought in. Greater frequency means more parts available to draw from existing products. And so the treasury of solar spares to draw from is limited. As the volumes of solar products being brought to Malo Malo increases, this may well change.

There are signs it already is. In 2017, when I spent a day shadowing each of the other mafundi in Bomet, I was surprised that in just one day with each of them at least one solar product appeared. This did not seem a surprise

to these mafundi, however. When I asked them about this, they said it was relatively common. In our interviews in the same trip Wilson and Hesbon confirmed that they were seeing more and more of solar products at Malo Malo, too. It seemed to be an empirical realization of those millions of products sold through the certified market over the last five years (70: Dalberg Advisors and Lighting Global, 2018).

The alternative to cannibalizing from previous or existing products would be to use new parts. But this, too, is limited. Certified manufacturers do not provide new parts to third parties and nor are there any generic components available, at least not yet. Unlike the situation facing repairmen in the US in the 1960s, it is not 'the jungle of similar-but-different models' (133: Packard, 1961) that make it difficult for mafundi like Wilson and Hesbon to stock all the variants but the simple fact that for most off-grid solar products no spare parts are available – it is a desert. Some mafundi do stock more generic new components like ICs, transistors, resistors and capacitors, but this requires an investment of capital that most are not able or not willing to make. If a new component was needed at Malo Malo (and was available in the market) Wilson and Hesbon would send customers to buy it from the hardware store immediately next door to the clinic or to another electronics shop further up the hill.

Were solar parts available perhaps the most in-demand part would be the battery, which, as Chapter 3 explains, is the most common point of product breakdown. Indeed, one survey respondent's landlord who doubled as a fundi in Sirisia, Bungoma County, told me that the unavailability of batteries was the biggest limit to his repairs of solar products in the village. Meanwhile, Willis at KIRDI told me that 'even the radio repairer [fundi] can't sort it out because that battery is nowhere to be found in the market'.

When visiting all the solar retailers in town, they were often selling generic phone parts and accessories including a large array of different battery types. On my return to Bomet in 2017 I saw for the first time a spare solar battery. It was for the non-certified but very popular GD Lite system. In Bomet, GD Lite was the most widely sold, and perhaps best-selling, home system, certainly for a cash sale (M-Kopa might have had more unit sales on pay-as-you-go [PAYG]). Whether or not more manufacturers will follow GD Lite's approach or specialist third party parts and batteries will become available for solar products as they are for mobile phones remains to be seen.

In addition to batteries, Samuel's landlord said a big problem was knowing the number of the ICs. Written in small, faint white writing on the black body of the IC, he uses a magnifying glass to read the numbers. There was no magnifying glass at Malo Malo – Wilson and Hesbon just used their eyes. In a day spent shadowing Yusuf, one of the other mafundi in Bomet, I watched as he used a small magnifying glass to check the connections on the back of Greenlight Planet panel. Unfortunately, during the same return

trip to Bomet in 2017, Wilson was struggling with a growth near his eye, which was impairing his vision and so making his work increasingly difficult.

It is not just the eyes that are important for fundi. Other parts of the body are central to their work: their nose to sniff the end of the soldering iron and check it is hot enough; their fingers to tap the circuit board and feel for current; their ears to listen for the whirr of a TV 'engine' or the *plump* of a woofer. Wilson and Hesbon regularly held things in their mouth or balanced them on the chest while shoulders and thighs became extra work surfaces on which to balance appliances, and wires and cables became temporary necklaces during a repair. Research in vehicle garages in the UK and with heating and ventilation mechanics in the US has found a similarly central role for the body and gesture (Henke, 1999; Dant, 2010). The intimate involvement of the repairman in the repair process again links with bricolage:

> [The bricoleur] 'speaks' not only *with* things, … but also through the medium of things: giving an account of his personality and life by the choices he makes between the limited possibilities. The 'bricoleur' may not ever complete his purpose but he always puts something of himself into it. (21: Lévi-Strauss, 1994)

While Lévi-Strauss is not referring to physical self of the bricoleur's body; the fundi's saliva or breath, for instance, the principle holds that repair like bricolage is a very personal project. It is both informed by and constitutive of the person doing it. This putting 'something of himself in to it' is another reason why repair is inconsistent. Not only might a repair make use of previously used parts, but it also varies according to who is conducting it.

When Stanley brought his unbranded solar lantern to Malo Malo, Wilson gave it to me to do. Mafundi generally prioritize products according to the amount they can make from a repair, TVs, although often a lengthy repair, are one of the more profitable appliances for a fundi. For this reason, solar was rarely a priority. And so it was not just for my interest that Hesbon and Wilson would pass solar jobs, like Stanley's on to me, it was also because there was less money in them; they were less complicated. Stanley, a community health worker, had knocked the lantern off the top of his car when he was cleaning it the day before. Although still functional at first, Stanley had twisted off the top of lantern to re-align the plastic lens over the LED as it had shifted in the fall. But, he told me when I visited him at home a few weeks later, that as he did so, some wires inside became unconnected. Pleased that Wilson had entrusted me with a job I wanted to do it well. But feeling the pressure of his gaze and that of Stanley, my sweaty hands struggled to manipulate the soldering iron, the solder wire and the flimsy, thin wires of the product. Wilson stepped in to resolder the connections, charge Stanley 50 Kenyan shillings and send him on his way. Despite using the same tool, it

was in Wilson's hands, honed from the experiences of countless comparable repairs over the years that he was able to make the very simple connection very quickly. It is not just the tools and gestures of the body then that make each repair unique but also how that body interacts with external tools: in this case, the soldering iron.

The soldering iron is the centrepiece of the fundi's external toolkit and is employed in nearly every repair at the clinic. Unfortunately, when Samuel arrived at the clinic with his SunKing Pro 2 there was no electricity and so no power for the soldering iron. Samuel's story actually starts a few days prior to this, however. When Samuel noticed his product was not charging, he summoned a local village fundi from the nearby centre – a 50-shilling motorbike ride east of Bomet – to come and fix it. Although able to open the product this fundi could not see what the problem was. His next step was to turn to the connector port where the panel cable is inserted into the lantern but, according to Samuel, the fundi broke this. So, when Samuel reached Malo Malo a few days later, he had two problems that needed fixing: why the product was not charging and the broken connector pin. Samuel waited on the chance that power might come back. This was not unusual. Customers often wait around to watch as their repairs are done, knowing and fearing that if they do not then other jobs will push them down the list of priority. What was unusual is that Hesbon rewarded Samuel's patience by using a friend's diesel generator to fix his product. Despite power cuts being an almost daily occurrence, this was the only time I saw such in my time at the clinic. Although frustrating for Wilson and Hesbon, power cuts were more often used as a welcome break allowing time to rest out of sight in a friend's sewing shop two doors down or to catch up on the odds for the day's football betting. The exception may have been due to Samuel's age and status as a *mzee* (old man); older people are well-respected in Kenyan culture (577: Ogola, 2006). Samuel's experience with the first fundi is not the only time I heard of a fundi creating, rather than solving problems. Several users in the survey had had negative experiences with mafundi either not being able to fix their products, losing parts of the product in the process (such as the rubber insert that holds a stand in place) or simply misplacing the whole product. Even for Samuel's actual repair at Malo Malo he had to return the next day because the product was still not charging. Repair then can be frustrating, repetitive and tiring for the customer. Emotions that come to colour the opinion and reputation of mafundi (see previous section).

The fundi's repair, like the user's in Chapter 4, is limited. Although with different skills, in different settings, the limits of these repairs at the home and in the clinic are because both user and fundi are bricoleurs. The difference at the clinic is that the knowledge, the skills and the tools are there. The physical make-up of solar products is little issue for most mafundi. Their work is limited by the relatively low volumes of solar products next to other

electronics: they have less familiarity with solar products and used products to cannibalize for parts are scarce. These two factors are only exacerbated in more rural areas for the village fundi. Hesbon told me in our interview that these village fundi: 'They can do *redio* only.'

Such limits, however, are exactly what makes the repair business one of bricolage. Working from an existing product, using parts of other used products and drawing on their physical selves, their trained gestures and their experience is why the fundi is also a bricoleur:

> the possibilities always remain limited by the particular history of each piece and by those of its features which are already determined by the use for which it was originally intended or the modifications it has undergone for other purposes. The elements which the 'bricoleur' collects and uses are 'pre-constrained' like the constitutive units of myth, the possible combinations of which are restricted by the fact that they are drawn from the language where they already possess a sense which sets a limit on their freedom of manoeuvre. And the decision as to what to put in each place also depends on the possibility of putting a different element there instead, so that each choice which is made will involve a complete reorganization of the structure, which will never be the same as one vaguely imagined. (19: Lévi-Strauss, 1994)

Economic repair

The fundi then is a new character in repair studies. The mafundi working to repair TVs, radios and other household electronics in Kenya are increasingly dealing with off-grid solar products. From more of a weekly occurrence in one clinic in 2016 to a near daily occurrence in six clinics across the town in 2017, these products are entirely compatible with the fundi's existing skill set and business model. This is particularly true for non-certified products, where there is no conflicting processes of warranty or authorized repair to navigate.

The fundi is a skilled person, most of the time a man, and overwhelmingly Luo. A key actor within the *jua kali* sector (that Wilson and others described to me as being characterized by 'daily work' and working for yourself), the repairs of off-grid solar products by mafundi are, like at home, limited. Similar to the pragmatism that drives users at home to break the imagined mould the certified market makes of them, the economic drive of the mafundi keeps them fixing, albeit within limits. However, mafundi engage in more material repairs than the repairs of practice that dominate at home (Chapter 4). Unlike at home the limitations for mafundi are not determined by tools, knowledge or skill but by parts, product design and business design. They are not limited by resources as some have characterized informal repair

in Kenya (Holt and Littlewood, 2017). The clinic was full of resources, the limits were not so much material but structural.

The mafundi I worked with do not struggle against such limits, however. They sought only to satisfy the customer at hand, not challenge the complex market chain in which they are both embedded (and marginalized). If anything, Wilson, Hesbon and others were respectful and accepting of political context and their position within it. They would tell customers, for instance, to return M-Kopa products to the company shop on the other side of town rather than interfere in that particular company's operations. Baba Nani, another fundi I shadowed, told me similar in our interview: '*Mimi najua sana sheria na mi-mimi nafuatanga ukweli sana sana* (Me I know the law well and I really follow it truthfully).'

And so he would refuse to touch what he called the Safaricom systems (in reference to M-Kopa's close partnership with Kenya's leading mobile network provider Safaricom). If Greenlight Planet keeps its SunKing shop in Bomet long enough the same may well start to happen with their products.

Admittedly, the servicing of non-certified products is, if not intentionally, political. In fixing non-certified products, the mafundi are subconsciously acting against those invested in organizations like Lighting Global and GOGLA. But, in general, the mafundi I learnt from were much more animated by discussions of national politics than engaging in political acts themselves. This is unlike the ingénieur who 'is always trying to make his way out of and go beyond the constraints imposed by a particular state of civilisation while the "*bricoleur*" by inclination or necessity always remains within them' (19: Lévi-Strauss, 1994).

The bricoleur then does not question the context or their position but in accepting it, works to make the best of what is available. A pragmatism that is reminiscent of the actions taken by users at home, as discussed in Chapter 4.

Mafundi also have different motivations than users' pragmatism. Although, like users' pragmatism, the economic motivation of the mafundi is not currently captured in repair studies literature. Repair scholars point variously to joy (Packard, 1961; Dant, 2010; Jackson and Kang, 2014; Callén and Criado, 2016; Big Clive, 2017), politics (McLellan, 2013; Rosner and Ames, 2014; Lepawsky et al, 2017) and the environment (Houston et al, 2016) as motivating factors for those who fix and tinker. But none of these three motivations were obvious in the work of the mafundi I learnt from. Mafundi's motivation points to the need to support oneself and one's family financially as the reason for repair in Kenya's electrical and electronic repair clinics. While I personally enjoyed taking apart products in the clinic, joy for Wilson, Hesbon and their colleagues in Bomet, comes from European football (and betting on it), *matumbo* (beef tripe) lunches and in some cases gospel music or alcohol. More commonly expressed or observed emotions around repair work were of fatigue from long days and difficult customers,

or frustration at difficult repairs. Politics, certainly with regards to product design and manufacture, was entirely absent as was any concern for the environment. If anything, mafundi disposal practices (discussed later) suggest a lack of awareness or total disregard for environmental impact.

The purpose of the fundi's work is economic: to make money. Wilson and Hesbon fix electronics to provide for their families. A typical day for Wilson and Hesbon might earn them anything from 100 shillings (~$1) to 3,500 (~$35) on a really good day. Wilson told me that you never know how the next day will be, a precarity being something regularly associated with the informal sector.

> Now, the characteristic feature of mythical thought, as of 'bricolage' on the practical plane, is that it builds up structured sets, not directly with other structured sets, but by using the remains and debris of events: … fossilized evidence of the history of an individual or a society. (21: Lévi-Strauss, 1994)

Working from leftovers the bricoleur (read: fundi) is already working with what others have deemed waste or superfluous. But through the trial-and-error process that is bricolage, ideas, bits and unused leftovers are themselves left to fall to the floor and be swept away. The next sections explore disposal at the clinic.

Daily sediments

During a repair, or during the many (and long) waits between repairs, Wilson and Hesbon would use the back of their hand to brush bits of wire, solder, screws and other debris off the workbench or counter on to the floor inside or the ground outside of the clinic. Even a bricoleur cannot re-use everything. First thing every morning on opening the clinic, Wilson, Hesbon, Duncan (a friend who runs a general store a few doors down from the clinic) or myself would sweep the floor of the clinic, the previous day's debris joining the bits and pieces in the shallow ditch outside. One day, however, I arrived at the clinic in the morning to see Wilson lightly tossing a series of things from the shelves to the floor. He stopped to put his fleece back on in order to keep the dust off of his Arsenal football shirt. I asked him what was going on and he told me that we were having a clear out. Wilson told me to put the stuff he was throwing on to the floor in to plastic bags and then put the bags out the front of the clinic. I crouched down to start collecting the bits of plastic, wire, circuit boards and batteries. That day we only threw out two identifiable appliances: an iron and a television. The latter of which Wilson told me to first take out its circuit board: we would hold on to that.

The rest of the chapter describes where waste moves from Malo Malo and what happens to it. I argue that like at home, most broken down products are held on to in the clinic. Waste does not generally leave the clinic in the form of recognizable electrical appliances and electronic products, the kind that are often pictured in studies of e-waste (see BAN and SVTC, 2002; Basel Action Network, 2005), but is instead closer to what has been called 'sediments' (vi: Gabrys, 2011; 219: Maycroft, 2015). Sediments are small pieces of e-waste that are beyond reclaim, of no use to repair or the waste from a repair, rarely attractive to inquisitive children and certainly not of interest to waste collectors or scrap dealers. They are typically trodden into the earth, eaten by animals or washed and blown away by the weather.

I did not put any obvious solar waste in the bags that day. Admittedly, it would be hard to tell at this sedimentary level if a fraction of wire or a shard of plastic that I put in the bags had come from a solar product or from a radio. Given the size of solar products, their constituent components and their minimal financial value to the business of the clinic, however, it can be assumed they have been disposed of in similar clear outs in the past and will be in the future. In leaving the clinic these sediments having broken down in relation to their previous form as an electronic good form new relationships. And in doing so, they move out of the gap (which at the clinic is on the shelves and in piles around the walls), leave the solar assemblage and enter into new assemblages of waste, materials, chemicals and elements.

Shadron and the opportunistic scavenger

Not long after I had placed the bags out the front Shadron came by. I had seen Shadron around before. He was often wandering around town with a white plastic sack over his shoulder, the kind also used to transport commodities like charcoal and carrots around the country. After a brief exchange with Wilson, he emptied the bags I had just filled on to the ground in front of the clinic and began to rifle through the pile. He was looking for any metal or 'scrape' (a Kenyanization of the English 'scrap'). He told me with pride that he was recycling and asked if people recycled in my country. I explained that yes, we do, although it looks somewhat different. In 'my country' – the UK – recycling is organized, if not conducted, by local government authorities. Shadron, meanwhile, works for himself. He complained audibly that there was no metal. After smashing off the bottom of the iron with a metal bar he had carried with him, Shadron put most of the stuff back in the bags. Some of the smallest bits remained on the ground akin to that left after the daily morning sweep-out of the clinic floor on to the same patch of ground. These would be found by children in the days to come and, like at home, taken (if only temporarily) as toys. Both that taken to play with and that left behind would ultimately be trod in to the dirt or tossed in to bushes and

waterways to be sniffed at and nibbled by roaming dogs or grazing goats. Having separated the metal that he wanted, Shadron took the three bags up to the bin area directly in front of the clinic, just off of the road. He took a hanging scale out of his pocket and weighed the metal he had extracted in his sack in front of Wilson. It was 4 kg. Shadron gave Wilson 50 shillings ($0.49, at the time) for the metal and went on his way.

This section shows that although there is professional engagement with waste through Shadron's work, there is also non-professional involvement as children and passers-by come to rifle through that which Shadron cannot make money from. Methodologically, it suggests a need not just to follow the thing but watch it too, as it is only through such observation that some more liminal actors come in to view.

Although Shadron describes himself as a recycler, his work does not involve much material transformation. His main work is to collect materials in to the one place. About seven weeks later, Shadron took me down to the store on the eastern edge of the town centre where he brings all of his metal. At the end of a narrow path we came to a wooden structure with chicken wire round the sides that was half-full of various shades of brown and grey paint cans, cooking pans, roofing sheets and lots of indiscernible pieces of metal. Shadron told me that a truck comes by about once a month to empty this store.

On a return trip to Bomet a year later I arranged with Shadron to shadow him for a day. When I arrived at the path down to Shadron's store, he was not there but there was a truck reversed up to the path with three young men stood on the back. Then I noticed there were five younger boys ferrying white sacks of metal from the store and throwing them on to the back of the truck where the older guys were ripping and cutting the bags open to empty out the metal. Waiting for Shadron to arrive, I sat and watched the booming, crashing, rustling and cracking as the metal was stacked, slotted and organized to maximize the use of the space. Paul, a neighbouring shopkeeper, appeared to be supervising the operation. He was watching in particular for brass, aluminium and tin, non-ferrous metals that sell for more than the iron and steel that make up the bulk of the scrape that was being loaded on to the truck. Keeping these to one side, Paul told me: '*Hii ni jackpot*' (This is the jackpot!).

On the day of the clear out when I had first spoken to Shadron the year before I had seen a different, less strategic kind of siphoning than Paul's. As I looked out from the clinic at the three bags Shadron had put by the roadside, I saw some people take interest in their contents. Steadily at first, one or two men flicked through the bags and took a few things. Soon this increased to a veritable crowd of ten people searching through the now up-turned bags (Figure 5.2) and taking bits and pieces until, less than half an hour later, there was barely anything left at all. After the adults had taken

Figure 5.2: Passers-by scavenging Shadron's leftovers at the bin area in front of the clinic

Source: Author's image, February 2016

their share some children began to play through the remainders. Even the next day children were playing with the plastic that was left. By the time a green-coated County Government employee tasked with waste management in the town, passed by, there was very little left. He raked the pile back together and moved on. It would be taken by some of his colleagues to the dump on the south-western edge of town the following morning.

These passers-by are evidence of the loops within Bomet's waste economy; some of these things will now be taken home and move through processes similar to that described in Chapter 4, others may be taken to a fundi in the village for sale or perhaps another scrap dealer elsewhere. The movement of people and goods within this research do not follow then the linear path charted by this book. The loops are evidence that waste can return (Hetherington, 2004). The movement from consumption to disposal is not linear.

Landfill and roadside incineration

Although not the case on this particular occasion, after the scavenging has been done, and before the County Government arrives, the waste in the bin area at the side of the road is sometimes burnt. This is not done directly by

Wilson or Hesbon but by others who share the bin area with them – like the café immediately next door or the fruit and vegetable sellers in front of the clinic to the left. The bin areas are communal and in the evenings many of them are set on fire in order to keep dogs and other pest animals away overnight from the organic waste (banana peel, mango skin et cetera) that is left there each day. I use the phrase 'bin area' as some of the green metal bins are more erect, and so discernible, than others. What is more they have long become signifiers of where to put waste rather than containers in which to put it. The bin in the earlier anecdote is one of the most dilapidated that line the north-western side of the main road through Bomet.

When I returned to Bomet in 2017, I wanted to try and spend some time shadowing those wearing the green lab coats as they did their rounds. For this I went through the County Government offices, across the road from Malo Malo. After being passed a few numbers, told to go to a few different offices and to come back another time, I ended up speaking to Nelly, from the Environment Department of the County Government. When I mentioned the possibility of doing a round *with* the waste collectors I had seen wearing the green coats the year before, she advised that we first did an interview with her and Zaheer, the supervisor of the Urban Planning team.

In the interview Zaheer explained that there are 55 'casuals' in his team who rotate around five sections: drain clearing, garbage collection, garbage transportation, slashing (of grass, trees and bushes) and weeding (flowers). All these 55 casuals included both men and women. The next day when I split my time between the garbage collection and garbage transportation rotations I was only with men. I spent the day raking rubbish together, pushing it on to ripped-open sacks like the one Shadron carries, throwing this into a trailer that was then driven by a tractor down to the dump.

I noticed that it was not just the bins that are dilapidated in the town's waste infrastructure. The casuals were sharing gloves in pairs and rakes between five. Those without rakes picked up branches or broke off bits of wood to spear or scrape the rubbish together into one pile. Zaheer had commented on the shortage of equipment, particularly the need for another truck, during our interview.

I also noticed that it was not just Malo Malo's preliminary contribution to the town's waste stream that loses bits and pieces to the ground. Sediments are also lost in the process of collection. The casuals scrape the recently consolidated piles on to open sacks that are laid on the ground and held down with one person at each end: a foot on the corner furthest from the trailer and a hand holding up the opposite edge to form a sort of fabric dustpan, while a third pushes the waste on to it. Some waste does not reach the sack while some goes under or round the sides. When full, the sack fabric is folded corner to corner and swung up to two guys stood in the trailer to arrange as I had seen the metal dealers do. And in this motion

some bits fall out the sides and fall back to the ground. Although there is some siphoning by the waste collectors most of it is involuntary as bits and parts fall away or are trodden in to the dirt, or left behind when a dump to which they deliver moves location: this had happened in Bomet at least three times in the 2010s.

The waste being moved was mainly from commercial properties but some residential flats, too. It mainly consisted of plastic bags, straws and food packaging, speckled with the metal caps of soft drinks. I did not see much electronic stuff in that we were putting on to the trailer, other than a bulb and a CD. However, this is the stream that waste from the shops selling solar products and the other repair clinics around town would make their way into. Indeed, our first stop on the day I was with Zaheer and the casuals was a large pile at the back of the bus station between Yusuf, David and Rono's clinics – three of the other *mafundi wa TV na redio* in the town. While for the retailers this is mainly marketing materials and packaging, the sediments of new products will also enter this system. Although some retailers will be sending back products to manufacturers and distributors in Nairobi (see Chapter 6), others will be in these roadside piles around Bomet. In an interview with David, formerly of Faulu, for instance, when I asked where the cannibalized bits of EcoSmart products went, he told me: 'Those ones we disposed of them.'

After five hours collecting we headed to the dump. The dump has moved places several times over the years, leaving sediments each time. In addition then to the deliberate siphoning of opportunists, much waste falls away; off sacks, under trailers and is left behind when entire dumps are moved. As demonstrated in Chapter 4, if studies of waste concentrate on sites of waste rather than the journeys to those sites then scholars miss the smaller sediments that are scattered along the way.

Holding on

People sometimes came to the clinic looking to sell old electronics to Wilson and Hesbon. I never saw either of them buy. They had enough 'stock' coming in from their own customers without giving custom to others. What is more, investing in used goods would have been inconsistent with the governing business ethos of the clinic – to minimize expenditure. Indeed, the clinic was so full of appliances in various states of wholeness and functionality, that Wilson and Hesbon regularly complained about how no one came back to collect their objects, or that people would come back after such a long time it was impossible to know which object was theirs or for anyone to remember what the problem had been in the first place. Unclaimed objects like the TV or the iron in the earlier episode will occasionally make their way out of the clinic, to make space. But the usable part, like a motherboard, which

is much smaller than the whole, will live longer in the clinic and might make its way out in parts (an integrated circuit or IC in a different TV) or as broken bits of circuit board (squashed by heavier appliances or stood on when accidentally knocked to the clinic floor).

Unlike with the users at home, there is little uncertainty or guilt in the disposal practices of mafundi; instead, linked to their economic preoccupation with repair, they dispose when things have no economic value to them or when their economic value is outweighed by the need for space for other perhaps new but certainly more useful products. None of the mafundi in Bomet expressed any concern for the environment in their work or disposal practices, nor were they especially interested in where their waste goes next. Wilson only wanted more money from scrap collectors like Shadron.

While the earlier episode focused on that which was removed from the clinic, it should be emphasized that disposal at the clinic is dominated by the act of holding on. Wilson used this clear out as a chance to straighten up the clinic; he put DVD players next to each other on the shelves on the back wall, re-stacked the TVs on the left-hand wall, lined up the woofers under the main bench and dropped phones in a plastic bag under the customer-facing counter. The post-clear-out clinic, while tidier, looked as full as it had done before. It looked so full I wondered where the stuff we had bagged up had even come from. The same holding on and waiting with objects has been identified in the Soviet Union where 'faith that a thing has infinite functional potential and will always be good for something' led citizens to build up 'a pool of bricolage-ready items' (69: Gerasimova and Tchoukina, 2009).

Deliberate and involuntary siphoning

None of the single days observing the six other mafundi in Bomet coincided with a clear-out as thorough as described earlier. In a day with Yusuf, however, he was sorting his clinic out as he wanted to stop doing repairs and just to sell spare parts and components instead. In terms of conscious disposal, it was mainly cardboard and plastic packaging that Yusuf left by the roadside for later collection by the County Government, but even clearer than out the front of Malo Malo one could see the sediments of independent repair work out the front of Yusuf's clinic including bits of wire, ICs, old plastic radio tuning dials. This chapter has described how the daily sediments of the clinic are swept out to be trodden in to the ground, washed away by rains, picked up by children or nibbled at by animals. Less frequently, bigger-sized pieces are removed which are first sorted for their metal content, then sorted by curious passers-by, before being burnt or dumped by county government 'casuals'. But most waste waits in the clinic. It sits in the gap identified at home (Chapter 4). Items that wait in this way

have been described as 'transitional goods' (683: Gregson et al, 2007). The transitional goods of the clinic are waiting: to be dismantled (in the repairs process), to be collected (by the previous owner), to be sold (as scrap metal), to be taken (by passers-by) or, failing that, to be dumped (by the County Government) or burnt. It is through this suite of practices (from dismantling to dumping) that transitional goods can break down to the sedimentary level or be looped back through as a passer-by takes a circuit board to another fundi to try and sell it there.

The focus of e-waste scholarship on legislation (Nnorom and Osibanjo, 2008; Lepawsky, 2012), the urban dump (Reno, 2015; Rifat et al, 2016) or transboundary movements (Lepawsky and McNabb, 2010; Lepawsky and Mather, 2011), diverts attention from that which is swept away, siphoned off and falls out, after use and before reaching sites of consolidation. Without a broader understanding of what e-waste is (at times in very small pieces) then we risk under-estimating the scope and scale of it that which is being domestically produced in countries like Kenya. Without a broader understanding of where (in rural areas) e-waste is, the intermediary scavenger (the interested passer-by or the imaginative child) is invisible. These are not people whose work falls easily under formal (like the County Government employees) or informal (like Shadron) labels. These are not career scavengers nor are they scavenging for survival but rather they are opportunistic. In addition to hoped-for financial gain, the opportunist might benefit in other ways like fun or putting their siphoned scrape to some as yet unknown future use in their own home. Although night-time 'alley scavengers' and 'scavengers at landfills' have been identified in Arizona, US (191: Rathje and Murphy, 2001) the idea of siphoning small amounts of waste with no immediate purpose or application for them is a set of actions and an actor that is yet to be closely explored in the literature. The category is also found in the channels of waste that flow from company offices, workshops and warehouses. It is to these locations that I now turn.

6

The Illusion of Authorized Repair

Satisfying customers, saving costs and keeping consistent

Before talking about after-sales processes nearly all company representatives prefaced their comments with the warning or insistence that problems with their products were rare or low in number. Volumes are small, Ramin, at Orb Energy, told me: 'cases are not many that's why it's easy for now at least'. Interviewees repeatedly stressed a confidence in their products. This confidence manifests itself in a lack of priority given to questions of after-sales service. When after-sales service is required, however, there was also confidence in those processes and in the capability of company-employed technicians. While users and mafundi are derided (Chapters 4 and 5) technicians are granted competency despite, as I will show later, similarities with mafundi in their training and practice. Company confidence extended to the types of problems too – the ones the company are responsible for are typically small and the majority of breakdowns were said to be the faults of users, mafundi and occasionally retailers or sales agents.

Although similarities are found with how repairs are done at home and in the clinic, the scale of operations and geographies is much greater here than in either of the other locations. Like in the clinic, keeping costs down is key, but this is balanced with keeping customers satisfied and maintaining a brand image which is based on consistent quality. This three-way trade off means that the most common response to breakdown at the company level is to replace. Companies often replace whole products (or parts of them) rather than enact material repairs or repairs of practice. Another key difference from the home and the clinic is the attempt to implement and follow a controllable, standardized process. Despite a couple of interviewees narrating a hierarchy of steps: 'I'm all you know, recycle, reuse, so if we, we can repair, then we will repair, if we can re-use, we will re-use, if we then have to recycle, we'll recycle that's sort of what we try' – this was contradicted in observations where company processes were bent and flexibility was

common. I suggest that this flexibility is due to the inherent inconsistency of repair which resists attempts at rationalization. Despite efforts to adopt an ingénieur's approach to after-sales, in practice company processes conform more to bricolage.

A defined repair process was prominent in both interviews with company representatives and observations of after-sales operations. Reflecting this, the chapter is structured along similar lines. It begins first by looking at the technician: their training, recruitment, the space where they work and the tools they work with. The next section looks at the first troubleshooting which often takes place remotely, or at least in the rural area. I then discuss the journey of products from the site of use (predominantly homes in rural areas) to the company premises (office, warehouse or workshop). Once there, attention turns to a more technical diagnosis of the product and to understanding its breakdown. I suggest that although repair at the company is more a case of replacement (the change is neither of practice or material) similar motivations are observed in a mix of both the pragmatism of the home and the financial imperative of the clinic. I then turn to other responses to breakdown, starting with the gifting of broken down products or their refurbishing for use in charitable projects. Other products make their way in to the local (now urban) waste stream while others still are waiting in warehouses. The penultimate section visits a recycling facility which several of the certified companies have partnered with. I conclude that despite efforts to the contrary company repair is bricolage and that disposal from company premises, although less characterized by sediments, is still prefaced by waiting.

The polyvalent technician

Over lunch under a canvas roof in a roadside café, I asked Benson, a technician at Sollatek, what he would do that evening, after work. He told me he would go to his '*jua kali* shop' which is on the way back to town. On evenings and at weekends Benson operates as a *fundi wa stima* (electrician). Despite working full time at Sollatek (a third-party distributor of certified solar products) for 13 years, Benson continued to supplement his salary with self-employed work doing electrical installations and wiring. He told me this halfway through the day I spent shadowing him in the workshop at the Sollatek headquarters in Mombasa in 2016.

Benson is one of eight company technicians that I shadowed. I also observed Alvin, Amos, George, Henry, Julius, Stephen and Frank at their places of work for certified manufacturers and distributors. In these eight workshops and warehouses I encountered other overlaps between the formal sector and the informal. In addition to their primary responsibilities within repair or after-sales operations, technicians are often assigned, or voluntarily take on, tasks in IT, logistics or catering. Technicians are often

recruited through personal or familial contacts. Others had first come in on a one-off, or 'casual' basis and later graduated to a full-time role. I heard of technicians who previously worked (and originally trained) as mafundi. At some companies the technicians either have no dedicated space to work in or they work from a small corner, at times using their own tools. I watched as technicians worked outwith company processes to help their 'brother' or earn some side income direct from the customer. In this section I argue that the polyvalent technician is the result of companies' desire to minimize costs and of the lack of priority assigned to after-sales activities.

Technician is the title given in some companies to describe the employee who works primarily on after-sales processes, particularly warranty claims. Others refer to these individuals as an 'engineer'. I avoid engineer here to avoid confusion with Lévi-Strauss' category of the ingénieur (engineer; Lévi-Strauss, 1994). It is people outside of Kenya – product designers and software engineers – that make the kind of decisions that correspond to Lévi-Strauss' ingénieur. In fact, the company-employed technicians are closer to being bricoleurs than ingénieurs. Although the work setting is different from the clinic: the tools available, the space they work in, the hours they work, the salary they take home and so on, the actual work they do is still bricolage. Technicians are not able to alter the product's initial design as an ingénieur would but instead work with pre-existing constraints established elsewhere (the US or Europe). Again, as with the mafundi, technicians were all men. Unlike the fundi, there is no dominant or shared ethnicity among technicians.

When I arrived at Sollatek I was first assigned to Shadrack. Benson, who would be working on the off-grid products that day, was out at an installation of a battery-based solar system and would not be in until a bit later. So for the first hour and a half of the day I stuck KEBS Import Standardization Mark (ISM) stickers on to products. Shadrack showed me how to open the cardboard boxes using a craft knife and apply the stickers to rows of new Voltlights that would be sent out to retailers later that day. I had done this same task during a day at d.light's warehouse in Nairobi too. The proximity of repair to logistics means technicians are often involved in preparing new shipments of products as well as receiving ones returned from customers.

A somewhat monotonous task, I occasionally looked around at what the others in the workshop were doing: fixing inverters, dealing with walk-in customers and arranging some other boxes for a delivery. I caught sight of a noticeboard, showing the schedule for the year: the four-man team were supposed to rotate monthly around set areas including repair, quality control and rework. I saw a similar schedule on the wall of the Powerpoint workshop in Nairobi a couple of days later. In both cases the schedule did not appear to be followed strictly. Indeed, at Powerpoint the weekly schedule on the whiteboard was empty bar the names of the technicians and the days of the week. The point here is that technicians move through different tasks,

ranging from taping up cardboard boxes to re-working circuit boards. Also, having processes in place does not necessarily mean they are followed. Jared, the head of Reverse Logistics at M-Kopa told me: 'we are a team of around five guys. And each and every person has his or her duty but you can always do anything, we are all rounded.'

Other technicians I shadowed would run to get tea and *maandazi* (a deep-fried bread snack) every morning for colleagues, arrange lunch for the office, collect and deliver parcels around town or help colleagues with technical issues on their mobile phones and laptops. Some of this polyvalence could stem from the time technicians have available to do these other activities. In interviews managers and supervisors repeatedly asserted that there are 'not so many' returned products. Technicians then might often be free to attend to other tasks. Another reading of this polyvalence is that the technician's work is not highly regarded or paid much attention by company management and so they are left to administer various other tasks too.

One can find both readings: a lack of need and a lack of priority, in the recruitment of technicians. Several technicians I shadowed had been recruited through informal means. Alvin, the technician at Sunlar for instance, had been hired by virtue of living on the same compound as the two brothers that run the company. While Amos at d.light had been recommended by his neighbour who was already working at the company when Wilson, the workshop manager, had asked his colleagues for young guys who are 'sharp' and 'learn quickly' to come in and work on two specific, short-term projects. Having excelled in these one-off arrangements Amos was invited to stick around.

Training is similar: Amos had learnt by watching Wilson while Alvin, like Hesbon, had taught himself as a schoolchild. When I visited EcoSmart in 2017, Stephen, who heads up finance for the company, was managing the replacements and repairs himself whenever he had time. He had been trained to do so by a (Luo) fundi that EcoSmart previously contracted in to service their products. In an interview with Stephen's boss, Simon, I had been told that because EcoSmart did not have products being returned on a daily basis, they did not want to hire somebody on a daily basis to deal with them. Unlike Walid's team of four at Sollatek or Jared's team of five at M-Kopa then, some have little, or in the case of Jua Energy and Philips no, technical presence in the country.

The variations in roles is closely reflected in or perhaps connected to the space technicians work in and from. Part of the reason I was involved in the labelling of products on days at Sollatek and d.light was also down to space: repair is often next to logistics. Meanwhile, during the day I shadowed Julius (GreenLight Planet) he got drafted in to help with IT issues because he is based at the main office and not down at the warehouse. Julius told me he prefers to work from the main office because the internet is better

there, but it does mean his product responsibilities are relegated to the balcony overlooking the car park. Meanwhile at SunnyMoney, space was at even more of a premium; George worked from the board room and some stock was kept in the office bathroom. So while this chapter and other parts of the book make reference to workshops or warehouses, these can look very different. Most often it is a table in the corner, although Sollatek and Powerpoint's repair operations had earned a separate room. This is likely the result of their older age and their engagement with product types beyond off-grid solar products including inverters, charge controllers, batteries and solar water heating systems which have always required, and whose designs have allowed, more repair and maintenance. M-Kopa's after-sales operations meanwhile grew so much that by 2018 they had been outsourced to a third party facility in Naivasha.

Having a dedicated space for repair did not necessarily mean that the equipment, materials or tools were provided to match however. Over lunch Benson said his employer does not buy good tools or replace old ones so he normally brought his own to work. At the end of the first day shadowing Julius, he told me that he labels his pens and hides away his screwdrivers as otherwise they go missing. At d.light the knife used to open boxes was a blade of metal wrapped with a rubber band at one end to act as a handle.

The importance of personal connections through family or where one lives and training on-the-job are two elements that are remarkably similar to the fundi model described in Chapter 5. The space and tools afforded to technicians could still be read as both a disregard or a reflection of the lack of requirement. Yet the at-capacity nature of these spaces with boxes and desks overflowing, again akin to the fundi model, suggests there are products to be serviced lending weight to the view of the technicians' polyvalence as an indication of ignorance rather than strategic response.

Troubleshooting

For companies in the certified market supreme confidence in the technical capacity of their products (perhaps partly a result of the Lighting Global certification) and a certain, widely shared understanding of the user, discussed in Chapter 4, means that the first step in dealing with breakdown is to decide whether a problem is 'real' – the alternative being that the user has not been using the product 'correctly' and so, in the company's view, there is no problem. It is only in the case of 'real' problems (variously referred to as 'actual', 'big', 'complex', 'major', 'technical' or 'internal') that products need to be sent on to the main company premises to be looked at. In all but two cases the company head offices are in Nairobi (Sollatek's are in Mombasa while Trony's base is in Kitale in the western region). The first diagnosis, or troubleshooting as interviewees more commonly referred to

it, occurs over the phone or in person when a user (referred to variably by interviewees as the client or customer) takes a product to a sales agent or sales point. The first troubleshooting then is performed by a retailer, sales agent or customer care representative.

In this section I suggest that assigning technical responsibilities to sales staff or remotely via a call centre reflects a general lack of importance ascribed by certified actors to after-sales activities and a lack of specialization in job roles. Interviewees talk confidently of their sales staff's training and capabilities to perform over-the-phone and in-person troubleshooting. There are, however, acknowledged limits to the sales staff's capabilities – field staff are not able to deal with 'real' problems. The outcome of the first troubleshoot is either to advise the user on correct usage of the product or, in the case of 'real' problems, to send it on to the main company premises.

Once the product has arrived at the main company premises the second troubleshooting begins. This troubleshooting is performed by someone in a technical or logistics role. The second troubleshoot generally involves two steps: first, a (re-)checking of whether or not the product is within warranty and second, a (re-)testing of the problem the product has in terms of functionality or performance (which is also part of the test for responsibility). Despite the efforts of the first troubleshoot to resolve issues early on and near to sites of use, many functional products make it to second stage, suggesting limits to the control the company has over the repair process.

Part way through my interview with George, of Tropikal Brands, in a Nairobi coffee shop, he answered his phone. I paused my audio recorder and tried not to listen as George continued his new conversation opposite me. It was one of his sales agents who had a customer complaining of a faulty product, George told me after he ended the call. He said his sales agent will now put the customer in touch with George directly, and he will talk the customer through how to test the product. If they cannot solve the problem that way, George told me, they will send the product to him in Nairobi. Tropikal Brands do not operate a call centre as such and so the first troubleshooting takes place on a more ad-hoc basis as I observed with George. For other brands, however, such queries come through a designated call centre.

Call centre staff will normally first give guidance over the phone. This is typically regarding things such as the position of the panel (in direct sunlight), the cleanliness of the panel (not covered in dirt or dust) and the charging of the battery (either too rapid a discharge or not a long enough recharge). Anthony (d.light) told me with confidence that: 'more often than not you'll be able to get your result' through that process. If not then call centre staff put the user in contact with the closest agent, ask the user to return it to the shop where they bought it, the branch of a partner such as a bank or micro-finance institution (MFI) or direct them to the nearest service centre.

At these physical points of sale a similar process takes place in person. Interviewees all emphasized the training given to their regional or field sales staff to perform 'initial' or 'basic' troubleshooting. Largely this troubleshooting consists of checking the battery is charging OK. Responses at the point of sale or service centre are either to charge the product, advise on 'proper' usage, or issue a replacement product or spare part. EcoSmart and Omnivoltaic, for instance, told me they provide battery boosters to their partners around the country to assist in cases of extreme or deep discharge, George also said that his retailers can charge products for customers from the grid (similar to seen in Chapter 4). If the battery is OK then guidance is given, as over the phone, regarding 'correct' charging of the product. Ramin estimated that 75 per cent of cases can be resolved at this first troubleshooting because '[the] issue is not technical failure it's basically customer usage related: either they're not charging it daily or are they are over-using the system, it's really how they use it, those type of concerns you know our engineers should be able to address'.

Sometimes replacements are given at this point: for some, like d.light, this would be a whole new product for others, like Tropikal Brands (Philips), they would replace the battery. This would be largely based on a visual check that the product has not been damaged or tampered with. But George and others lamented the fact that some retailers or sales agents will prematurely replace the product or part of it (say the battery) when the problem was only that the product was not properly charged. Despite confidence in the training given to regional staff to make these decisions, it appears that the 'correct' decision is not always made.

Such disconnects can have material consequences. Instead of using new parts, for instance, George said that retailers of Philips products will scavenge new components from whole products. This practice occurred at several companies. David for instance told me that: 'every time somebody would have a problem with the product they [Faulu staff] would scavenge the stock that is there. If somebody says my panel is not working they'll pick a panel from a new product since the products are there.'

But like Tropikal Brands, Faulu found that many branches were scavenging these components to repair products that did not have real problems. David told me that in the first year Faulu wrote off 'a significant percentage' of their stock due to this practice. He explained that although branches would have 30 products on their records, 'You find ten products that have components missing which you can't sell.' In order to address this, while avoiding the higher taxation on importing spare parts, Gijs said that distributors for Barefoot Power will deliberately order a few extra products and 'then pilferage on those systems.' In the East African Community (EAC) home systems are exempt of tax, as are solar panels, but spare parts and accessories such as cables, controllers, batteries et

cetera are all charged with VAT (41: EAC, 2016; see Chapter 2 for more on this).

Most of the certified actors see the first troubleshoot as a form of triage aiming to ensure that products sent back to the after-sales team in Nairobi 'really' have problems. Interviewees expressed doubts about their field staff's ability to perform any actual repair work beyond the initial diagnosis, opting to perform actual repairs centrally where they can control it better and they have the resources and capability to deal with real problems. Martin, for instance, said that Greenlight Planet do not want component level repair at their service centres because it is 'risky still for them [the technicians] to do something wrong'. Even where more distributed service models were in operation such as for Orb Energy and One Degree Solar, who have both previously run service centres around the country, greater capability was assigned to and associated with Nairobi than regional sites. Ramin (Orb Energy) said that most of the time products are returned to Nairobi 'because you know even, even in the shops their availability of, of, their sophistication … to do fixing and the checking is not as big as here in Nairobi'.

Ramin said that at the service centres:

> they can do everything when it comes to checking it, checking the, charging the battery, discharging it, seeing if the battery is working, testing if the module is working by putting it in the light, checking if the lights works, those type of things but when it really comes to electronics we do it in Nairobi.

'Electronics' for Ramin meant if a product requires 'soldering on the PCB or, you know, things like that'. It is not just the user (see Chapter 4) or the fundi (see Chapter 5) whose abilities are questioned then but company employees, too.

This next step from regional (sales) representative to the company main premises is organized by the company itself, their representative (in case of a partnership) or more often a courier service. On rare occasions products are taken directly to company headquarters by users. Julius spoke of users occasionally bringing their products to Greenlight Planet's main office, where he works on the balcony – the office shows up on a Google Map search of the city. Often Julius said these will be cases where someone has bought the product in Nairobi for their grandmother in the rural area. Walk-ins are more common and so more formal at Powerpoint or at Sollatek where all the business functions, including the warehouse, are on the same site and there is a member of staff to greet any members of the public. Most products, however, do not arrive individually like this but in a batch from wholesalers, partners, agents and company-owned retail outlets.

For distributors like SunnyMoney, Sollatek and Powerpoint there is an extra step once the product reaches Nairobi (or Mombasa) as they have to forward faulty products, or samples of, on to the manufacturer as part of the warranty process. This extra step causes a further delay for customers as the distributor might wait for a month to build up a sizeable enough batch to send on to the manufacturer. Although regretful about this Charles, one-time manager at SunnyMoney, explained that: 'once they come in even before we send them out we try and manage the expectations and tell them: "Look, we, you've given us one light we just can't take one light to them we need to do it at the end of the month."'

Charles also regretted that in this time, as was the case for most companies, when a product moves from the 'field' to Nairobi users are left without a product. Jared told me that in the past when M-Kopa did not have so many customers, dealers had been able to offer interim replacements to customers but these days 'they will just have to wait'.

The first thing that typically happens when a product arrives at the company premises is to check whether or not a product is within the warranty period. For this the majority of companies use serial numbers on products. Walid, the workshop manager at Sollatek, explained how they check the products they receive:

> So, for example, if it starts with let's say 102014, that means it was manufactured in October 2014 so if it's anything more than three years automatically that is already out of warranty. Yeah because normally they give I think two years from date of sale or three years from date of manufacture. Yeah so, that one is one of the quick tests they can do.

During a day shadowing Julius at Greenlight Planet, the first task he assigned me was to go through a series of boxes of products and check their serial numbers against a spreadsheet. These would later be updated within a company software platform, I observed similar processes at d.light and M-Kopa. Whether or not a warranty had been activated (via SMS, over the phone or a filled-in, stamped warranty card) did not appear important in my conversation with Walid or in my checking of serial numbers for Julius, the date of manufacture was the main measure.

However, many of the products I saw in workshops had faded numbers or the labels they were on had peeled off. At this point other markers might be used, such as user-written names in black marker pen or scratched in to the casing of the product, perhaps there for when leaving at a phone-charging shop alongside other products. From the very first step on company premises then the process is subject to a degree of flexibility.

The other test for whether or not a product is 'in' warranty is also visual and looks for marks of forced entry, external damage or what the companies

often refer to as 'tampering'. Any physical intervention upon the product would void a warranty. The motivation or reason for that intervention does not matter. Nor does it matter whether that unauthorized intervention was made by the user or by a sales agent, fundi or other intermediary. In the company setting, the categories of fundi and user, already shown to be overlapping and changeable (see Chapters 4 and 5), are further blurred. For the technician, the distinction is irrelevant as the warranty is void regardless. During a day shadowing Amos, at d.light, he noticed a screw missing on a radio and told me: 'customers always take these things to the electrical engineers [mafundi] outside. But it is always easy for us to detect.'

From my experience at Malo Malo such a small oversight is entirely feasible as screws fall to the floor during a repair or they are not screwed in with the same care or attention after the job is done. Indeed, Wilson and Hesbon would often pass objects to me to close up again while they moved on to the next job – indicating the lesser importance, and easier task, of closing up a product.

If the date on the serial number is wrong or there are visible signs of damage, I was told in interviews that these products are out-of-warranty. Company representatives were rarely clear or certain about their process for these out-of-warranty products, however. They can be sent back as is, users can pay for the repair, buy a replacement product (in some cases at a discounted price) or, ironically, are advised to visit a fundi. None of those interviewed were looking to make money off out-of-warranty repairs instead telling me: 'Er no we normally don't charge for those', 'we don't necessarily make a massive profit on, on those repairs' and '[we are] not really focusing on making massive profits on the spares'. Rather than to make money most companies were servicing (or replacing) out-of-warranty products in order to keep customers happy. This was both in a positive sense, like Walid who told me laughing: 'It's just like a community service.' And a negative one like David who said that Faulu had to help customers because 'if you don't fix his product he is going to spoil your name so you have to fix it'. Such unofficial or informal transactions are an example of the similarities that persist between the company workshop and the repair clinic.

Replacing repair

If the outcome of the second troubleshoot is that the product is *in* warranty (or not but a technician shows leniency) then the product is either repaired (material repair) or replaced. Repairs of practice are not found in this location. This section suggests that replacement of products is more common because companies want to guarantee quality and trust their products to deliver this more than their technician. In replacing a broken down product with a new, unsold one, companies can be confident in the

performance of that new replacement product as it has passed the Lighting Global certification process and internal quality controls too. The company cannot say the same if a technician (read: human) has intervened to effect a material repair, especially if, the act of repair is itself inherently inconsistent. But again this desire to keep customers satisfied and maintain a brand image has to be balanced with keeping costs down: replacing a whole product is more expensive for a company than repairing it would be and so some material repairs do happen. When a material repair is made it is usually still a replacement but at the component level. Preference is given for new spares, again for quality reasons. Although at times this is balanced with previously used parts again in order to keep costs down.

The one for one replacement of products was for some about keeping customers happy. Charles told me that it was about saving face; he did not want to 'disappoint a customer, … any customer'. For others the reason to replace whole products was more about guaranteeing a consistent performance and quality in their products, Anthony told me that d.light 'will never [repair products], because of the quality we stand on, we will never give you something that we don't believe will last you for the rest of the period we have promised'.

There was also a cost-saving reason to do whole product replacements though. For Omnivoltaic it did not make financial sense to do any material repair because:

> the battery represents something like 50 even sometimes even 60 per cent of cost of the light so if the battery's gone, the product's gone, there's not a whole lot of value you can salvage by replacing the battery. So, so, so for lantern products we typically design in such a way the battery is not replaceable.

Those companies who *do* replace batteries (and other components) obviously need a source of spare parts. These come from three places: as standalone new parts, cannibalized from new stock or cannibalized from returned products. For some, like Tropikal Brands, the only new components replaced are batteries. But in other interviews and warehouses and workshops I heard and saw companies replace panels, switches, LED boards and printed circuit boards (PCBs) from new stock. I did not hear or observe of any company replacing product casings. During the day with Amos at d.light we were fitting *new* LED boards. Tropikal Brands are one of the companies who were taking components from new stock, although this was something George was working to limit because it was costing the business financially.

Martin (Greenlight Planet) and Gijs (Barefoot Power) both told me their companies design products to make replacement of parts as *easy* as possible. Martin said: 'We are trying our best to make the design as simple as possible.'

Where earlier products had three or four wires 'flying around inside', Martin said that Greenlight Planet were now 'trying to make everything in to one board'. While Gijs told me that for Barefoot Power repairs:

> The most you need is a few screwdrivers and a multimeter to test and a battery booster would be helpful to assess you know, overnight, if that maybe you just drained it too much, maybe it simply was faulty. Even a PCB is fairly easily detached from the system, erm, as long as you know what is positive and negative you are able to connect it back to the battery so we've done it to a point where you don't need to be a technical, technical guy to now start soldering on the connection, even if, for example, a weak point in the switch wire for a lot of systems, including ours, is that if you keep using it, on-off, on-off, on-off some of the rocker switches behind the lights will break, it's just wear and tear. Don't even bother to go look for a new rocker switch just take the cable in full and give the guy a new cable. We try to take out the whole nitty-gritty of soldering and fixing and stuff like that so that it's easier for a lot of people to simply do replacements.

I was struck during by the contradiction. Mafundi were derided somewhat, in tone and language, as being incapable yet the product was deemed easy to repair without much fiddling or tools. The difference perhaps lying in the access to spare parts, the company emphasis on, and access to, spare parts is the distinguishing feature; replacement trumps repair.

Repair at the company then, although more possible than at the clinic, with greater access to new parts or pre-existing stock from which to cannibalize parts, is marked by a trade-off between the need to ensure consistent quality, the desire to keep costs down and keeping customers happy. This approach has a material impact in the production of greater volumes of waste. We can think of this as a case of *un*-planned obsolescence. The effects are to create obsolete equipment, but they are not designed to be such.

Repair persists

Although not always written down (as it was on the whiteboard and noticeboard at Powerpoint and Sollatek), there is a more defined process that occurs, or at least is articulated, at the company than at the clinic. Starting with a first troubleshooting over-the-phone or in person the emphasis is always on a diagnosis of responsibility and cause as much as on the nature of the problem at hand. If deemed a major problem the product is transported to the company main premises, mostly in Nairobi, for a second troubleshooting which looks even more closely at indicators of warranty (serial numbers and visible markings). The fault is sometimes logged in an

Excel spreadsheet or bespoke software. Others use a more analogue system of pen, paper and sticky labels to track their products – a feature of the process that is again not found at the clinic but is perhaps a symbol and result of the far greater volumes of products moving through the company setting than the independent repair clinic. Despite the volumes, little repair actually happens here though. Instead, in-warranty products are replaced, with the old ones kept for spares (like they are in the clinic), while out-of-warranty products are supposed to be charged or returned untouched to customers. Interviews and observations, however, suggest that for reasons of customer satisfaction and brand image some out-of-warranty products are repaired at no cost to the user.

Despite an outward formality: narrated in interviews, displayed on noticeboards, reflected in job titles and (sometimes) in the repair space or tools, informality persists. There is variation in the process and the technicians active in it often start work casually or through a friend or family member akin to the mafundi met in the previous chapter (Chapter 5). The company's confidence in the performance of their products contributes to the neglecting of after-sales, which, in turn, despite claims to the contrary in interviews opens the door for flexibility. Repair at the company is aimed at maintaining customer or partner satisfaction, on the one hand, and minimizing cost on the other, while at the same time maintaining a consistent product quality.

These processes themselves have changed over time and are continuing to do so as companies go under, leave markets, switch suppliers introduce new products or hire new employees. These changes are another reason why informality persists as companies are forced to be flexible. By early 2017 One Degree Solar had closed down operations, in April that year SunnyMoney Kenya followed, as Tough Stuff (an early partner of Faulu) had done a few years earlier. Meanwhile, when on a return trip to Kenya in 2017 I was told that Philips no longer had any staff in the country working on its solar products. Despite these business changes the products these companies have sold are still in homes and shops around Kenya, some of which will be in need of repair or disposal. These will likely now be serviced by the mafundi discussed in Chapter 5.

In our interview Anthony was extremely confident that d.light will still be there for their customers in the future. At the time of writing (December 2024) d.light *is* still in Kenya but in recent years has concentrated more on direct sales than third party distribution (through companies like Sollatek). Back in 2010 when Sollatek were the main distributor for d.light in Kenya they replaced components. But in our Skype interview Walid told me that this had changed in 2014 when they were instructed to replace whole products instead. When I asked Walid why this was he told me d.light had not given a reason. Walid suggested that maybe it was just 'easier' for them. Changes might also be made by the distributor rather than the

manufacturer. Before closing down in late 2016, SunnyMoney had changed suppliers: moving from selling d.light and Greenlight Planet products to those manufactured by Jua Energy.

These changes in the market have led to confusion for third party retailers and users who may try and return products to the wrong company: during my day at Sollatek, for instance, a customer walked in with a One Degree Solar product, only to be informed that the company no longer exists, and so Sollatek no longer service their products. And on my day working with Julius at Greenlight Planet I came across a warranty card for a d.light product, its separation from the product and being in the wrong place presumably jeopardizing the chances of that product being repaired at the d.light warehouse on the other side of the city. Meanwhile, Paul at One Degree Solar empathized in our interview with third party retailers having to remember the various different phone numbers and warranty processes for the variety of products they were selling.

Rather than dwell on past relationships and partnerships, however, most interviewees spoke of the future. Company representatives consistently downplay product breakdown as a problem in volume (there are not so many) or urgency (when we reach scale) at the moment and were confident their systems would cope, or that they would have the problem solved in the future. Both the past changes in company constellations and companies' postponing of prioritizing after-sales until some point in the future means that many products will go un-serviced, and like the sediments described in the previous chapter, these are left to fall through the gaps perhaps to enter the local repair economy of mafundi or to be disposed of. Charles conceded as much with regards the low number of returns to SunnyMoney: 'there are usually not too many, maybe in a month I would say even less than 50 [combined d.light and Greenlight Planet]'
might mean that the majority of their impressive sales volumes (SolarAid, 2014a) do not find their way back to the company. The future orientation of companies is perhaps clearest in their treatment of broken products that are not, or cannot be, repaired and of those that are replaced or their leftover parts. These futures are the focus of the rest of the chapter.

Decorations, demonstrations and gifts

When I visited the Greenlight Planet office in the affluent Hurlingham neighbourhood of Nairobi, I noticed a collection of old products attached to the front of the reception desk. These were not functioning products but faulty ones, reincarnated as decoration. As Adrian, a product designer, led me past the desk and in to a glass-sided board-room I noticed how many other products were littered around the open plan office. We even handled one during a Skype interview with Adrian's colleague Martin, who runs

the company's manufacturing operation in China, to discuss certain design features. These products on the desks, shelves and windowsills will never be sold but exist for demonstration and marketing purposes. It was similar at d.light's headquarters in Lavington and M-Kopa had demonstration systems all over its 'campus' in Kilimani, including one installed in mock-up home in the garden of their compound. Sollatek, meanwhile, had even older history on display with a few Glowstar lanterns (discussed in Chapter 1) sitting on shelves around.

At Sollatek I was told of a different sort of creativity. At one point in our interview Walid laughed and told me that: 'You know, when some of our technicians are right now here are bored they will basically go to this junk, remove the LEDs, try to make up some LED light system.'

Intrigued I asked Walid if this was to take home with them or a bit of fun? 'Yeah a bit of fun maybe or try and link up some panels together and make a bigger panel system which is faulty because maybe you know just try and be creative with those things.'

Such a playful interaction with the sediments was reminiscent of the children at home or those who picked up the pieces outside Malo Malo. Or the children who take or are given broken down solar products to play with at home. Rather than providing light or electricity, in the company office, products become playthings, artefacts of design and objects of history. Similar to some users at home, after breakdown, products become symbolically valuable rather than functionally or materially so.

In addition to being used as decorations and exhibits the remaining sections explore what else happens to products at the company office and their warehouses; sites that in some cases are in the same place. Holding is again the dominant response to breakdown. The gap is again motivated, at least in part, by the uncertainty of the future. Similar to users at home, company representatives are not sure of what the 'right' thing to do is. Broken down products at company premises are also subject to siphoning as was observed at the clinic (see Chapter 5). The siphoning leaves the same sediments that are found across the three locations. The difference, however, at the company level is, as it was with repair, a matter of scale. The volumes of waste that are waiting at the company are much larger than in the home or repair clinic.

Four days before our meeting with Laurens in 2014, the same colleague and I went to the SunnyMoney office where my colleague asked for, and was duly given, a couple of broken down solar products. If it cannot be sold, and is not kept, an old solar product can be given away. At Greenlight Planet in 2016, Julius told me that some replaced products are given away as part of corporate social responsibility (CSR) projects, he gave the example of a donation to a children's home. Julius' counterpart at d.light told me similar, he had first been drafted to the d.light warehouse to work on a project refurbishing a series of their popular S2 lights to donate to some

schools. This benevolence, however, escapes the tracking of the impact metric market device.

More frequently, and more systematically, certified manufacturers will use broken down solar products for testing purposes and to inform future product design. This section shows a distinction between the fundi who holds on to products in order to re-work them, or parts of them, into life, versus the companies (ingénieurs) where products are held to *inform* a future creation not to be *part* of one.

Other products are sent to China or India. As we sat on the picnic bench outside his office, Anthony told me that d.light return some products to China as samples for testing and future product improvements. Anthony said that these samples could be anything from 10 to 1,000 units and were all part of the scientific process that he emphasized throughout our conversation. He re-iterated several times that 'there is no gut feeling' in d.light procedures. This contrasts with Orb Energy where Ramin initially forgot that any of their products are taken out of Kenya. When I asked about faulty products he first told me that 'they are still sitting here [*gesturing behind me to the other side of the office*]'. It was not until the end when I asked him, as was my custom in all interviews, whether he had any questions for *me* that he told me:

> Actually for the, for the batteries by the way one thing I just remind myself, what we have done is actually that's what happened, you will not find many here, you might find but what happened I remember one day when somebody from, from India, from the factory came here, he took back the defective batteries for them to study it, to find and to discuss, take it up with the supplier for replacement also. So I remember one day he came here and the batteries that were there he took them back to, he just put them in his suitcase and brought it back, and then they were wanting to find out also what happened to these batteries and then take it up with the supplier, but that's I remember, that's what happened once.

SunnyMoney and Sollatek would also send products back to manufacturers (Jua Energy and Niwa) based in China. The same interviewees that had emphasized the small number of technical failures on their products contradictorily admitting breakdown told me of their use of failure and returns data to make changes to product designs.

On the face of it the transboundary movement of (e-)waste from an African country to China or India is in keeping with existing studies of global waste flows (Grant and Oteng-Ababio, 2012; Furniss, 2015). But crucially, compared to that literature, this flow of e-waste is both minute in volume (relative to that which is being held or stored for the future) and is *not* destined for 'informal' dismantling or recycling, at least not immediately, but rather to feed in to future product designs. Its value is held as an assembled product rather than

for its constituent materials. After the testing has been done or the supplier warranty claimed, perhaps then these solar products join more visible (and documented) e-waste circuits on the edge of Chinese or Indian manufacturing districts but such movements are beyond the scope of this book.

I asked Huashan, the founder of Omnivoltaic, on Skype, whether Omnivoltaic returned products to Hong Kong, where he and his company are based. He told me that this would be 'prohibitive' in terms of cost and so rather than bring the products to Hong Kong Huashan sends his engineers to Kenya to test the products there, typically once every three months or once 50 to 100 units have accumulated. They would only bring the products to Hong Kong in the event of a 'large-scale failure' citing the possible scenario of a batch of batteries. Otherwise Huashan said: 'You know we, we, at this moment we do not have a clear disposal policy because nobody is qualified to really do a proper disassembly so my suspicion is that they will just go in to the rubbish stream.'

With no operational presence in Kenya, companies like Omnivoltaic have even less control over their supply chains – especially the retail segment; and so it is even harder for those absent brands to control their reverse logistics. If they do not have a warehouse, storage of waste, as more visible companies do, is not an option and so waste products are added to the local (and general) waste stream. Despite having an office and sales and technical teams in Kenya Ramin said that Orb Energy generally throw broken down panels into the office waste, entering the same rubbish stream Huashan spoke of. Ramin said that the rest of Orb Energy systems were 'probably still sitting there [in the office]'. Indeed there were boxes scattered all around the office where I interviewed Ramin.

Although most companies do not officially throw solar products in to the regular waste, some parts, sediments, do join other office waste (paper, food, plastic packaging and so on) and other types of non-electronic solar waste such as brochures, leaflets and stickers in the general waste stream. During days spent shadowing technicians at eight different companies and organizations I saw bits of solar products: the odd wire and bit of plastic, tossed in to the bin. I did so myself too.

The rubbish stream

I tried to find out where this office waste went. Few people at any of the solar companies and organizations knew who collected their waste, especially when they were in a shared office building. Instead, I contacted the building management or, on one interviewee's suggestion, I asked the security guards: guardians not just to who comes in and out of the compound but also what and, crucially, *when*. With a few phone numbers I collected I then set about calling and asking if I could join the round for a day.

The local rubbish stream that Huashan had referred to is the private waste collection system that serves office blocks and business compounds in Nairobi by taking their rubbish to one of the city's three main dumps. In 2016 I spent a day with one of the companies that make up this system and collect from one of the solar companies I had interacted with. Three times a week, Kevo, Odhiambo and Charles (all men), employees of 'Major Enterprises', drive their truck around the south-west of the city. As I rode around town with them and helped throw (mainly) black bin bags in to Odhiambo who sorted them at the back I noticed, similar to what I had seen on the day of the clinic clear-out, that there were two other characters involved in this process. Two characters I would not have encountered had I not been on the truck: the ambulant scavenger and the watchman or security guard (also male roles).

★★★

Although my gender helped me gain access to this site of observation, my race once again made me stand out. My Whiteness made us more visible on the roads and attracted more attention on the estates. People's heads would turn as we sped past hanging out the side of the truck and watchmen were particularly interested as to what the White guy was doing with them. Although I was part of conversations and did the same work as Kevo and the others, I only did so for one day, whereas they have been doing it daily for years. Similarly, although I looked through the rubbish I did not take the opportunity to scavenge for myself. At one point on the route we passed the house where I was staying. It was a much bigger building, on a much bigger plot and much more central than where they were staying. This is to say that while I spent a few hours with them, there was no hiding that I was closer to being a client of Major Enterprises than a colleague.

★★★

When we pulled up to one residential compound there was a bedraggled-looking man with dreadlocks in dirty rags going through the bins. I asked Kevo if he was allowed to do that and he told me no, but they would let him. The man with the dreadlocks would collect enough plastic bottles to sell in order to buy some food to survive the day, Kevo explained to me. He also said that we would struggle to fit everything in the truck as it was so in some ways the dreadlocked man was doing us a favour by reducing the waste the guys had to collect. Generally specializing in PET or glass bottles, these scavengers would not deliberately seek out solar waste but in browsing for their chosen material one can imagine them, like the passers-by outside Malo Malo in Bomet, taking a solar product or panel on the off-chance that they could use or sell it elsewhere.

Although we did not see any more ambulant scavengers that day I saw and heard of several security guards or watchmen having a look through the waste themselves, with keys to access lockers and huts where waste is stored, or time to wander the compound during their shifts. There will also be scavenging that we did not witness, outwith official collection times. Again, Kevo and the boys did nothing to stop this. And here security guards would be looking particularly for more typically valuable objects such as electronics, including off-grid solar products.

Then there was the siphoning of Kevo and the boys themselves. The day I was with them Kevo proudly showed me a USB phone charger that appeared to be brand new and still in its original packaging as we climbed back in to the front of the truck. He placed it on the dashboard where it would stay for the rest of the round. Kevo told me that they generally only took electronics and at the end of the day would try and sell them to retailers or mafundi in the neighbourhoods where they lived to get a bit more cash on top of their pay from Major Enterprises and the metal they sell part way through the day (again to alleviate the limited capacity of the truck).

The truck I rode with Kevo et al was heading to Dandora, Nairobi's biggest dumpsite on the north-east side of the city. On a visit there in 2014, I had been told that no e-waste reaches there anymore because of 'the Chinese'. None of the ambulant scavengers, security guards or the Major Enterprises team are Chinese, but they are definitely getting to the e-waste (and so, solar waste) before it reaches Dandora. This kind of intermediary scavenging appears in existing work in discard studies (Rathje and Murphy, 2001; Reno, 2009). Contrary to dominant popular discourses of scavenging as being motivated by survival and sustenance, many scavengers speak more positively of 'the *opportunities* afforded by other people's wastes' (32: Reno, 2009). While the figure of a bedraggled man going through the bins of others is likely doing so for survival, scavenging is not always thus. The passers-by in Bomet, the watchmen in Nairobi and the truck-riding waste worker represent instead an opportunistic scavenging; a scavenging that is characterized by chance and occurs alongside or on top of, other, more organized or formalized, work. However, even those that live by scavenging are not interested in everything. They too leave waste. When burning off the plastic housing to access copper wire, for instance, recyclers on dumps like Dandora will leave behind cable connectors, plugs and computer mice (219: Maycroft, 2015). These are the bits and pieces that 'accumulate into a sort of sedimentary record' (vi: Gabrys, 2011). And these sediments wait once more, only now they do so for epic periods of time.

Waiting in the warehouse

Most replaced products or parts for most companies, however, do not enter the local waste stream directly but are stored in the warehouse (or equivalent

if the company does not have a dedicated warehouse like SunnyMoney who were storing some stock in the office bathroom). After a morning testing and sorting products together at the Greenlight Planet office where I had previously met with Laurens and Adrian, Julius taped up the box of products we had worked through and gave it to two of his colleagues to take in a taxi down to the warehouse, on the south side of the city. Once in the warehouse the products would wait. George told me similar: 'all in all you find a chunk of the faulty products in the warehouse that one I am very sure … we find like most of the suppliers or like manufacturers who are the main distributors they still have they still have the faulty products in their warehouse.'

Jared told me that M-Kopa were also holding on to their returned and unsold products (these could be previous product generations or demonstration stock):

> OK, at the moment, they're just, they've just been stored. Every item that is beyond repair we have never disposed them. So they are just somewhere. Yeah. But, sometime back there were guys, they were working on how, we were working on how they will be disposed, but we are still waiting on a word from the senior management team, yeah.

This combination of storing solar waste and working on or a discussing a more permanent plan for them was common across all interviews. Anthony told me that d.light are also storing their faulty products but assured me that 'sooner or later I'm sure we will have a discussion of what we intend to do with them.'. Not only did interviewees all talk about holding on to used solar products, but they all spoke voluntarily of the future: Jared (M-Kopa) was 'waiting' for direction from his managers, Simon (EcoSmart) was 'looking at ways' of dealing with them and Anthony (d.light) 'will' have the discussion. Like the clinic or the home, it is a transitional state, the products are waiting in the gap between breakdown and waste. And, like at home, in this gap things get lost. Similar to the lack of control identified in the after-sales processes, Gijs conceded, as did Charles, that not everything is accounted for and, like at home, things can go missing. He told me that his: 'warehouse guys … don't really care whether it's 50 units or 52 units right?' Keeping track of waste, like dealing with repairs, is not a priority for certified actors.

'Recycling'

There are two other places broken down products moves to within Kenya: Associated Battery Manufacturers (ABM) and the WEEE Centre. Both, based in Nairobi, can be identified as recyclers. The first, ABM

(more commonly known as Chloride Exide after its leading product: the Chloride Exide battery), is the oldest and biggest battery manufacturer in Kenya (see Chapter 1 for some background). As a result of the volume of their business and standing in the market Chloride, as they are locally known, have established themselves as the leading recycler of lead acid batteries in the country as well. Tropikal Brands gives its waste batteries, from Philips solar products, to Chloride Exide. For the rest of the materials, the sediments, George told me, 'we [Tropikal Brands] have just accumulated' because having only started distribution the previous year, in 2015, they 'have never received as much'. George, like his peers at other companies, planned to look for a recycling company to collect these other parts in the future.

The brands at the centre of this book are increasingly using lithium, rather than lead, based batteries, however, and so the recycling service offered by Chloride Exide will become increasingly redundant for the off-grid solar industry. The 14 companies I am focused on here use the second recycler. The WEEE Centre, whose name bears reference to EU Directive 2012/19/EU on Waste Electronic and Electrical Equipment (WEEE), was set up by a Belgian non-governmental organization (NGO) called World Loop which specializes in supporting e-waste projects in Eastern Africa (Close the Gap, 2013). Set up to deal with all electronics, rather than just batteries, the WEEE Centre have signed memorandums of understanding (MoUs) with many of the leading certified companies in the last couple of years. Almost as soon as we had sat down for our interview Gijs told me how the WEEE Centre collects Barefoot Power's used and replaced batteries once a month. Two to three months after which, he told me cheerfully, they 'receive a disposal certificate indicating that we have disposed of it in a friendly way'. At the time of my fieldwork SunnyMoney, Greenlight Planet, d.light and M-Kopa were all also using the WEEE Centre. Such apparently responsible disposal, however, is not yet captured in the market device of the impact metrics.

I first visited the WEEE Centre in 2014. I was in contact with Seth, the manager, again in 2015 as part of my role on the GOGLA Sustainability Working Group. After much effort, in 2017 I was able to spend a day with Seth's team at their re-located facility in Embakasi. After the typical tour, an updated version of what I had been shown in 2014, I spent the day with Seth's team manually dismantling and sorting a pile of electronics. Although seen by the solar companies who send their waste there as a 'recycler' the WEEE Centre does not do any material processing at this site but instead sells fractions for processing elsewhere some locally and others abroad. The most telling moment of my day there, however, was when I asked one of the worker's about the panels, which he told me were just being stored. Some solar waste then is moved from waiting in the warehouse to waiting at the 'recyclers'.

Waiting with waste

Disposal at the company can, like in other locations, take various forms: it can be held on to, sent away, given away, thrown away, siphoned off, stored or 'recycled'. The crucial difference in the company setting is the volume of products being dealt with. Like with repairs, there is much more disposal happening at company offices, warehouses and workshops. Although sedimentation does occur here through the cannibalizing of old and new products, much more of that which is disposed takes the form of whole products, rather than the bits and pieces that are secreted from homes and repair clinics. Despite differences in size and frequency however, like at the home and the clinic, most waste from the company waits. It waits because companies are unsure what to do. There is a constant uncertainty of waste – people do not know where it goes, what should happen to it, what they should do with it, or sometimes whose responsibility it is. So although waste is something that remains, the remnants of a previous event or action, and is studied by archaeologists or garbologists, this waiting means it is also a thing of the future.

Companies send products back to factories in China and India not only to see what happened (in the past) but also to see what can be done next time (in the future). In doing so broken down products at the company linger longer in the solar assemblage than those at home or the repair clinic. The same is true of the lights on the Greenlight Planet desk that, like the paint-splattered tables made of old doors and window frames, serve an aesthetic purpose in the present but also act as a museum to previous designs of the company. When the products on the desk are eventually taken down they will presumably move in to the waste stream from the office towards one of Nairobi's dumps, be given to or taken by employees, or sent on to the company warehouse in the south of the city and perhaps later moved on to the WEEE Centre. When I left BBOXX, my former employer, I was given an out-of-production product not to light my home but as a memento of my past work experience and something to show others. I keep it for the same reasons. I keep it in the same way that some survey respondents keep their solar lantern; as a *kumbusho* (memory) of the past.

This chapter (and the book as a whole) has, necessarily, if regrettably, followed a linear structure. An attempt has been made, however, to stress the recursivity of broken down products that escape a linear progression from consumption to dumping or recycling. Objects have been shown to move into and out of 'the gap' between consumption and waste. In the company setting waiting in the gap could mean standing on the shelf in an office or sitting in a box in the warehouse only to come back as a gift or as the subject of testing. Rather than think of end-of-life electronics then, perhaps it is more accurate to talk in terms of afterlives (Cross and Murray,

2018). Similarly, the structuring of the book around discrete locations has sidelined their peripheries and the movements between them. It is only in attending to these margins, however, that one can see the opportunistic scavenging of the child, the passer-by or the watchman and the sediments that fall away along the way, both of which are absent from academic and industry discussions of e-waste.

The conclusion that follows suggests that the repair and disposal of off-grid solar products, as part of a particular historical and contemporary context within International Development, may hold insights for better development practice.

Conclusion: The Repair Mindset

Repair is an increasingly mainstream concern. The 'Right to Repair' movement is gathering pace globally: legislation is in place in the EU, France, Japan, South Korea, the UK and the US. It is in progress in South Africa and has been proposed in Australia and Canada (21: Spear and Cross, 2021). This movement involves the protection in law of consumer electronics and domestic appliances being designed in a repairable way complete with available parts and knowledge to enact those repairs. The Right to Repair movement runs in tandem with efforts towards building a 'circular economy'. A circular economy is one where 'materials never become waste' and economic activity is decoupled from 'consumption of finite resources' (Ellen MacArthur Foundation, nd). However, research has shown that the economy was never entirely linear. Instead, poverty and ingenuity have combined to create an 'actually existing circularity' (2: O'Hare, 2021) in many parts of the world. It is important then in discourses of the right to repair and the circular economy not to ignore that which is already there. Indeed, working from what already exists is a key aspect of bricolage.

Historically, there have been connections between poverty, thrift and repair. If budgets are tight then individuals, households, communities often seek to fix something rather than replace it, if and when the fix is cheaper than the replacement. However, as areas and regions have become more closely integrated into global circuits of trade, particularly in consumer goods, that equation has flipped and the economies of scale from manufacturing centres such as China have made replacement with a new item cheaper than fixing the old one. Another key trend is that as capitalism has advanced further – and the distances between creator and user have grown wider – products have become more bounded and more closed, which has in turn made repair (material ones especially) more difficult. Taken together these trends have threated cultures of repair. It is in response to this threat, more established in some parts of the world than others, that the Right to Repair movement has emerged.

It remains to be seen how the global consumer repair movement will affect the off-grid solar industry. It might be that the companies of the off-grid solar industry come to adopt more repairable design if that trend continues

in the countries where they are based or if pressure was to be applied by investors and funders. Or it might be that pressure spreads from the user-side, in country, although given the various other rights still being fought for in many African countries it seems unlikely that the right to repair will be a top priority. Although most African countries have good environmental policies, indeed in some areas they are world-leading (on single-use plastics for instance), governments often face challenges in terms of enforcement of and compliance to those laws.

With a series of record-breaking years for global average temperatures and increasingly extreme flooding and wildfires around the world, the climate crisis is here and the need for the energy transition away from fossil fuels has never been more urgent. At the same time, population growth in Africa and a growing middle class on the continent means demand for consumer electronics and domestic appliances, among other things, is increasing. In such a context the need for both alternative forms of energy, like solar, and to keep devices lasting longer and recycling them when that is no longer possible is great. In lieu of a rights-based approach or any co-ordination of the very diffuse repair industry in a country like Kenya, users, repairmen and technicians will continue to adopt instead their Repair Mindset, which, although frustrated by the constrains of modern capital, can never be eliminated. The Repair Mindset means accepting breakdown and responding to the world as-is rather than trying to design it otherwise. The Repair Mindset is informed by past experience, draws from resources at hand and promotes functionality ahead of appearance. It incorporates the material and immaterial legacies of past interventions.

Development by bricolage

International Development, as articulated in global initiatives such as the Millennium Development Goals (United Nations, 2015b) and more recently the Sustainable Development Goals (SDGs) (United Nations, 2015a), is concerned with reducing global inequality in areas such as health, education, energy, hunger, poverty and gender. Such initiatives, and the communities of practice and research that they create and are created by, in their very existence acknowledge that the world is not in an adequate state; it is broken. The pursuit of these development goals in bi- and multilateral policies, non-government programmes and increasingly business opportunities are a response to that broken world. We can think of these responses as attempts to repair. And so development, like repair studies, as starting from breakdown. However, unlike repair, development efforts rarely recognize that any unbrokenness they ever achieve will be temporary because future breakdown is inevitable. Development tends to work with new plans and new ideas rather than remnants and remains, which it may associate with failure

(the world is still broken) and so seek to distance itself from. Development, like design, 'is a representation of an intentional future' (105: Heeks, 2002). 'It is a world in miniature that contains elements that have been inscribed either explicitly or implicitly' (105: Heeks, 2002). In looking forward then, as an ingénieur might, development denies itself the capacity to see that the world will keep on breaking and its best repairs (through infrastructural investments, economic restructuring or innovations at the base-of-the-pyramid) can only ever be temporary. The ingénieur, Lévi-Strauss writes, 'is always trying to make his way out of and go beyond the constraints imposed by a particular state of civilization' (19: Lévi-Strauss, 1994) while the bricoleur, by inclination or necessity, stays within them. I suggest that international efforts to reduce global inequality might be better served by adopting the approach of the bricoleur, the Repair Mindset: acknowledging the inevitability of breakdown, working from the remains of previous efforts and putting function before form.

That not everyone in the world has regular, reliable or proximate access to electricity is one way the world is broken. SDG7 seeks to address this particular deficiency. The Kenyan government's response to the lack of electricity access was historically to extend the grid. In 2016, while I was in Kenya conducting the research for this book, the government released new electrification figures estimating coverage at 56 per cent nationwide (Bungane, 2016). That figure has since climbed to 76 per cent in 2022 (World Bank, 2024d). This is in large part due to the fact that in 2018 the country began, after pressure from the Department for International Development (DFID) through its Energise Africa programme, to include off-grid solutions in how it calculated electrification figures (Government of Kenya, 2018).

Financed, advocated and promoted by International Development actors, notably the World Bank through its Lighting Global programme, the off-grid solar product is an example of a 'development device' (Collier et al, 2017). The incredible growth in the sales of these things, from 0.2 million products in 2010 to 26.2 million globally by 2016 (11, 14: Bloomberg New Energy Finance and Lighting Global, 2016; 58: Dalberg Advisors and Lighting Global, 2018), make this an important industry to examine. For more and more people infrastructure takes the form of a development device (or humanitarian good) like the off-grid solar product. In this book I have told the story of one infrastructure-as-product in one country. But breakdown, repair and disposal are equally relevant to other development devices like mosquito nets, clean cookstoves, glucometer foils, rapid diagnostics tests and water filtration systems. Objects that like the solar product are offered as boxed or packaged solutions, yet rely on their own assemblages of actors and ideas to make them work, until their inevitable breakdown.

Assemblage thinking helps highlight that although physically and materially less visible than grid electricity, off-grid solar products still require a series of

connections in order to reach sites of use and once there to remain in use. Thinking in terms of relations drew attention to the organizing regimes of quality standards and impact metrics that make and measure the off-grid solar market, its products and its actors. The new material products, new companies and new business models that the market devices qualify and quantify show the off-grid solar market to be the work of an ingénieur rather than a bricoleur. These introductions (or impositions) however, like with any infrastructure, still end up integrating with pre-existing local contexts. In this case the solar products were shown to interact with the wider (and older) electronics market in Kenya as users treat products the same as other electronics, turn to mafundi in cases of breakdown and fit the products in to their existing household disposal routines as well. This integration undermines the ingénieur's approach and creates problems when certified actors seek to introduce their own repair and disposal regimes as well. I argue that the use of development devices, and the 'alchemy of innovative design and empirical monitoring' (158: Redfield, 2012), serves to limit bricolage; an approach that ironically has been shown at the home, the clinic and the company, is how people in Kenya already make the solar assemblage work for them. Universal energy access may come sooner should development facilitate bricolage by drawing more from the bricoleur than the ingénieur.

Not only this but in adopting the Repair Mindset I suggest we might also fix some of the political problems inherent to development and well documented by others (Ferguson, 1994; Escobar, 1995; Mosse, 2005). BP's early foray into solar in Africa (see Chapter 1) has been followed in more recent years by other global (Western) fossil fuel giants like Shell, Total, EDF and Engie through a mixture of corporate social responsibility (CSR) funding, sales partnerships (with d.light) and direct acquisitions of some of the smaller companies discussed in this book. These activities can easily be seen as a form of neo-colonialism with profits extracted based on African resources, in this case the Sun. Although the repairs recounted here were not politically motivated, they can still be politically transformative. The Repair Mindset offers a subversive route to independence and freedom from market constraints by frustrating the designs of the ingénieur – here in the shape of massive European energy companies.

I continue the conclusion with a recap of the preceding chapters. I then discuss the progress that has been made to date on this topic in the industry, particularly the activity that has taken place from 2018 to 2024. In the final section I highlight the remaining gaps in the field and explain how to fix off-grid solar.

Recapitulation of chapters

This book has followed off-grid solar products in Kenya through time from the 1980s to now, and then space through sale, use, repair and disposal.

Chapter 1 showed how the applications of solar photovoltaic (PV) in Kenya to a large extent mirrored the trends of International Development over the same time: from local, appropriate, engineered solutions to innovative, sustainable businesses. The trend has been away from bricolage towards the blueprint of the ingénieur. I argue that the influence and role of (male) outsiders has cast Kenyans in the role of users and beneficiaries. This has limited the re-use of older materials and the ability of Kenyans to adapt and repair solar to suit their needs.

Chapter 2 set up the contemporary market in two parts: certified and non-certified. The certified market is made and maintained through two main market devices: quality standards and impact metrics. The devices do not allow for quality of assembly or service, nor do they acknowledge the material longevity of solar hardware and any associated negative environmental impacts. Despite presenting as standalone or independent, these market devices demonstrate that off-grid solar products, 'require and entail the assembly of new kinds of expertise, … new articulations of populations, and new instruments' (Collier et al, 2017). This supporting labour, that brings the impact investor and testing laboratory as new sites and actors into the assemblage, again suggests an ingénieur's approach whereby the certified actors seek to impose a whole new system rather than engage with existing local ones.

The expanding solar assemblage, however, breaks down. Chapter 3 worked with a relational understanding of breakdown to describe the many and various types of breakdown that occur: from vehicle accidents to company closures. Demonstrating that not all breakdowns are material and that not all breakdowns create waste I used the 'gap' (Hetherington, 2004) to account for the delay in time and inconsistency in actions that occur after breakdown. The conditions, locations and types of breakdown were shown to be integral to shaping the possible options for responses to it.

Chapter 4 argued that the options available at the moment breakdown is realized are shaped by the image of the user that is portrayed by the certified market. The certified market's understanding of what use is or should be does not include repair. Despite the best efforts of certified actors (donors, funders, NGOs and companies) to the contrary, I demonstrate that repair occurs at home in two ways: through changing *how* the product is used (repairs of practice) and affecting physical changes to the product (material repairs). The argument begun here is that trial and error, the use of resources 'at-hand' and inconsistency in outcome (and functionality) all point to repair as a form of bricolage (Lévi-Strauss, 1994).

Acknowledging, however, that repair at home is limited and infrequent, I also looked at other responses to breakdown. Informed by a survey of users, the most common response is to hold on to broken down products. This holding is understood as a 'gap' between breakdown and disposal.

The range of responses users make to breakdown and the variety of things that can happen in and after the gap are better understood by thinking of afterlives rather than the dominant framing of end-of-life electronics (Cross and Murray, 2018). Products were seen to be used as decorations, toys and teaching tools or sold for scrap, thrown down the toilet or users try to get them repaired by someone else.

That someone else is the fundi – the central character of Chapter 5 and a further addition to the solar assemblage. Fundi is a Swahili word to describe a skilled individual who works with their hands, in this instance to repair electronic and electrical things. Based on my apprenticeship to two mafundi (plural) in the town of Bomet I showed that they, like users, are engaged in bricolage. Although doing a lot more repairs and doing more material repairs than were found at home, the fundi proceeds in much the same way as the user, through trial and error, drawing on previous experience, using existing parts and prioritizing functionality over aesthetics. What makes the fundi distinct is the difference in their motivations. Rather than repairing for pragmatic reasons (as users do) the mafundi in Kenya work to fix things so as to provide for their families, for economic reasons.

The fundi's work, and his constant desire to keep costs down, necessitates that he holds on to a lot of broken down products from which to draw on in repairs. Through the process of bricolage, however, bits and pieces of these products are not used and, for the fundi, are useless. I tracked these bits and pieces, or sediments (Gabrys, 2011), as they move out of the repair clinic. Prefaced again by a period of waiting, I presented a similar range of afterlives as found at home with sediments of solar products being sold as scrap, siphoned off by passing children and adults, burnt by the roadside or dumped on the edge of town, reaching as they do so the outer reaches of the solar assemblage forming from breakdown new relationships with other wastes and elements in the ground and atmosphere.

Chapter 6 left Bomet and returned to Nairobi where the certified actors have their offices, workshops and warehouses. Where independent repair (by the fundi) was motivated by making money, repair at the company is driven by the desire to *save* money. If, after two rounds of troubleshooting, a product is deemed to have a 'real' problem (not just 'incorrect' usage) it is either returned untouched (if out-of-warranty), replaced or repaired. Despite the outward formality of a process: narrated in interviews, displayed on noticeboards and reflected in job titles, I demonstrated that through recruitment and training of technicians as well as the work itself flexibility remains and bricolage is observed.

Another element that is constant in the company setting is waste. I returned to waste for a third time to follow the products and sediments as they leave company offices, workshops and warehouses towards rubbish dumps, recycling facilities and manufacturing operations in Asia. I showed that

holding is again the dominant and first response to breakdown and is again motivated by the uncertainty of the future: similar to users at home, company representatives are not sure of what the 'right' thing to do is. Siphoning, as observed at the clinic was found again here. The main difference at the company level is, as it was with repair, the far greater volumes that are being dealt with.

If you finish your school, your plan?

Declan: I don't know if you wanted to ask me anything or? Hmm?
Wilson: What I want to ask?
Declan: Yeah
Wilson: If you finish your, your school, your plan?

Wilson was not the only person to ask me this question. Many of my research interactions concluded with a respondent asking me where this information was going, what it was for, what I will do afterwards. Meanwhile journalists, investors, practitioners and university students, learning of my research through other means (such as blog, media articles, Twitter, conferences), contacted me asking for practical advice as to what they could do to improve the situation 'on the ground'. From such conversations I came to be involved as a consultant on a couple of projects applying the findings of this book to the sector. I will describe these, and other progress that has been made from 2018 to 2024, in this section.

In 2018, longstanding presence in the sector, the United States Agency for International Development (USAID), funded an awards programme called the Solar E-waste Challenge (USAID, 2018). The Challenge saw two rounds of funding go out to a total of 12 projects that aimed to facilitate end-of-life management of solar e-waste and enhance repairability and product lifespans. I was also involved in a programme funded by the Norwegian government to look at sustainability of off-grid solar products within the humanitarian setting. The project, implemented by the International Organization for Migration (IOM), has trialled product repair in a refugee camp in Uganda. The UN Refugee Agency, United Nations High Commissioner for Refugees (UNHCR), have also shown interest in the topic, commissioning a report that argued for the inclusion of reparability criteria into contracting and procurement processes (Spear and Cross, 2021).

Elsewhere there has been a spate of research articles into the topic coming out of the University of New South Wales in Australia. These have explored the structural challenges for addressing solar waste (Munro et al, 2023a); barriers to product repair (Munro et al, 2023b); and the need to support third-party repair ecosystems (Samakaroon et al, 2022). The World Bank has issued a toolkit on solar e-waste management (ESMAP, 2024). The toolkit

aims to incentivize companies 'to adopt circular business models throughout their entire supply chain' (pxv; ESMAP, 2024). It proposes to do that with a mixture of procurement-led criteria and technical assistance to help companies become more circular. SolarAid, meanwhile, have published a couple of documents advocating for greater repair in the sector, specifically the incorporating of repair criteria into the quality standards and increasing the availability of repair guidance and information (Munro et al, 2023b; Keane et al, 2024).

There has in recent years emerged a community of interest into this topic. However, it remains peripheral to main industry activities and action is also limited to a few individual case studies, most notably the work of SunnyMoney in Zambia.

How to fix off-grid solar

It is clear that the job is not done. The COVID-19 pandemic of 2020–21 demonstrated the vulnerability of global supply chains and led to disruptions in service and stock provision that local, on-the-ground repair technicians were best placed to serve. The risk is that the certified market's response to greater involvement in end-of-life matters looks set to once again be that of an ingénieur – introducing a new system of product collection and processing rather than looking to integrate, as a bricoleur might, with existing networks of material recycling. Furthermore, the trend of discussions by certified actors in workshops and reports has tended towards recycling rather than the other options to reduce waste or extend product lives (see Cross and Murray, 2018). One other area to stay attuned to is the use of artificial intelligence (AI) in the industry. Already employed to analyse customer data and climatic conditions, will there be a future role for AI in repair diagnostics? Or in extending product lifespans (of batteries)? A more cynical concern might be the possible use of AI to deliberately shorten product lifespans; a sort of enhanced planned obsolescence.

Whatever exact form future developments take, centralized product designs and associated software systems will further block users from their products. This trend in the off-grid solar industry matches with other research that has identified how northern development interventions reveal the 'continued salience of neo-colonial relationships' which produce waste management systems 'developed from external notions of what waste is and how it should flow' (1051: Millington and Lawhon, 2019). These external notions often lead to the exclusion of those already operating with and depending upon waste (see Gidwani and Reddy, 2011). Apart from this postcolonial critique there are practical challenges to the establishment of solar waste recycling such as the difficulties of ensuring collaboration between rival companies. Companies see waste management, like repair, as a difficult area

in which to collaborate because it involves sharing or revealing information around product failure rates. The sector should work instead towards what I call 'planned repair-escence'. Planned repair-escence means planning for the always impending repair. The concept reflects the unavoidability of breakdown as it means a product is always in the process of becoming a repair; it is always reaching the point at which it needs to be repaired. I suggest the following as realistic, practical solutions for the industry moving forward:

- Consider alternative causes of breakdown;
    - Theft: Design products (and panels) to be less visible or less portable.
    - Casualized labour: Pay workers fairly and train them appropriately to reduce accidents in the warehouse and on the road.
    - Stock generations: Phase introduction of new product lines to allow previous ones to still be sold (rather than written off) *and* ensure that new product generations are compatible with existing ones as far as possible (rather than needing to be replaced).

- Encourage interoperability and standardization of components: A 2021 GOGLA report offered limited support for this, advocating a mixed market where proprietary technology still exists alongside interoperable ones (George and Corbyn 2021).
- Make spare parts available, especially those which are handled on a daily basis and so liable to early failure like switches and cables, and their connector pins in particular. Replacement batteries should also be provided.
- Engage with repairmen and those in the waste management industry at the stage of product design so as to design products that are more compatible with their livelihoods.
- Introduce collection schemes to recover products that are 'waiting' in homes and repair shops.
- Include measures for repairability and theft-proofing in the quality standards: This was one of six 'pathways to repair' identified in a 2020 report commissioned as part of a UKAID funded programme (Spear et al, 2020).
- Acknowledge, and so incentivize, the potentially positive impact of off-grid solar for repair and waste livelihoods in future versions of the Impact Reporting and Investment Standards (IRIS) impact metrics.

There is also a need for more research. Future research should explore the use of solar products in informal settlements and in urban environments that have not been included here. Are the dynamics of breakdown and responses different in urban settings? Staying in the countries of use more

research could follow more rural materials trading and product repair such as door-to-door ambulant waste collectors or the village fundi. Are their practices distinct from their town-based counterparts? How do they connect with the networks articulated here? There are also some manufacturers and distributors that were not included in this book; perhaps there are different practices being employed by other companies. Research must also look to other countries to like Somalia where the market is less developed or West Africa where industry and academia have been less active. If looking to other markets, one might compare to this book and ask how much of it has been specific to Kenya. Kenya is a developed market and things have changed in the time since I conducted my research. But lots of markets today are in a situation comparable to where Kenya was previously and so could learn lessons now to avoid the same problems in other places if those emerging markets are going to continue growing. Further research could expand the sites of the multi-sited ethnography in other ways, too, such as following solar waste produced at manufacturing and testing sites in east Asia.[1] A 2022 review article also called for greater research into the non-certified market which represents the majority of the products in use (Kinally et al, 2022). Fieldwork in places such as China could open up greater access to and understanding of the non-certified market which has been covered less here. How do manufacturing processes contribute to breakdown? What does the distinction between certified and non-certified look like there?

The job will never be done. Off-grid solar will never be fixed. But, by adopting the Repair Mindset, we can be better placed to respond, continually, to keep fixing it.

Notes

Introduction

[1] Solar photovoltaic (PV) technology uses light from the sun to generate electrical energy as opposed to other forms of solar power such as solar thermal where it is used to generate heat. 'Photo' means light and 'voltaic' means of electricity.

[2] A kilowatt hour is a measure of energy equivalent to 1,000 watts of power being sustained for one hour. The annual average for solar irradiance in Europe is half that of sub-Saharan Africa at nearer to 1,000 kWh/m^2 (World Bank, 2024a).

[3] Solar lanterns are sometimes called 'solar lamps' and PSPs or SHSs are sometimes called 'solar energy kits'(SEKs). However, the name 'solar lamps' neglects these products' abilities to do other things beyond lighting, like charge mobile phones. SEKs, meanwhile, implies a level of assembly that is not present for these 'plug and play' products, many of which are consolidated in a single unit. It is for these reasons I also avoid these two terms in favour of the category of 'off grid solar product'.

[4] The actual figure is unknown because we only knew the products bought from SunnyMoney. During home visits I learnt that users had often purchased other products through other channels as well.

[5] Premises is the preferred collective term as company activities take place in offices, warehouses and workshops. Furthermore, the work performed in each of these locations does not always correspond to preconceptions of the location's intended use (an office, for instance, may include storage of stock normally found in a warehouse or repair activities more typically associated with a workshop) nor is the relationship between work and space consistent across companies. This is discussed in Chapter 6.

[6] And they *are* all men.

Chapter 1

[1] The bottom-of-the-pyramid, or BoP, is a term used to refer to the poorest people in the world. It was popularized by business scholars C.K. Prahalad and Stuart L. Hart in the early 2000s to denote those whose annual income is under $1,500 (Prahalad and Hart, 2002). BoP sometimes refers to 'base of the pyramid', the meaning of the two variations is the same. Last mile distribution is a term borrowed from supply chain management that refers to the delivery of goods and services in remote, often rural areas and generally targets those at the bottom of the pyramid. The focus of the BoP concept is to make consumers of the poor, and very often it involves the last mile delivery of goods (and services) from company to customer being delivered by the poor themselves, transformed into entrepreneurs.

[2] Perlin lists Burris as having started his service in 1977 (132: Perlin, 2002), yet a Freedom of Information Act (FOIA) request to the Peace Corps revealed that his service started

in October 1970. Similarly, Byrne has Burris as being dismissed from the Peace Corps (82: Byrne, 2009), yet the FOIA states he resigned in November 1971.

3 When I was struggling to track down any trace of Burris in the Yatta area I phoned Daniel Kithokoi. He told me to head up to Chuka on the eastern side of Mount Kenya and when there to ask around the town for Silas Kinyua. Even with Silas' help, trying to track down the remaining three schools was not straightforward: on the phone Daniel had told me to go to Ukuu, Baka'ini and Ndagani but Silas said we needed to go to Njuri, Iruma and Kiini. Meanwhile, the only other of the four that Hankins could recall over email was Kibugwe. Resigned to the uncertainty of memory, Silas and I visited a handful of schools that he had worked on in that period. We are confident that Ndagani is one of the four original schools.

4 Jacobson writes that Burris' activities from Kithimani had a trading name: Kidogo Systems (125: Jacobson, 2004), but none of Daniel (his apprentice), Schellenberg (his friend) nor Pascal (his landlord) recognized this when I suggested it to them. Whether or not Kidogo Systems existed, or in what form it did so, matters less, the word *kidogo* means 'small'. Burris was not interested in reaching scale but rather in keeping things local and appropriate.

5 Burris' departure from Kenya was quite sudden. The exact reasons why he left are unknown but are likely due to Burris' personality. Byrne, who met Burris during his time in Dar es Salaam, Tanzania, says Burris was 'known to make enemies of those he considered to be less technically conscientious than he was' (96: Byrne, 2009), and an obituary describes him as a colourful character not afraid to speak his mind (8: SolarNet, 2001). Similarly, Burris' contemporary and disciple, Dan Schellenberg told me that he had bailed Burris out of custody after he was arrested in connection with the attempted *coup d'état* in 1982. Finally, Daniel Kithokoi suggested that a faulty installation at a school in Garissa, in the north-east of the country, had annoyed the Ministry of Energy and could have been a contributing factor. Burris died in 2001.

6 A charge controller prevents overcharging or draining (discharging) of a battery by stopping current from flowing in to a battery which is fully charged or out of one that is at low charge. The controller allows current to flow again, and so charging to resume, once the battery has fallen below a certain voltage or is charged above a certain level. Over and dis-charging reduce battery performance and can pose a safety risk (Hankins, 1995).

7 ESMAP, established in 1983, is still operating today. The partnership seeks to help low and middle-income countries reduce poverty and boost growth through investments in sustainable energy (World Bank, 2024c).

8 Related organization Ashden plays a prominent role in the off-grid solar industry to this day running an annual awards programme 'supporting climate innovators to build a fair and sustainable future' (Ashden, 2024).

9 LEDs are small pieces of semi-conductive material that, without a filament, are more robust, use less energy and last longer than incandescent bulbs which were used in Solar Shamba systems or fluorescent tubes like in the Glowstar (1: Sollatek, 2014).

10 In 2018 the programme was operating in 11 countries: Burkina Faso, Democratic Republic of Congo, Ethiopia, Liberia, Mali, Niger, Nigeria, Rwanda, Senegal, Tanzania and Uganda (2: Lighting Africa, 2017). The Kenya programme ended in 2018 (Lighting Global, 2018e). It was succeeded by another programme called the Kenya Off-Grid Solar Access Project for Underserved Counties (KOSAP), which targeted the more sparsely populated north and north-eastern regions of the country where the private market has been less active.

Chapter 2

[1] The figure has since fallen to 750 million according to the International Energy Agency's World Energy Outlook report for 2024 (56: IEA, 2024).

[2] IRENA is an intergovernmental organization that 'encourages governments to adopt enabling policies for renewable energy investments, provides practical tools and policy advice to accelerate renewable energy deployment, and facilitates knowledge sharing and technology transfer' (IRENA, 2018).

[3] Goldman was, at the time of writing (December 2024), president, not CEO, of d.light design. Goldman was also, like some of the individuals met in Chapter 1, a Peace Corps volunteer.

Chapter 3

[1] My colleague, Dr Jamie Cross, spoke as part of a session on 'Technical Advances and Environmental Issues Related to Off-Grid Energy Systems'.

[2] Solar lanterns are used by fishermen who work at night, particularly on Lake Victoria.

[3] One can also consider breakdown as the process through which an object moves from being ready-at-hand to be present-at-hand, as discussed by Heidegger (1962). Heidegger offers a broken hammer as an example of an object that when in use (ready-at-hand) we barely think of it but when it breaks it becomes visible (present-at-hand).

Chapter 5

[1] Ntapanta lists some other examples of types of fundi including of cookstoves and fridges (58: Ntapanta, 2025). Some in Ntapanta's list are unique to the Tanzanian context, where the use of Swahili is different from Kenya.

Conclusion

[1] This is important because, as e-waste scholar Josh Lepawsky writes, post-consumer repair, like recycling, is 'insufficient to substantively mitigate – let alone eliminate – total pollution and waste arising from electronics' (48: Lepawsky, 2025).

References

Abolafia, M.Y. (1998) 'Markets as Cultures: An Ethnographic Approach'. *The Sociological Review* 46 (S1): 69–85. https://doi.org/10.1111/j.1467-954X.1998.tb03470.x

Akrich, M. (1992) 'The De-Scription of Technical Objects', in W.E. Bijker and J. Law (eds) *Shaping Technology/Building Society: Studies in Sociotechnical Change*, The MIT Press, pp 205–24.

Allen, S. (2011) 'Barefoot Engineers: The Non-Mobility of Knowledge in a Knowledge-Transfer Project'. *Anthropology Matters* 13 (1): 1–13. https://www.anthropologymatters.com/index.php/anth_matters/article/view/226

Ames, M.G. (2019) *The Charisma Machine: The Life, Death, and Legacy of One Laptop per Child*. MIT Press.

Amoah, P., Drechsel, P., Schuetz, T., Kranjac-Berisavjevic, G. and Manning-Thomas, N. (2009) 'From World Cafés to Road Shows: Using a Mix of Knowledge Sharing Approaches to Improve Wastewater Use in Urban Agriculture'. *Knowledge Management for Development Journal* 5(3): 246–62. https://doi.org/10.1080/19474190903451116

Ashden (2024) 'The Ashden Awards'. Ashden. [webpage] https://ashden.org/awards/ Accessed 31 December 2024.

BAN and SVTC (2002) *Exporting Harm: The High-Tech Trashing of Asia*. BAN and SVTC.

Basel Action Network (2005) 'The Digital Dump: Exporting Re-Use and Abuse to Africa.' https://www.cs.swarthmore.edu/~turnbull/cs91/f09/paper/DigitalDump.pdf Accessed 18 December 2024.

Batteiger, A. (2015) 'Towards a Waste Management System for Solar Home Systems in Bangladesh', in *Decentralized Solutions for Developing Economies*, Springer Proceedings in Energy, Springer, pp 133–40.

Bawakyillenuo, S. (2012) 'Deconstructing the Dichotomies of Solar Photovoltaic (PV) Dissemination Trajectories in Ghana, Kenya and Zimbabwe from the 1960s to 2007'. *Energy Policy*, Special Section: Fuel Poverty Comes of Age: Commemorating 21 Years of Research and Policy, 49 (October): 410–21. https://doi.org/10.1016/j.enpol.2012.06.042

BBC. (2018) 'Off-Grid Battery Storage Brings Power to People'. *BBC News* [Video], 03:46. 6 March 2018. https://www.bbc.co.uk/news/av/business-43264646/off-grid-battery-storage-brings -power-to-people Accessed 18 December 2024.

Bennett, J. (2005) 'The Agency of Assemblages and the North American Blackout'. *Public Culture* 17 (3): 445–66. https://doi.org/10.1215/08992363-17-3-445

Bhattacharya, S. (2018) 'The Afterlife of Things in a Delhi Junkyard'. *Economic and Political Weekly* 53 (46): 7–8.

Big Clive (2017) 'SM100 Solar Light For Off-Grid Communities'. *YouTube* [Video], 13:38, posted by 'bigclivedotcom' 29 May 2017. https://www.youtube.com/watch?v=kqmdIV_gBfo Accessed 18 December 2024.

Bisaga, I. (2016) 'Users' Voices: Insights from BBOXX Solar Home Systems Customers in Northern Rwanda'. *BBOXX* [Blog]. 25 August 2016.

Black, M. (2007) *No Nonsense Guide to International Development*. New Internationalist.

Bloomberg New Energy Finance and Lighting Global (2016) 'Off-Grid Solar Market Trends Report 2016'. Bloomberg New Energy Finance and Lighting Global. https://about.bnef.com/blog/off-grid-solar-market-trends-report-2016/ Accessed 18 December 2024.

Bollinger, B. and Gillingham, K. (2012) 'Peer Effects in the Diffusion of Solar Photovoltaic Panels'. *Marketing Science* 31 (6): 900–12. https://doi.org/10.1287/mksc.1120.0727

Brew-Hammond, A. (2010) 'Energy Access in Africa: Challenges Ahead'. *Energy Policy* 38 (January): 2291–301. https://doi.org/10.1016/j.enpol.2009.12.016

Brew-Hammond, A. and Kemausuor, F. (2009) 'Energy for All in Africa – to Be or Not to Be?!' *Current Opinion in Environmental Sustainability* 1 (1): 83–8. https://doi.org/10.1016/j.cosust.2009.07.014

Brock, T. and Stopford, W. (2003) 'Bioaccessibility of Metals in Human Health Risk Assessment: Evaluating Risk from Exposure to Cobalt Compounds'. *Journal of Environmental Monitoring: JEM* 5 (4): 71N–6N. https://doi.org/10.1039/B307520F

Bulkeley, H. and Gregson, N. (2009) 'Crossing the Threshold: Municipal Waste Policy and Household Waste Generation.' *Environment and Planning A* 41 (4): 929–45. http://dx.doi.org/10.1068/a40261

Bungane, B. (2016) 'Kenya: Electricity Access Stats at 56%'. *ESI Africa*, [online] 1 August. https://www.esi-africa.com/kenya-electricity-access-stats-at-56/ Accessed 18 December 2024.

Busch, L. and Tanaka, K. (1996) 'Rites of Passage: Constructing Quality in a Commodity Subsector'. *Science, Technology, & Human Values* 21 (1): 3–27. https://doi.org/10.1177/016224399602100101

Byrne, R.P. (2009) 'Learning Drivers: Rural Electrification Regime Building in Kenya and Tanzania'. PhD diss., University of Sussex. http://sro.sussex.ac.uk/6963/

Cabraal, R.A., Barnes, D.F. and Agarwal, S.G. (2005) 'Productive Uses of Energy for Rural Development'. *Annual Review of Environment and Resources* 30 (1): 117–44. https://doi.org/10.1146/annurev.energy.30.050504.144228

Callén, B. and Criado, T.S. (2016) 'Vulnerability Tests. Matters of "Care for Matter" in E-Waste Practices'. *TECNOSCIENZA: Italian Journal of Science & Technology Studies* 6 (2): 17–40. http://www.tecnoscienza.net/index.php/tsj/article/view/234

Callon, M., Méadel, C. and Rabeharisoa, V. (2002) 'The Economy of Qualities' *Economy and Society* 31 (2). https://www.tandfonline.com/doi/abs/10.1080/03085140220123126?journalCode=reso20

Cervantes-Barrón, K. (2016) 'Business Models for Recycling Waste from Solar Homes Systems in Rwanda'. Master's thesis, University College London.

Chakrabarty, D. (2008) *Provincializing Europe: Postcolonial Thought and Historical Difference*. 2007 edition. Princeton Studies in Culture/Power/History. Princeton University Press.

Chaurey, A., Ranganathan, M. and Mohanty, P. (2004) 'Electricity Access for Geographically Disadvantaged Rural Communities: Technology and Policy Insights'. *Energy Policy* 32 (January): 1693–1705. https://doi.org/10.1016/S0301-4215(03)00160-5

Close the Gap (2013) *Close the Gap Annual Report 2013*. Close the Gap.

Collier, S.J., Cross, J., Redfield, P. and Street, A. (2017) 'Preface: Little Development Devices / Humanitarian Goods'. *Limn*, November 2017. https://limn.it/articles/precis-little-development-devices-humanitarian-goods/

Colmellere, C. (2015) 'Repair in Socio-Technical Systems. The Repair of a Machine Breakdown That Turned into the Repair of a Shop'. *TECNOSCIENZA: Italian Journal of Science & Technology Studies* 6 (2): 81–112. http://www.tecnoscienza.net/index.php/tsj/article/view/237

Comaroff, J. and Comaroff, J.L. (2012) 'Theory from the South: Or, How Euro-America Is Evolving Toward Africa'. *Anthropological Forum* 22 (2): 113–31. https://doi.org/10.1080/00664677.2012.694169

Cook, I. (2004) 'Follow the Thing: Papaya'. *Antipode* 36 (4): 642–64. https://doi.org/10.1111/j.1467-8330.2004.00441.x

Cook, I. and Harrison, M. (2007) 'Follow the Thing: "West Indian Hot Pepper Sauce"'. *Space and Culture* 10 (1): 40–63. https://doi.org/10.1177/1206331206296384

Cracknell, B.E. (1996) 'Evaluating Development Aid: Strengths and Weaknesses'. *Evaluation* 2 (1): 23–33. https://doi.org/10.1177/135638909600200103

Crang, M. and Cook, I. (2007) *Doing Ethnographies*. SAGE.

Cross, J. (2012) 'The Solar Assemblage'. *The Solar Assemblage* [Blog]. 18 January. https://solarassemblage.wordpress.com/2012/01/18/solarassemblage/ Accessed 18 December 2024.

Cross, J. (2013) 'The 100th Object: Solar Lighting Technology and Humanitarian Goods'. *Journal of Material Culture* 18 (4): 367–87. https://doi.org/10.1177/1359183513498959

Cross, J. (2017) 'Solar Basics'. *Limn*, 2017. https://limn.it/articles/solar-basics/

Cross, J. and Murray, D. (2018) 'The Afterlives of Solar Power: Waste and Repair off the Grid in Kenya'. *Energy Research & Social Science* 44 (October): 100–9. https://doi.org/10.1016/j.erss.2018.04.034

Cross, J. and Street, A. (2009) 'Anthropology at the Bottom of the Pyramid'. *Anthropology Today* 25 (4): 4–9. https://doi.org/10.1111/j.1467-8322.2009.00675.x

Cunningham, P.J. and Kearney, J. (eds) (2016) *Then There Was Light: Stories from Ireland's Rural Electrification*. Ballpoint Press Limited.

d.light (2018) 'd.Light S3'. d.light. [webpage] https://www.dlight.com/products/s3 Accessed 18 December 2024.

Dados, N. and Connell, R. (2012) 'The Global South'. *Contexts* 11 (1): 12–13. https://doi.org/10.1177/1536504212436479

Dalberg Advisors and Lighting Global (2018) 'Off-Grid Solar Market Trends Report 2018'. Dalberg Advisors and Lighting Global. https://gallery.mailchimp.com/cb42ca6d63b6f335fac8f0694/files/40b8690a-3325-4c05-89fa-21931059c24f/2018_Off_Grid_Solar_Market_Trends_Report_Full.pdf Accessed 18 December 2024.

Dant, T. (2010) 'The Work of Repair: Gesture, Emotion and Sensual Knowledge'. *Sociological Research Online* 15 (3): 7. https://doi.org/10.5153%2Fsro.2158

Darrow, K. and Saxenian, M. (1993) *Appropriate Technology Sourcebook: A Guide to Practical Books for Village and Small Community Technology*. Volunteers in Asia.

Davies, A.R. (2012) 'Geography and the Matter of Waste Mobilities'. *Transactions of the Institute of British Geographers* 37 (2): 191–6. https://doi.org/10.1111/j.1475-5661.2011.00472.x

Davies, G. (2014) 'Rethinking Market-Based Development Approaches: Increasing Access to Domestic-Scale Sustainable Energy Goods and Services in Sub-Saharan Africa'. PhD diss., University of Edinburgh.

de Laet, M. and Mol, A. (2000) 'The Zimbabwe Bush Pump Mechanics of a Fluid Technology'. *Social Studies of Science* 30 (2): 225–63. https://doi.org/10.1177/030631200030002002

DeLanda, M. (2016) *Assemblage Theory*. Edinburgh University Press. https://doi.org/10.1515/9781474413640

Demayo, A., Taylor, M.C., Taylor, K.W., Hodson, P.V. and Hammond, P.B. (1982) 'Toxic Effects of Lead and Lead Compounds on Human Health, Aquatic Life, Wildlife Plants, and Livestock'. *CRC Critical Reviews in Environmental Control* 12 (4): 257–305. https://doi.org/10.1080/10643388209381698

Denis, J. and Pontille, D. (2017) 'Beyond Breakdown: Exploring Regimes of Maintenance'. *Continent* 6 (1): 13–17. http://www.continentcontinent.cc/index.php/continent/article/view/273.

DFID (2015) 'Energy Africa Campaign'. gov.uk, [webpage] 20 October. https://www.gov.uk/government/news/energy-africa-campaign Accessed 18 December 2024.

DFID (2018) 'Low Energy Inclusive Appliances'. DFID, [webpage] https://devtracker.fcdo.gov.uk/programme/GB-GOV-1-300111/summaryV-1-300111 Accessed 2 December 2025.

Dolan, C. (2012) 'The New Face of Development: The "Bottom of the Pyramid" Entrepreneurs'. *Anthropology Today* 28 (4): 3–7. https://doi.org/10.1111/j.1467-8322.2012.00883.x

Duke, R.D., Graham, S., Hankins, M., Jacobson, A., Kammen, D.M., Osawa, B. et al (1999) 'Field Performance Evaluation of Amorphous Silicon (a-Si) Photovoltaic Systems in Kenya: Methods and Measurements in Support of a Sustainable Commercial Solar Energy Industry'. http://documents.worldbank.org/curated/en/108491468753008259/pdf/multi-page.pdf Accessed 18 December 2024.

EABC (2018) 'Who We Are: East Africa Business Council'. EABC. http://eabc-online.com/index.php?/eabc/about/category/who-we-are Accessed 18 December 2024.

EAC (2016) 'The East African Community Customs Management Act, 2004' Legal Notice in *East African Community Gazette* 1 (5), 30 June, by Hon. Amb. Dr Augustine Mahiga (MP), EAC.

EAC (2017) 'Overview of EAC'. EAC. https://www.eac.int/overview-of-eac Accessed 18 December 2024

Echegaray, F. and Hansstein, F.V. (2017) 'Assessing the Intention-Behavior Gap in Electronic Waste Recycling: The Case of Brazil'. *Journal of Cleaner Production*, Cleaner production towards a sustainable transition, 142 (January): 180–90. https://doi.org/10.1016/j.jclepro.2016.05.064

Edgerton, D. (2008) *Shock of the Old: Technology and Global History since 1900*. Profile Books.

Ellen MacArthur Foundation (no date) Circular economy introduction. [webpage] https://www.ellenmacarthurfoundation.org/topics/circular-economy-introduction/overview Accessed 31 December 2024.

Elyachar, J. (2005) *Markets of Dispossession: NGOs, Economic Development, and the State in Cairo*. Duke University Press.

Escobar, A. (1995) *Encountering Development: The Making and Unmaking of the Third World*. Princeton Studies in Culture/Power/History. Princeton University Press.

ESMAP (2024) Off-Grid E-Waste Management Toolkit. ESMAP Paper. World Bank. http://documents.worldbank.org/curated/en/099100924165027587/P17436116fe65e0011b7bb1418188e2e137 Accessed 18 December 2024.

The European Parliament and the Council of the European Union (2008) Directive 2008/98/EC of the European Parliament and of the Council of 19 November 2008 on Waste and Repealing Certain Directives. 22 November 2008. Official Journal of the European Union.

The European Parliament and the Council of the European Union (2012) Directive 2012/19/EU of the European Parliament and of the Council of 4 July 2012 on Waste Electrical and Electronic Equipment (WEEE). 24 July 2012. *Official Journal of the European Union*.

Ferguson, J. (1994) *The Anti-Politics Machine: 'Development', Depoliticization, and Bureaucratic Power in Lesotho*. University Press.

Forlano, L. (2017) 'Maintaining, Repairing and Caring for the Multiple Subject'. *Continent* 6 (1): 30–5. http://continentcontinent.cc/index.php/continent/article/view/277

Furniss, J. (2015) 'Alternative Framings of Transnational Waste Flows: Reflections Based on the Egypt–China PET Plastic Trade'. AREA 47 (1): 24–30.

Gabrys, J. (2011) *Digital Rubbish: A Natural History of Electronics*. The University of Michigan Press.

George, T. and Corbyn, D. (2021) The Connect White Paper. Defining a universal connector and firmware for 12V SHS Kit and Appliance interoperability. GOGLA. https://efficiencyforaccess.org/wp-content/uploads/gogla_whitepaper_the-connect-initiative_def_3.pdfdf Accessed 2 December 2025.

Gerasimova, E. and Chuikina, S. (2009) The Repair Society. *Russian Studies in History* 48: 58–74. https://doi.org/10.2753/RSH1061-1983480104

Gidwani, V. and Reddy, R.N. (2011) 'The Afterlives of "Waste": Notes from India for a Minor History of Capitalist Surplus'. *Antipode* 43 (5): 1625–58. https://doi.org/10.1111/j.1467-8330.2011.00902.x

Gille, Z. (2007) *From the Cult of Waste to the Trash Heap of History: The Politics of Waste in Socialist and Postsocialist Hungary*. Indiana University Press.

Godt, J., Scheidig, F., Grosse-Siestrup, C., Esche, V., Brandenburg, P., Reich, A. et al (2006) 'The Toxicity of Cadmium and Resulting Hazards for Human Health'. *Journal of Occupational Medicine and Toxicology* 1 (September): 22. https://doi.org/10.1186/1745-6673-1-22

GOGLA (2014) 'Adoption of Industry Opinion on Lifecycle and Recycling'. GOGLA.

GOGLA (2016) 'Standardised Impact Metrics for the Off-Grid Energy Sector. Version 2.0'. GOGLA.

GOGLA (2024) *Powering Lives and Livelihoods: Scaling Productive Uses of Renewable Energy (PURE)*. GOGLA. https://gogla.org/wp-content/uploads/2024/12/Gogla_PURE-Handbook_for_Governments_Development_Partners.pdf Accessed 26 December 2024.

GOGLA and IFC (2013) 'Symposium on Solutions for E-Waste in Developing Countries'. GOGLA.

GOGLA and IFC (2015) 'Conference Programme. 4th International Off-Grid Lighting Conference and Exhibition'. GOGLA.

GOGLA, EPD, UNREA, BUREA, USEA and UNREEEA (2016) GOGLA, EPD, UNREA, BUREA, USEA, and UNREEEA to Ministers for Energy for: Burundi, Tanzania, Kenya, Rwanda and Uganda, 4 August, 'RE: Legal Notice No. EAC/39/2016. / Amendment of EAC Customs Management Act §26 Part B General Exemptions'.

Goldstein, J. (2012) 'Waste', in F. Trentmann (ed) *The Oxford Handbook of the History of Consumption*, Oxford University Press, pp 1–25.

Government of Kenya (2018) 'Kenya National Electrification Strategy: Key Highlights'. https://www.seta-kenya.org/images/2023/KenyaNationalElectrificationStrategyKNESKeyHighlights2018.pdf Accessed 31 December 2024.

Graham, S. and Thrift, N. (2007) 'Out of Order: Understanding Repair and Maintenance'. *Theory, Culture and Society* 24 (3): 1–25. https://doi.org/10.1177%2F0263276407075954

Granovetter, M. and McGuire, P. (1998) 'The Making of an Industry: Electricity in the United States'. *The Sociological Review*, 46(1_suppl): 147–73. https://doi.org/10.1111/j.1467-954X.1998.tb03473.x

Grant, R. and Oteng-Ababio, M. (2012) 'Mapping the Invisible and Real "African" Economy: Urban E-Waste Circuitry'. *Urban Geography* 33 (1): 1–21. https://doi.org/10.2747/0272-3638.33.1.1

Greenpeace (2005) 'Recycling of Electronic Wastes in China & India: Workplace and Environmental Contamination'. Greenpeace. https://www.greenpeace.org/static/planet4-international-stateless/2005/08/ee56bf32-recycling-of-electronic-waste.pdf Accessed 18 December 2024.

Gregson, N. (2011) *Living with Things: Ridding, Accommodation, Dwelling*. Sean Kingston Publishing.

Gregson, N., Metcalfe, A. and Crewe, L. (2007) 'Identity, Mobility, and the Throwaway Society'. *Environment and Planning D: Society and Space* 25 (4): 682–700. https://doi.org/10.1068/d418t

Gregson, N., Metcalfe, A. and Crewe, L. (2009) 'Practices of Object Maintenance and Repair: How Consumers Attend to Consumer Objects within the Home'. *Journal of Consumer Culture* 9 (2): 248–72. https://doi.org/10.1177/1469540509104376

Gregson, N., Crang, M., Ahamed, F., Akhter, N. and Ferdous, R. (2010) 'Following Things of Rubbish Value: End-of-Life Ships, "Chock-Chocky" Furniture and the Bangladeshi Middle Class Consumer'. *Geoforum* 41 (6): 846–54. https://doi.org/10.1016/j.geoforum.2010.05.007

GSMA (2017) 'The Mobile Economy. Sub-Saharan Africa 2017'. GSMA. https://www.gsma.com/about-us/regions/sub-saharan-africa/wp-content/uploads/2018/11/2017-07-11-7bf3592e6d750144e58d9dcfac6adfab.pdf Accessed 18 December 2024.

Gustavsson, M. and Ellegård, A. (2004) 'The Impact of Solar Home Systems on Rural Livelihoods: Experiences from the Nyimba Energy Service Company in Zambia'. *Renewable Energy* 29 (7): 1059–72. https://doi.org/10.1016/j.renene.2003.11.011

Hancock, K.J. (2015) 'The Expanding Horizon of Renewable Energy in Sub-Saharan Africa: Leading Research in the Social Sciences'. *Energy Research & Social Science*, Special Issue on Renewable Energy in Sub-Saharan Africa, 5 (Supplement C): 1–8. https://doi.org/10.1016/j.erss.2014.12.021

Hankins, M. (1995) *Solar Electric Systems for Africa: A Guide for Planning and Installing Solar Electric Lighting Systems in Rural Africa*. Commonwealth Science Council; Motif Creative Arts.

Hankins, M. (2000) 'A Case Study on Private Provision of Photovoltaic Systems in Kenya', in Penelope Brook and Suzanne Smith (eds) *Energy and Development Report 2000: Energy Services for the World's Poor*, World Bank, pp 92–9. http://regulationbodyofknowledge.org/wp-content/uploads/2013/03/Hankins_A_Case_Study.pdf Accessed 18 December 2024.

Hansen, U.E., Pedersen, M.B. and Nygaard, I. (2015) 'Review of Solar PV Policies, Interventions and Diffusion in East Africa'. *Renewable and Sustainable Energy Reviews* 46 (June): 236–48. https://doi.org/10.1016/j.rser.2015.02.046

Harper, D. (1987) *Working Knowledge: Skill and Community in a Small Shop*. University of Chicago Press.

Harrington, E. and Wambugu, A.W. (2021) 'Beyond Technical Standards: Creating an Ecosystem for Quality and Repair in Kenya's Off-Grid Solar Sector'. *Energy Research & Social Science* 77: 102101. https://doi.org/10.1016/j.erss.2021.102101

Heap, T. (2013) 'Electrifying Africa: Beyond the Grid'. On *Costing the Earth*, *BBC Radio 4*, [Radio] 6 March. https://www.bbc.co.uk/programmes/b01r0gj6 Accessed 18 December 2024.

Heeks, R. (2002) 'Information Systems and Developing Countries: Failure, Success, and Local Improvisations'. *The Information Society* 18: 101–12. https://doi.org/10.1080/01972240290075039

Heidegger, M. (1962) *Being and Time*. Translated by J. Macquarrie and E. Robinson. MPG Books.

Henke, C.R. (1999) 'The Mechanics of Workplace Order: Toward a Sociology of Repair'. *Berkeley Journal of Sociology* 44: 55–81.

Herring, M. (2017) 'How Data Drives the Business of a Clean Energy Company'. DevOps.com, 29 November. https://devops.com/data-drives-business-clean-energy-company/ Accessed 18 December 2024.

Hertz, R. (1961) 'A Contribution to the Study of the Collective Representation of Death'. https://catalogimages.wiley.com/images/db/pdf/9781119151746.excerpt.pdf Accessed 2 December 2025.

Hetherington, K. (2004) 'Secondhandedness: Consumption, Disposal, and Absent Presence'. *Environment and Planning D: Society and Space* 22 (1): 157–73. https://doi.org/10.1068/d315t

Hicks, C. (2004) 'Kenya Slum Turns Sun into Energy'. *BBC News*, [online] 12 November. http://news.bbc.co.uk/1/hi/world/africa/4001061.stm Accessed 18 December 2024.

Hiemstra-van der Horst, G. and Hovorka, A.J. (2008) 'Reassessing the "Energy Ladder": Household Energy Use in Maun, Botswana'. *Energy Policy* 36 (9): 3333–44. https://doi.org/10.1016/j.enpol.2008.05.006

Hodder, I. (2014) 'The Entanglements of Humans and Things: A Long-Term View'. *New Literary History* 45 (1): 19–36. https://doi.org/10.1353/nlh.2014.0005

Holt, D. and Littlewood, D. (2017) 'Waste Livelihoods Amongst the Poor – Through the Lens of Bricolage'. *Business Strategy and the Environment* 26 (2): 253–64. https://doi.org/10.1002/bse.1914

Houston, L. (2013) 'Inventive Infrastructure: An Exploration of Mobile Phone Repair Practices in Downtown Kampala, Uganda'. PhD diss., Lancaster University.

Houston, L. (2017) 'The Timeliness of Repair'. *Continent* 6 (1): 51–5. http://www.continentcontinent.cc/index.php/continent/article/view/280

Houston, L., Jackson, S.J., Rosner, D.K., Ahmed, S.I., Young, M. and Kang, L. (2016) 'Values in Repair'. In *Proceedings of the 2016 CHI Conference on Human Factors in Computing Systems*, pp 1403–14. CHI '16. ACM. https://doi.org/10.1145/2858036.2858470

Huang, J.Q. (2017) 'The Ambiguous Figures of Social Enterprise: Gendered Flexibility and Relational Work among the IAgents of Bangladesh'. *American Ethnologist* 44 (4): 603–16. https://doi.org/10.1111/amet.12560

Hulme, A. (2017) 'Following the (Unfollowable) Thing: Methodological Considerations in the Era of High Globalisation'. *Cultural Geographies* 24 (1): 157–60. https://doi.org/10.1177/1474474016647370

IEA (2024) *World Energy Outlook 2024*. https://iea.blob.core.windows.net/assets/a5ba91c9-a41c-420c-b42e-1d3e9b96a215/WorldEnergyOutlook2024.pdf Accessed 31 December 2024.

IRENA (2018) 'About IRENA'. IRENA. https://www.irena.org/about Accessed 18 December 2024.

Jackson, S.J. (2013) 'Rethinking Repair', in T. Gillespie, P.J. Boczkowski and K.A. Foot (eds) *Media Technologies: Essays on Communication, Materiality and Society*, The MIT Press, pp 221–39.

Jackson, S.J. (2015) '"Repair" Theorizing the Contemporary'. *Cultural Anthropology* website. 24 September. https://www.culanth.org/fieldsights/repair Accessed 2 December 2025.

Jackson, S.J. and Kang, L. (2014) 'Breakdown, Obsolescence and Reuse: HCI and the Art of Repair'. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems*, pp 449–58. CHI '14. ACM. https://doi.org/10.1145/2556288.2557332

Jackson, S.J., Ahmed, S.I. and Rifat, M.R. (2014) 'Learning, Innovation, and Sustainability Among Mobile Phone Repairers in Dhaka, Bangladesh'. In *Proceedings of the 2014 Conference on Designing Interactive Systems*, pp 905–14. DIS '14. ACM. https://doi.org/10.1145/2598510.2598576

Jackson, S.J., Pompe, A. and Krieshok, G. (2012) 'Repair Worlds: Maintenance, Repair, and ICT for Development in Rural Namibia'. In *Proceedings of the ACM 2012 Conference on Computer Supported Cooperative Work*, pp 107–16. CSCW '12. ACM. https://doi.org/10.1145/2145204.2145224

Jackson, T. (2015) 'Africa's New Breed of Solar Energy Entrepreneurs'. *BBC News*, [online] 27 January. http://www.bbc.co.uk/news/business-30805419 Accessed 18 December 2024.

Jacobson, A. (2004) 'Connective Power: Solar Electrification and Social Change in Kenya'. PhD diss., University of California.

Jacobson, A. (2005) 'The Market for Micro-Power: Social Uses of Solar Electricity in Rural Kenya'. Working Paper No. 09/2005, Tegemeo Institute of Agricultural Policy and Development, Egerton University.

Jacobson, A. (2007) 'Connective Power: Solar Electrification and Social Change in Kenya'. *World Development* 35 (1): 144–62. https://doi.org/10.1016/j.worlddev.2006.10.001

Jacobson, A., Hall, B., Duke, R. and Lane, F.I. (2000) 'Field Performance Measurements of Amorphous Silicon Photovoltaic Modules in Kenya: Methods and Measurements in Support of a Sustainable Commercial Solar Energy Industry'. ESMAP Paper, World Bank.

Kale, S.S. (2014) *Electrifying India: Regional Political Economies of Development*. Stanford University Press.

Kanagawa, M. and Nakata, T. (2008) 'Assessment of Access to Electricity and the Socio-Economic Impacts in Rural Areas of Developing Countries'. *Energy Policy* 36 (6): 2016–29. https://doi.org/10.1016/j.enpol.2008.01.041

Karanja, S. (2016) 'Monkey Caused Nationwide Blackout, KenGen Says'. *Daily Nation*, [online] 8 June. https://www.nation.co.ke/news/Monkey-caused-blackout/1056-3239366-nk0g6jz/index.html Accessed 18 December 2024.

Keane, J. (2014) *Pico-Solar Electric Systems: The Earthscan Expert Guide to the Technology and Emerging Market*. Earthscan Expert Series. Routledge.

Keane, J., Kearnes, M., McCloskey, J., Munro, P. and Samarakoon, S. (2024) State of Repair in the Off-Grid Solar Sector. https://solar-aid.org/wp-content/uploads/2024/10/State-of-Repair-Off-Grid-Solar-Sector-Oct-2024.-UNSW-SolarAid.pdf Accessed 18 December 2024.

Kinally, C., Antonanzas-Torres, F., Podd, F. and Gallego-Schmid, A. (2022) Off-grid Solar Waste in Sub-Saharan Africa: Market Dynamics, Barriers to Sustainability, and Circular Economy Solutions. *Energy for Sustainable Development* 70: 415–29. https://doi.org/10.1016/j.esd.2022.08.014

King, K.J. (1975) 'Skill Acquisition in the Informal Sector of an African Economy: The Kenya Case'. *The Journal of Development Studies* 11 (2): 108–22. https://doi.org/10.1080/00220387508421528

King, K.J. (1977) *African Artisan*. Heinemann Education.

King, K.J. (1996) *Jua Kali Kenya: Change and Development in an Informal Economy, 1970–1995*. Ohio University Press.

Kipkoech, C.W. (2014) 'Determinants of Household Solid Waste Management in Kenya: A Case of Eldoret Municipality'. Master's thesis, University of Nairobi.

Kiplang'at, J. (2018) 'Kenya Beats all Odds to Become First EA Nation to Export Oil'. *Daily Nation*, [online] 3 June. https://nation.africa/kenya/news/kenya-beats-all-odds-to-become-the-first-ea-nation-to-export-oil-50882 Accessed 2 December 2025.

KNBS (2019) '2019 Kenya Population and Housing Census, Volume IV: Distribution of Population by Socio-Economic Characteristics'. KNBS, December. https://www.knbs.or.ke/wp-content/uploads/2023/09/2019-Kenya-population-and-Housing-Census-Volume-4-Distribution-of-Population-by-Socio-Economic-Characteristics.pdf Accessed 7 February 2026.

Knowles, C. (2014) *Flip-Flop: A Journey Through Globalisation's Backroads*. Pluto Press.

Kothari, U. (2005) 'From Colonial Administration to Development Studies: A Post-Colonial Critique of the History of Development Studies', in U. Kothari (ed) *A Radical History of Development Studies: Individuals, Institutions and Ideologies*, Zed Books, pp 1–13.

Kothari, U. (2006) 'An Agenda for Thinking about "Race" in Development'. *Progress in Development Studies* 6 (1): 9–23. https://doi.org/10.1191/1464993406ps124oa

Kumar, A. (2021) 'Between Metis and Techne: Politics, Possibilities and Limits of Improvisation'. *Social & Cultural Geography* 22: 783–806. https://doi.org/10.1080/14649365.2019.1645201

Kumar, A. and Turner, B. (2020) 'Sociomaterial Solar Waste: Afterlives and Lives After of Small Solar', in G. Bombaerts, K. Jenkins, Y.A. Sanusi and W. Guoyu (eds) *Energy Justice Across Borders*, Springer International Publishing, pp 155–73. https://doi.org/10.1007/978-3-030-24021-9_8

Larkin, B. (2008) *Signal and Noise. Media, Infrastructure, and Urban Culture in Nigeria*. Duke University Press.

Larkin, B. (2013) 'The Politics and Poetics of Infrastructure'. *Annual Review of Anthropology* 42 (1): 327–43. https://doi.org/10.1146/annurev-anthro-092412-155522

Lepawsky, J. (2012) 'Legal Geographies of E-Waste Legislation in Canada and the US: Jurisdiction, Responsibility and the Taboo of Production'. *Geoforum*, Themed issue: Spatialities of Ageing, 43 (6): 1194–206. https://doi.org/10.1016/j.geoforum.2012.03.006

Lepawsky, J. (2018) 'Almost Everything You Know about E-Waste Is Wrong'. *The Conversation* [Blog]. 15 May. http://theconversation.com/almost-everything-you-know-about-e-waste-is-wrong-93904 Accessed 18 December 2024.

Lepawsky, J. (2025) *Electronic Waste: A Reference Handbook*. Bloomsbury Academic.

Lepawsky, J. and Mather, C. (2011) 'From Beginnings and Endings to Boundaries and Edges: Rethinking Circulation and Exchange through Electronic Waste'. *Area* 43 (3): 242–49. https://doi.org/10.1111/j.1475-4762.2011.01018.x

Lepawsky, J. and McNabb, C. (2010) 'Mapping International Flows of Electronic Waste'. *The Canadian Geographer / Le Géographe Canadien* 54 (2): 177–95. https://doi.org/10.1111/j.1541-0064.2009.00279.x

Lepawsky, J., Liboiron, M., Keeling, A. and Mather, C. (2017) 'Repair-Scapes'. *Continent*. 6 (1): 56–61. http://www.continentcontinent.cc/index.php/continent/article/view/281

Lévi-Strauss, C. (1994) *Savage Mind*. Oxford University Press.

Liboiron, M. and Lepawsky, J. (2022) *Discard Studies: Wasting, Systems, and Power*. The MIT Press. https://doi.org/10.7551/mitpress/12442.001.0001

Lighting Africa (2013) 'After-Sales Service: Electronics Service Technicians'. *Market Intelligence Note* 3 (November 2013), Lighting Africa. http://documents.worldbank.org/curated/en/702551495092100981/text/115041-BRI-PUBLIC-series-Market-intelligence-note-LA-MarketIntelNote3-Technicians.txt Accessed 19 December 2024.

Lighting Africa (2017) 'Catalyzing Markets for Modern Off-Grid Energy'. Lighting Africa. https://documents.worldbank.org/en/publication/documents-reports/documentdetail/173571495091176494/catalyzing-markets-for-modern-off-grid-energy Accessed 19 December 2024.

Lighting Global (2012) 'Battery Toxicity and Eco Product Design'. *Eco Design Note* Issue 1 (September 2012), Lighting Global. https://www.lightingglobal.org/resource/eco-design-note-1-battery-toxicity-and-eco-product-design/ Accessed 19 December 2024.

Lighting Global (2013) 'Restriction of Hazardous Substances (RoHS) and Pico-Powered Lighting Products'. *Eco Design Note* Issue 3 (April 2013), Lighting Global. https://www.lightingglobal.org/resource/restriction-of-hazardous-substances-rohs-and-pico%e2%80%90powered-lighting-products/ Accessed 19 December 2024.

Lighting Global (2016a) 'AC Charger Safety Approval.' Version 1, July 2016, Lighting Global. https://www.lightingglobal.org/wp-content/uploads/2016/07/LG_AC_Charger_Safety_v1_160728.pdf Accessed 19 December 2024.

Lighting Global (2016b) 'Renewable Energy Product Repair Part I: Overview.' *Eco Design Note* Issue 6 (November 2016), Lighting Global. https://www.lightingglobal.org/resource/renewable-energy-product-repair-part-i-overview/ Accessed 19 December 2024.

Lighting Global (2017a) 'Pico-PV Quality Standards.' Version 7.1, September 2017, Lighting Global.

Lighting Global (2017b) 'Product Repair Part II: Manufacturer Best Practices.' *Eco Design Note* Issue 7 (March 2017), Lighting Global. https://www.lightingglobal.org/resource/product-repair-part-ii-manufacturer-best-practices/ Accessed 19 December 2024.

Lighting Global (2018a) 'Market Check Testing Policy'. Version 6, August 2018, Lighting Global.

Lighting Global (2018b) 'Policy for Renewing Test Results'. Version 3, May 2018, Lighting Global. https://www.lightingglobal.org/resource/policy-for-renewing-test-results/ Accessed 19 December 2024.

Lighting Global (2018c) 'Quality Matters'. *Technical Notes* Issue 27 (August 2018), Lighting Global. https://www.lightingglobal.org/wp-content/uploads/2018/08/Quality-Matters_LG-QA_Report-on-non-QV-product-testing-2018.pdf Accessed 19 December 2024.

Lighting Global (2018d) 'Solar Home System Kit Quality Standards'. Version 2.3, February 2018, Lighting Global.

Lighting Global (2018e) 'Kenya: Lighting Global'. https://www.lightingglobal.org/country/kenya/ Accessed 26 December 2024.

Lighting Global (2024) 'Our Standards'. Lighting Global. https://www.lightingglobal.org/quality-assurance-program/our-standards/ Accessed 19 December 2024.

Lorenzo, E. (1997) 'Photovoltaic Rural Electrification'. *Progress in Photovoltaics: Research and Applications* 5 (1): 3–27. https://doi.org/10.1002/(SICI)1099-159X(199701/02)5:1<3::AID-PIP158>3.0.CO;2-H

MacGregor, N. (2011) *A History of the World in 100 Objects*. Viking.

Magalini, F., Sinha-Khetriwal, D., Rochat, D., Huismann, J., Munyambu, S., Oliech, J. et al (2016) 'Electronic Waste (e-Waste) Impacts and Mitigation Options in the Off-Grid Renewable Energy Sector'. Evidence on Demand. https://www.gov.uk/dfid-research-outputs/electronic-waste-e-waste-impacts-and-mitigation-options-in-the-off-grid-renewable-energy-sector Accessed 19 December 2024.

Malinowski, B. (1964) *Argonauts of the Western Pacific: An Account of Native Enterprise and Adventure in the Archipelagoes of Melanesian New Guinea*. Studies in Economics and Political Science; No. 65, Monographs. G. Routledge & Sons Ltd.

Marcus, G.E. (1995) 'Ethnography in/of the World System: The Emergence of Multi-Sited Ethnography'. *Annual Review of Anthropology* 24 (January): 95–117. https://www.annualreviews.org/doi/abs/10.1146/annurev.an.24.100195.000523

Martínez, F. (2019) 'Introduction. Insiders' Manual to Breakdown', in F. Martínez and P. Laviolette (eds) *Repair, Brokenness, Breakthrough: Ethnographic Responses*, Berghahn Books, pp 3–16.

Matiza, T. and Oni, O.A. (2014) 'The Case for Nation Branding as an Investment Promotion Methodology for African Nations: A Literature-Based Perspective'. *Mediterranean Journal of Social Sciences* 5 (3): 262–72. https://pdfs.semanticscholar.org/b1e0/7a2e562d302719ba0df02d65f12802ae1cec.pdf Accessed 19 December 2024.

Mavhunga, C.C. (2014) *Transient Workspaces: Technologies of Everyday Innovation in Zimbabwe*. The MIT Press.

Maycroft, N. (2015) 'Obsolete Peripherals: The Ghost of the Machine?' In *PLATE Conference proceedings*, 17–19 June 2015, Nottingham Trent University: 216–20. CADBE. https://hdl.handle.net/10779/lincoln.25168169 Accessed 2 December 2025.

Mbembe, A. (2001) *On the Postcolony*. Studies on the History of Society and Culture 41. University of California Press.

McLellan, T. (2013) *Things Come Apart: A Teardown Manual for Modern Living*. Thames & Hudson.

Mellström, U. (2004) 'Machines and Masculine Subjectivity: Technology as an Integral Part of Men's Life Experiences'. *Men and Masculinities* 6 (4): 368–82. https://doi.org/10.1177/1097184X03260960

Michael, B. (2003) 'Corporate Social Responsibility in International Development: An Overview and Critique'. *Corporate Social Responsibility and Environmental Management* 10 (3): 115–28. https://doi.org/10.1002/csr.41

Miller, D. (2009) *Selling Solar: The Diffusion of Renewable Energy in Emerging Markets*. Routledge.

Millington, N. and Lawhon, M. (2019) 'Geographies of Waste: Conceptual Vectors from the Global South'. *Progress in Human Geography* 43 (6): 1044–63. https://doi.org/10.1177/0309132518799911

Mosse, D. (2005) *Cultivating Development: An Ethnography of Aid Policy and Practice*. Anthropology, Culture and Society. Pluto Press.

Muniesa, F., Millo, Y. and Callon, M. (2007) 'An Introduction to Market Devices'. *The Sociological Review* 55 (s2): 1–12. https://doi.org/10.1111/j.1467-954X.2007.00727.x

Munro, P. and Bartlett, A. (2019) 'Energy Bricolage in Northern Uganda: Rethinking Energy Geographies in Sub-Saharan Africa'. *Energy Research & Social Science* 55: 71–81. https://doi.org/10.1016/j.erss.2019.04.016

Munro, P., Samarakoon, S., Kearnes, M. and Paisley, C. (2023a) 'The Right to Repairable Energy: A Political Ecology of Off-Grid Solar Repair in Zambia'. *Political Geography* 106: 102962. https://doi.org/10.1016/j.polgeo.2023.102962

Munro, P., Samarakoon, S., Ngwenya, T.N., Kanyanga, K., Keane, J., McCloskey, J. et al (2023b) Off-Grid Solar Repair in Africa: From Burden to Opportunity (White Paper). SolarAid. https://solar-aid.org/wp-content/uploads/2023/10/SolarAid-Whitepaper-off-grid-solar-repair-in-Zambia-12.10.2023_compressed.pdf Accessed 18 December 2024.

Murray, D. (2017) 'Disruptive Renovation: Reducing e-Waste in Africa through Repair'. St Gallen Symposium. 19 May 2017.

Nail, T. (2017) 'What Is an Assemblage?' *SubStance* 46 (1): 21–37. https://muse.jhu.edu/article/650026#info_wrap

Namunane, B. (2016) 'Kenya to Export Oil by June, 2017'. *Daily Nation*, [online] 11 August. https://www.nation.co.ke/news/kenya-to-export-oil-by-june-next-year/1056-3341692-ad0g3o/index.html Accessed 18 December 2024.

National Council for Law Reporting. (2010) *The Constitution of Kenya, 2010*. Kenya Law Reports. http://www.icla.up.ac.za/images/constitutions/kenya_constitution.pdf Accessed 19 December 2024.

Nieuwenhout, F.D.J., van Dijk, A., Lasschuit, P.E., van Roekel, G., van Dijk, V.a.P., Hirsch, D. et al (2001) 'Experience with Solar Home Systems in Developing Countries: A Review'. *Progress in Photovoltaics: Research and Applications* 9 (6): 455–74. https://doi.org/10.1002/pip.392

Nnorom, I.C. and Osibanjo, O. (2008) 'Overview of Electronic Waste (e-Waste) Management Practices and Legislations, and Their Poor Applications in the Developing Countries'. *Resources, Conservation and Recycling* 52 (6): 843–58. https://doi.org/10.1016/j.resconrec.2008.01.004

Noll, D., Dawes, C. and Rai, V. (2014) 'Solar Community Organizations and Active Peer Effects in the Adoption of Residential PV'. *Energy Policy* 67 (April): 330–43. https://doi.org/10.1016/j.enpol.2013.12.050

Ntapanta, S.M. (2023) 'Let There Be Light: Frontiers of Techno-Solar Capitalism'. https://allegralaboratory.net/let-there-be-light-frontiers-of-techno-solar-capitalism/ Accessed 26 December 2024.

Ntapanta, S.M. (2025) *Gathering Electronic Waste in Tanzania. Labor, Value, and Toxicity*. Lexington Books.

Nuwer, R. (2017) 'Rural Rwanda Is Home to a Pioneering New Solar Power Idea'. *BBC Global News*, [online] 9 October. http://www.bbc.com/future/story/20171009-rural-rwanda-is-home-to-a-pioneering-new-solar-power-idea Accessed 18 December 2024.

Nygaard, I. (2009) 'The Compatibility of Rural Electrification and Promotion of Low-Carbon Technologies in Developing Countries-the Case of Solar PV for Sub-Saharan Africa'. *European Review of Energy Markets* 3 (2): 125–58.

Obeng, G.Y., Akuffo, F.O., Braimah, I., Evers, H. and Mensah, E. (2008) 'Impact of Solar Photovoltaic Lighting on Indoor Air Smoke in Off-Grid Rural Ghana'. *Energy for Sustainable Development* 12 (1): 55–61. https://doi.org/10.1016/S0973-0826(08)60419-6

Odum, H.T. and Odum, E.C. (1981) *Energy Basis for Man and Nature*. McGraw-Hill.

OECD and IEA (2015) 'World Energy Outlook 2015'. OECD/IEA. https://iea.blob.core.windows.net/assets/5a314029-69c2-42a9-98ac-d1c5deeb59b3/WEO2015.pdf Accessed 23 December 2024.

OECD and IEA (2017) 'Energy Access Outlook 2017/: From Poverty to Prosperity'. OECD/IEA. iea.blob.core.windows.net/assets/9a67c2fc-b605-4994-8eb5-29a0ac219499/WEO2017SpecialReport_EnergyAccessOutlook.pdf Accessed 23 December 2024.

Ogola, G. (2006) 'The Idiom of Age in a Popular Kenyan Newspaper Serial'. *Africa* 76 (4): 569–89. https://doi.org/10.3366/afr.2006.0075

O'Hare, P. (2021) 'Cambridge, Carnaval, and the "Actually Existing Circularity" of Plastics'. *Worldwide Waste* 4 (1): 4–4. https://doi.org/10.5334/wwwj.66

Okonjo-Iweala, N. (2015) 'Green Energy for the Poor'. *New York Times*, 9 September. https://www.nytimes.com/2015/09/10/opinion/green-energy-for-the-poor.html Accessed 23 December 2024.

Okoth, E. (2017) 'Losses Loom in Stalled Crude Export Plan'. *Daily Nation*, [online] 30 June. https://www.nation.co.ke/news/Losses-loom-in-stalled-crude-export-plan/1056-3993572-1066c7j/index.html Accessed 23 December 2024.

Ondraczek, J. (2013) 'The Sun Rises in the East (of Africa): A Comparison of the Development and Status of Solar Energy Markets in Kenya and Tanzania'. *Energy Policy* 56 (May): 407–17. https://doi.org/10.1016/j.enpol.2013.01.007

Ong, A. and Collier, S.J. (2008) Global Assemblages: Technology, Politics, and Ethics as Anthropological Problems. Wiley-Blackwell.

Orr, J.E. (1996) *Talking About Machines. An Ethnography of a Modern Job*. Cornell University Press.

Packard, V. (1961) *The Waste Makers*. Longmans.

Pachauri, S. and Rao, N.D. (2013) 'Gender Impacts and Determinants of Energy Poverty: Are We Asking the Right Questions?' *Current Opinion in Environmental Sustainability* 5 (June): 205–15. https://doi.org/10.1016/j.cosust.2013.04.006

Patel, P., Okechukwu, C.A., Collin, J. and Hughes, B. (2009) 'Bringing "Light, Life and Happiness": British American Tobacco and Music Sponsorship in Sub-Saharan Africa'. *Third World Quarterly* 30 (4): 685–700. https://doi.org/10.1080/01436590902867110

Peet, R. and Hartwick, E. (1999) *Theories of Development*. Guilford Press.

Pellegrini, L. and Tasciotti, L. (2013) 'Rural Electrification Now and Then: Comparing Contemporary Challenges in Developing Countries to the USA's Experience in Retrospect'. *Forum for Development Studies* 40 (1): 153–76. https://doi.org/10.1080/08039410.2012.732108

Pepinster, C. (2012) '*Développement sans Plomb. Enquête Sur La Faisabilité de l'implantation d'une Unité de Recyclage Des Batteries Plomb-Acide Dans La Région de Kigali- Rwanda*'. Master's thesis, Université catholique de Louvain.

Perlin, J. (2002) *From Space to Earth: The Story of Solar Electricity*. Harvard University Press.

Peters, J., Harsdorff, M. and Ziegler, F. (2009) 'Rural Electrification: Accelerating Impacts with Complementary Services'. *Energy for Sustainable Development* 13 (1): 38–42. https://doi.org/10.1016/j.esd.2009.01.004

Pless, J. and Fell, H. (2017) 'Bribes, Bureaucracies, and Blackouts: Towards Understanding How Corruption at the Firm Level Impacts Electricity Reliability'. *Resource and Energy Economics* 47 (C): 36–55. https://doi.org/10.1016/j.reseneeco.2016.11.001

Prahalad, C.K. (2006) *The Fortune at the Bottom of the Pyramid*. Wharton School Publishing.

Prahalad, C.K. and Hart, S.L. (2002) 'The Fortune at the Bottom of the Pyramid'. *strategy+business* First Quarter 2002. Issue 26.

Prisco, J. (2016) 'The $7 Plan Bringing Solar Power to Tanzania'. *CNN*, [online] 15 December. https://www.cnn.com/2016/12/15/africa/off-the-grid-tanzania-rwanda/index.html Accessed 23 December 2024.

Puckett, J., Westervelt, S., Gutierrez, R. and Takamiya, Y. (2005) *The Digital Dump. Exporting Re-use and Abuse to Africa*. 24 October. The Basel Action Network.

Radjou, N., Prabhu, J., Ahuja, S. and Roberts, K. (2012) *Jugaad Innovation: Think Frugal, Be Flexible, Generate Breakthrough Growth*. John Wiley & Sons.

Rathje, W.L. and Murphy, C. (2001) *Rubbish!: The Archaeology of Garbage*. University of Arizona Press.

Redfield, P. (2012) 'Bioexpectations: Life Technologies as Humanitarian Goods'. *Public Culture* 24 (1): 157–84. https://doi.org/10.1215/08992363-1443592

Redfield, P. (2016) 'Fluid Technologies: The Bush Pump, the LifeStraw® and Microworlds of Humanitarian Design'. *Social Studies of Science* 46 (2): 159–83. https://doi.org/10.1177/0306312715620061

Redfield, P. (2017) 'On Band-Aids and Magic Bullets'. *Limn* Issue 9. https://limn.it/articles/on-band-aids-and-magic-bullets/ Accessed 23 December 2024.

Reno, J.O. (2009) 'Your Trash Is Someone's Treasure: The Politics of Value at a Michigan Landfill'. *Journal of Material Culture* 14 (1): 29–46. https://doi.org/10.1177/1359183508100007

Reno, J.O. (2013) 'Waste', in P. Graves-Brown, R. Harrison and A. Piccini (eds) *The Oxford Handbook of the Archaeology of the Contemporary World*, Oxford University Press, pp 1–16.

Reno, J.O. (2014) 'Toward a New Theory of Waste: From "Matter out of Place" to Signs of Life'. *Theory, Culture & Society* 31 (6): 3–27. https://doi.org/10.1177/0263276413500999

Reno, J.O. (2015) *Waste Away: Working and Living with a North American Landfill*. University of California Press.

Rifat, M.R., Siddique, A., Abouzied, A. and Chen, J. (2016) 'From Alley to Landfill: Challenges of and Design Opportunities for Cleaning Dhaka's Communal Trash'. In *Proceedings of the Eighth International Conference on Information and Communication Technologies and Development*, 9 (1–9): 10. ICTD '16. ACM. https://doi.org/10.1145/2909609.2909648

Rivoli, P. (2014) *The Travels of a T-Shirt in the Global Economy: An Economist Examines the Markets, Power, and Politics of World Trade*. John Wiley & Sons.

Roberts, A.F. and Ratajczak, A.F. (1989) 'The Introduction of Space Technology Power Systems into Developing Countries'. NASA. https://ntrs.nasa.gov/search.jsp?R=19890015903 Accessed 23 December 2024.

Rosner, D.K. (2014) 'Making Citizens, Reassembling Devices: On Gender and the Development of Contemporary Public Sites of Repair in Northern California'. *Public Culture* 26 (1 (72)): 51–77. https://doi.org/10.1215/08992363-2346250

Rosner, D.K. and Ames, M. (2014) 'Designing for Repair?: Infrastructures and Materialities of Breakdown'. In *Proceedings of the 17th ACM Conference on Computer Supported Cooperative Work & Social Computing*, pp 319–31. CSCW '14. ACM. https://doi.org/10.1145/2531602.2531692

Roy, A. (2012) 'Ethical Subjects: Market Rule in an Age of Poverty'. *Public Culture* 24 (1 (66)): 105–8. https://doi.org/10.1215/08992363-1443574

Samarakoon, S., Munro, P., Zalengera, C. and Kearnes, M. (2022) 'The Afterlives of Off-Grid Solar: The Dynamics of Repair and E-waste in Malawi'. *Environmental Innovation and Societal Transitions* 42: 317–30. https://doi.org/10.1016/j.eist.2022.01.009

Schumacher, E.F. (1993) *Small Is Beautiful: A Study of Economics as if People Mattered*. Vintage.

Sen, A. (1999) *Development as Freedom*. Oxford University Press.

Simiyu, S. (2018) 'GENDER: 12th Parliament shows Kenya deeply patriarchal'. *ICJ Kenya*, 30 January. https://icj-kenya.org/news/gender-12th-parliament-shows-kenya-deeply-patriarchal/ Accessed 26 December 2024.

Singh, P. (1991) 'Incorporating Solar Electric Power into Rural Electrification Programs: A Case Study of Kenya'. *Energy Sources* 13 (1): 67–75. https://doi.org/10.1080/00908319108908969

SolarAid (2014a) '1 Million Solar Lights Shining in Africa'. SolarAid, [online] 2 April. https://solar-aid.org/news/1-million-solar-lights-shining-in-africa/ Accessed 23 December 2024.

SolarAid (2015a) 'Impact Report. Autumn 2015.' SolarAid. https://socialvalueuk.org/reports/solaraid-impact-report-autumn-2015/ Accessed 23 December 2024.

SolarNet (2001) 'PV Africa Pioneer Harold Burris Dies'. *The Solar Energy Network Newsletter* 3 (3) Sep/Dec 2001: 8. SolarNet.

Sollatek (2014) 'Glowstar Solar Lanterns Light up Adult Literacy Classes in Ghana'. Sollatek. https://www.sollatek.com/wp-content/uploads/2014/06/Glowstar-caseHistory.pdf Accessed 23 December 2024.

Sovacool, B.K., D'Agostino, A.L. and Bambawale, M.J. (2011) 'The Socio-Technical Barriers to Solar Home Systems (SHS) in Papua New Guinea: "Choosing Pigs, Prostitutes, and Poker Chips over Panels"'. *Energy Policy* 39 (3): 1532–42. https://doi.org/10.1016/j.enpol.2010.12.027

Spear, R. and Cross, J. (2021) 'Towards a Circular Economy in UNHCR: A Focus on Core Relief Items (Solar Lamps)'. https://logcluster.org/en/document/towards-circular-economy-unhcr Accessed 23 December 2024.

Spear, R., Cross, J., Tait, J. and Goyal, R. (2020) 'Pathways to Repair in the Global Off-Grid Solar Sector'. Efficiency for Access. https://efficiencyforaccess.org/wp-content/uploads/Pathways-to-Repair-in-the-Global-Off-Grid-Solar-Sector_final.pdf Accessed 23 December 2024.

Spelman, E. (2003) *Repair: The Impulse to Restore in a Fragile World*. Beacon Press.

Star, S.L. (2002) 'Infrastructure and Ethnographic Practice'. *Scandinavian Journal of Information Systems* 14 (2): 107–22. https://dl.acm.org/citation.cfm?id=782695 Accessed 23 December 2024.

Star, S.L. and Ruhleder, K. (1996) 'Steps Toward an Ecology of Infrastructure: Design and Access for Large Information Spaces'. *Information Systems Research* 7: 111–34. https://doi.org/10.1287/isre.7.1.111

Sterling, B. (2016) 'Anarchist Technologies Repair Manual'. *Wired*, [online] 12 June. https://www.wired.com/beyond-the-beyond/2016/06/anarchist-technologies-repair-manual/ Accessed 23 December 2024.

Strasser, S. (1999) *Waste and Want: A Social History of Trash*. Henry Holt and Company.

Strebel, I., Bovet, A. and Sormani, P. (eds) (2019) *Repair Work Ethnographies: Revisiting Breakdown, Relocating Materiality*. Palgrave Macmillan.

Street, A. (2017) 'Deep Diagnostics'. *Limn* Issue 9. https://limn.it/articles/deep-diagnostics/ Accessed 23 December 2024.

SVTC (2004) 'Poison PCs and Toxic TVs'. SVTC. https://iwaste.epa.gov/rpts/svt_poisonpcstoxictvs.pdf Accessed 23 December 2024.

The Economist (2016) 'Africa Unplugged'. *The Economist*, [online] 29 October. http://www.economist.com/news/middle-east-and-africa/21709297-small-scale-solar-power-surging-ahead-africa-unplugged?platform=hootsuite Accessed 23 December 2024.

Thompson, M. (2017) *Rubbish Theory. The Creation and Destruction of Value*. Pluto Press.

Trovalla, E. and Trovalla, U. (2015) 'Infrastructure as a Divination Tool: Whispers from the Grids in a Nigerian City'. *City* 19 (2–3): 332–43. https://doi.org/10.1080/13604813.2015.1018061

Turing, J. (2015) 'Pico-Solar Product Recycling in East Africa'. Master's thesis, University of Edinburgh.

United Nations (2015a) 'The Millenium Development Goals Report 2015'. United Nations. http://www.un.org/millenniumgoals/2015_MDG_Report/pdf/MDG%202015%20rev%20(July%201).pdf Accessed 23 December 2024.

United Nations (2015b) 'Transforming Our World: The 2030 Agenda for Sustainable Development'. United Nations. https://documents.un.org/doc/undoc/gen/n15/291/89/pdf/n1529189.pdf Accessed 23 December 2024.

United Nations University (2014) *Solving the E-waste Problem (Step) White Paper: One Global Definition of E-waste*. United Nations University.

USAID (2018) 'Sustainable E-Waste Management and Battery Technologies for the Off-Grid Solar Sector: Notice of Funding Opportunity'.USAID. https://www.highergov.com/document/rfa-7200aa18rfa00023-soge-pdf-274159/ Accessed 23 December 2024.

Verhoef, J. (2016) 'Key Success Factors for Solar Home System After-Sales Service and Maintenance in Uganda. An exploratory study into closing the reverse cycle of product repairs as a step towards a Circular Economy'. Master's thesis, Rotterdam School of Management. https://thesis.eur.nl/pub/35119/

White, C. and Fearnon, K. (2010) 'Developing the Next Generation of Glowstar Solar Lantern'. In *EWB-UK National Research Conference proceedings*, 19 February, Engineers Without Borders UK Research.

WHO (2024) 'Mercury and Health'. World Health Organization, 31 March. http://www.who.int/news-room/fact-sheets/detail/mercury-and-health Accessed 23 December 2024.

Wilson, G.T., Smalley, G., Suckling, J.R., Lilley, D., Lee, J. and Mawle, R. (2017) 'The Hibernating Mobile Phone: Dead Storage as a Barrier to Efficient Electronic Waste Recovery'. *Waste Management* 60: 521–33. https://doi.org/10.1016/j.wasman.2016.12.023

Winther, T. (2008) *The Impact of Electricity: Development, Desires and Dilemmas*. Berghahn Books.

World Bank (2012) 'Lighting Africa Program Awards Innovative Solutions'. World Bank, 5 December. http://www.worldbank.org/en/news/feature/2012/12/05/lighting-africa-program-awards-innovative-solutions Accessed 23 December 2024.

World Bank (2024a) 'Global Solar Atlas'. World Bank Group. http://globalsolaratlas.info/ Accessed 23 December 2024.

World Bank (2024b) 'Rural Population (% of Total Population)'. Data, World Bank Group. https://data.worldbank.org/indicator/SP.RUR.TOTL.ZS?locations=ZG Accessed 23 December 2024.

World Bank (2024c) 'ESMAP at a Glance'. World Bank. [webpage] http://www.esmap.org/node/70853 Accessed 23 December 2024.

World Bank (2024d) 'Access to electricity (% of population) – Kenya'. Data, World Bank Group. https://data.worldbank.org/indicator/EG.ELC.ACCS.ZS?end=2022&locations=KE&start=1993 Accessed 31 December 2024.

Index

References to figures are in *italic* type.