Diffusion on the ground: Rethinking the logic of scale and access in off-grid solar in Sri Lanka

Abstract:
Off-grid solar photovoltaics have come to play a leading role in the current challenge of achieving the 7th Sustainable Development Goal of access to modern energy for all by 2030. In this context, the goal of achieving scale and accelerating growth in the off-grid solar market is now considered prominent and urgent.
This paper presents an ethnographic account of the diffusion of Solar Home Systems (SHSs) under the Renewable Energy for Rural Economic Development (RERED) project in Sri Lanka which came to an end in 2011. Based on ethnographic data from 2012 and 2018 it shows that a successful model for the diffusion of SHSs is not necessarily or automatically the same as a successful model for lasting energy access. The paper thus challenges the assumption that accelerated growth in the off-grid solar market will lead straightforwardly to sustainable access to electricity for people in countries of the global south. Focusing on the experiences of project administrators, solar installers and owners of SHSs during and after the RERED project it provides insight into how diffusion was achieved on the ground and with what consequences after the project came to an end. It argues for a need to look at the different kinds of relations, imaginaries, ideas and practices involved in diffusion in action in order to better understand what is being achieved on the ground.

Keywords: Solar; diffusion; scalability; energy access; Sri Lanka

1 Introduction

In the context of increasing global consensus around the urgency and importance of access to energy, the challenge of providing clean electricity to people living in un-electrified areas, assembles a large and complex set of actors including civil society, multilateral development banks and market-based organisations. Solar photovoltaics (PV) have become a major technology in what Hilton Simmet has recently in this journal referred to as a particular socio-technical imaginary of energy transition, in which the promise of development and the notion that energy technologies are key to bringing about growth and

eliminating poverty, receives both financial and political support from a large pool of international organisations, politicians and celebrities (Simmet, 2018).

The image of the sun with a power standby symbol (IEC 60417-5009) as used to illustrate the 7th UN Sustainable Development Goal (SDG) of "Affordable and Clean Energy" indicates the central role photovoltaics play in this socio-technical imaginary. In terms of actual sales, the latest Off-grid Solar Market Trends Report published by the World Bank Group's Lighting Global Program, shows that the global off-grid industry has seen dynamic growth in the last decade with an estimated 130 million off-grid solar products sold and 360 million people reached globally since 2010, representing a cumulative sales value exceeding USD 3.9 Billion (GOGLA, 2018). The same report also shows significant market entry and private sector engagement from an increasingly diverse pool of manufacturers including "affiliates" who are engaged with Lighting Global and/or GOGLA and "non-affiliates", about which less is known. The "non-affiliate" sector comprises an estimated 71% of pico sales (lanterns and simple multi-light systems of up to 10 Wp). (GOGLA, 2018)

As off-grid solar power as a solution to the problem of energy access has become more widespread, so has a consensus that more sales of solar technologies equal more energy access. An example of this is 'Scaling Off-grid Energy', an initiative between USAID, DFID and the Shell Foundation set up "to accelerate growth in the off-grid market to provide 20 million households in sub-Saharan Africa with access to modern, clean and affordable electricity"[1]. The means through which growth will translate into energy access is the market and the larger the market, the greater the access. The vision for the scaling off-grid initiative is to "spur a vibrant marketplace of enterprises that provide off-grid energy solutions that meet the needs low-income consumers across the African continent"[2] This initiative is, therefore, an excellent example of the kind of market-based approach to energy access which focuses on the notion of the 'fortune at the bottom of the pyramid' (Cross, 2013; Prahalad, 2009). The economic principle of 'economies of scale' here comes to imply that a large market will produce a reduction in price which will enable even more people living without access to electricity to benefit from solar PV systems. According to this logic, the goal of ensuring global access to energy seems to converge smoothly with the challenge of up-scaling or expanding the off-grid solar market across the Global South.

[1] www.scalingoffgrid.com

[2] www.scalingoffgrid.com

Despite the dominance of this narrative, it is not uncontested. This paper builds on a growing body of social science literature in this journal and elsewhere which argues that the relationship between access to energy and socio-economic development is less than straightforward. In a recent Special Issue in this journal focusing on the uptake and diffusion of solar power for energy access in developing countries, Ockwell et al (2018) argued that there is now an urgent need for greater attention to the political and socio-cultural dimensions of unfolding energy transitions. The need to re-examine the ways in which transitions towards sustainable energy provision can be achieved, as called for by these authors, brings together two related concerns. Firstly a concern that development benefits, particularly in relation to the assumed impact of solar lighting on education, livelihoods and health may not materialise in the manner imagined (Cloke, Mohr, & Brown, 2017; Kumar, 2018) or may not endure over time (Kumar et al., 2019). Secondly, and particularly pertinent for this paper a concern that the processes of creating and facilitating markets for small scale solar have political and socio-cultural effects beyond the achievement of energy access (Ockwell et al., 2018).

With these critical perspectives on the process of achieving energy access in mind, this paper focuses on the socio-cultural dimensions of solar diffusion. It uses the example of Sri Lanka and the market-based distribution of Solar Home Systems (SHSs) during the Renewable Energy for Rural Economic Development (RERED) project to show how a successful model of diffusion of SHSs is not necessarily or automatically a successful model for providing sustainable and lasting renewable energy access. It draws on Anna Tsing's analysis of "scalability in action", which offers an empirically grounded means of analysing how the process of expansion or scalability is achieved on the ground and with what social, political and technical consequences (Tsing, 2012). The paper focuses on the frequently mundane and ambiguous everyday practices involved in the diffusion in action of SHSs. It investigates the compromises needed to design a product suitable for a particular market; the practices of selling, financing and installing solar; and the everyday experiences of living with the technology over time. And it shows how different communities of interest were involved and how social and cultural relations and orderings were set into motion.

The paper proceeds as follows: Section two begins by outlining the literature relevant to understanding the diffusion of SHSs as part of efforts to provide global access to energy. It then proceeds by outlining how a diffusion in action approach can contribute to an enquiry of the social and cultural impacts of achieving scale with solar. Section three provides the background and context for the Sri Lankan case study and explains the research methods used. Section four presents the research findings detailing (in subsection 4.1) how SHSs were designed and framed as products in a marketplace, (in subsection 4.2) what

kinds of energy access they provided in everyday life after installation and (in subsection 4.3) what kinds of "afterlives" or longer-term impacts they left behind. Section five concludes that achieving large-scale diffusion of SHSs is a social and spatial process with successes and failures that are inadequately understood in terms of the logic of accumulative sales. It finally proposes that the relationship between growth in the global solar market and increased access to energy needs further enquiry.

2 From "counting installations" towards diffusion in action

The literature on SHSs in Sri Lanka and in developing countries more broadly has been dominated by questions of how to achieve successful diffusion and social acceptance, with a particular interest in how to identify and remove barriers (McEachern & Hanson, 2008; Miller, 2011; Painuly, 2001; Yaqoot, Diwan, & Kandpal, 2016). In this literature, diffusion is predominantly framed as a neutral means of enabling greater uptake of technology, underpinned by the notion that removing barriers to diffusion would lead to greater access to energy. The solution of supporting the scaling up of the solar market through initiatives such as the Scaling Off-grid Energy initiative sits within this logic, through which the task of achieving scale comes to converge with the task of providing widespread energy access.

What constitutes 'energy access' however remains a contested issue in both policy and scholarly literature, where aspects of basic needs and the quality, reliability and affordability of particular energy services are given different emphasis by different approaches (Kumar et al., 2019). While initial approaches tended to frame energy access as a single step transition, there is now greater recognition of energy access as a continuum of improvements – reflected in the multi-tier framework adopted by the UN and the World Bank.

Further debate exists around how to capture and evaluate the impact of energy access initiatives and the diffusion of energy technologies. The question of what happens after diffusion has mostly focused on an evaluation of diffusion models with a primary focus on quantitative assessments of cumulative sales, technical performance, battery life, repair and maintenance structures, customer satisfaction and reduction in kerosene consumption (Barman, Mahapatra, Palit, & Chaudhury, 2017). The question of economic development following basic energy access has received some attention, however, the evidence base is not strong. Recent results from a randomized field experiment focusing on solar micro-grids in India showed that 'despite strong electrification and expenditure effects, no systematic evidence for changes in savings, spending, business creation, time spent working or studying, or other broader indicators of socioeconomic development could be found' (Aklin, Bayer, Harish, & Urpelainen,

2017). The absence of systematic evidence or quantitative indicators, however, does not mean that the diffusion of energy technologies does not change lives. Anthropologist Tanja Winther, in particular, has argued that in terms of understanding the social impact of interventions, electricity poses a particular challenge because of the multifaceted and indirect ways in which it conditions different aspects of daily life and the time it often takes for effects to show (Winther, 2015). Questioning the reliance on quantitative methods in the evaluation of electrification projects, she argues that the gap in our understanding of the complex and sometimes ambiguous effects of efforts to provide access to energy, relates to the inability of quantitative indicators to capture parts of the story (Winther, 2015). This relates to the wider criticism of the dominant logic of accounting and audit in development aid more generally as described by Jensen and Winthereik (2013). While the need for transparency and accountability in energy access projects is unquestionable, it is disconnected from the insights created by the now large body of social science research which has been interrogating energy access, not least since the early days of this journal (Sovacool, 2014). To paraphrase David Sparkman's critique of the inadequacy of "counting toilets" in the monitoring of improvements to sanitation systems (Sparkman, 2012); these contributions suggest a need to combine efforts of "counting installations" with efforts to interrogate what actually happens on the ground as a result of these connections, particularly over time.

A strong body of social science literature already exists which has focused on exactly this question of how access to electricity is connected to social change. Seeking to challenge and counter what they see as an over-emphasis on technology and finance in an energy access literature which has been dominated by economics and engineering (Bhattacharyya, 2012; D Ockwell & Byrne, 2016; Rolffs, Ockwell, & Byrne, 2015), these authors call for analysis which better attends to sociocultural aspects of energy access. Arguing for further scrutiny of a number of more or less untested assumptions about the social impact of access to energy in different configurations (Cloke et al., 2017), social scientist have been attempting to 'up the bar' for the diffusion of devices such as SHSs: the achievement of getting them 'out there' and getting them to work out there is not ambitious enough, if diffusion is a means of achieving 'affordable, reliable, sustainable and modern energy' as it is now coined in SDG 7 (Ockwell & Byrne, 2016).

Further to this growing understanding of how energy access works as a situated social process, is an increasingly critical awareness that particularly market-based approaches to providing clean energy products have a number of externalities and unintended consequences in need of further scrutiny. Jamie Cross has convincingly shown how "Bottom-of-the-pyramid markets in Africa and Asia for things like a low-cost solar light do not emerge: they are made."

(Cross, 2013). Their making involves the creation of new corporate-community encounters involving more and different people and communities than a narrow focus on cumulative sales and individual consumers can capture (Davies, 2018; Huber, 2015; Thieme, 2015). That not all effects of the diffusion of technologies such as SHSs are positive, is becoming clearer, as recently raised in this journal by Gillian Davies who showed how private sector approaches to deliver domestic scale energy products to consumers in Sub-Saharan Africa inadvertently came to reinforce inequalities along the value chain (Davies, 2018). Questioning whether 'green jobs are just jobs' Dustin Mulvaney has further drawn attention to environmental justice concerns in the manufacturing of photovoltaics (Mulvaney, 2014) and together with Peter Newell called for greater attention to the political economy of the 'just transition' (Newell & Mulvaney, 2013). Bringing these insights together opens up questions of how the diffusion of SHSs works empirically. What happens on the ground and with what social, cultural, political and material consequences?

Anthropologist Anna Tsing offers a useful approach to analyzing and evaluating the process of achieving scale with SHSs in a manner which takes into account the wider impact and perhaps unintended and ambiguous consequences, through her empirically grounded enquiry into the process of expansion or what she refers to as "scalability"(Tsing, 2012). Scalability for Tsing refers to the capacity to "expand without rethinking basic elements…scalable projects are those that can expand without changing" (Tsing, 2012). The trouble with this Tsing argues, is that expansion creates externalities: "it is a form of design that has a long history of dividing winners and losers. Yet it disguises such divisions by blocking our ability to notice the heterogeneity of the world; by its design scalability allows us to see only uniform blocks, ready for further expansion"(Tsing, 2012). Arguing that "scalability spreads – and yet is constantly abandoned, leaving behind ruins" (Tsing, 2012), she calls for more critical enquiries of "scalability in action". Investigating scalability in action or more precisely in this paper "diffusion in action", widens the analysis and evaluation of diffusion beyond the logic of cumulative sales and end-users, towards a more empirically situated interrogation of how different communities of interest are involved (Campbell, Cloke, & Brown, 2016) at different times and places. Diffusion in action, as opposed to diffusion, asks about the processes and practices that make diffusion happen and how its effects are constructed, made real and countered.

3 Context and methods

Sri Lanka is a good place to investigate the processes of diffusion in action because it has now been some time since the diffusion of off-grid solar technology was at its peak. In 2009, when Damien Miller, the then CEO of Orb

Solar and previous Director of Rural Operations for Shell Solar first wrote the book *Selling Solar – The Diffusion of Renewable Energy in Emerging Markets* (Miller, 2011), Sri Lanka was seen as a model example of how successful diffusion of solar technology, SHSs to be more precise, could be done. The Renewable Energy for Rural Economic Development (RERED) project ran from 2002 – 2011. It was a continuation of the previous Energy Services Delivery (ESD) project, which ran from 1997 – 2002, both funded by credit lines from the International Development Association (IDA) of the World Bank, together with grants from the Global Environment Facility (GEF). During the ESD and RERED projects, a total of 131,528 SHSs were bought by people in rural Sri Lanka [3]. According to the market-based logic referred to above, this project had got the model for successful diffusion of SHSs in *emerging markets* right (Miller 2011). The story, unfortunately, does not end there. The primary research underpinning this paper took part in 2012, beginning only a month after the RERED project had finished. It formed part of a larger PhD project, which focused primarily on the role of solar power in everyday life (Turner, 2016). In 2012, when the 5 months long ethnographic fieldwork was carried out it had already become clear that the successful diffusion of a large number of SHSs at one point in time, did not relate quite so straightforwardly to a large number of well-lit houses a few years down the line as was perhaps assumed (Laufer & Schafer, 2011; Palit, 2013).

During the 5 months, repeat in-depth interviews were undertaken with more than 30 rural households as well as 15 interviews with intermediaries of the off-grid solar market; such as current and former solar installers, representatives of the RERED project administration and the Sri Lankan solar industry. A follow-up visit to Sri Lanka in 2018 included 8 interviews with installers, policymakers and electricity company employees.

Methodologically this paper situates itself within the growing category of 'energy ethnographies'. As recently argued in a special issue in this journal entitled 'Exploring the Anthropology of Energy: Ethnography, energy and ethics', ethnographic approaches are particularly suited to illustrate the diversity in how different people engage with and make judgements about energy in order to open up and reflect on taken-for-granted assumptions (Smith & High, 2017), and to grapple with the socio-cultural aspects entangled with energy use (Chatti, Archer, Lennon, & Dove, 2017). In the case of solar diffusion in Sri Lanka, it enabled the research to challenge the notion of homogeneity at local scales, by including multiple communities of interest, which had different experiences of the process of SHS diffusion (Campbell et al., 2016).

[3] www.energyservices.lk

4 How solar came to the village - Diffusion in action in Sri Lanka

4.1 Designing, diffusing and selling Solar

Solar PV is capable of adjusting to both the needs and spending power of intended users, making it appropriate for both small off-grid devices and large solar parks. This section shows however that the relationship between the needs and the spending power of intended users in the context of rural Sri Lanka was both complex and precarious. As such, the process of designing a product which would work well in a marketplace (match the spending power) as well as in the homes of rural Sri Lankans (match their electricity needs) involved both compromises and clever tactics.

The RERED project was administered by the DFCC Bank in Colombo. In January 2012 the project had just finished and efforts to wrap up and evaluate were underway. Whilst the majority of this was happening in a quantitative manner, accounting for overall numbers of systems sold compared against sets of estimates, for example, interviews with project administrators told a less neat story: administering SHSs is a messy business. Far from being the neutral technology for rural electrification, a means of securing the abstract phenomenon of "access to energy", represented in figures of cumulative sales, up close SHSs were troublesome devices which were difficult to control and manage both financially, technically and socially.
SHSs were difficult devices from the beginning of the project: matching the spending power of the rural poor with a relatively expensive technology is not easily done. Lessons learned from the previous ESD project and other World Bank solar projects around difficulties in financing the systems (Wong, 2012), made keeping the price down very important. It therefore became necessary to create a technical system which could be financed by a 3-year microfinance loan (Laufer and Schafer 2011). Framed according to this challenge SHSs were not sized and designed to deliver a certain amount of solar electricity, or meet a specific need, but rather to deliver electricity at a certain price. Within the cost limit, system design came to consist of a 20-60 Wp panel, a charge controller and 2-5 loads. The system would provide a DC current as the addition of an inverter to convert the power into AC would be prohibitively expensive. Another way of keeping the cost down was to replace the technically more appropriate but also more expensive deep cycle batteries with standard car batteries. Car batteries, however, are different technologies to deep cycle batteries; designed to deliver short but high current bursts of power, only discharging a small amount of their capacity, they do not operate well when frequently drained of their total capacity. That this was exactly what would happen to them in the context of everyday life was well understood by the RERED project officers, but first and

foremost SHSs were designed for diffusion - to become products in a marketplace.

Diffusion of SHSs is not (just) an abstract and quantitative matter of achieving and recording an increasingly higher number of systems installed. It is a spatial process; SHSs are always installed some*where*, by some*one*. The people doing the mundane work of diffusion, in this case, was predominantly the solar installers in Sri Lanka. By setting up a support system which made the selling of SHSs 'good business' the RERED project succeeded in boosting the number of solar installers in Sri Lanka from 2 to 14 during the project timeline (Sri Lankan Solar Association, personal communication, March 2012). Initially, it was a lucrative business. The RERED project provided start-up assistance for new installers. Installed systems were paid to the installer in full at the time of installation, leaving the credit arrangement and risk of default with the Micro-finance provider. For the increasing workforce of installers and salespeople, the relatively generous bonuses made solar installation an attractive job. But after a few years, as the market began to saturate and the competing politics and promises of the simultaneously rapidly expanding electricity grid began to spread to rural villages across the country, selling solar became increasingly difficult. At the beginning of the project, solar installers would target villages in areas that were easily accessible, not far from towns and cities and with good road access. As market saturation and grid expansion made this strategy less viable, solar installers would begin to target areas that were more remote. Selling solar in more remote areas was challenging both because of the increase in overheads for the solar installers and because the more remote villages often had fewer households with the purchasing power to take up the loans required for the installations. This was a difficult time for the installers, where increasingly "creative" salesmen's-tactics became more widespread as did the number of re-possessed SHSs. A representative from the Sri Lankan Solar Association explained this:

> "*A lot of the people who got the loans, couldn't actually afford to pay the instalments. But the salespeople got a bonus for every system they sold, and when the market slowed down, they had to become cleverer to sell enough. So in some places, they would make a deal with the person from the Bank who approved the loan: the salesperson would give him 50% of his bonus to approve the loan. So they both got paid and the loan got approved, but the people didn't have the money. So a lot of systems went back to the bank*." (Representative from the Sri Lankan Solar Association, March 2012)

At first, the re-possessions did not hurt the installers directly as the risk was borne by the micro-finance providers, but as these began to pull out making cash-sales the only option, the number of installers dwindled to the two SHS

installers which were left in 2012 when the RERED project had finished. For the people employed in the off-grid solar industry, diffusion was an ambiguous achievement; once a certain market saturation was reached, they were out of work. And as solar installation companies went out of business, so did their warranties and the services of repair and maintenance they had offered their customers.

4.2 Living with solar - everyday life after installation

When Damien Miller, the then Director of Rural operations for Shell Solar drove from Bibile in the Sri Lankan province of UVA to Ampara in the Eastern province in 2005, he came across a lot of solar panels and thought to himself:

> "this is what large-scale diffusion looks like… when every home in sight is using the technology. When one house buys it and has light at night, then neighbours come to see it, talk about it, get convinced and then buy it themselves" (Miller 2011: vii)

Anthropologists Harvey and Knox have described what they call the 'enchantment of infrastructure' in the context of roads; the powerful social promises of speed, connectivity and economic prosperity that surrounds large-scale road building projects even in the face of specific circumstances where they fail to deliver on these promises (Harvey & Knox, 2012). Translating their insight into the context of off-grid solar prompts the following question: does the achievement of scale, of many SHSs sold, necessarily mean that they are a good product, that they work well?
Damien Miller's excitement about the process of large-scale diffusion above, is an example of a related enchantment of solar, or what Jamie Cross has referred to as the 'economy of appearances' of solar (Cross, 2012); a faith in technology and market mechanisms to deliver both the elusive goal of access to electricity and that of the fortune at the bottom of the pyramid. It relies on the one hand on keeping the focus firmly on the quantitative logic which says greater diffusion equals greater distribution of benefits and on the other hand on controlling and ignoring particular 'externalities'. One such externality is the mundane work of sales and service provision as described in the previous section and a second externality is the question of the spatiality and temporality of use: what are the situated powers of SHSs in their context of use, and how long do they last?

In March 2012 I drove along the B527 from Bibile to Ampara, where Damien Miller had seen the spectacle of 'large-scale diffusion' 6 years previously. I stopped in the village of Galgamuwa. Seven years after installation and many battery replacements later, almost two thirds of the domestic 2-lightbulb systems still worked, at least to a fashion, as did about 10 of the 52 street lamps

that were part of the project. *After* diffusion was a different reality than the one which excited Damien Miller and counting connections is not the same as interrogating about their social capacity. Technologies fall into disrepair or lose their parts for many reasons already well documented, but of the ones that were still working, what exactly was the capacity of access to energy configured as a 2-lightbulb SHS? Questioning the role of solar electricity in everyday life is remembering that electricity is "capacity to do work" and enquiring about the capacity, particularly over time provides important empirical information.

For the people of Galgamuwa and Sri Lanka more generally, the notion of "access to energy" made little sense. SHSs provided a particular portion of power. Villagers would refer to this power as 'solar' as opposed to 'electricity', which was understood to be grid-based, and known as 'the line'. SHS users did not consider 'solar' to be 'electricity', but rather saw it as a temporary solution for powering certain devices, until finally in some either short term or long term future 'the line' would arrive. In relation to the enchantment of 'the line', solar electricity was understood and enacted much more like an extended battery. And as a battery, SHSs sometimes worked for a relatively long period of time and sometimes not for a very long period of time. Not many people expected them to last.
Living with 'solar' as opposed to 'the line' was an enactment of budgeting; of making daily choices about how much power to use for what and at the expense of what:

> *"You can see here how much power is left* [looking at a traffic light –style display on the charge controller]. *It still works when it's in the red, it just means that you probably won't have any power in the morning, or maybe the lights won't work all of the night… we use the kerosene lights when it doesn't work because the TV and the stereo use up most of the power"* (SHS user, April 2012)

For people in rural households in Sri Lanka TVs are important devices that often take priority over lights, which can more easily be replaced by kerosene lamps. TVs had also long been part of the daily lives of people living in rural Sri Lanka. A RERED customer satisfaction survey revealed that 78% of the households who purchased an SHS had previously been running black and white TVs off car batteries (ACNielsen, 2006). Standard car batteries have powered devices in rural Sri Lanka for a long time and exist within an infrastructure where battery charging stations can most often be found within a reasonable distance; a practice which continued after households invested in SHSs as a backup solution during periods of bad weather or in the event of over-use.

> *"If my husband is going to work, there is a shop on the way, so he can take the battery on his bike. It doesn't cost much so if there is no sun for a few days and we haven't got very much power, we do that"* (SHS user, May 2012)

Understanding how the particular capacity of SHSs was incorporated into existing practices of using different sources of power for different purposes, helps highlight how SHSs came to provide an incremental rather than a transformative change to their everyday practices. This is where the sizing of SHSs in order to create a product which poor people could afford catches up: solar came to power TVs in a different way rather than power a range of new devices and services. And as a result, although many people purchased SHSs after installation they were still waiting for energy infrastructure to arrive.

4.3 Ruins of diffusion – understanding solar afterlives

That the diffusion of SHSs across the developing world is fraught with difficulties around repair and maintenance, defaulted re-payments and repossessions has long been known in the literature concerned with evaluating and analysing projects of this kind (Nieuwenhout et al., 2001). The problem of initiatives and devices failing to live up to expectation has been framed predominantly as one of barriers to deployment. The experiential knowledges of SHS owners in rural Sri Lanka provide an excellent source of information about how the contingent achievement of energy access might come to fall apart. Importantly for this paper, they also show how the process of diffusion itself might come to impact social orders and relationships on the ground. Speaking with Anna Tsing, 'paying attention to the mounting pile of ruins that scalability leaves behind' (Tsing 2012: 506), investigating whether the technology works a few years down the line is not the same as interrogating about the longer term impact of its diffusion.

Overuse of batteries is often cited as a reason for why SHSs come to fail and in Sri Lanka, this was also the case. Speaking to installers and project administrators, the issue of overuse was put down to a lack of understanding of the technology because the users were "just people from the villages":

> "*Some people took the charge controllers out. But the charge controller was there to help make sure that they didn't overuse the battery, so without it, they overused the battery and then it didn't last very long. So they thought they were being clever but the batteries died like that"* (Installer, Monoragela, May 2012)

From the point of view of SHS users, the question of longevity of batteries was less straightforward:

> *"We could stop using the TV and the stereo and just have lights, but that's not what we want. The battery would last longer that way, but then what's the point of having it? We hope that one day soon the line comes, and it will be cheaper and better and we will not need a battery. But now we just have this*" (SHS user, March 2012).

Re-possessions of SHSs became more frequent towards the last part of the RERED project. Often these failures have been described as a problem of poor people struggling to pay for expensive devices. But for the SHS owners in Sri Lanka, this explanation was not entirely adequate. Although these people were not affluent, the decisions to stop repayments were not simply a case of lack of available funds; often people could have paid had they chosen to do so. Instead missed payments were about malfunctioning technology, about technology which no longer lived up to the 'value for money' scenario which had made people buy them in the first place and about the enchantment of 'the line' and the latest information about when it was assumed to come to the village. The notion of "Qualculation" put forward by Callon and Law (2005) can help explain this. For Callon and Law, the distinction between rational and irrational behaviour is a matter of which framework the behaviour is set or understood in accordance with (Callon & Law, 2005). Qualculation as opposed to calculation is contextualised and takes in a number of relevant qualitative or non-numerical concerns. For SHS users in Sri Lanka, the framework in which the decision-making around whether to "overuse" the batteries or continue repaying the loans on an SHS was a lot more complex than the question of how much money was available to spend. SHSs had entered into their lives as market products and they continued to be market products; with questions of their value for money being continually re-evaluated in the light of current circumstances. Being frugal with your battery or paying back the loan on something you do not feel is giving you value for money is not particularly rational if you consider your SHS a temporary solution, a stepping stone until electricity proper, 'the line' arrives in the village.

The enchantment of 'the line' was not merely a romanticized assumption of a better life with full electricity, but frequently a matter of a specific material inadequacy of the SHS. Again, a few years down the line, the design of SHS based on what people could afford rather than what they wanted and needed was key. The problem many households had with their SHS was not simply a matter of the quantity of energy available to them, but a problem of what kind of power or current it provided. DC electricity powers certain things, but not others:

> *"It's good that we can watch TV, but if we had the line I would get an Iron. They are not that much money. I have to use this one* [showing her heavy cast-iron iron] *and it takes a lot of time every day because I have to first make a fire to light the coconut husks and then put them in and then I iron but the sparks get everywhere and I burn both myself and the clothes almost every day"* (SHS owner, May 2012)

SHSs provided predominantly a kind of 'living-room power': TV, stereo, phones and light, but not rice cookers, electric irons, spice-grinders or kettles, which all required AC power. These were devices however which people were familiar with and which were on sale in shops in nearby towns. During household visits it was not unusual to see a rice-cooker sitting in a box on top of a cabinet, waiting for the line. In households where the line had arrived, the newly 'electrified' kitchen was frequently presented with particular importance by the woman in the households, providing a very clear picture of the gendered spatiality of solar versus grid electrification and DC versus AC power. For SHSs which were still functioning by the time grid electrification made it to the village, there were two immediate pathways: either they came to enter the second-hand market of cheaper and less reliable systems with no form of warranty, predominantly bought by people who were not able to get credit to buy a new system, or who had insufficient funds to pay for grid connection, or they were used as back-up to the grid.

At the time of writing in 2018 Sri Lanka has achieved almost full grid-based electrification, leaving almost no role for off-grid solar in the country.

> *"We learnt some bitter lessons from the RERED project. Many things went wrong and some people lost out. Some of the banks tried to connect some of the reclaimed panels to make big roof-top systems but that didn't really work either. I don't really know what happened to all those systems"* (Solar Installer, 2018)

5 Conclusions and further research

In the Oxford Dictionary, the word diffuse is defined as "spread over a wide area or between a large number of people". The RERED project in Sri Lanka was successful in achieving this. But what a longer-term ethnographic lens revealed was that this achievement did not lead to a situation in which a large number of people had solar powered access to energy after the project finished and further down the line. More sales did not lead to more access for a very long time. Based on the Sri Lankan case study, this paper draws two main conclusions:

Firstly it suggests that achieving scale with off-grid solar is not necessarily or automatically the same as providing 'access to affordable, reliable, sustainable and modern energy' for a large number of people across the Global South. Although considered a successful model for the diffusion of SHSs, the RERED was not a successful model for providing sustainable and lasting energy access. The paper has shown how the need to design a product suitable for large-scale diffusion and the practices involved in achieving this diffusion on the ground contradicted meeting the needs of end-users and contributed to the creation of a temporary affordance, a stepping stone technology rather than a sustainable solution to energy access.

While the support for the achievement of economies of scale in the off-grid solar market is already leading to cheaper solar products for more consumers, there is reason to question empirically whether the increased energy access this implies is indeed reliable and sustainable in different places over time. Speaking to the particular socio-technical imaginary of energy transition referred to in the introduction to this paper (Simmet,2018) and the focus on removing barriers to diffusion in much of the literature as outlined in section 2, this suggests a need to question whether achieving scale in the off-grid solar market, or removing barriers to diffusion for off-grid energy technologies in the Global South, have become goals in themselves. This paper argues that such a goal is inadequate and fails to take into account the insights created by the now large body of social science research on energy access and social change.

Secondly, this paper argues that a greater focus on the social and spatial processes of diffusion and achieving scale with off-grid solar is needed. By adopting and adapting the 'scalability in action' approach outlined by Anna Tsing (2012) the paper has shown how the achievement of large-scale diffusion of SHSs in Sri Lanka included distributed and ambiguous social and spatial processes and involved many more communities of interest than merely the end-users. By incorporating the different and frequently opposing views and experiences of different actors in the process, the paper has begun unpacking the manner in which unexpected consequences and ambiguous effects came into being. It showed that this happened partly through the process of diffusion itself with its ambiguous relations between project administration, sales, finance provision and end-users and partly through interaction with the particular socio-political context in Sri Lanka. This suggests that a focus on end-users or household level impact alone leaves out large chunks of the story about how the diffusion of off-grid solar technologies come to affect different communities and intermediaries.

The research underpinning this paper poses questions about the long-term impact of the diffusion of SHSs and similar technologies in terms of energy access

and more widely. It proposes a need for further research to be done. On the one hand, it argues for a need to create a more systematic mixed methods evaluation of the long-term impact of similar 'finished' projects in different places. On the other hand, it argues that there is a need for further qualitative research which looks into the manner in which different processes of diffusion enrol and affect wider communities beyond end-users. If achieving scale with off-grid solar is not a goal in itself but a means to achieve energy access and socio-economic change we need to better understand how it happens on the ground.

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