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From dualism to convergence – A research agenda for energy access

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Abstract

The global off-grid energy and policy landscape has undergone a profound transformation on different levels during the last decade, leading to new empirical problems and research challenges for the emerging academic community working on access to energy. In this paper, the research group Microenergy Systems outlines and discusses avenues for future research on energy access, based on ten years of own cross-disciplinary research. Its key line of argument is that in order to reach universal electrification in a cost-effective way, it is necessary to overcome the dualistic perception of off-grid/ on-grid, which is associated with a wider set of assumptions about energy provision, often missing out vital aspects of energy use on the ground. This discussion paper begins by delineating the historical root causes for the low rates of rural electrification in countries of the Global South and their consequences on infrastructure legacies and discourse, such as the dichotomy on-grid/off-grid as a key criterion for measuring access to electricity. Taking up the current debate for alternative definitions of energy access, recent research results on the applicability of the multi-tier framework are discussed. Two case studies support the argument that patterns of electricity usage on both sides of the grid are increasingly converging among poor households. We further explore the swarm electrification concept and different service design approaches as examples of how technology and business model development are not only be informed by, but actively build on and advance the convergence of legacy dualistic perceptions. Finally, this paper discusses the implications this convergent process has on the dissemination of electronic devices in rural areas, warning of a sharp increase in electronic waste in the foreseeable future, and the need for new recycling concepts.

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1. Introduction

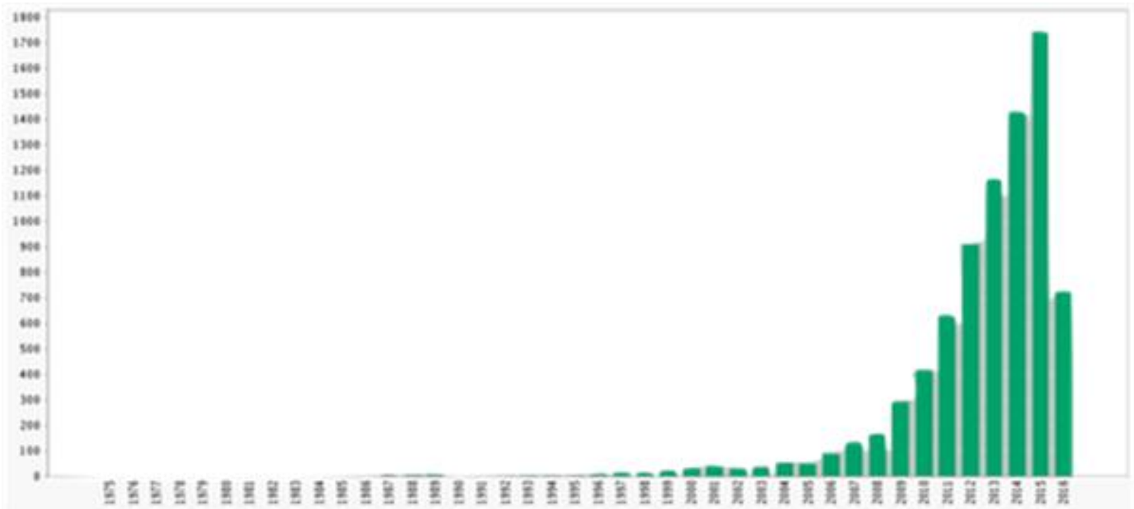
In 1878, Thomas Edison demonstrated for the first time in history his incandescent light bulb with the words "[w]e will make electricity so cheap that only the rich will burn candles" (Edison 1878). Historians at that time reckoned that the world population was around 1.3 billion people (McEvedy & Jones 1978). This number may sound familiar, appearing in almost every publication on energy poverty over the last decade as the number of people today not having access to the electricity grid; and only recently has growth in grid connections started to outpace population growth (SE4ALL 2016). Yet, when in 2005, the Millennium Development Goals (MDGs) were declared, access to energy was not part of them. In the years to come researchers studied intensively the linkage between energy access and development opportunities (Ki-moon 2012; Groh 2014; Alstone et al. 2015). The conviction grew that "none [of the MDGs] can be achieved without the availability of adequate and affordable energy" (Sovacool 2012, 272).

In 2006, the concept of microfinance received international attention when the Grameen Bank jointly with Prof. Muhammad Yunus received the Nobel Peace Prize "for their efforts to create economic and social development from below" (Nobel Media 2006). The bank essentially did the opposite of what traditional banks would do (e.g. lending to the poor instead of the rich, going to the people instead of the other way round, no collateral, etc.) (Yunus 2013). At that time solar photovoltaic was considered by no means as economical viable and was heavily subsidized. Nonetheless, the IDCOL program for micro-financed solar home system (SHS) in Bangladesh began its success story (IDCOL 2014; Khandker et al. 2014).

Inspired by this apparent contradiction, in the same year, the multi-disciplinary Research Group Microenergy Systems (MES) was established at Technische Universität Berlin, devoting itself to the analysis of the planning, the potential assessment, the design of products and services, the implementation, the use and the impacts of microenergy systems. Analogous to the approach of microfinance, the group takes a micro perspective on energy supply, thus challenging the top-down and centralized planning approach of the conventional energy sector. Inspired by the idea of reverse innovation, MES follows the principle of learning from the Global South. The approach focuses on concepts for decentralized energy supply at household or community level, where production and consumption of energy are spatially interlinked (van der Straeten et al. 2014). Going beyond the technical artifacts, the approach looks at energy systems as socio-technical systems and derives its research questions directly or indirectly from users' needs and the question of how to address them with appropriate energy solutions.

In the decade since the group's foundation, its object of study - the global off-grid energy and policy landscape - has undergone a profound transformation on different levels. The global development agenda, which had previously been guided by the MDG's and the global climate agenda, signified by the COP Process and Kyoto Protocol has converged into the Sustainable Development Goals (SDGs) in 2015. Specifically, "[a]ccess to affordable, reliable, sustainable and modern energy" is goal number seven (UN 2015). At the same time, rural electrification based on solar PV has gained global prominence, and considerable momentum in some regions. In Bangladesh over four million SHS have been installed in the regulated market alone, leading to an understanding that "off-grid electrification becomes a viable complement to conventional electrification approaches" (Khandker et al. 2014, 1). Other examples can be found in countries like India, Ethiopia, Kenya, Tanzania, and Peru (Jacobson 2015). The sector has made tremendous progress in building on the synergies with the information and telecommunication technology (ICT) sector, in particular, its mobile payment applications. Innovative Pay-As-You-Go (PAYG) approaches have led to a sharp rise in the distribution of solar systems in regions like East Africa where close to 700,000 cumulative unit sales have been sold by 2016 (Alstone et al. 2015; BNEF 2016).

Figure 1: Exponential growth of academic literature on rural electrification



Number of scientific articles on rural electrification according to Web of Science (http://webofknowledge.com).

These trends have reverberated in the academic world. It seems to be no coincidence that along with the advance of off-grid power systems, the number of journal publications on rural electrification rose exponentially in the last decade (Figure 1). Similar growth is seen in newly founded initiatives, campaigns and industry organizations for global energy access such as the Alliance for Rural Electrification (founded 2006), Lighting Africa (2007), the Global Off-Grid Lighting Association (2012), the Smart Villages

Initiative (2014) and Power for All (2015), forming and consolidating a scientific community explicitly dedicated to energy access. With the rapidly rising momentum in the sector, it is important to formulate a clear direction for further research. The debate on a future cross-cutting research agenda (e.g. Sovacool 2016) is therefore the point of departure for this discussion paper. Focusing on access to electricity as one form of energy supply, it delineates four avenues of future research, derived from a decade of interdisciplinary research in this field. Its key argument is centered on the dualistic perceptions of access to electricity concerning on-grid versus off-grid, centralized versus decentralized, public sector versus private sector, top-down versus bottom-up or micro-perspective versus macro-perspective. This discourse still dominates policy-making, international development finance for rural electrification and even exists in research (e.g. Nordhaus et al. 2016). We argue that the dual nature of colonial identity politics (e.g. racial biases) and international development aid still reverberates with adverse implications for the endeavor of universal electrification. While the problematic implications of this legacy are widely recognized and - as we will see - slowly being addressed on the level of definitions and measures, we suggest here that the convergence of the largely formerly dual nature of energy supply can open up new perspectives for future research where one and the other can be included.

Thus the first research avenue focuses on gaining a more profound understanding of the historical legacies (*Section 2*) which form the root causes not only for the crises of centralized power systems in many countries of the Global South but also for their inability or unwillingness to adopt more adapted and cost-effective technologies for electrification. This includes not only an analysis of the material legacy but also of the discoursive legacy - the terms, measures and planning principles underlying electrification policy. The second research avenue reconsiders the central concepts, definitions and measures of energy poverty and energy access, such as the Multi-Tier Framework (*Section 3*). The third research avenue discusses the premise that the technologies and services expected on-grid and off-grid are in a certain regard converging; it assesses innovation in technology, business model and service design which can help bridge dualism in electricity provision (*Section 4*). The last avenue of research considers the future implications of transitions in the off-grid world, taking the example of global electronic waste (e-waste) to illustrate the need for appropriate end-of-life management systems (*Section 5*).

2. Legacies

In the discussion of the agenda for universal access to clean energy until 2030 – 14 years from now – surprisingly few scholars have raised the question why, in retrospect, many countries of the Global South have not reached electrification rates beyond 15-20 percent until today; about 120 years after electricity first became commercially available. The question of appropriate policies and technological pathways to universal access, as we argue here, cannot be answered without investigating the historical root causes for many of the issues associated with access to electricity today. In order to do so, the energy access scientific community needs to take up insights from the relatively young but growing scholarship on the history of electrification and other infrastructures in the non-Western world (for an overview see van der Straeten & Hasenöhrl, in press). Notably, history is not mentioned in Sovacool's (2016) overview of disciplinary approaches to sustainable energy access and development.

Using the example of Kenya, Tanzania and Uganda, van der Straeten (2014) looks into electrification policies during different historical periods, all of which have left their traces on today's infrastructure layout. These traces firstly stem from the way electricity supply was linked with imperialism and the rise of global capitalism prior to World War I (see also Hausman et. al. 2008). Far from using it as a "tool of empire" (Headrick 1981) most colonial administrations gave concessions to narrowly profit-orientated multinational enterprises. In the cities, which were shaped by colonial identity politics, electricity therefore remained an small-scale luxury industry, closely geared to non-African needs. Half a century of underinvestment into electricity supply and literal non-existence of attempts for rural electrification left the region with only a total of around 30,000 – 40,000 urban users at a time when universal access was nearly reached in most of the industrial world.

The second period started with the "developmentalist colonialism" of the 1940s and 1950s, which led to a profound change of pace and scope with which electricity infrastructures were expanded in East Africa (van der Straeten 2014). In these efforts, however, industrialization came before grid access. Cases like the Owen Falls dam in Uganda, a large-scale hydropower scheme which triggered the construction of the first long-distance grid in East Africa, show that the first attempts for rural electrification were not a result of any political agenda but rather of the unused capacities of an overambitious power generation project - and largely failed because utility managers were ignorant about the specific needs and characteristics of African customers or even bluntly dismissed them as potential customers (Hoag 2013).

Third, central characteristics of electricity planning and policy persisted throughout decolonization into the post-independence era of multilateral development aid. The "high modernist" (Scott 1998, 4) faith in development by means of technology and science, the rise of development economics and the aspirations for industrialization of the authoritarian post-independence governments and international funders often materialized in mega-engineering projects – most notably large hydropower dams. In many countries a handful of large scale generation projects became the backbone of newly constructed centralized grids which determined the layout of electricity infrastructures in these countries until today. These systems were highly vulnerable to factors such as droughts and mismanagement (Walsh 2012). They tied electricity supply even closer to political and technical elites - most of them inexperienced in working with private companies or investors.

Fourth, as a consequence, many states in the Global South were strikingly unprepared when electricity provision - under pressure of the international community - was to be rewritten along market lines in the early 1990s. The hasty and intransparent way in which reforms were implemented opened the door for vested interests, state-capture and corruption, depriving many utilities of the capital which was urgently needed for maintaining their systems, let alone rural electrification. Ambitions of making utilities fit for privatization shifted the focus further away from low-income and rural users - in fact, efforts to increase payment rates sometimes entailed disconnection campaigns, temporarily even bringing down electrification rates (Ghanadan 2009). It has been only recently, with a more pragmatic approach towards public-private partnerships and the establishment of rural energy agencies that rural electrification rates are significantly rising - albeit from a small base and with clear geographical and techno-economic limitations, which cannot be overcome in a cost-effective way by expanding centralized grids (IEA 2011).

In sum, we argue that in their transition towards more sustainable and more comprehensive energy infrastructures, many countries of the Global South struggle with infrastructure legacies on two levels: On a material level, the centralized but highly vulnerable and often ineffective power systems are particularly difficult to reform and expand in a cost effective way - a notion that has led some scholar to talk about a crisis of the centralized power model (Karekezi 2002). On a discoursive level, many countries have inherited a model of top-down planning, large-scale generation and centralized transmission, which focuses on large energy consumers with direct impact on macro-economic indicators like GNP, but labels a broad range of domestic and rural electricity benefits as "uneconomic" (Showers 2011; Hermwille & van der Straeten 2015). This legacy becomes apparent in the way the benefits of development projects (van der Straeten et al. 2014) or access to electricity (Groh et al. 2016) are measured. A recent analysis of the shifting approaches to energy access from the 1970s to today describes how this discourse has evolved over time (Sovacool et al. 2016). The authors argue that the "simple model of top-down, bilateral technology transfer must give way to partnerships between public and private sectors, involving co-investment or private investment coupled with more comprehensive economic, social, and environmental incentives" (p. 5). The following chapter provides an example on how a more adequate set of measurement criteria and tools can nurture this process.

3. Measures

Electricity supply has always echoed and - to a certain extent - reproduced the relationship between the (former) colonial metropolis and the periphery, signified by dualistic perceptions of primitive/civilized, tribal/Western, traditional/modern or pre-capitalist/capitalist. The predominant criterion for measuring electricity access continues to be the ratio of people with electric grid connection to the total population. Using this measure, about 1.166 billion people, 17% of the world population, suffer from an electricity access deficit. Most of this population resides in Sub-Saharan Africa and South Asia (87%), and in rural areas (85%) (IEA/WB 2014). Notwithstanding its crucial role in fostering development, present 2030 projections estimate that under business as usual "600-850 million people in rural South and Pacific Asia and sub-Saharan Africa could remain without electricity" (Pachauri et al. 2013, 4).

In order to effectively act on these broad global measures, we must also understand their meaning from the perspective of the energy poor. In an attempt to empirically assess and differentiate the implications of energy poverty, Groh (2014) establishes the concept of an energy poverty penalty (EPP). His results show that, the deprivation of a certain level of energy service quality exacerbates poverty and a clear indication of a uni-directional (or at least bi-directional) causality running from energy service quality to economic development.

These implications contribute to the argument for the existence of an energy access ladder. The IEA notes that "[t]here is a growing consensus that measurements of energy access should be able to reflect a continuum of improvement" (IEA/WB 2014, 6) in contrast to relying on a (binary) uni-dimensional measure as outlined above. The value of energy access is determined by a range of factors, which in part are very difficult to measure such as "intra-household power dynamics, electric grid management, geographic diversity, political relationships and concurrent access to complementary technology" (Alstone et al. 2015, 306). There is no general rule on what might cause a status of energy poverty as there is no universally accepted set of minimum basic needs and it is highly contextual (Pachauri et al. 2004).

Considering energy poverty as an "absence of sufficient choice" with reference to the capability approach (Sen 1999), one needs to pin down individual welfare components and assess their interaction as multidimensional causes of development and deprivation. Under the Global Tracking Framework, the World Bank's Energy Sector Management Assistance Program (ESMAP) in consultation with several stakeholders put forward the multi-tier framework (MTF), heralded as a new "milestone" in energy measurement (Bensch 2013). The MTF assesses energy access along several attributes (e.g. durability, affordability, etc.) measured either by binary indicators or along a graded scale. The lowest of all attributes-assessments determines the assignment to a specific tier, whether a household, a microenterprise or a community institution. It thus aims to measure a "continuum of improvement, based on the performance of the energy [service] supply" (ESMAP 2014) and to enable policy makers to identify critical shortcomings in order to design the right interventions to bridge the gaps.

Groh et al. (2016) critically assess the ESMAP approach, arguing that the MTF addresses multiple objectives, thereby offering less value as a single composite index than as a set of dimensions along which to evaluate different aspects of electricity access. The study showcases very high sensitivities to parameter changes, different algorithms, and data requirements. Notably, applying the MTF for a sample in rural Bangladesh, findings show significantly higher tier levels for SHS than for the national grid which stands in contrast to the ruling narrative of off-grid being 'second class' and highlights how payment flexibility has been set aside, despite its apparent importance shown by the PAYG sector (Moreno & Bareisaite, 2015). Addressing the drawbacks of the MTF approach, a similar recent case studying southern Colombia, portrays the level of energy access of the grid connected population and compares the results with poverty indicators (Realpe-Carrillo 2016). The results reveal the inefficiencies of the current grid service, not reflected in the national statistics. To enhance such assessment, Realpe-Carrillo (2016) developed an improved metric that incorporates recommendations from Groh et al. (2016), Stevens et al. (2015) and Bensch (2014) within the ESMAP MTF approach labeled as the Progress out of Energy Poverty Index (PEPI) and aligned to SDG 7.

When it comes to the consensus building process for a universal measurement framework among the SE4ALL member countries, further research is necessary to address the performance evaluation of country specific energy interventions, as this is currently sensitive to parameter changes and can differ significantly depending on the measuring algorithm used. Furthermore, the a balance between a standard condensed national energy access index calculation and region specific variations is needed to reflect diverse communities in the same region. While emerging measures and concepts are moving in the right direction, there is significant opportunity for improvement and adaptation to accelerate the development of appropriate technologies and services. Research avenues for such technologies and services and their impact on the convergence of the modes of energy provision are discussed in the following chapter.

4. Convergence

At a recent forum of energy access practitioners it was argued that "[t]he biggest deterrent that prevents off-grid energy access enterprises from scaling up is the word off-grid" (Bali, 2016, 1). This legacy dualistic perspective is being steadily challenged through advances in policy and technologies. Field studies applying the MTF show that SHS perform equally if not better in a comparative assessment against national grid connected households in nearby areas in Bangladesh (Groh et al. 2014), whereas rapidly advancing energy-efficient DC-appliances enable household energy services at as little as 25W, enjoying a great advantage in a greenfield environment[1] (Phadke et al. 2015; Groh et al. 2014). Nonetheless, the majority of literature and case studies on rural electrification around the globe continue to follow the conventional centralised utility path based on AC grid infrastructure.

In an effort to overcome the prevailing discourse, convergence of the two approaches is investigated through the 'swarm electrification' hypothesis - namely that microgrids built from the bottom-up can overcome path dependencies and lead to more flexible, resilient and ultimately more sustainable infrastructure (Groh et al. 2015). In the investigated swarm electrification approach, individual SHS users connect to a LVDC microgrid to trade electricity with their peers. Economic user-value is created through 1) the ability to buy and sell electricity and 2) the ability to power larger loads for longer periods of time. The ability to integrate existing infrastructure improves asset utilisation, enables dynamic growth and allows for stable subsystems that can function independently. When it comes to the decision of whether or not to extend a regional or national grid to remote areas, the swarm electrification model has the potential to improve economic viability, as the target community already has an established last-mile smart distribution grid infrastructure. The point of convergence here is the point of common coupling (PCC), meaning that a cluster of houses connects to the nearest national or rural grid at a single point of connection. The smart microgrid could run in "island mode" when power from the grid is not available, or "grid-connected" when power from the grid is available. The swarm electrification approach therefore bridges the conceptual gap between what is considered 'on-grid' and 'off-grid', and to some extent, the debate between AC and DC power distribution.

Field studies of the swarm electrification approach began in Bangladesh, with a view to leverage on its existing infrastructure of over four million SHS installed to date (IDCOL 2016). Groh et al. (2015) have shown here

[1] Greenfield environment here means in the absence of an established AC-based electricity grid infrastructure.

how higher tier electrification can be achieved through compounding network effects when linking multiple SHS. Investigations on suitable control concepts for swarm type DC microgrids are in progress. Special emphasis is given to variable network topology and multi-directional power flow as key technical characteristics - ongoing work is found in (Belk et al. 2016) and (Strenge 2016]). Notably, trading of solar electricity began in the North (Brooklyn[2]) and the South (rural Bangladesh[3]) at almost the same time. Kirchhoff et al. (2016) discuss this parallel development, emphasizing the key role of user participation in bottom-up approaches, while noting the importance of top-down mechanisms; in particular with regard to technology standards.

It is important to note that the goal of universal energy access cannot be reached purely by adjusting the technology or cost lever. Legacy intervention strategies have been criticized due to their typically disciplinary grouping to address either technical, institutional, financial or cultural barriers (Watson et al. 2012; Schillebeeckx et al. 2012; Hirmer & Cruickshank 2014). It is argued that energy access is to be seen as a wicked problem that needs a more holistic approach [Manzini, 2011]. In response to this criticism, service design has gained attention as a promising strategy (Mager 2009). While earlier definitions of 'services' denoted them as optional extensions of a product, contemporary interpretations say that "service is the fundamental basis of exchange", and products are mere artifacts inside a service ecosystem (Vargo and Lusch 2007, 6).

Product Service Systems (PSS) was introduced as a concept to integrate products and services under one scope for planning, development and delivery (Müller et al. 2009). Expanding on this, Kebir & Philipp (2016) developed a PSS Quality Framework for SHS, strongly recommending to avoid creating preferences for products from industrialized nations and instead to emphasize on local manufacturing and services. Lindner (2016) summarizes three major challenges to the application of service design in rural electrification; methodological competence, diversity during development and systemic collaboration. Suggested approaches to address these challenges are the provision of toolkits and coaching, the promotion of interdisciplinary teams and the replacement of sector-specific programs with cross-sector incentive programs that recognize the interplay of different sectors such as energy, education, labor market, distribution networks and healthcare.

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[2] Example of Brooklyn Blockchain Microgrid: https://www.fastcoexist.com/3058323/is-brooklyns-microgrid-on-the-blockchain-the-future-of-the-electric-system

[3] Example of ME SOLshare: http://unfccc.int/secretariat/momentum_for_change/items/9940.php.

The premise that energy access technologies and services are converging opens up several avenues for future research. Technology concepts which could take this convergence further and bridge the gap between on-grid and off-grid (e.g. swarm electrification) show promise, however it is critical to ensure that principles which place emphasis on user-value and encourage local service ecosystems are included in the research paradigm. An often ignored aspect of energy access technology development and research is the end of life perspective, to which the following chapter is dedicated.

5. Implications

Despite the rapidly growing body of literature on rural electrification, relatively few publications address environmental impacts other than greenhouse gas emissions (Durlinger et. al 2012). In 2012, Lighting Global started publishing Eco-Design Notes referring to Battery Toxicity, Eco Product Design, Restriction of Hazardous Substances (RoHS) and Life-Cycle Management Options (Lighting Global n.d.). Additionally, the global off-grid lighting association published an industry opinion piece stressing the importance of extended producer responsibility (GOGLA 2014). IDCOL (2014) identified improper disposal of batteries, PV panels and CFL bulbs as the most pressing environmental concerns of the SHS-program in Bangladesh. Schützeichel (2015) proposed to either integrate recycling concepts directly into energy access tender processes or put the development of appropriate standards and rules on the global agenda. At the 4th Off-Grid Lighting Conference a session was dedicated to environmental and social sustainability, highlighting the overall benefits and the remaining challenges in turning the sector into a 100% ‘circular economy’ (GOGLA & Lighting Global 2015). For good reason, Sovacool et al. (2016) identified a research need for the evaluation of relationships between energy service provision and environmental degradation. The published statements follow clearly the narratives in the Global North: From climate change mitigation, to extended producer responsibility, to recycling strategies ending at concepts of circular economy.

Taking the example of electronic waste (e-waste), global generation reached a record high of 41.8 million metric tons in 2014 (Baldé et al. 2015). Waste from microenergy systems currently is a negligible portion of this [Magalini et. al., 2016], however the projected six million metric tons of global PV-panel waste by 2050 paints a different picture (IRENA 2016). The implications of these numbers underpin the argument for proper end-of-life management, in both the on- and off-grid world. Taking the case of Bangladesh where over four million SHS already exceed a total installed capacity of 200 MW_p, solar batteries were identified as early as 2010 as an emerging source of scrap lead (DOE 2010). The estimated amount of scrap lead for 2016 was found to be roughly half of planned formal recycling capacity (Batteiger 2015a). In order to tackle this challenge, environmental prequalification for battery suppliers was instituted and a take-back mechanism installed. In response to these measures, battery suppliers and recyclers complied with environmental standards (Batteiger 2015b).

Research into appropriate concepts for the management of e-waste in the Global South is still in its infancy (Wang et. al. 2012). If at all, it is mostly available for urban areas or on a country level. To address this gap for solar off-grid products, Batteiger and Rotter (2015a) developed a methodology to assess material implications of electrification. Access to electricity data proved to be a reliable source to approximate solar off-grid waste (Batteiger and Rotter 2015a). Assessment of weight-based possession of electrical and electronic equipment (EEE) shows this is almost zero for off-grid households, whereas the median household being electrified with SHS possess around 6,5 kg of EEE and a median grid connected household 11.5kg (Batteiger and Rotter 2015b). It should be noted that an average European inhabitant currently generates 15.4 kg of e-waste per year (Baldé et al. 2015) - significantly more than a rural household in Bangladesh possesses.

The global market for off-grid appliances is expected to grow eight-fold to around 4.2 billion € by 2020 (Global Leap 2016). Most of the SHS distributors already sell bundles including TVs, fans and in the near future fridges. The solar off-grid industry may follow the same growth patterns as seen in the mobile phone industry. In this scenario, the example of e-waste described above illustrates quite well the argument for the urgent need to develop and adopt appropriate end-of-life management systems for solar off-grid products.

6. Outlook

Twenty-five to thirty years from now, almost all the growth in energy demand will be attributed to the developing world (Wolfram et al. 2012). The world's poor and nearly poor will play a key role in driving medium-run growth in energy consumption. Energy consumption on a global scale is not only a key factor for economic growth but at the same time the main driver of greenhouse-gas emissions (Jakob et al. 2014). It has been shown however, that aspirations to provide universal electricity access should be given clear priority, independent from its generation source (Pachauri et al. 2014). The perspective to be taken should rather be on the findings that raising basic living standards contribute less to CO_2 emissions than growing affluence (Rao et al. 2014). Nonetheless, a successful universal energy access policy must be paired more robustly with the climate agenda because only then will sustainable energy systems gain the necessary spotlight to become visible for policy makers and the finance community, which in turn is needed for a major scale-up (Leopold 2014).

Despite growing acknowledgement that energy access is in fact an interdisciplinary wicked problem, historically motivated narratives centered on the dualistic perceptions of on-grid and off-grid, of AC and DC, of centralized and decentralized and lastly of public and private sector players, continue to reverberate across the energy access sector. "When you've had a monopoly for a hundred years, and you've never seen change, change may seem like death to you" (Rive 2015). This quote was made in response to the fear of US utilities that solar PV increasingly decentralizes the power supply which may threaten the utilities' market position. Kammen (2016) refers to a new group of skeptics (e.g. Nordhaus et al. 2016) that continue to insist on a strictly dualistic view based on arguments that today seem out of place, given the growth of off-grid energy markets, the convergence of electricity provision, and the development of entire industries built around clean electricity services. The argument for recognising the convergence in electricity provision is supported by the fact that the situation in the Global South is rather different. Legacy energy policy is confronted with severe service gaps due to restricted capacity paired with limited interest in serving the significant rural population often characterized by low demand and physical remoteness. The political reluctance for innovation, when it comes to decentralized systems often based on solar, faces similar realities. Nevertheless, increasing trends for convergence can be observed and need to be nurtured. Through both bottom-up and top-down innovations such as the emergence of digital finance, smart load prioritization and tariffing, electricity sharing and blockchain, among others, a range of convergent grid technologies are emerging in the Global South. Notably, the seemingly parallel trend in the Global North bears a great potential of future research, including possible reverse innovations (Govindarajan & Trimble 2012). We firmly believe that a stronger emphasis on convergence in both the academic and practitioner community will significantly improve our efforts for sustainable energy for all. Will clean electricity be cheap enough that only the rich in the Global South will use candles?

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