Energy Research & Social Science 44 (2018) 152–171

Contents lists available at ScienceDirect

Energy Research & Social Science

journal homepage: www.elsevier.com/locate/erss

Original research article

Energy (in)justice in off-grid rural electrification policy: South Africa in focus

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ARTICLE INFO

Keywords:
Energy justice
Policy implementation
Hybrid electricity generation
South Africa

ABSTRACT

Generally speaking, increasing rural marginalisation in sub-Saharan Africa has sat alongside a rise in energy poor homes in rural off-grid communities. Even measures meant to improve electricity access have exacerbated the energy access gap between grid connected and off-grid homes. For example, the South African Non-Grid Electrification Policy Guidelines for electrifying off-grid, rural poor homes promote the adoption of Solar Home Systems (SHS), which are expected to produce 7.5 kWh/month on average. However, for poor homes within grid coverage, the Free Basic Electricity (FBE) programme allocates 50 kWh/month. This paper investigates the resulting disparity in terms of electricity cost (ZAR/kWh), including associated costs for heating, cooking and other needs. It does so through the energy justice framework, highlighting the mismatch in policy formulation (procedural injustice), resource distribution (distributive injustice) and spatial distribution (injustice in the recognition of population groups' special needs). Through a combination of mathematics and social science perspectives, it then moves beyond a critique of the current SHS system to proposes a new one: a hybrid generation approach with a flexible pricing scheme and centralized system of operation that is both ethically compliant *and* capable of improving electricity access to off-grid communities with standards comparable to grid access.

1. Introduction

As of 2014, sub-Sahara Africa (SSA) had 62.8% of its population living in rural areas, of which only 35.3% had access to electricity. In comparison, urban areas had a 71.6% electrification rate [1]. In striving to bridge the widening energy access gap between rural and urban areas, countries in SSA have adopted varied measures. Notable among these has been the use of Solar Home System (SHS),[1] designed with the aim to increase the availability of energy to all. Yet, despite the widespread penetration of SHS in rural communities and the regional variations therein, there has been no noticeable or systematic reduction in rural peripheralisation[2] and poverty alleviation to date. We make this perhaps controversial statement based on the exhaustive findings on the failure of 29 trans-regional renewable energy projects in SSA by Ikejemba et al. [3], the findings on the failure of SHS projects and in particular the Lucingweni project by Azimoh et al. [4] and the position of [5]. Each of these has inadvertently created instances of rural peripheralisation. For South Africa in particular, Azimoh et al. [4] state that "*despite substantial government spending on SHS, assessment of the socio-economic impact of the South African SHS program revealed that the energy needs of the households are seldom met due to the low power capacity of the system.*" Indeed, according to [1], 727 million people in SSA continue to rely on traditional biomass and charcoal as their primary cooking fuel.

Urmee and Md [5] further corroborate this situation as they explain that end-users expectations of SHS and the performance of these SHS did not match, especially in terms of load capacity and hours of utilisation. Most end-users had expected grid quality electricity level from SHS and did not have their expectations fulfilled. This implies, in effect, that the increasingly widespread use of SHS has not improved

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[1] Which are made up of 1–50 Wp photovoltaic panel, 1 charge controller, wiring and small outlets for small appliances, 1–105 Ah battery and 4 energy efficient compact fluorescent lamps.

[2] By rural peripheralisation we extend its meaning beyond [2] to mean discrimination in quality and quantity of electricity access to households of the same income bracket due to their proximity to the national grid

https://doi.org/10.1016/j.erss.2018.05.002
Received 17 January 2018; Received in revised form 16 March 2018; Accepted 2 May 2018

electricity access per capita (kWh) (which is about 511.90 kWh compared to 3064.50 kWh for the world (average)) [1]. Thus, the huge costs of installation of these SHS and their limited usage options creates a gap in terms of energy access between grid connected and off-grid households, leading to rural peripheralisation (a somewhat similar example to the case of the smart meter roll out in the UK, perhaps [2]). Further, this low rate of electricity access (which some may argue is a product of ineffective policy, see [4]), increases the exposure of off-grid rural households to diseases such as childhood pneumonia, chronic obstructive pulmonary disease (COPD), and lung cancer caused by the smoke emanating from alternative energy sources like firewood [1].

This paper comes to this challenge from two perspectives. Firstly, it seeks to outline that this peripheralisation and maldistribution of electricity access is an issue of energy justice. Secondly, in order to move past what would otherwise just be a critique of off-grid electrification policies, it makes a practically oriented contribution to addressing these failings through mathematics and modelling. Specifically, we address this gap by examining the efficacy of the current SHS system and based on its failings, proposing an alternative hybrid generation system that meets the demands of the energy justice framework. As an impact-oriented output, we provide, in effect, an alternative means of electrifying off-grid communities that incorporates energy justice values and in terms of its modelled impact, is ethically compliant.

This work is as timely as it is necessary for (at least) two reasons. Firstly, despite the claim that energy justice scholarship appears across many disciplines [6], few mathematics and modelling techniques have been applied. Indeed, this paper is arguably the first of its kind (although we do acknowledge the work of [7] which also uses modelling techniques, albeit in a very different way). In this regard, we provide an important applied contribution. Secondly, and practically, according to [8], about 60% of additional electricity generation needed to provide universal access to energy is expected to be generated through off-grid systems. For this reason, we require sustainable generation schemes that are both ethically compliant *and* capable of improving electricity access to off-grid communities with standards comparable to grid access. This paper illustrates one potential means of achieving this. This has implications across SSA countries, developing countries in Asia, and indeed, many regions of the world.

This paper proceeds as follows. We begin with an overview of the energy justice concept followed by the South African case. Then, using modelling techniques, we investigate the potential SHS output power across seven provinces in South Africa using weather data from nine South African weather stations. We illustrate that a lack of consideration for the spatial distribution of the population and the stochasticity of weather conditions negates the benefits of SHS schemes with energy justice knock-ons in terms of procedure (procedural justice) and resource distribution (distributive justice). Our paper also shows that the current electrification plans for off-grid rural poor homes do not guarantee adequate energy access. To remedy this failing, we then present a concerted approach to a viable and sustainable generation platform that hybridizes SHS and diesel-generators. A flexible pricing scheme (for pricing electricity) along with a smart load distribution board [9] (that incorporates an artificial intelligence tool (MGA) by [10] for dispatching electricity needs) are also presented. As energy justice scholars seek to take their work beyond academic scholarship to practical application (including through engagement with innovative business models [11], for instance), this is one exciting example of how just electrification processes may be achieved.

2. Energy justice – 5 guiding principles

The concept of energy justice is becoming a much-researched topic that seeks to establish a nexus between energy generation and delivery and justice (equity/fairness) [6,12]. Islar et al. [13], p. 671 define it as "respecting universal human rights and ensuring that every person has a right to the level of energy required to attain a minimum of well-being". Sovacool and Dworkin [12] posit that energy justice is capable of assisting the energy decision process and choices of consumers and energy planners by presenting itself as a useful decision-making tool. With this potential in mind, we utilize the energy justice approach to (1) critique the Non Grid Electrification Policy Guidelines, which we argue impedes the development of the off-grid poor rural households, and (2) to argue for our proposed hybrid generation scheme, which can improve off-grid poor rural households quality of life (QoL) and overall welfare whilst achieving energy justice.

Several energy justice frameworks have emerged. The first is the tripartite distributional justice, procedural justice and justice as recognition approach – terms that we have mentioned in passing and continue to apply throughout this piece (see [14,6]). The second elaborates on energy justice as an analytical tool that helps in understanding how values can be built into energy systems [12] and provides the building blocks for a series of core principles later elaborated by Sovacool et al. [15]. Within this paper, we focus on five of the eight principles originally presented[3]:

- The availability principle [Principle 1];
- The affordability principle [Principle 2];
- The due process principle [Principle 3];
- The intra-generational equity principle [Principle 4];
- The sustainability principle [Principle 5].

We also consider an explicitly spatial dimension brought to the fore by Bouzarovski and Simcock [16] as they conceptualize energy poverty as a form of injustice.

We do not take these approaches to be exclusionary. That is to say, we do not believe that one is better than the other and that they cannot be used in tandem. In our approach, the tripartite energy justice framework offers a means of evaluating energy (in)justices of a spatial nature and principles 1–5 offer a series of goals we should seek to achieve. For this reason, we use these 5 principles alongside the spatial dimension to reflect on the simulation results obtained through our model we present in the proceeding paragraphs.

Before going further, however, and in order to navigate the gap between descriptive and prescriptive claims, the need arises for the formulation of a realistic utopia. For the purposes of this paper, we define a realistic utopia to be an ideal setting in which households are able to meet their monthly billing obligations. With reference to the four major standards of justice theory, Table 1 illustrates the conditions this leaves. This is, in effect, our own normative goal.

3. Electrification in South Africa: an introduction

With attention to the United Nations (UN) Sustainable Development Goals (SDGs) 7 and 11 [17], and in mitigating the effects of the planned decommissioning of ageing power plants [18], Eskom, a South African electricity public utility, has recently stepped up its construction of additional electricity supply capacity (see [19]). The accelerated efforts by Eskom coincide with the energy crisis that has plagued South Africa since 2008, leading to massive blackouts, load shedding and huge economic losses [20,21]. This rapid electrification programme has seen electrification rate move rapidly from less than 33% (in 1990) to 58% (1996) and 90% (2016) and has succeeded largely due to various government policies and interventions [22].

Yet in terms of the socio-economic background of the population, evidence suggests that electrification rates remain deeply uneven between differing ethnic groups, as evidenced by the following tables. Table 2 shows the provincial distribution of South Africa's population

[3] Where a full list would include availability, affordability, due process, transparency and accountability, sustainability, equity and responsibility [15]