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Transforming Access to Clean Energy Technologies in the Global South: Learning from Lighting Africa in Kenya

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Abstract: As SDG7-related interventions seek to transform access to clean energy, this paper presents an analysis of both a previous transformative intervention (Lighting Africa) and a theoretical approach to understanding how such transformations can be achieved in the Global South (socio-technical innovation system, STIS, building). The paper makes four contributions. First, it tests the extent to which the STIS-building concept is useful in understanding and conceptualising how Lighting Africa transformed the market for solar lanterns in Kenya from an estimated market size of 29,000 lamps in 2009 to one where 680,000 Lighting Africa certified lamps were sold in Kenya by the end of the Programme in 2013. Second, it presents the most in-depth analysis of Lighting Africa that we are aware of to date. Third, it presents a conceptual framework that illustrates the Lighting Africa approach, providing a framework for future policy interventions aiming to transform access to clean energy technologies in the Global South. Fourth, it reflects on weaknesses in the STIS approach. In particular, these include a need to better attend to: the gendered implications of interventions (and social justice more broadly); implications of different scales of technologies; value accumulation and the extent to which interventions benefit indigenous actors and local economies; and the political and economic implications of any intervention and its distribution of benefits.

Keywords: energy access; sustainability transformations; solar lanterns; clean cooking; electric cooking

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1. Introduction

Delivering against the ambitions of UN SDG7 (ensuring access to affordable, reliable, sustainable and modern energy for all by 2030) requires nothing short of a transformation in access to clean energy technologies in the Global South. In 2018, 860 million people still lacked access to electricity and much of the recent progress made in this area is unevenly concentrated in Asia, with Africa still experiencing the lowest levels of electricity access [1]. Furthermore, 2.6 billion people globally lack access to clean cooking facilities, relying instead on biomass, kerosene, or coal [1] with significant negative health and environmental implications. Understanding how to transform access to clean energy technologies via deliberate policy interventions in the Global South therefore represents an urgent global priority. Indeed, many such policy interventions have begun to emerge, such as the UK FCDO funded Modern Energy Cooking Services (MECS) Programme that aims to transform access to cleaner cooking technologies across the developing world over a five year time period [2].

Attention paid to the problem of energy access is nothing new in the academic literature. Decades of research have focussed on finding solutions to facilitating energy access in the Global South. However, the literature has been dominated by considerations of only the technical and financial aspects of the problem, drawing on disciplinary perspectives from economics and engineering (for a systematic review that demonstrates this two-dimensional disciplinary dominance, see [3]). Whilst technology hardware and finance are undoubtedly part of the jigsaw, more recent social science-based research (summarised briefly below) has demonstrated that earlier failures to address the energy access challenge were due to the lack of attention paid to the socio-cultural and political contexts within which technology and finance intersect with the lived realities of people in the Global South. For example, even where interventions are finance based, such as in the pay-as-you-go mobile-enabled payment models for energy access, success has relied upon in-depth understandings of, and conscious alignment with, the social practices of poor women and men in consuming and paying for energy [4,5].

The emerging energy access literature, informed by critical social science perspectives, has brought to bear previously absent disciplinary voices (e.g., see the introduction by [6] to a journal special issue showcasing such approaches). This "socio-cultural turn" [7] has introduced insights from: social anthropology [8–14]; socio-technical transitions [4,7,15–24]; innovation systems [7,25,26]; social practice inspired analyses [27–31]; and work inspired by common-pool resource management theory from the broader institutional economics literature on sustainable natural resources management [32]. Politics and political economy inspired critiques that focus specifically on energy access are also beginning to emerge [33,34], following a notably earlier intervention by Sovacool [35]. This is accompanied by other relevant works that focus on the level of climate change, energy, and development more broadly [36–41].

These political economy inspired voices have important contributions to make, especially bearing in mind the increased emphasis on neoliberal market-based interventions and entrepreneurialism, which privileges the interests of some actors over others, with material implications for the poor and marginalised [42,43]. They also speak to the highly uneven nature of current changes in access to sustainable energy in the Global South [44,45]. Relatedly, there is a growing, but arguably still too small, body of literature emerging that focusses on the gendered nature of energy access and development [28,29,46–48]. Recent work has also seen the introduction of STS (science and technology studies) inspired critiques of dominant international framings of the energy access problematique and their material implications for poor and marginalised women and men [49].

This paper seeks to advance an area of this work in an effort to continue to address the "scholarly deficit" [7] in energy access research that the decades-long dominance of economics and engineering has created. Our aims are both theoretical and policy focussed. Theoretically, we seek to test and extend the work developed by Ockwell and Byrne [7], which bridges insights from the innovation studies and socio-technical transitions literatures, to develop the idea of "socio-technical innovation system building" (STIS building, described in more depth further below). STIS building is used to conceptualise the reasons for the success of the off-grid solar PV market in Kenya, for which it provides a more systemic understanding of processes of innovation and wider technological change, whilst also attending better to the social practices of technology users and the role of existing regimes of politics and practice.

One example discussed briefly in Ockwell and Byrne [7] is that of Lighting Africa in Kenya. Lighting Africa transformed the Kenyan market for solar lanterns from an estimated 29,000 lamps in 2009 to one where 680,000 Lighting Africa certified lamps were sold by the end of the Programme in 2013 (and this may have represented only around 30% of the total market) [50]. The economic rate of return on Lighting Africa's investment is estimated to be plausibly as high as 2000 percent [50]. Thus, we can argue that Lighting Africa is an example of the kind of transformation in poor people's access to clean energy technologies that delivering against SDG7 demands. It is surprising, then, that so little analysis of the Programme exists within the academic literature. A literature review conducted for this paper only identified three academic outputs (other than [7]) that engage in relatively brief analyses of Lighting Africa in Kenya, namely the works of Baptista and Plananska [51], Abdul-Salam and Phimister [52], and Sergi et al. [53], although Baptista and Plananska [51] are notable in their acknowledgement of the uniqueness and relevance of Lighting Africa's attention to consumer behaviour and education. Questions still need to be asked, therefore, as to how Lighting Africa achieved such a transformation so quickly and whether there might be transferable lessons for contemporary international policy and practice, as well as for theoretical understandings of clean energy access transformations.

We aim to address this gap by analysing the Kenyan Lighting Africa story more deeply than has been done to date. Extending theoretical work, but with a firm focus on contributing insights of use to policy makers, the paper seeks to make the following contributions. First, it tests the extent to which the STIS-building concept is theoretically useful in understanding and conceptualising the Kenyan Lighting Africa experience. Second, to the best of our knowledge, it presents the most in-depth analysis so far of this experience. Third, it presents a novel conceptual framework that illustrates the Lighting Africa approach in Kenya, thus providing a framework for future policy interventions that aim to transform access to clean energy technologies within contexts in the Global South. Finally, the paper provides a critical analysis of the STIS-building approach with reflections on where it requires further work.

The paper begins by summarising STIS-building theory, including its theoretical roots and the arguments used to justify its utility in analysing transformative interventions around access to clean energy technologies. It then summarises the methodological approach that underpins the research presented in this paper, before presenting focussed analysis of Lighting Africa's success in Kenya. This analysis then feeds into the conceptualisation and illustration of the Lighting Africa approach, with practical utility for policy makers and practitioners. The paper concludes by reflecting on the usefulness and limitations of the STIS-building approach.

2. Socio-Technical Innovation System Building

STIS building is presented by Ockwell and Byrne [7] as a way of theorising how transformations in poor and marginalised women's and men's access to clean energy technologies can be achieved. This conceptualisation is preceded by several other relevant works, where engagement first with the innovation studies literature and later with the socio-technical transitions literature can be seen to emerge [5,6,34,43,54–61]. However, it is in the 2017 monograph [7] where the proposed fusion of the innovation systems perspective from the innovation studies literature and the strategic niche management perspective from the socio-technical transitions literature is articulated. The fusion is based on an in-depth historical analysis of the emergence of the often lauded off-grid solar PV market in Kenya. Here, we briefly summarise the theoretical and empirical underpinnings of the STIS-building idea before moving on to this paper's main focus of using this as a lens for understanding the especially noteworthy success of Lighting Africa in Kenya.

The STIS-building approach invokes an innovation systems perspective to account for the fact that, when one considers transforming access to clean energy technologies for poor and marginalised women and men in the Global South (as per SDG7), what is effectively being considered is a process of significant technological change, with accompanying social changes as a result of, and in order to enable, new technology use. Levels of technology ownership in different countries are also directly correlated with levels of economic wealth, thus emphasizing the close relationship between technological change and economic development. The concept of "innovation systems" emerged in the 1990s to better explain the success of different countries in achieving economic development—success that conventional economic theory was unable to explain (e.g., [62,63]). These innovation studies scholars, through detailed empirical analysis, demonstrated that the missing link in conventional economic theory was its inability to account for different countries' capabilities to innovate and achieve technological change. By invoking the idea of an "innovation system", these scholars drew attention to the role of the myriad actors within specific country, regional and local contexts who are involved in any kind of broad technological change. They argued that it was conventional economics' failure to account for the role of the network of actors (firms, universities, research institutes, government departments, NGOs, technology users, including poor and marginalized women and men) within which innovation and technological change occurs, and the strength and nature of the relationships between them, that meant a conventional economic perspective could not explain examples of widespread and rapid technological change. An innovation system perspective, in contrast, illuminates how such change can happen and can do so across a wide diversity of contexts: e.g., the Korean steel industry, the Kenya off-grid solar PV market, various clean technology sectors in China and India, and in countries from the Asian tigers to long-standing members of the OECD [64].

An "innovation system" refers to the relationships between the network of actors mentioned above, the strength of their relationships, and quality of their respective capabilities. The stronger these relationships are, and the greater the quality of capabilities they possess, the better the innovation system will perform (see [59] for a discussion of technological capabilities in the context of the innovation studies literature). Where innovation systems are weak or non-existent around specific types of technologies (e.g., electric cooking technologies or solar lighting), as they often are in so-called developing (but especially low-income) countries, technology availability and uptake are likely to be patchy or unsuccessful.

Within the context of transforming access to clean energy technologies in the Global South, then, it is clear why the STIS-building approach gains analytical purchase from the innovation systems concept. However, the concept has some potentially important limitations. In particular, an innovation systems perspective misses the socio-cultural and political dimensions of technological change. It is here that the STIS-building approach makes use of the socio-technical transitions literature and, more specifically, the strategic niche management stream of this literature.

When referring to the socio-cultural aspects of technological change, it is clear that STIS building is referring to the everyday lived experiences and needs of the women and men in low-income countries whom it is assumed will adopt these new technologies. Unless new technologies can easily fulfil the function of existing technologies (or "fit" with current practices), or are able in some way to "stretch" and disrupt existing practices (think, for example, of the uptake of mobile phones and mobile money in sub-Saharan Africa), they are highly unlikely to be adopted. Moreover, in order for people to spend money on a new technology, they must first perceive either a material improvement in their experiences of different social practices (or their lives in general) as a result of the new technology, a cost saving over time, or both.

A way that these everyday realities of potential technology users can be accounted for is by focussing on the "social practices" that any given technology aims to facilitate. So, for clean cooking technologies, for example, these social practices would be cooking and eating. Moreover, these social practices will interact directly with other social practices, such as commuting to work (e.g., via a new cooking technology reducing cooking times), or opportunities for women to socialise whilst collecting wood. For clean lighting, relevant social practices include reading, or doing housework, schoolwork, or paid work after dark, as well as cooking after dark. For mobile phones, social practices would include communication and broader connectivity with others, for either social or economic purposes.

The field of socio-technical transitions studies has emerged in direct response to this need to foreground the social as much as the technical in understanding the likelihood of widespread transitions towards the adoption of technologies that align with sustainability goals. Socio-technical transitions theory recognises that social and technical changes tend to co-evolve, often resulting in societies locking into the use of certain technologies, making it hard for niches of new technologies to compete with established, dominant socio-technical regimes (e.g., [65–72]). A classic example of a dominant socio-technical regime is the use of the internal combustion engine for facilitating the social practice of personal mobility. Here, it is not just the technology that matters. It is also the social practices of users, who have developed preferences for the freedom of mobility that cars can facilitate. Moreover, as social practices around personal mobility have co-evolved with the development of the internal combustion engine, so too have social norms, the hard infrastructures that facilitate these (i.e., roads, towns and traffic control systems built for cars rather than buses or bicycles) and the rules, regulations, and formal and informal institutions that govern mobility practices. This acts to lock societies into building and maintaining roads and towns that suit cars rather than bicycles or public transport.

As will become clear below, acknowledging the existence of these dominant socio-technical regimes and how hard it is for new niches of cleaner technologies to compete with these can provide us with important insights into how policy and practice, or programmes of research and implementation, can act in ways that nurture clean socio-technical niches to maximise their chances of competing with existing regimes. It is in this latter sense that the socio-technical transitions literature allows a focus on the political and socio-cultural dimensions of technological change ([26,34]). Within this literature, the strategic niche management (SNM) approach is most relevant, an approach that has emerged out of numerous empirical studies in both Global North and South contexts.

A key feature of the SNM literature is that it directs our attention to the co-evolution of actors' expectations about a technology in the future, their learning as they experiment with that technology in real-world settings, the networks of other actors they develop, and the extent to which various socio-technical practices relevant to that particular technology become embedded in society. These co-evolutionary dynamics are assumed to happen in what amounts to a protective space—the niche—in which the normal pressures of market forces and technical performance are weakened, enabling essential learning to take place [73]. These dynamics unfold within a broader context, which is conceived as consisting of the various "regimes" (mainstream, normal or dominant ways of doing things) and a wider "landscape" (difficult-to-influence changes such as demographics, events such as wars, etc.) [74]. Eventually, some niches come to influence regimes over time, and can even replace them entirely. Helpfully, the SNM literature summarises four key processes through which successful niches of clean technologies can be nurtured. These are:

1. Building networks of diverse stakeholders who work together in projects, programmes, and other interventions
2. Fostering and sharing learning from research and experience
3. Promoting the development of shared visions amongst stakeholders
4. Supporting diverse experimentation with technologies and practices

By bridging the two conceptual areas of innovation systems and socio-technical transitions, based on an in-depth historical analysis of the factors that explain the remarkable success of the off-grid solar PV market in Kenya, Ockwell and Byrne [7] thus develop the idea of "socio-technical innovation systems" (STISs). This provides a more comprehensive definition of the systemic context within which the kinds of transformation in access to clean technologies that SDG7 oriented policies and programmes seek to catalyse might be realised in practice. It hypothesises that transformative changes in the use of clean energy technologies will be achieved as a result of developing well-functioning STISs around specific clean technologies in specific contexts. The overall goal must be to build functioning STISs that augment the transfer, development and diffusion of clean technologies and related social practices in developing countries, enhancing technological capabilities through a range of targeted interventions. These must be inclusive in their approach—attending to the self-defined needs of those countries and different groups within—if clean technology uptake is to be widespread and underpin future pro-poor sustainable development pathways. As we will see in the next section, notable in this regard is Lighting Africa, which conducted highly detailed studies of the lighting practices and needs of potential users in Kenya (and elsewhere). This suggests that further gains might be achieved by including users more actively in the design of promising solutions to their needs, rather than merely eliciting users' feedback on products that have already been developed. The overall desired approach is to provide protective spaces in which clean technologies and practices can be fostered and thus promote their broader adoption, adaptation, and further innovation.

The empirical basis for developing the STIS-building approach evolved over multiple contexts, including India [54,58] and Malaysia [59]. However, the core focus of the work for developing the STIS-building theory is the off-grid solar PV market in Kenya [7]. This market is often cited by donors and other commentators as an example of free-market success (relative to other countries in that region of Africa that are less "market friendly"). In its detailed historical account of how this market emerged and grew, which looks back to the 1980s, the analysis demonstrates that this is a story about key actors undertaking focussed work over several decades to understand the needs of poor and marginalised women and men and how solar PV might be developed to meet these needs. It is not a simple story of free-market success. The analysis shows how understanding the needs of poor and marginalized groups was translated into focussed activities, e.g., technical innovation, local and high-level political advocacy, demonstration and further incremental innovation, training of local technicians, implementation of standards, developing networks of vendors and so on and so forth. All of this added up, over several decades, to the bedrock of a functioning innovation system, based on a fundamental understanding of the needs and aspirations of poor and marginalised women and men. It is this bedrock that then provided a platform upon which a market around solar PV could develop and grow. Furthermore, this story provides a powerful example on which actors (e.g., intergovernmental organisations committed to delivering against SDG7) can model future interventions. It is on this claim that we base the analysis presented in this paper, focussing on the much more specific example of solar lighting (as opposed to a focus on solar PV in general) and the transformative impact of Lighting Africa in Kenya.

3. Methodology

This paper adopted a historical, case study-based approach to its analysis. Lighting Africa was selected as an appropriate case study due its transformative impacts on the solar lighting market in Kenya. This facilitated direct scrutiny of the ways in which Lighting Africa achieved these transformative effects and the extent to which the STIS building idea was able to both conceptualise the Lighting Africa approach and inform future interventions that aim to transform access to clean technologies in the Global South (e.g., the current FCDO funded Modern Energy Cooking Services, MECS, programme (https://mecs.org.uk, accessed on 1 July 2021)).

Data consisted of a combination of the existing detailed innovation history of the emergence of the solar PV market in Kenya constructed by Ockwell and Byrne [7], plus additional, new primary and secondary data. Ockwell and Byrne's [7] innovation history of the solar PV market in Kenya was developed based on Douthwaite and Ashby's [75] innovation histories method. This uses a combination of stakeholder workshops and follow-up interviews to construct a detailed historical account of how any given new technology or technique came into being in specific contexts (see [76] for more detail on how this was applied).

The data that Ockwell and Byrne [7] based their innovation history on was collected in two separate phases in Kenya, consisting of two stakeholder workshops and a large number of follow-up interviews (over 100 h of interview testimony in total). The first phase of data collection took place between 2007 and 2008 (see [66]) and the second phase in 2014 (see [76]). This included engagement with an extensive range of different stakeholders with detailed knowledge of/involvement in the solar PV market in Kenya (see Table 1 for a breakdown of stakeholder type, number interviewed and interview focus). The data were analysed using a historically informed, inductive narrative analysis based approach [77] which sought to identify the key enabling factors that led to the much lauded success of the solar PV market in Kenya. For the purposes of the current paper, these data were then re-analysed to extract all data of relevance to Lighting Africa.

Table 1. Summary of interview topics, interviewee type and number of interviews.

Development	Donor	Finance	Government	NGO	Private	University	Total
General				6	9	3	18
UN Conference 1981	1					1	2
Early SHS Period					5		5
Solar Shamba					1		1
Three-schools					1		1
Regional Workshop	1			1	1		3
SolarNet				1			1
KSTF				3	1		4
Pico-Solar	1				10		11
MOE RE Department	1		2				3
PVMTI		1			1		2
PV Standards	1		1	1			3
KEREA				1			1
Policy Making	4	2	8		3	1	18
PV Schools			3		2		5
PV Curriculum			1		2		3
KESTA				1			1
Micro-Finance		3		1	2	1	7
Market Entry					7		7
Lighting Africa *		3			4		7
Ubbink EA					2		2

* i.e., specific focus on Lighting Afirca only—many other interviews also covered Lighting Africa due to its significance in the solar PV market in Kenya.

The original data were then augmented via a review of grey and peer reviewed literature on Lighting Africa, which yielded 15 pieces of grey literature but nothing peer reviewed other than the aforementioned brief coverage in Ockwell and Byrne [7]. Recognising that the primary interview data had been collected during and just after the end of the Kenyan Lighting Africa Programme (it ended in 2013), two additional interviews were conducted with key actors at the World Bank and the International Finance Corporation (IFC) who had been central to the Lighting Africa Programme. The aim of these latter interviews, as well as the literature review, was to reflect on whether insights yielded from the original data had been superseded by later events or reflections.

Once the complete data set had been assembled, it was analysed, again using a historically informed, inductive narrative analysis approach [77] in the same way that Ockwell and Byrne [7] analysed the whole of the solar PV market in Kenya. In the case of the current paper, however, the focus was specifically on answering two key questions. Firstly, what were the key activities that Lighting Africa carried out which led to such a transformative intervention in the solar lighting market in Kenya? Secondly, to what extent could these activities be seen to constitute STIS-building? Via this latter question the authors were also able to question the broader utility of a STIS-building perspective for theorising how transformations in access to clean energy technologies can be achieved in different contexts in the Global South, as well as considering how different technologies might raise different considerations, particularly given the small scale, modular nature of solar lighting as a technology. Once the data analysis was complete, the authors then attempted to conceptualise and visually illustrate the Lighting Africa approach in such a way that both explained the programme's remarkable success and might inform future programmes that aim to transform access to clean technologies in the Global South.

4. Lighting Africa in Kenya: How Did It Transform Access to Solar Lighting?

4.1. State of the Clean Lighting Market in Sub-Saharan Africa

The global market for solar portable lanterns (SPLs) sold by affiliates of the Global Off-Grid Lighting Association (GOGLA) was estimated to exceed 5.5 million units in 2018, with East Africa registering about 30% of this total ([50], p. 21 and p. 37). Sales of SPLs by those not affiliated to GOGLA are not easily estimated but could be as much as twice these numbers, suggesting there was a global market of around 15 million SPLs in 2018. This is a remarkably rapid growth story, considering there was little or no market in 2007 when the Lighting Africa Programme commenced. For example, according to Castalia Strategic Advisors (2014), only 29,000 lamps were sold in Kenya in 2009. The extent to which it is possible to attribute these market outcomes to the Lighting Africa Programme and subsequent efforts is arguable, but it is unlikely the SPL market would have grown so rapidly without the Lighting Africa interventions [7] It is therefore instructive to examine the Lighting Africa story in some detail to see what lessons can be learnt for designing and conducting systemic interventions such as those we argue are needed for achieving transformations in energy access, systemic interventions that amount to what we have above called STIS building. This section provides a brief account of the Lighting Africa story followed in Section 5 by an analysis of its activities and what seem to be the reasons for its success.

4.2. Pre-Programme Intervention

Prior to the implementation of Lighting Africa, the IFC spent almost three years consulting with actors in the global lighting industry, building an understanding of their interest in LED-based products for unelectrified populations, the barriers they perceived to preventing the sale of such products, and what the IFC could do to address these barriers [78]. In the year leading up to the launch of Lighting Africa, the IFC aggressively promoted the Programme to lighting companies across the world, with 198 companies signing-up to the project by July 2007. In terms of the STIS-building framework, we can see these actions as the beginning of building networks of diverse stakeholders along with advocacy to develop a shared vision of clean off-grid lighting in Africa.

4.3. Lighting Africa Programme

In September 2007, in collaboration with the World Bank and a range of supporting donors, the IFC launched the Lighting Africa Programme. Specifically in collaboration with the World Bank's Development Marketplace initiative, Lighting Africa got underway with a global call for project proposals aimed at developing lighting products and delivery models for Africa's unelectrified off-grid population [79]. The hope was that advances in the performance of key technologies, especially LEDs, could be harnessed to provide cheaper and better lighting for the consumers at the bottom of the income pyramid, with the call for proposals offering grants of up to USD 200,000 each to projects that would develop new products and delivery models. Here, we see Lighting Africa supporting experimentation, in both technologies and in ways in which access to technologies could be increased. This is especially significant insofar as it provided assurances to manufacturers entering a potentially risky new market. More than 400 proposals were received and 16 were funded, with the winners being announced at Lighting Africa's first international business conference held in Accra from 6–8 May 2008 [80]. This conference marked another significant step in broadening the network of stakeholders working towards clean off-grid lighting, extended further with two more business conferences under the Lighting Africa Programme, one in Nairobi in 2010 and one in Dakar in 2012, during which awards for "outstanding" lighting products were given (no further grant competitions were run) [7]. Other conferences have taken place since 2012, but these have been run under Lighting

Global (See https://www.lightingglobal.org/about/ (accessed on 13 April 2021)), an affiliate programme of Lighting Africa.

4.4. Research Phase

Alongside the call for proposals, Lighting Africa initiated a research phase to develop detailed understandings of different aspects of the off-grid lighting market in SSA. Nine types of studies were conducted covering consumer lighting preferences and practices, market trends and other market intelligence, supply chain mapping, gender, lighting technologies, and a study of solar lamps in chicken farming in Kenya. A total of nine policy-focussed reports covering eight African countries were also published. For Kenya, by October 2008, there were highly detailed qualitative and quantitative market assessments reporting consumer lighting preferences and practices [81,82]. These studies of consumer preferences and practices constituted the centrepiece of Lighting Africa's work: the interviewees contacted for this paper emphasised the importance of the understanding this research facilitated, with further consumer-focussed work following later (see the next sub-section on the active intervention phase). Moreover, one year later, Johnstone et al. [83] published a baseline study for Lighting Africa of off-grid lighting products available in three Kenyan towns. In October 2010, the first report on the state of the global solar lighting market was published [84], and the Kenyan policy environment relevant to solar lighting was analysed in a report in March 2011 (summarised in a policy note, see [85]). Beyond Kenya, similar kinds of studies to those listed above were conducted in Ghana (the other pilot country in Lighting Africa) and six other SSA countries [50]. From early in the Programme, therefore, Lighting Africa had commissioned work that provided a strong basis for understanding the broad contours of STISs for off-grid lighting in seven African countries, and more detailed understandings of the lighting practices in the pilot countries Kenya and Ghana.

4.5. Active Intervention Phase

Lighting Africa's more active interventions began in late 2008, starting with a targeted version of the quantitative study that had been conducted earlier the same year. The new quantitative study sought to identify the specific types and designs of lighting products, i.e., lighting product concepts, that were most acceptable to low-income consumers, conducting research for this purpose in November and December 2008 in Ethiopia, Ghana, Kenya, Tanzania, and Zambia [86]. A total of 1500 consumers and traders were interviewed across the five countries. This was followed in April to May 2009 by a qualitative study in which 20 consumers per country were given lighting products to test for five nights in their own homes. Once the consumers had tested one product, they were given another for five nights again, and so on until all consumers had tested all five product types. Ten key insights arose from these studies. Affordability was, perhaps unsurprisingly, the most important concern, but there were also insights around: recharging methods (solar was popular); adequate light intensity (general room lighting was preferred to task lighting, for example); multipurpose lights were preferred (e.g., to light more than one room simultaneously, or to act as either a room light or torch); lights should be portable; lights should be able to stand freely; the battery should last at least 5 h; lights need to be easy to use; they should be safe to leave unattended (i.e., present no risk of fire, even when left on overnight); and it should be easy to secure the light and its solar panel (e.g., preference was for a panel to be roof-mountable with a long-enough lead to keep the light itself inside while charging). With these studies, Lighting Africa was able to build a strongly evidenced understanding of what we referred to above as the fit-stretch characteristics that lighting products could embody. In connection with understanding preferred product characteristics and functionality, Lighting Africa sought to develop quality assurance standards and in-country capabilities to test the quality of lighting products. The Programme worked with global lighting stakeholders, using the feedback the Programme had received from the detailed studies of consumer preferences, to develop the standards and, after about 2–3 years of work, the standards were accepted by the International Electrotechnical Commission, paving the way for the standards to be adopted at the national level [7]. In Kenya, Lighting Africa was successful at building basic capabilities for the initial screening of new lighting products, working with the University of Nairobi where a screening test facility was established along with training of test technicians [87].

Other active interventions included business support, facilitation of access to finance on both supply and demand sides of the market, and consumer and policy engagement, while continuing with the networking (e.g., business conferences) and advocacy initiated from before the Programme began (when the IFC consulted the global lighting industry). Business support included convening business-to-business workshops, providing training for solar technicians and new supply chain entrants, and funding to encourage manufacturers to develop their own marketing strategies [50]. The facilitation of supply-side finance entailed consultation with local commercial banks to establish finance for distributors of quality-assured lights, and with international banks and venture capital funds to mobilise working capital for manufacturers. On the demand side, Lighting Africa worked with microfinance institutions (MFIs) such as Savings and Credit Cooperatives (SACCOs) to provide consumer finance, bringing MFI representatives to the awareness-raising (or advocacy) roadshows the Programme conducted (see the next paragraph), also for quality-assured lights [7].

Consumer engagement, in addition to the research described above on lighting practices and preferences, included an aggressive marketing campaign, demonstrating solar lighting products in 254 roadshows in market towns and 1378 forums in communities and trade fairs [50]. Lighting Africa also ran media campaigns using text messaging and radio and TV advertising. Learning in the process of this marketing campaign, Lighting Africa later included MFIs in their roadshow teams so that customers could sign up to buy products immediately [7]. In 2012, the Marketing Society of Kenya awarded Lighting Africa a prize for the "best experiential campaign in the NGO/Government category" [88]. At a more general level, in addition to developing quality assurance standards and testing procedures, policy engagement included efforts to influence other policies relevant to the off-grid lighting market. For example, the Programme worked with rural energy agencies in several countries to develop off-grid lighting programmes for incorporation into national energy policies. However, the Programme did not, perhaps surprisingly given the engagement at the policy level, intervene at any community institutional level (e.g., schools, hospitals, etc.). It seems to have focussed entirely on individual customers. Whether the policy-focussed efforts the Programme did implement were successful or not, the Programme did manage to get the Kenyan Government to abolish import tariffs on LED-based products in 2010 ([89]. However, in October 2013, the Kenyan Government imposed 16% VAT on solar products, with some claiming this reduced sales by up to 30% [7].

Whilst available data on Lighting Africa in Kenya mentions the importance of MFIs and SACCOs and "affordability" arising as a key concern in the original quantitative study [82], our analysis revealed no specific data on price. Given its importance, this is surprising and would benefit from more focussed research. It is also important to note that, at the time of Lighting Africa's intervention in Kenya, pay-as-you-go (PAYG) finance models were not available (or, at least, were only in their infancy). As emphasized elsewhere in the literature, PAYG finance models are highly significant due to their ability to better reflect the day-to-day financial and linked social practices of people in off-grid areas, as well as the seasonal or cyclical nature of agricultural and other income (e.g., [4,5,90–92]). Field-based observations in Guatemala by one of this paper's authors have also demonstrated that PAYG was significant in moving beyond MFI-based finance: PAYG minimised both the financial risk being taken and the possibility that people's loan requests would be rejected.

4.6. Summarising Lighting Africa

The Lighting Africa pilot officially finished in July 2013, but there was a post-implementation phase up to June 2014 [50]. As noted earlier, it is difficult to attribute the rapid growth of the off-grid lighting market in SSA solely to the actions of Lighting Africa, but it should be clear from the above description that the Programme is likely to have had a significant effect and important aspects of the market's development (as opposed to its growth) would not have happened in the absence of the Programme. Indeed, the evaluation of the Programme conducted by Castalia Strategic Advisors [50] is confident in attributing much of the credit for the emergence of the off-grid lighting market to the actions of Lighting Africa. We would argue that the Programme resembles something approximating the STIS building discussed in Section 2 above. Below, we unpack the actions of Lighting Africa to show the specifics of this particular STIS-building example. The work of the Programme amounted to what we would describe as a systemic intervention, where Lighting Africa transformed access to clean technologies by foregrounding concerns with the social practices of poor people as well as attending to several other dimensions of the STIS, and this combined set of activities was fundamental to the Programme's success.

5. Conceptualising and Illustrating the Lighting Africa Programme

Having described Lighting Africa's work in Kenya, we provide in Section 5.1 a conceptualisation and illustration of its intervention in STIS-building terms. In Section 5.2, we discuss the implications of this, focussing especially on the current areas of weakness in the STIS-building approach, as we see them.

5.1. Explanation of the Lighting Africa Programme as Depicted in the Diagram

Figure 1 provides the first attempt (as far as we are aware) to illustrate the core components (in blue hexagons) of the functioning STIS around solar lanterns that Lighting Africa focussed on building and strengthening in Kenya. It also illustrates the core activities (in red circles) that Lighting Africa implemented in order to achieve this. Figure 1 shows three phases of work. The first phase involved activity A1 (advocacy/shared visions) and mainly raised awareness of off-grid lighting market opportunities among producers and intermediary supply chain actors. Soon after, phase two got underway by adding activity A2 (consumer engagement): that is, in phase two, both activities A1 and A2 progressed simultaneously. Phase three then rapidly expanded activities to include those remaining (A3–A8) alongside activities A1 and A2. In other words, once the Programme was fully underway, all activities were being implemented simultaneously and so, as they affected multiple dimensions of the STIS, we call the intervention systemic. Below, we first describe the core STIS components (C1–C7) and then discuss the core activities (A1–A8).

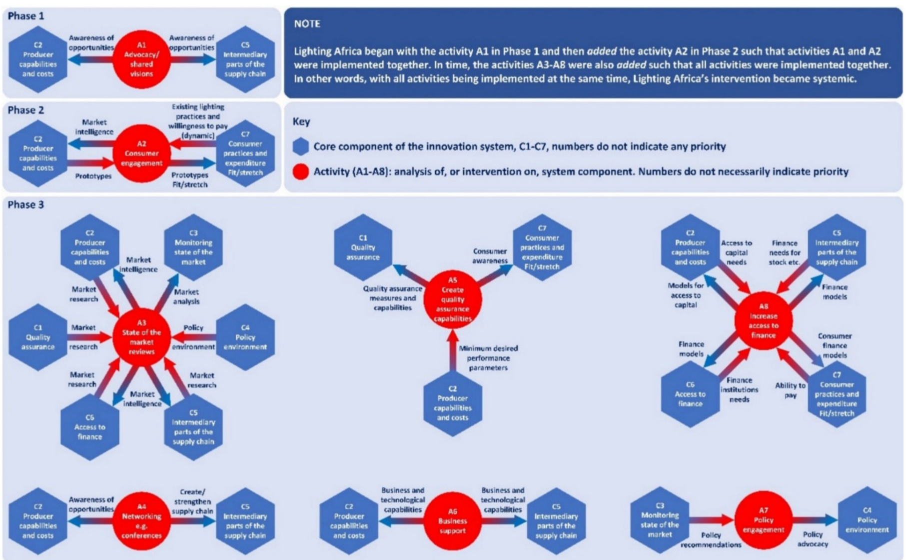

Figure 1. An illustrated conceptualisation of how Lighting Africa transformed access to solar lanterns in Kenya.

5.1.1. Core Components of the Innovation System Nurtured by Lighting Africa

C1 Quality assurance: This component of the innovation system includes the quality standards and testing procedures, as well as the capabilities and facilities to enforce standards and conduct tests on lanterns.

C2 Producer capabilities and costs: Manufacturers of lighting products are the producers referred to here, who need the capabilities to develop and make products that suit the lighting practices and preferences of off-grid populations. Suiting the preferences of off-grid populations can include products that offer functionality beyond just lighting, or what we can call "stretching" of practices. However, all this must be done within cost structures that promise attractive profits for the producers, and an important element of these is the nature of finance available to producers for securing working capital.

C3 Monitoring state of the market: Knowledge of the state of the market, in its broadest sense, is essential to ensure that all stakeholders can continue to make informed decisions based on analysis of evidence. This applies throughout the supply chain, to policy makers, and to analysts of all kinds.

C4 Policy environment: The policy environment is crucial for setting the appropriate "rules of the game" under which all actors must play, such as quality standards, and for incentivising the direction of market development. The latter can include positive incentives to, for example, invest in solar lighting supply chains or negative incentives such as taxing polluting lighting technologies.

C5 Intermediary parts of the supply chain: This component of the innovation system includes all the actors between the manufacturers and customers. Each kind of supply chain intermediary will need specific kinds of capabilities appropriate to the products and the off-grid lighting business, as well as specific kinds of finance needs. They also need to be well-connected to each other and foster good working relations between each other.

Source: Authors

C6 Access to finance: Finance plays a crucial role in most parts of the innovation system, on both the supply and demand sides of the market. However, each kind of actor will have different kinds of finance needs, requiring different kinds of finance models.

C7 Consumer practices and expenditure, and fit/stretch characteristics: Consumers will have various existing lighting practices shaped by a range of conditions that may be different across contexts. For low-income consumers, these conditions and contexts may be especially constraining of the practices that are possible. Lighting products will tend to be attractive if they can not only meet the existing needs (or fit with existing practices, including expenditure patterns) but also if they meet other preferences (or stretch what is possible into new desirable practices). Examples of these fit-stretch characteristics are the provision of lighting (fit) that is clean, bright, and safe (stretch). The idea that clean, bright, and safe lighting (stretch) practices refer to the new or improved (or desired) practices this facilitates, such as enabling children to study more effectively (and more safely) compared with studying under kerosene lanterns. Further stretching could include the additional functionality of charging a mobile phone.

5.1.2. Core Activities in the Lighting Africa Programme

Having sketched what each component of the STIS does, here we explain what actions Lighting Africa took to nurture these components.

A1 Advocacy/shared visions: This activity got underway before the Lighting Africa Programme started, beginning with the IFC's engagement in extensive global advocacy around the issue of access to clean lighting in off-grid areas of SSA. Through this, IFC persuaded companies with an interest in lighting products (manufacturers, assemblers, distributors) of the market opportunities of LED-based technologies for meeting the lighting needs of off-grid and poor populations. By the time Lighting Africa launched in 2007, about 200 organisations had signed-up to participate in the project [78]. With the launch of the Development Marketplace Grant Competition, the Programme began to share the vision more widely, promoting the market opportunities of the unserved needs of "poor households, communities and businesses” who constituted this “market segment” [79].As the Programme continued, so did its development of a vision for clean off-grid lighting, evolving through the more detailed understandings of lighting practices and research into the emerging market. All this was promoted and shared widely by making reports publicly available, further widening the constituency of support for the Programme and the vision of clean off-grid lighting.

A2 Consumer engagement: One of the actions identified for intervention in the Lighting Africa Programme was understanding customer needs and preferences, addressing the lack of information on lighting and energy use in off-grid areas. Specific information gathered through end-user survey and consultation methods included needs and preferences of lighting services, total spending, purchasing criteria, and social and cultural drivers of lighting choices. Qualitative and quantitative results from research into these lighting practices were published in October 2008 [81,82] and made freely available on Lighting Africa’s website, providing market intelligence for lighting technology producers and others interested in the off-grid lighting challenge. Moreover, the research included testing a range of electric lighting prototypes whereby consumers were given test products for five nights at a time and then asked to comment. Ahead of the start of the Programme, the idea that lighting products could include more functionality than simply lighting was already part of the thinking, and appeared in the Development Marketplace Grant Competition call where, for example, there was reference to charging mobile phones [79].However, not all manufacturers adopted this idea of “stretch”. One of the interviewees for this report spoke of a manufacturer who decided including mobile phone charging functionality would make their lighting products too expensive for the market. The product they released (without phone charging functionality) did not do well, while those who did release lanterns with phone charging did sell their products. As a result, the manufacturer changed their products to include phone charging. This anecdote underlines the importance of paying attention to user needs.

A3 State of the market reviews: In addition to research into consumer lighting practices and the pre-Programme intervention supply chain, Lighting Africa commissioned research into the policy environment relevant to off-grid lighting. Further research monitoring the evolution of the market during Lighting Africa’s interventions and beyond was also commissioned, including attention to the evolving policy environment, the quantity and quality of available lighting products, the development of producer and supply chain capabilities and business models, and various finance needs. As with the initial research into poor people’s lighting practices and needs, all these research reports were made available freely on Lighting Africa’s website. We can see the various forms of state-of-the-market reviews as performing several nurturing functions in the STIS-building process. Most obviously, the knowledge generated was important to many existing, but also new, actors, providing evidence for them to further evolve their various activities (marketing, business decisions, policy recommendations, etc.). However, we can also see these research activities as progressively improving articulations of the STIS. That is to say, by providing detailed information about various aspects of the emerging innovation system, the specifics of a shared vision also became clearer, and the evidence became more robust for promoting the benefits to others in support of the intervention. This last point is important for widening the adoption of a shared vision, attracting an increasing number and diversity of stakeholders into the evolving off-grid lighting actor networks.

A4 Networking: The IFC began networking when engaging in advocacy and fostering shared visions prior to implementing Lighting Africa. Networking continued throughout the project, especially through three biennial international conferences. The first of these took place in Ghana in May 2008 (attracting over 500 participants), where the 16 winners of the Development Marketplace Grant Competition were announced [80]. Networking also occurred through business-to-business workshops and training events for various stakeholders in the supply chain, from product manufacturers through to technicians [50]. However, as we noted above in regard to the state-of-the-market reviews, other actions contributed to network-building. The documentation made freely available was useful, especially to those interested in detailed understandings, but it also helped to foster a specific and well-evidenced vision that could then be further shared, persuading others to join the growing networks of off-grid lighting stakeholders. This has outlived the specific intervention period of Lighting Africa in the form of the Global Off-Grid Lighting Association.

A5 Create quality assurance capabilities: Part of the work to understand consumer needs and preferences involved identifying minimum performance parameters for lighting products. Examples of such parameters, determined in close consultation with consumers, included acceptable light levels and hours of operation for lighting products, the nature of lighting provided (e.g., task or flood lighting), battery recharging times, additional functionality (e.g., mobile phone charging), and acceptable price points. In further consultation with manufacturers, a set of minimum performance parameters was agreed that would also be technically realistic and economically viable for producers. Over time, and in continuing consultation with stakeholders, Lighting Africa facilitated the development of off-grid lighting product quality assurance standards that were eventually adopted at the global level via Lighting Global. In Kenya, Lighting Africa worked with the University of Nairobi to create in-house capabilities for initial quality screening of new lighting products, where those products successfully passing initial tests would be sent elsewhere for full quality assurance assessment. According to Lighting Global (Lighting Global is an affiliated programme of Lighting Africa, see https://www.lightingafrica.org/what-we-do/quality-assurance/ (accessed on 20 April 2021)), as of December 2019, 360 products (See the Quality Assurance statistics at https://www.lightingglobal.org/quality-assurance-program/product-testing-data/, but see VeraSol at https://data.verasol.org/products/sek for current data on quality-assured solar energy kits (both websites accessed on 20 April 2021)) (pico-products and solar home system kits) had met the quality assurance standards. An important element of the process of creating quality assurance standards, according to the interviewees contacted for this research, was the continual engagement with consumers, seeking their feedback during the roadshows mentioned above. This feedback was passed onto producers so that they could improve their products, learning directly from the market in a way similar to that reported by Foster and Heeks [93] in regard to feedback about mobile phones to Chinese manufacturers. Here, again, we see the importance, and effectiveness, of paying attention to consumer preferences, even in what might usually be taken to be the exclusive domain of technical expertise. However, some aspects of quality assurance are not yet clearly resolved. There is still work to do, for instance, to understand the extent to which consumers use quality assurance when they choose their solar products, and this may be something that is context-specific. For example, recent research in Kenya (According to work by Anne Wacera Wambugu (Strathmore Energy Research Centre) and others, reported during the online conference "3rd Generation PV in the Developing World" held on 6–8 January 2021, although customers of solar products can get information from product paperwork, the vast majority (90%) get their information from a solar agent or someone in their community.) suggests that consumers rely more on word-of-mouth information than standards or product warranties, whereas service warranties seem to be important to (at least some) customers in Guatemala (This is based on the experiences of one of the co-authors who has worked in the PAYG space in Guatemala.).

A6 Business support: In addition to more general private sector support (e.g., networking, consumer and market research, development of quality assurance standards), Lighting Africa provided more specific training and advisory services to actors in the supply chain. These included training solar lighting technicians and new entrants to the supply chain, as well as advice about and support for business finance (see below). The Programme also went beyond networking to establish a private sector consortium that evolved into an advisory council that discussed how Lighting Africa could improve its activities to better meet the needs of private sector stakeholders [50]. Here, we see Lighting Africa nurturing the private sector aspects of the STIS—the business ecosystem as some might call it—helping to build capabilities specific to the needs of the SPL supply chain. However, again, the approach reflects how Lighting Africa paid attention to consumer preferences, this time paying attention to business needs. Interestingly, for an actor such as the IFC, who might be considered to assume market forces would alone drive businesses to build their own capabilities, this was a highly interventionist strategy.

A7 Policy engagement: Along with providing analysis of the policy environment (as part of its market research efforts), Lighting Africa provided advice to policy makers based on evolving evidence and analysis from the entirety of its market research. As noted in Section 4, this included attempts to influence the wider policy environment, such as developing frameworks for promoting clean off-grid lighting within rural energy strategies and advocacy to remove regulatory disincentives to the growth of the off-grid lighting market, with mixed results. One of the ways in which the Programme attempted to strengthen its advocacy was by working in alliance with Kerosene Free Kenya, for example, but the mixed results of these efforts suggest that too few policy makers were persuaded to adopt the vision of clean off-grid lighting articulated through these campaigns. In the end, the main focus of the Programme's policy advocacy was on encouraging governments to adopt its quality assurance standards and tests, which had been developed in consultation with stakeholders of all kinds, including consumers. At least in Kenya, this advocacy was achieved by working with local solar PV stakeholders through the national industry association KEREA (Kenya Renewable Energy Association) who worked closely with the Kenya Bureau of Standards to develop PV-specific standards and regulations aimed at ensuring high quality practices and technologies in the Kenyan PV market. This is another example of working closely with stakeholders on the ground as opposed to attempting a more top-down imposition of policy change. In the process, stakeholders could develop closer relations, adopt the shared vision, and "own" the results of any policy change achieved. So, this work, although aimed at providing policy advice, also benefited the STIS in other ways.

A8 Increase access to finance: From the outset, Lighting Africa's intent was not to provide finance itself but, rather, to facilitate better access to producer, vendor and consumer finance "where the need is apparent and the uptake feasible" [78]. On consumer finance, for example, Lighting Africa worked with MFIs by including, as we noted above, their representatives at the roadshows they conducted across Kenya [7]. This meant potential customers could immediately start the process of purchasing a clean light, if they had been persuaded by the information presented to them during the roadshow, as opposed to having to investigate further themselves after the roadshow had finished. On the supply side, Lighting Africa worked at two levels of finance. For local distributors of quality-assured lighting technologies, it worked with local banks to establish credit facilities for companies to increase their stock of products. Moreover, Lighting Africa worked with international banks and venture capital funds to establish finance facilities so that product manufacturers could access working capital [50]. In terms of STIS building, these activities most obviously nurtured the finance elements of the system. However, we can also see a further broadening of the networks, this time recruiting different kinds of finance institutions, from the local-level SACCOs through to global capital. These efforts seem to have paid off well in terms of the increasing number of clean off-grid lighting products available and the increasing number of people getting access to them. However, we also need to be cautious about the longer-term impacts of what is an evolving political economy around off-grid lighting [34], with the potential for its "disciplining" effects on the policy space open to governments [39], and the potentially punishing impacts of repayment demands on low-income consumers [94]. These kinds of political economy implications were not addressed by Lighting Africa, along with a number of other issues that we now reflect upon.

5.2. Socio-Technical Innovation System Building Theory: Utility and Gaps

The above analysis illustrates how the focussed and systemic approach adopted by Lighting Africa can be broadly understood to constitute something close to the kind of STIS building that Ockwell and Byrne [7] hypothesise as being fundamental to transforming access to clean technologies in the Global South. To a large extent, then, the STIS-building arguments seem to hold within this much more in-depth analysis and conceptualisation of Lighting Africa. It is important to note, however, that there are arguably several ways in which Lighting Africa was weak. These areas also highlight aspects of STIS-building theory that are less well developed.

A first area, somewhat ironically given the critique of the dominance of engineering in the field of energy access, is the extent to which either STIS-building theory or Lighting Africa's approach fails to attend enough to technical considerations. This was less of an issue at the LED lantern level at which Lighting Africa focussed. However, consider technologies that have far greater energy demands. For example, a transformation in levels of electric cooking in any country has significant potential implications for electricity supply. The intersection between on-grid and off-grid electricity supply and increasing electricity demand therefore warrants close attention. Similarly, increased use of mobile PAYG energy supply and payment systems could have significant implications for mobile network capacity and infrastructure. Moreover, potential waste implications and opportunities for re-use and recycling also require explicit attention at early design and programme planning stages [14]. These areas are not explicitly addressed at present in the STIS-building perspective.

A second area requiring further work is that of the political economy of transformations in access to clean technologies. Ockwell and Byrne [7] are upfront in their acknowledgement of the weakness of the STIS-building approach in this regard, despite attempts to deal with it via the niche-regime aspect of SNM such as in Byrne et al. [34]. Nevertheless, it is important to emphasise here the reasons why this failure to properly attend to the political economy dimensions of transformations in access to clean technologies in the Global South is of such concern.

For example, analyses need to examine the extent to which the value-added benefits new technologies and accompanying social practices generate are accumulated within low- or middle-income countries, or whether value accumulation is actually accrued in other countries that are supplying technology hardware. Qualitatively, different types of value creation are also important to consider, e.g., the types of jobs that are created, and the internal distribution of surplus within in-country production sites, etc. Similarly, know-how and know-why knowledge transfers are also critical parts of ensuring that a transformation in access to clean technologies leads to long term capacity building in low-income countries, as opposed to being retained by international technology firms based elsewhere [95]. Moreover, analyses need to consider the balance-of-payments impacts in low-income economies of importing clean technologies, although this may be offset to some extent by reductions in imports of fossil fuels if, for example, people switch away from cooking on kerosene.

Politics and political economy dynamics can also be definitive of the success of interventions around new technologies and social practices (e.g., see [26,34]). These might, for example, relate to the extent to which national level policy priorities support or oppose clean technology initiatives, as well as the extent to which such initiatives are aligned (or not) with powerful interests in any given country [41] or internationally [39]. This also flags the importance of balancing between delivering against local versus national priorities. For example, it has been suggested that, where governments are most in touch with local aspirations, there tends to be a greater focus on cooking and other basic energy needs within national policy and planning.

Importantly, the impacts of politics and political economy dynamics have been observed to play out as much at the village or community level (as well as inter-village levels), as at regional, national or international levels [38]. Moreover, even where politics and political economy considerations are not definitive of whether or not a project or programme goes ahead, they can nevertheless exert significant influence over who gains and who loses from any specific intervention [96]. These are all areas that require better development within the STIS-building conceptualisation of transformations in access to clean technologies in the Global South and to which interventions like Lighting Africa, or contemporary ones such as the UK FCDO MECS Programme on clean cooking, need to attend.

A third underdeveloped area in the STIS-building approach, and one that is not explicit within the Lighting Africa model conceptualised above, is that of social justice considerations. For example, socio-technical transformations often have unintended consequences that are both good and bad. As much as possible, it is important to think through how these might play out if transformations in clean technology access are achieved. For example, potential positive and negative implications for gender equality need to be considered (as elaborated below). This goes much further than a narrow market focus on, for example, the number of e-cookers in use, asking instead what broader development goals are being impacted and how. This is being increasingly considered in relation to results-based finance, for example. Results-based financing electrification programmes currently refer to connections made, whereas there is a growing recognition that what should be measured (and, in the market model, paid for) is the impact of those connections.

Another social justice consideration pertains to the fact that interventions around clean technologies in developing countries are likely to have significant implications in terms of sources of social inequality. The source of social inequality that gets most attention tends to be gender differences. However, other sources of inequality, such as ethnic background, class, education and so on may be equally affected, or definitive of the distribution of benefits that are accrued from any interventions around clean technologies. Assuming, for example, that any intervention might be gender neutral is erroneous. Even seemingly beneficial advances, such as the emergence of PAYG payment models, can impact on gender relations and other aspects of social inequality, sometimes serving to reinforce existing gendered inequalities [5,8,17,28,29,47,48,97]. Bearing in mind that many social practices where clean technologies intersect tend to be gendered practices, e.g., cooking, with the burden falling principally on women and girls—specific consideration of the gendered implications of interventions via policies and programmes is important and necessary. These are not addressed in the framework presented above based on Lighting Africa, nor in a STIS-building perspective. Recent work in the field of gender, energy, and development has been insightful with regard to the kinds of interventions that might have more positive impacts on gender relations (e.g., see [28,29]). Despite the culturally attuned approach adopted by Lighting Africa, we were unable to identify anything specific on how the initiative may have targeted women and men differently (where appropriate), although campaign rhetoric did emphasise benefits likely to be of more relevance to women (e.g., the health benefits of not using kerosene or fire for light). This is surprising and is an area that would benefit from specific research.

One final potential weakness of both the Lighting Africa framework conceptualised above and STIS-building theory is the danger of users of these approaches assuming they are technology neutral. As the example of Lighting Africa demonstrates, and as illustrated in work on solar PV more broadly [7,34], as well as other applications like PAYG finance models [4,5], the need to build innovation systems, align technological interventions with users' social practices and attend to political and political economy considerations are likely to remain germane regardless of what kind of technology is being considered. These are all dimensions of broader processes of technological change, as implicitly envisaged under SDG7, as much as are technological engineering and financial dimensions of such change. Nevertheless, it is important to emphasise that different technologies intersect with social practices, as well as politics and political economies, in different ways. Moreover, these context specificities are essential to attend to when thinking through how to apply the theoretical perspective (STIS building) and conceptual framework (based on Lighting Africa's success in Kenya) that are articulated in this paper.

Consider, for example, the differences between lighting via solar lanterns and cooking via new cooking technologies (e.g., the kinds of electric pressure cookers promoted via the UK FCDO MECS Programme mentioned above). As the MECS Programme acknowledges, "cooking is a cultural experience" [18] and so innovations towards clean cooking are likely to be resisted if they mean changes to the way people eat, the taste of the food, and perhaps even cooking processes. The cultural embeddedness of cooking is therefore the most obvious difference compared with lighting, and potentially poses the most significant challenge for translating the Lighting Africa approach to a framework for achieving transformative goals around cooking. Furthermore, this implies a need to understand the ways in which the cultural significance of cooking extends beyond people's needs and preferences centred on food, needs and preferences that themselves go beyond nutrition and the satisfaction of hunger. That is, culture is expressed and reproduced to some extent through food and cooking practices. In contrast, lighting is much less culturally specific and more functional. The extent of any deeper significance associated with lighting may include electric light as symbolic of modernity and higher social status, but arguably it is relatively straightforward to identify lighting needs, preferences, and practices, and to express these in technical terms for use in product design. Moreover, it is relatively easy to design a clean lighting product with extra functionality, such as mobile phone charging, that creates opportunities for attractive stretching of practices.

The cultural embeddedness of cooking also reinforces wider gender norms [98], presenting further complexity in the challenge of translating Lighting Africa's approach. Reinforcement of gender norms can have both positive and negative consequences. For example, the adoption of e-cookers could mean reduced burden on women to collect firewood [35], but it might also limit their space for socialising with other women. This too can have positive and negative implications. In Guatemala, for example, being seen to be milling corn three times a day for tortillas can demonstrate fulfilment of women's perceived social obligations (These findings are emerging from doctoral research conducted in 2019 by Victoria Kasprowicz.), with implications for community acceptance or isolation. Moreover, in the home, the cookstove or fireplace may form an important centre of family social life, with associated norms for a woman's role as homemaker, connected in cultural and practical ways with the technologies, tools and arrangements of domestic space. [99] develop the concept of "oscillating domestic space" as a way to capture the shifting nature of the relationships between needs, time, space and practices, where complex contexts (e.g., culturally-specific cooking practices) require new technologies to fit with existing domestic infrastructure, needs, aspirations and the meanings people evolve with these new technologies.

Clean cooking technologies are likely to be more complicated than those for clean lighting. This extra complication is in part to do with the configuration of pieces of hardware, but it also arises from the nature of cooking itself compared with the simple operation of lights (notwithstanding some extra complication for charging the lights). That is, new cooking technologies could be more disruptive of home life, at least during a period of transition, and so, bearing in mind the previous note about oscillating domestic spaces and practices, it cannot be assumed that the adoption of clean cooking technologies will only require some minor behaviour change. Transforming access to clean cooking technologies in practice may therefore face many unforeseen challenges related to the more or less significant disruption of domestic spaces.

Understanding the context-specific complexities of cooking and its embeddedness in cultural and social life is therefore important for avoiding the pitfalls of so many former clean cooking interventions [100]. This would require using a wider lens than one that focusses only on cooking processes. Moreover, it would be important to not only consider what the benefits are of clean cooking technologies but also the benefits (perceived or real) of current "dirty" cooking practices. For example, fire and smoke can fulfil other roles such as curing meat or repelling insects.

In short, clean cooking technologies will disrupt—more so than clean lighting—existing practices and could reshape social structures, so consideration is needed of what is being displaced by clean cooking technologies and what the implications of this will be. This serves as a good illustration of how the application of a STIS-building approach, or the Lighting Africa framework conceptualised above, needs to be carefully considered in relation to the specificities of any given technology and the ways in which it intersects with existing social practices. The same holds for considering the politics and political economy dimensions of advocating any given technology. For example, electric cooking technologies may run up against vested interests in kerosene and charcoal at a local level, but on a scale much larger than the ways in which solar lanterns have impacted on kerosene. Electric cooking may also have implications for grid based electricity, thus opening up another level of political considerations, from village scale inequities, in terms of the access to and provision of electricity [38,101], to national level considerations around electricity generation and transmission [41].

6. Conclusions

As illustrated, for example, by the GBP 40m UK FCDO funded Modern Energy Cooking Services (MECS) Programme, efforts to address the transformative ambitions of SDG7 are gaining pace. An important part of these efforts centres on ways to transform access to the clean energy technologies needed to make use of sustainable energy services. One real-world example that achieved something approaching a transformation in clean energy technology access is Lighting Africa. The Lighting Africa Programme supported the development and promotion of clean off-grid lighting products (solar portable lanterns, SPLs) to address the lighting needs of millions of unserved people across Africa. In 2009, when Lighting Africa began its active intervention work, an estimated 29,000 lamps were sold in Kenya, one of Lighting Africa's two (The other Lighting Africa pilot country was Ghana {Ockwell, 2017 #7}.) pilot countries. In 2013, when the Programme's intervention ended in Kenya, the market had expanded to an estimated 680,000 Lighting Africa-certified SPLs. Alongside this, a market for uncertified SPLs had grown to perhaps twice the size of that for certified lamps [50]. Although we cannot attribute this transformation in access to SPLs entirely to the actions of Lighting Africa, it is highly likely that the Programme had a profound impact on the nature and scale of these outcomes. Without the Lighting Africa Programme, little SPL market development would have occurred and there would have been no transformation in access to these clean off-grid lighting products. Understanding how the Lighting Africa Programme contributed to SPL market development could, therefore, be highly instructive for other efforts to achieve SDG7 ambitions.

In this paper, we used a socio-technical innovation system (STIS) building perspective to examine the experience of the Lighting Africa Programme and, as a result, made several contributions. First, we tested the extent to which the STIS-building concept is theoretically useful in understanding and conceptualising the Kenyan Lighting Africa experience. Second, we presented, to the best of our knowledge, the most in-depth analysis so far of this experience. Third, we presented a novel conceptual framework to illustrate the Lighting Africa approach in Kenya, thus providing a framework for other policy interventions aiming to transform access to clean energy technologies within contexts in the Global South. Finally, we critically analysed the STIS-building approach itself, providing reflections on where it requires further work.

Our testing of the STIS-building concept as applied to the case of Lighting Africa in Kenya has illustrated its analytical traction. It is clear that Lighting Africa acted as an "innovation system builder" within the Kenyan context, intervening systemically in multiple ways that attended to the socio-cultural practices and aspirations of potential technology users, connected up disparate, yet vital, actors to form a functioning innovation system around SPLs, and undertook advocacy work to harness political support and overcome potential political barriers. As such, our conceptualisation of the Kenyan Lighting Africa approach, illustrated in Figure 1 and described in Section 5, provides a potential framework for intervening to transform access to clean energy technologies in the Global South, in line with SDG7.

Despite its analytical traction, however, we also highlighted several potential areas where the STIS-building idea needs further development. This raises a range of important considerations that also apply to future applications of the Lighting Africa approach, especially where applied to different technologies. As with the example of electric cooking technologies (discussed in Section 5), different technologies intersect in different ways with the socio-cultural and political economic specificities of any given context. Whilst the Lighting Africa framework conceptualised in this paper is therefore likely to be highly useful to future policy and practice, it nevertheless remains vital that it be carefully analysed with due attention to specific technologies and contexts that are the focus of any given intervention. Furthermore, the analysis above highlighted a range of other areas where the STIS perspective needs to be extended, areas that apply equally to any application of the Lighting Africa approach. These include fundamental considerations around: the gendered implications of any given intervention (as well as social justice considerations more broadly); differing implications of different scales of technologies; value accumulation and the extent to which interventions benefit indigenous actors and local economies; and the political economic implications of, and influence on, any intervention and its likely distribution of benefits.

As one reviewer of this paper pointed out, there is also an important question to be asked of the STIS-building idea in terms of the extent to which it retains analytical traction when applied more broadly to the issue of grid-based rural electrification. STIS building focusses on how actors might intervene to promote the development, availability, and uptake of a specific energy technology within different contexts. As the reviewer rightly implied, changing the focus of analysis to the level of grid-based rural electrification raises questions that differ significantly from the single technology focus that has characterised the application of the STIS-building idea to date. For example, is there an innovation system around grid-based rural electrification? How does thinking at the level of large-scale infrastructure, rather than specific small-scale technologies, change the nature of the problem and what are the conceptual implications of this? Would the nature of technical, socio-cultural, and financial considerations change depending on the physical infrastructure where grid connection was needed, e.g., fire safety considerations in different types of rural dwelling? How does physical geography intersect: e.g., the hilly nature of parts of rural Rwanda? Significantly, how do social practices intersect with and change as a result of access to high-voltage grid-based connectivity? Moreover, and equally significant, what are the political/political economy dynamics that intersect at this much larger infrastructure level?

Although some work cited in this paper has touched on several of these considerations (e.g., [34,48]), it is clear that more work needs to be done to better integrate them into a broader theorisation of STIS building. The kinds of transformations envisaged by SDG7 have fundamental implications for myriad aspects of social justice, politics, value accumulation, and so on [96]. Such transformations therefore demand even more deeply interdisciplinary work than has so far been synthesized in the STIS-building approach.

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