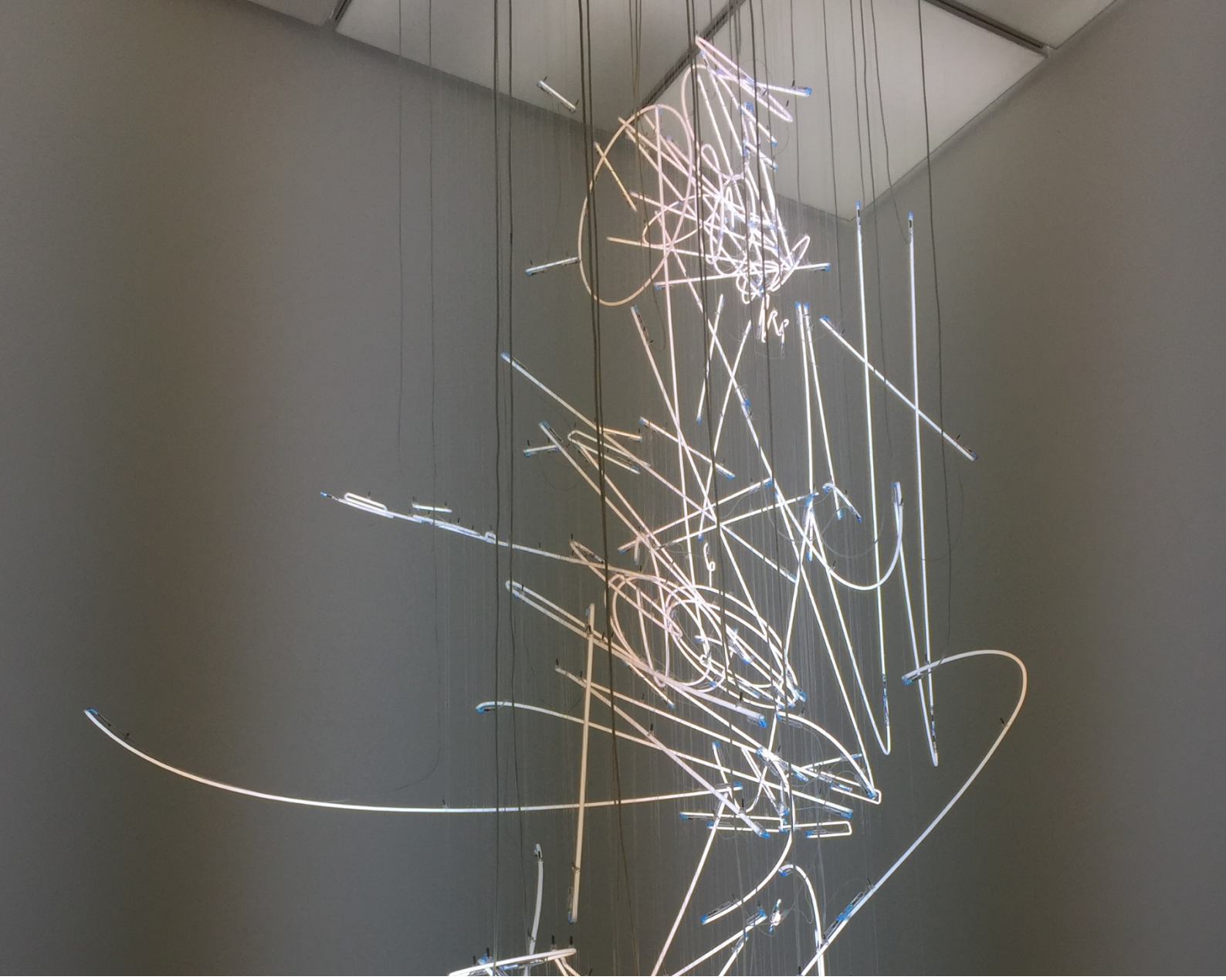

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Radical Solar Energy Startups in Kenya and Tanzania

Finland Futures Research Centre (FFRC)

NEO-CARBON ENERGY WP1 WORKING PAPER 2/2018

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Cover Photo

Joni Karjalainen, Neon Forms (After Noh IV) by Cerith Wyn Evans in exhibition in '9x9x9' White Cube gallery at Bermondsey, London, United Kingdom (2017)

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“Radical”

Definition:
(especially of change or action) relating to or affecting the fundamental nature of something; far-reaching or thorough

Oxford English Dictionary

CONTENTS

EXECUTIVE SUMMARY

This working paper focuses on radical startups of solar photovoltaics (PV) in Kenya and Tanzania. The research was conducted in the **Neo-Carbon Energy project (2014-2017)** and finalized in the science-communication project **Great Electrification in Peer-to-Peer Society (2018)**, conducted at the Finland Futures Research Centre (FFRC) in the University of Turku.

The purpose of the working paper is to test one of the Neo-Carbon Energy project's transformative scenarios, called **Radical Startups 2050**, and reflect it in Kenya and Tanzania. In East Africa, over 80 million people could benefit from mobile-enabled energy services. Kenya and Tanzania are pioneering solar energy markets in sub-Saharan Africa, where policy makers are seeking to achieve 'sustainable energy for all' objectives, and are increasingly focussed on entrepreneurial clean energy technology ventures. Many solar companies have started their operations in these markets, which has strengthened a narrative of a market-led energy transition in East Africa. Remarkably, there has been limited analysis about the factors that have enabled these pioneering ventures to emerge.

The scenario testing is performed by first examining the historic evolution of the solar PV niche in Kenya and Tanzania, which shows how multiple pioneers built a solar energy niche over a few decades before the current solar innovation boom. The situation at the present shows how a growing number of 'heroic' solar entrepreneurs from home and abroad are now addressing energy poverty in East Africa. The company case studies describe their business models, proposed solutions and corporate histories to explore how they have emerged, and tell a story of 'radical' startups now pioneering in different ways.

This exercise opens up novel avenues to think critically about the role of innovation in development. At least six important considerations seem to deserve further attention:

1) **The promotion of innovation in developing countries requires critical and a more rounded analysis.** Novel developmental solutions are easily lauded for their potential. ***More detailed insights can demonstrate benefits, areas to improve, as well as highlight the learning processes and outcomes of such problem-solving exercises***.

2) **If innovation is the hammer to hit a nail, who is holding the hammer?** Further study is needed on the role of innovation capabilities and what prerequisites there are to perform innovation locally. ***Could micro-level studies of learning processes or in-depth company case studies investigate these issues in more detail?***

3) **Too few locally know about design-driven entrepreneurship tools, have access to supportive tools, or get to exercise such critical skills.** Radical innovation delivers higher value added returns, which points to the importance of creativity, learning processes and problem-solving capabilities beyond technological, sales or marketing know-how. ***How to support local entrepreneurs' aspirations to create innovative services or products suitable for the local context?***

4) **A more nuanced understanding of the role of global innovation networks is needed**. Many aspiring companies seem to be innovative thanks to their experience, global orientation and related networks. However, all startups or small-and-medium sized enterprises, especially local ones, do not possess such abilities. ***Would there be a reason to think about the interaction and networking strategies more carefully?***

5) **A next step in Kenya and Tanzania concerns the advancement of their innovation ecosystems.** Amidst the flurry of solar innovation activities, the 'national' innovation ecosystems are weak and educational attainment is undermined by quality. ***How can it be ensured that value creation out of innovation activities is maximized?***

6) **Pioneers have made solar electricity in Kenya and Tanzania a reality, but the world is never ready**. The progress achieved so far is remarkable, but novel solutions may be required ***to deliver solar energy to extremely low-income households. Other emerging issues concern (at least) e-waste, recycling processes, data, and privacy.***

One purpose of the working paper is to think more critically of the promise of innovation and entrepreneurship, of increasing attraction in global development policy. In 2017, **United Nations Global Compact launched a search for the pioneers of Sustainable Development Goals**. It is believed that an ethically motivated private sector can solve an array of global problems, to tackle injustices, protect the environment, and even fight inequalities. The discussion in this working paper opens up novel debates and questions related to this strategy, and provokes thoughts on the everyday practices that are promised to make innovation to deliver on environmental, social and economic goals. ***Of particular future policy relevance is the issue of learning and value retention from innovation activities***.

Keywords: business models, innovation capabilities, global innovation networks, radical innovation, solar, startups, sustainable development goals, East Africa, Kenya, Tanzania

1. INTRODUCTION

The **Neo-Carbon Energy project (2014–2017)** aimed to study and develop a 100% renewable energy based energy system, a technological set-up in the form of a neo-carbon energy system, as one of the strategic research openings of Tekes – the Finnish Funding Agency for Innovation. The project is joint work by the VTT Technical Research Centre of Finland (as co-ordinator), Lappeenranta University of Technology, and the University of Turku, Finland Futures Research Centre (FFRC). The foresight part of the project was led by the research team at the Finland Futures Research Centre (FFRC)[1]. Based on the project outcomes, a science-communication project called **Great Electrification in Peer-to-Peer Society (2018)**, probes the novel and innovative discoveries of the Neo-Carbon Energy project. This project studies the aim of a comprehensive electrification of society, shaped by the uptake of renewable energy technologies, emerging peer-to-peer interactions and services, and novel innovations. This latter project is funded by the University of Turku, Stek ry and The Finnish Innovation Fund – Sitra[2].

This working paper builds on the Neo-Carbon Energy project's foresight work with **transformative scenarios**[3], which assumed a socio-cultural perspective to the study of energy transitions and the uptake of renewable energy. A research scope that extends beyond techno-economic thinking includes contextual factors from innovation dynamics to socio-cultural or even political forces, and can be used to stimulate thinking on alternative energy futures. This working paper follows previous exercises to test the scenarios (Heinonen et al. 2017a[4]; Lang et al. 2016), which themselves are generic, universal and global in nature, and were worked and deepened throughout the research process.

The purpose of this working paper is to focus on the testing of one of the project's four scenarios, called ***Radical Startups 2050***, in Kenya and Tanzania. The Radical Startups scenario is described in more detail in the Chapter 2. The idea with testing scenarios owes

[1] The Neo-Carbon Energy project (2014-2017) foresight part is headed at the Finland Futures Research Centre (FFRC) in co-operation with VTT and LUT. Kenya and Tanzania were case study countries of the project. See: www.urly.fi/WDs, www.neocarbonenergy.fi and www.utu.fi/en/units/ffrc/research/projects/energy/Pages/neo-fore.aspx.

[2] The Great Electrification in Peer-to-Peer Society project has been worked by Prof. Sirkka Heinonen and Joni Karjalainen. https://www.utu.fi/fi/yksikot/ffrc/tutkimus/hankkeet/Documents/Savays-En.pdf

[3] These scenarios were mainly written by Juho Ruotsalainen at FFRC within our Neo-Carbon Energy research project.

[4] In one exercise, a role play was organised to think who are the key actors in a world of 2050 that uses solely renewable energy (Heinonen et al. 2017a).

to the fact that while the scenarios in hand are based on comprehensive foresight work i.e. the identification of several megatrends, trends and weak signals, which point to the possible realisation of a particular type of a future, it is never exactly sure when, how and where such futures may come about. Therefore, scenario-testing can provide evidence about alternative futures that may be realised. In the initial scenario narrative, the future economy is primarily driven by the ambition, passion and networks of nimble startup companies who gradually begin to turn their creative ideas into novel products, services and lifestyles, and begin to influence the society as a whole. The innovation drive of the startups is combined with an increasingly profound ecological awareness, and so the startups commence to 'transform innovation for sustainability' (Leach et al. 2012). In such a future world, many startups specialise in energy, including the provision of energy services.

Startups have emerged as a major focus of attention in business circles, and their role is also of growing policy and academic interest. As agents of 'creative destruction' (Schumpeter 1934), startups are significant contributors to innovation, able to observe emerging consumer needs, venture into niche markets, often being more agile than large firms. ***A startup has been called as "a human institution, which is designed to create new products or services under conditions of extreme uncertainty"*** (Ries 2011). Startups often operate with limited experience, constrained resources, and are influenced by several factors. A startup advances through four phases: startup, transition, scaling and exit (Picken 2017). In recent years, the 'lean startup methodology' has mainstreamed as a schema applied to startups, where failing fast and often is necessary, as it allows finding out what actually works[5] (ibid.). Certain elements that may promote startups can may be omitted when promoting entrepreneurship, such as product development or service design methodologies (Tripathi et al. 2019, 57). Startups today operate in a globalized world, and an emerging fascination promotes entrepreneurial ventures to solve numerous developmental problems.

Drawing on the foresight work, the reason for testing the scenario in two case study countries, namely **Kenya and Tanzania**, results from multiple reasons. Previous research on the relevance of sustainable development goals (SDGs) in the two countries identified energy as a major topic for these countries (Luukkanen et al. 2015). Subsequently, in the Neo-Carbon Energy project, specific focus was paid on the potential role of renewable energy technologies as a game-changer of energy futures. In an international survey on

[5] Their product development runs through four distinct stages: startup, stabilization, growth, and evolution (Crowne 2002). Wang et al. (2015) analyzed software startups and identified six product development stages: concept, in development, working prototype, functional product with limited users, functional product with high growth, and mature product.

future energy solutions, shared with experts who commented the project's transformative scenarios, the respondents in Kenya and Tanzania primarily identified solar energy companies as local forerunners (Lang et al. 2016)[6]. Consequently, the focus in this research was narrowed down to the study of innovative solar energy companies, and especially startups, in these countries.

The promotion of innovation in development suggests that unlike in the past, when the role of the private sector was often contested, there is an increasing recognition of the potentially positive role that the private sector can play in the African continent. Even so, the conditions for entrepreneurship in developing countries differ from developed countries. To begin with, informal sector entrepreneurship is ubiquitous. What is more, the least-developed countries (LDCs) in the Sub-Saharan Africa have been claimed to be institutionally 'hostile' environments, with possibly the most underdeveloped institutional environment in the world (Abubakar et al. 2019). Typically, many developing country entrepreneurs and firms operate considerably below the technological frontier, and local firms' innovation efforts have principally been concerned with technologies that have been developed elsewhere (Goedhuys and Sleuwaegen 2010). What is more, many mechanisms that support entrepreneurs in developed countries are typically not in place for local entrepreneurs.

An extensive report in the early 2010s makes several observations and a set of recommendations for 'accelerating entrepreneurship in Africa' (ON 2013). It expresses concerns of a lacking culture of innovation in local schools, which undermines entrepreneurship. Those in possession of technical capabilities were reported to be often in need of training in business management and entrepreneurial skills. Actually, the report argues, entrepreneurship is all too often merely associated with the pursuit of material wealth. The report further points to limited opportunities for hands-on learning activities that would cultivate competencies in practical thinking, creative problem-solving and independent judgment. The local entrepreneurs, who responded to the survey underpinning the report, reported a difficulty of their new companies to access financing, when compared against well-established firms. This suggests a lack of network access. However, funders also reported many local entrepreneurs' project proposals to lack in innovativeness and quality. The report ***called for more opportunities for managing small projects, more avenues and support to help people identify their passion, and an ethos of nurturing businesses that have an innovative 'culture' and are responsive to their clients'***

[6] Overall, respondents in the survey suggested that startups have the ability to introduce radical business models, technology, bring disruption to the markets, generate new thinking as well as set an example to others.

needs (ibid.). In light of such situational factors, what explains the rise of solar energy startups in Kenya and Tanzania?

1.1 Kenya and Tanzania as case study countries

The choice of studying Kenya and Tanzania draws from a growing market and policy attention to the East African solar photovoltaics (PV) space. A mounting excitement is building following the increasingly rapid adoption of various off-grid type of solar products and services in the countries. (At least) the following nine reasons can be mentioned as drivers for the on-going changes: theoretical potential, economics, niche-nurturing, regulatory environment, investment, market growth, innovation, technology, and expectations. Each of these dimensions is next summarized shortly.

1) Verified theoretical potential: From the point of view of physics, it has been recognised for a long time that the amount of sunlight received yearly in the latitudes near the Equator is considerably more in the northernmost and southernmost latitudes (Barasa et al. 2016). Both the daily and annual solar irradiation received in countries such as Kenya and Tanzania exceeds well that of many other countries, even pioneering solar photovoltaics markets, such as Germany, which initially emerged as a global leader in the technology development, policy development and solar energy deployment at the household level.

2) Improving economics: The cost of solar photovoltaics, as a technology, has fallen considerably in the 2010s. ***Manufacturing a solar panel today only costs 1/100 of what it used to cost in the 1970s, at the early days of the technology development.*** Such advances owe to strong efforts in Germany to provide an initial strong push in the development of the solar energy sector, inspiring other countries globally. More lately, the prices of manufacturing lowered significantly as an outcome of the economies of scale achieved by China's mass manufacturing of solar photovoltaics. These efforts have already dramatically changed the global energy landscape. Starting from a very modest base, the generation from solar photovoltaics has expanded in the 2010s even by as much as 50% annually worldwide. (Huang et al. 2016; Lazard 2016; IRENA 2016b, 2016a.)

3) Determined niche-nurturing: Despite the theoretical potential and improving economics, the diffusion of solar photovoltaics, also in East Africa, was for long held back by numerous obstacles (Ahlborg 2012, 17-19; Ahlborg & Hammar 2014; Abdulganiyu 2017).[7] There have been, however, niche nurturing and capacity-building efforts in Kenya and Tanzania for a sustained period of time through multiple activities, which have evolved from initial efforts

[7] A useful overview in this regard on the general reasons is provided by Negro et al. (2012).

to increasingly sophisticated efforts, such as consumer educational campaigns. These processes have also ***built up initial skills and knowledge about solar photovoltaics and related technologies***. Such efforts have been pursued by multiple actors – initiated by early pioneers, then supported by often development-aid financed non-governmental organisations (NGOs), to entail an increasingly diverse range of actors. Gradually, even the national governments and a growing pool of private companies have shown an interest in the topic. When taking their combined effect, these efforts have supplied initial capabilities to a range of actors in Kenya and Tanzania (Byrne 2011, Ockwell and Byrne 2016a).

4) Evolving regulatory environment: The growth of the solar industry in Kenya, and later also in Tanzania, has been aided by an active community that has helped to promote several policy guidelines, such as advocate for exemptions on value added tax (VAT). Kenya has gradually developed its policy environment for renewable energy. Even so, solar energy was ignored by the government for a long time, and not all has been smooth sailing. For instance, businesses in Kenya complained how the VAT and duty regulations concerning solar products frequently changed between 2013 and 2015[8]. Kenya has approved a new Energy Act (2015), which among other things suggests a new state entity, Rural Electrification and Renewable Energy Corporation, to be established to coordinate sector activities, though this legislation has not been enacted to this date. In Tanzania, the country's large geographical area and low electrification rate and poor electricity grid coverage make the country attractive to solar home systems, and a potential "sweet spot" to the mini-grid sector. For small mini-grid systems, below 100 kilowatts, regulation is conducive: startups or SMEs only need to report about their activity to the government, allowing companies to test their solutions.

5) Growing investment: Although it is a more recent phenomenon, investment into solar photovoltaics in developing countries is growing (Baker and Sovacool 2017), and ***today Kenya and Tanzania are among the main attractors of investment in off-grid solar photovoltaics in the entire world*** (REN21 2016, 21). The investment climate for renewables, particularly in Kenya, has been deemed favourable.[9] The off-grid market is drawing increasing investment from a variety of sources – public, philanthropic and even private sources, including venture capital. However, in general terms, an investment gap between early stage funding, and angel and venture capital in Africa has been reported (Coetzee 2017).

[8] https://www.howwemadeitinafrica.com/manufacturing-solar-panels-east-africa-rising-demand-challenges-remain/53859/

[9] Especially in large-scale projects, however, social risk, land and governance issues, may arise as considerations (see e.g. Pueyo 2018, 91–93).

6) Rapid market growth: In the recent years, countries in the sub-Saharan Africa have witnessed a surge in the introduction of solar photovoltaics related products. For example, 1.77 million solar products were sold in Sub-Saharan Africa in the period of January-June 2017, which equalled revenues up to USD 40 million. This accounted for half of the entire solar industry sales globally. In Kenya and Tanzania, they amounted to USD 6.4 million and over USD 300 000, respectively. Most sold systems in East Africa have been small solar home systems (below 10 watt-peaks, Wp). ***Kenya is today the second largest off-grid solar market after India, and Tanzania has moved up to sixth place***, when measured by the cash sales of revenues (GOGLA and Lighting Global 2017a; 2017b; 2018).

7) Rise in innovation and startup activities: Market growth has not only meant a growth in the size of sales volumes, but resulted in a diversification in the solar sector activities. Many types of novel companies have emerged, performing different types of innovation activities in Kenya and Tanzania. It is worth noting that ***Kenya and Tanzania were already coined as pioneering countries in the invention and adoption of mobile money***. M-Pesa was established in Kenya around the year 2007, and mobile money was taken up in Tanzania soon after. Innovation hubs initially geared for information and communication technologies have mushroomed in the past years especially in Kenya, but also in Tanzania, followed by accelerators and incubators. They act increasingly as platforms for the activities of startup companies who are developing their solutions and pitching their activities. Many innovative solar startups have benefited from these platforms, their events, networks and related initiatives. In both countries, several solar energy startups have started to deliver their customers lighting and electricity with their radically new and innovative business models and products, and turned energy into novel types of services, to make it increasingly user-friendly (Karjalainen and Heinonen 2017).

8) Emerging technological convergence: Kenya and Tanzania, specifically, are hyped as the "cradle" for mobile based pay-as-you-go deployments. Solar energy is a modular solution, which can be combined with ICTs, mobile banking, and machine-to-machine communications. It has been assessed that ***over 80 million people in East Africa could benefit from mobile-enabled energy services*** (Gauntlett, Nique, and Smertnik 2016). Startups and SMEs have begun to also integrate emerging technologies into their operations. Recent efforts include experiments with data optimization, machine learning, and blockchain.

9) Heightening expectations: As a consequence of all these (and perhaps other) drivers, solar energy is becoming an increasingly powerful sociotechnical imaginary in the Global South (Gies 2016; Cloke, Mohr, and Brown 2017). In the past, activists promoted the feasibility

of solar energy to validate its potential in addressing unmet energy needs. These days there are increasingly strong arguments about ***the future potential of solar energy as a systemic solution to drive entire energy futures in the sunny latitudes***, and beyond. Even so, concrete actions will be needed because heightening expectations alone cannot guarantee that futuristic visions will be turned into reality, or realised in desirable ways.

This list of nine reasons provides a starting point for exploring and understanding the emergence of solar energy startups in Kenya and Tanzania. ***Many previous studies on solar energy have focused on the techno-economic and political elements, whereas the aspects of innovation and future trajectories have received less attention.*** Therefore, studying Kenya and Tanzania as pioneering niches and markets could be important for better understanding how and why solar energy is adopted, and what implications such dynamics have for other African countries, increasingly interested in adopting solar energy, through strategies that are progressively more labelled as market-driven approaches.

1.2 Working paper structure

The methodology and data is presented next, after which the Radical Startups 2050 scenario and the scenario logic is opened up in **section 2**. **Section 3** discusses the history of solar energy in Kenya and Tanzania, drawing on Byrne (2011), Ockwell and Byrne (2016a) on Kenya, and Byrne (2013) on Tanzania. **Section 4** describes selected companies and entrepreneurs as case studies to exemplify the role of radical startups operating in Kenya and Tanzania. **Section 5** provides a reflection to the original scenario narrative with a discussion in the light of innovation literature to discuss more analytically the emergence of solar energy startups in Kenya and Tanzania. **Section 6** features the conclusions.

1.3 Methodology and data

Scenarios are a commonly used foresight tool. There are multiple ways to craft scenarios, which is why next a short explanation is provided how scenarios were here used to explore the role of solar entrepreneurs in the context of long-term energy transitions in Kenya and Tanzania.

Socio-cultural scenarios as test-beds to explore transformations

The purpose of scenarios, as compelling and evidence-based narratives, is to open up thinking of different possibilities, not to predict the future. In the foresight part of the Neo-Carbon Energy project, four transformative scenarios had been constructed to provide a holistic framework to explore how a growing uptake of renewable energy intertwines with other types of drivers of societal and technological development. There is a pressure to deliver drastic changes in the energy landscape in the coming years (IPCC 2018), and therefore, all of the scenarios were designed to be transformational (Dator 2009) i.e. to envision the potential changes that could come about. This falls in line with the use of scenarios as an explorative tool in governing energy transitions (Miller et al. 2015). Scenarios that hold a socio-cultural viewpoint were, in this way, used to envision different routes to a renewable energy based world in the year 2050 (Heinonen et al. 2017b).

According to Peter Schwartz (1991, 1996), already at the point of drafting a scenario, each key factor and trend should be given some attention. This ensures that the scenarios have a consistent internal logic. Then, when fleshing out the scenarios, it is useful to think of connections, implications and events that can be crucial and necessary to make the scenario be realised, or alter its realisation. This makes it useful to assess the possible implications of a scenario. These considerations are related to the use and usefulness of scenarios as a whole: the relevance of scenarios depends on how they are translated to diverse experts, policy-makers, and citizens.

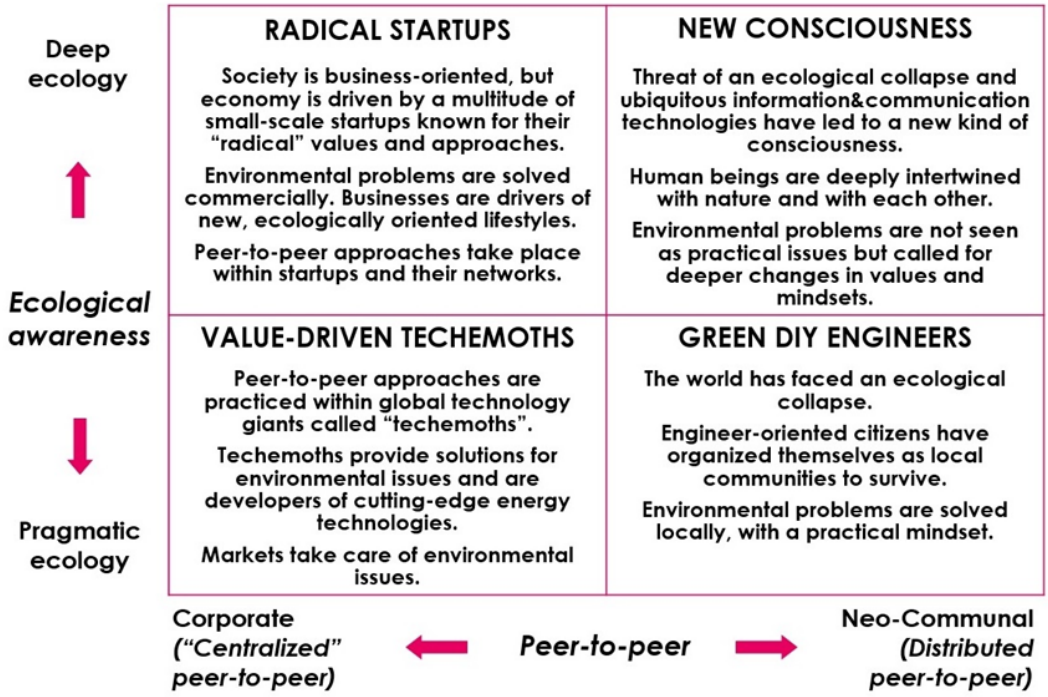

Figure 1. Four transformative scenarios 2050 assume a long-term perspective.

The scenarios were constructed on the basis of a horizon scanning where special emphasis was paid to emerging issues and weak signals. Two axes would underpin the scenarios: ***ecological awareness (x-axis)*** and the manifestation of ***the peer-to-peer ethos (y-axis)***. In terms of ecological awareness, growing environmental and climate change concern are pushing actors to find new solutions, in a profound or more pragmatic manner. In a peer-to-peer based logic, society is organised in an increasingly non-hierarchical way, and there are fewer hierarchical, centrally organized structures. The peer-to-peer mode, which is already embedded in ICTs and increasingly in other technologies, can be harnessed by existing organisations (in a "corporate" mode) or by individuals, groups and communities (in a "neo-communal" way).

It is worth noting how these two axes are also illustrative of recent economic change. For instance, Malaska (2010) wrote of neo-growth, promoting a future model of economic growth, which is increasingly based on services, immaterial growth and the minimal waste of resources. Such changes are symptomatic of increasingly bottom-up driven organisational structures and an emergent cultural change of flattening hierarchies. Renewable energy technologies, in principle, align with such developments, as their modular nature supports an increasingly distributed way of energy production and consumption (Ruotsalainen et al. 2017). When such elements are combined with self-learning, a do-it-yourself attitude, and decentralised production of material goods, including digital manufacturing or an increasingly common use of 3D printers, the structure of society can to a growing degree be built from the grassroots. (Again, this will be further illustrated in Chapter 2 and the original scenario narrative.)

Once scenarios have been written, they should be tested. From a decision-making perspective ***these connections can reveal key vulnerabilities that can make different strategies for a particular scenario more or less robust***. Schwartz (1991, 232-233) mentions that it may also be worth spending some time and imagination to monitor the realisation of a scenario and come up with actual indicators: "The logical coherence of a scenario *built into* the scenarios can allow logical implications of leading indicators to be *drawn out* of the scenarios" (sic). In scenario language, ***environmental monitoring refers to trends, events, technologies that can either support or question the realisation of a scenario*** (Ralston and Wilson 2006).

In essence, the scenarios combine multiple types of evidence to envision transformations, and their aim is to be used as test-beds for future worlds. One research strategy to explore transformations within futures research is to ***look at change through its early seeds*** (Hiltunen 2008). Pioneering acts are understood to provide early information and potential symptoms

of future trajectories (Heinonen 2017; Heinonen and Karjalainen 2019). In this case, while the scenarios are of generic and universal nature, they are ***made meaningful in a particular geographical context***. When put to test in a regional or country context, new insights can be gained of the potential applicability of a scenario. In our case, the voices of local and international stakeholders were even used as feedback to make the scenarios more contextual.

Data collection in Kenya and Tanzania

For the scenario-testing, complementary research methods were taken. First of all, the applicability of each of the four scenarios was considered, which over the course of the research led to the selection of the Radical Startups 2050 scenario in Kenya and Tanzania as the most insightful one to be tested. When working with scenarios, it is important to know as soon as possible which of several scenarios seems to be closest to 'the course of history', as it actually unfolds (Schwartz 1991). In the scoping phase, initial fieldwork was conducted in September to October 2015 in Kenya and Tanzania (and then again in October in 2017 only in Kenya) to understand the countries' energy landscape and the local solar photovoltaics sector more deeply. Two futures workshops were organized during the fieldwork, the first one in Nairobi 24.9.2015, and then a second one in Dar es Salaam 8.10.2015, each with around 15-20 participants[10]. In the futures workshops, ***the participants were presented with on-going foresight work, such as the transformative scenarios and latest trends in renewable energy, which they commented on and provided their own viewpoints***.

At this stage, interviews with the energy sector and innovation stakeholders in both countries provided key insights that further shaped the focus of the research. The main round of interviews was conducted in September-October 2015, further interviews were conducted in early 2016, and again later in mid-2017, as displayed in Appendix 1. In total, discussions were held with 38 interviewees (Kenya: n = 19, Tanzania: n = 19). ***The key interviews that informed this research include those with the pioneering entrepreneurs of the off-grid solar photovoltaics sector***. Overall, the interviewees typically had several years of expertise either in the energy sector, innovation collaboration or on entrepreneurship, consisting of both junior and senior staff, local and foreign actors/experts, and were more often male than female. The interviews were conducted primarily face-to-face and occasionally by using skype, and typically lasted from a half an hour to over an hour. The interviews were

[10] In addition, a third futures workshop was organised in Nairobi October 18, 2017. However, the transformative scenarios and the role of solar energy startups was not at the focus of this workshop.

recorded, notes were taken or both. The interview questions typically concerned the role of renewable energy in the country, including the solar PV sector, and future expectations, and were adapted in consideration of the expertise and role of the actor. Related participant observation culminated into participation in the ***Energy & Environment Partnership (EEP) Knowledge Exchange Seminar*** in Kampala, Uganda 11 October 2017 (Appendix 2). In the seminar, project researcher Joni Karjalainen (FFRC) organized a roundtable on the theme of "Innovation in the Business Model"[11].

Desk-based work then followed, and has complemented the initial efforts. The ***collection of industry reports, project reports, donor databases, and media coverage,*** as so called "grey literature", has been conducted throughout the research, particularly focusing on the developments in the innovation and renewable energy space in Kenya and Tanzania. In light of the rapid expansion of the innovation activities, desk-based work was particularly helpful in the identification of multiple entrepreneurs, startups as well as established solar companies. The actual research, as illustrated in this working paper, then focused on the innovation activities of solar energy startups.

Case study companies

As radical startups are the central actors in the chosen scenario to be tested, the research framework was narrowed down to the study of firms, the entrepreneurs behind them, and especially the radical startups (as well as small-and-medium sized enterprises) that exist and operate in the countries. It should be noted that a large number of companies dealing with solar products and services actually operate in the countries, many in both markets. A non-exhaustive list is provided in Appendix 3. During the desk-based research, information on the background, history, business model, investment, partners, and proposed social impact of the solar companies was collected. ***In Section 4 of this working paper, the histories and operating models of 9 entrepreneurs and firms in Kenya and Tanzania are provided for the reader.*** The case study descriptions are mainly drawn from both desk-based research, including news stories and company websites, but also include interviews with some of these companies.

It is interesting that in spite of a considerable policy attention and belief in innovative companies leading the way for a sustainable future, owing to the novel principles and technologies at their disposal, there has been limited research about the impact of such a

[11] The EEP Knowledge Exchange Forum organised since 2014 is an active event of discussions, sharing of experiences and networking in the renewable energy and energy efficiency sector. http://eepafrica.org/invitation-to-6th-eep-knowledge-exchange-forum-in-kampala-uganda/

mode of development. This applies also to the clean energy sector where there is surprisingly little analysis of what the actions of 'green entrepreneurs' mean against broader 'ideals' (O'Neill and Gibbs 2016). Arguably, more detailed enquiries are required, not least to ensure that the private sector is conscious of its role as a 'development agent' (Newell and Frynas 2007; see also Blowfield and Dolan 2014), but also to understand previously unstudied impacts of this mission.

One important criteria that influenced the selection of these particular companies was the aspect of pioneering. Business literature has been interested in entrepreneurs and companies as market pioneers (Covin et al. 2000). Entrepreneurs themselves are often perceived as opportunity focussed, determined to create new processes, innovate new products and services, open new markets or organize new industries (whom followers can then freely imitate) (Brush 2008; Wagner and Zahler 2015). ***The aspect of pioneering, acting as a forerunner, is of particular interest in the field of futures studies from the aspect of crafting and pursuing alternative futures***. If entrepreneurs as pioneers determinately look for opportunities to drive change outside the mainstream, they are also consciously building activities on the goals that they see meaningful, aspiring to realize a future that they desire.

In a nutshell, ***this working paper explores how the initial Radical Startups 2050 scenario relates to Kenya and Tanzania, two countries which have been identified as pioneers in the solar energy sector.*** What is more, a focus on startups, which themselves are pioneering actors, aligns with efforts to understand scenario actors. Understanding scenario actors is important because it looks for answers on 'how change could take place' and 'who could change' (Wangel 2011a, 2011b). The next chapter presents the original scenario narrative.

2. RADICAL STARTUPS 2050 SCENARIO

Figure 2. Radical startups 2050 (Image: http://www.e-architect.co.uk/images/jpgs/barcelona/fab_lab_house_p200710_ag8.jpg)

In the Radical Startups scenario[12] [13], peer-to-peer is realised in startup companies and their networks. Economy and society are driven by startups known for their culture, values, and bold aspirations. Startups are tribes of affinity and places for self-expression and self-organisation rather than companies in the traditional sense. They work to change society and the environment for the better, at least from their perspective. Environmental problems are solved foremost by businesses, which are also advocates of new, deep-ecologically oriented lifestyles.

[12] The scenario narrative here is described as in the original "Radical Transformation in a Distributed Society – Neo-Carbon Energy Scenarios 2050" report (Heinonen et al. 2016). The footnotes referring to the various identified weak signals have been removed for editorial reasons, but are included in full here: https://www.utu.fi/fi/yksikot/ffrc/tutkimus/hankkeet/Documents/NeoCarbon-WP1-1-2016.pdf

[13] The final scenarios are provided in a subsequent book (Heinonen et al. 2017b), which is available at: https://www.utu.fi/fi/yksikot/ffrc/julkaisut/e-tutu/Documents/eBook_10-2017.pdf

Key global trends in the present:

- **In a networked economy small and medium enterprises are increasingly responsible for creating value and growth. Innovations often stem from startup enterprises.**
- **Consumers' needs are diversifying and fragmenting, and startups can often supply these niche markets better than large, rigid enterprises.**
- **Startups are vanguards of a new working culture, where expressing oneself through work becomes an important motivator – and possibly a threat to occupational well-being.**
- ***In an ecological transition where everything is to be transformed as ecologically smart, diverse ecosystems of startups are needed to make the change possible.***

Some weak signals in the present:

- ***Firms are increasingly emphasizing collaboration over competition, establishing so called business ecosystems where information is exchanged in an open manner***
- ***Open source is spreading outside software businesses – in the form of e.g. open patents***
- ***People are increasingly working as freelancers. This may indicate a change in work ethos, where person's identity is hard to distinguish from his or her work identity***
- ***Many startups are emphasizing other than mere economic values, driven by ethics***

Company names like SitAtMyDesk, Chipps and Timber are omnipresent – startups and their open networks reign in economy. Especially three factors have contributed to their rise, which has outmanoeuvred technology giants like Amazon, Apple, Google, and Facebook. First, many technology companies, especially Google and Facebook, reached an almost-monopoly status already in the 2010's, and legislatives forced them to open their data to public use. This opened vast possibilities for smaller companies to develop products and services from the data. Second, both consumer demand and workers' preferences shifted to highly specialised niche products and intimate workplaces. Technology giants could not meet this demand as well as smaller and more nimble companies. Gradually innovative startups claimed markets from their big brother competitors. Thirdly, the decentralised renewable energy system provides clean energy with low costs, and this levels the playing field for small ventures.

Moreover, from the 2030's onwards, automation and ubiquitous artificial intelligences, powered by renewable energy, have taken care of a major part in production and economic value-creation. Little by little this has transformed notions of work and economy, and the role and functions of companies, especially startup enterprises. When "original" startups aimed for rapid, exponential growth, today's startups operate in a world of economic abundance and thus have more moderate growth expectations. **Startups are not mainly economic actors, but create first and foremost cultural and social value**. As they did in previous times, they still seek to disrupt society and social practices, but not primarily with the aim for new possibilities for revenue. **The "valuation" of startups is not based on their productivity and expectations of future profits, but on their reputation and the shared cultural and social value they create**.

However, creating economic value is still important to some extent. **Economy is a hybrid of monetary and sharing economy, and the production of both exchange and use value**. Scarce products and services are still exchanged through money, but the abundant ones are shared more or less freely or with very low prices. Startups also still focus on offering new products and services, often for consumer niches. However, the novelties are not so much products sold on markets, but **new ideas, values, cultural meanings, experiences, and practices**. **Startups are "radical" because they constantly seek to renew culture and forms of social interaction**. Their success and "radicality" is measured by the novelty, effectiveness, and attractiveness of their ideas.

Another significant change has been the mainstreaming of open networks and the principles of open-source. In the early 2000s, during the first startup boom, successful startups were eventually either bought by big, established companies or became established companies themselves. As the startup ecosystem matured, startups were able to stand on their own. An essential factor in this emerging ecosystem was open cooperation between startups, along the lines of open-source principles.

Startups became increasingly powerful, and especially by the end of 2020's began to shape the values, culture and social relations of societies. During this gradual "startup revolution", the whole society became organized as horizontal peer-to-peer networks. Startups acted as promoters of peer-to-peer culture and practices, and were often the organising hubs around which peer-to-peer communities began to take form.

Due to their openness, startups became community-like. In today's startups hierarchies are very flat and workers have lots of autonomy. Startups collectives have leveraged the Silicon Valley ethos of individual emancipation, creativity, communalism and networked practices

as society's mainstream. "Disruption" has become an all-encompassing feature in society, affecting everything from politics to personal identities.

Startups dissolve the barriers between companies and the rest of society

Instead of traditional, hierarchical and bureaucratic firms aiming for mass-markets, startups embrace organisational egalitarianism and niche-markets. Working in startups is often leisure-like, as workers are encouraged to bring their hobbies and free-time interests to work. Startups can be seen as **communities that create business out of their way of life**. In this way they are better able to create more compelling and innovative products and services. Small enterprises have become the places where people can express themselves best and do things that are meaningful to them. **As hotspots of human and social capital startups can cultivate and enhance human potentials.** This is not without its problems, though, as work and corporate interests easily claims too big a role in people's lives.

As it merged work with hobbies, the new corporate culture began to evaporate the division between companies and the rest of society by the end of 2020. Consumers demanded moral, aesthetic and value-related integrity from companies, just as they expected these virtues from each other. *Authenticity* became the guiding value for the new breed of startups. These new companies firmly stood behind what they believed in, instead of trying to please as many customers as possible. In many ways, today's startups resemble protest and citizen movements of the past. "**Doing good rather than doing well**" is the slogan for many startup entrepreneurs.

The step away from narrow economics has sped up the adoption of new, holistic wellbeing metrics. Progress is measured especially by **The Happy Planet Index (HPI)** instead of Gross Domestic Product (GDP). HPI takes into account not only human well-being but also environmental impacts. The index was introduced by the New Economics Foundation (NEF) in July 2006. Since its introduction, the index has been modified to include political freedom, human rights and labour rights.

Postnormality, hacker ethos and the open source business model

Startups being a major driving force, society has become unstable and constantly changing – society can be described as *post-normal,* defined by chaos, complexity and contradictions. In part the radicality of startups stems from this very uncertainty. Radical means something that affects the root causes of and basic assumptions on phenomena. With their forward-looking, change-driven and futures-oriented mindsets, startups have created a society that is in a constant state of flux, with few stable, sustaining structures.

Their "business" is in large part based on creating *expectations of a wholly new kind of future* (and related business/reputation opportunities), and in this way they keep society in constant change.

Change and disruption are being promoted by the hacker ethos of startup culture. At the heart of the hacker ethos is the aspiration to understand the workings of complex systems – whether they are computers, programming code, politics etc. – and thus being able to tinker, modify and improve them. This helps startups in setting established structures, practices and cognitive processes in motion, and is an essential driver of innovations and productivity.

Another pivotal part of the startup ecosystem are principles and practices of open source. Because there are usually a lot of people involved in open source projects, open source projects change constantly, and thus contribute to the changes in wider society. Open source began to realize its potential in 2010's, when companies such as Tesla, LinkedIn, Facebook and Microsoft adopted it as a part of their business and development models. Little by little, open source spread from the software world to all industries. One of the forerunners in generalized open source was Assembly, a startup which provided a platform for individuals to offer their expertise for open development projects. As a return for their contributions, individuals got a share of the future profits of the projects they were involved in.

Freelance economy and the new precariat

In society of constant change, precarity has become the new normal. Roughly a half of workers are employed by companies and other organisations, the other half are freelancers and contractors. This means that fewer and fewer have the luxury of services, perks and the community provided by organisations. To deal with precarity, new platforms pair talents with businesses and thus aid freelancers in getting a steady income. Co-working spaces provide freelancers with community and with support and resources. Freelancers often establish their own **micro businesses**, employing only themselves or at maximum 10 others. Because of the dense network of highly specialised niche startups, the business ecosystem is vibrant.

New ways of coping with constant uncertainty and mitigating its effects have been developed to replace schemes advocated by labour unions[14]. The ecosystem of

[14] Some of these coping strategies were discussed in "The Fuzzy Futures of Neo-Carbon Work", the 2nd Futures Clinique of the Neo-Carbon Energy project, which was organised in April 2016 in Helsinki.

microbusinesses is kept vitalized by **micro loans** and crowdfunding. Everyone is also entitled to universal basic income. Thus establishing a new business or production line is relatively easy. For entrepreneurs and employees, income often comes from a broad palette of sources. This requires ample **networking skills**. Sharing economy makes the use of resources more efficient and affordable. People have also gotten used to uncertainty, and temporary unemployment or a failed business is not a big deal. Perhaps the most important thing in terms of coping with precarity, however, is that **the costs of living and production are low due to highly efficient energy and production system, augmented and enhanced by robots and artificial intelligences**.

Some startups manage the challenges of uncertainty and constant change through **projects of long time-scales**. As the success of startups is based on expectations of a "different kind of future", the most ambitious startups feed on expectations of very long time-scales – such as Jeff Bezos' "The Clock", an atomic clock designed to last for millennia. Investors have a central role in ensuring longer time-scales than a few quarters. Individual companies may come and go, but investors committed to long-term efforts make sure the projects of long time-scales don't fall with failing companies.

Investment funds in general are crucial in creating stability in the fluxing environment. **Traditional energy companies of the early 2000's have often adopted the role of investors.** Funding companies have become platforms of sorts, managing allegiances, connections and information streams between individual companies. Angel investors have a much broader role than only providing investments: they are mentor-like figures, taking part in designing business plans, offering valuable information, et cetera.

Deep ecology as a driver of societal change

By now, 2050, not only have ecological lifestyles become widespread, but most citizens have adopted the worldview of deep ecology. The wide spread of veganism on the 2010's was one of the first weak signals of deep ecology. Deep ecology is characterized by its advocacy of the inherent worth of living beings regardless of their instrumental utility to human needs. Deep ecology argues that the natural world is a subtle balance of complex inter-relationships in which the existence of organisms is dependent on the existence of other organisms within ecosystems.

Startups were among the original vanguards of deep ecological thinking. At first a marketing gimmick to gain credibility, authenticity and rigorous moral standing, deep ecology became little by little an integral part of the startup culture in the 2030s. Because startups are intertwined with the civil society and embrace openness in all aspects,

practices and cultures developed in them scale up efficiently. Startups aren't withholding and guarding their social innovations, but try to spread them as wide as possible.

Startups of deep ecology are, however, only a symptom of deeper undercurrents in the zeitgeist. Especially from the 2010s onwards, many craved for deeper meaning in life and for new kind of spirituality. With the rising consciousness of the ecological crisis, ideas related to deep ecology began to gain ground. People felt they could be a part of something bigger than themselves by deeply engaging with nature and seeing nature as inherently valuable. This tendency was further enhanced by the constant communication with other people, which eroded the idea of bounded, autonomous individuals and emphasised networks and communities instead.

Deep ecological values have changed practices throughout society. **Environmental externalities have been integrated into prices**. **This has led to a revolt in markets as investments are flowing to eco-savvy startups**. Earlier in history, consumers chose environmentally sound products and services **only if they were practical and cheap enough; ecology was not the first, second or even the third criteria for choosing a product over another**. Now ecological sustainability is self-evidently the most important criteria of choosing a product instead of another.

Figure 3. Ski slope at Amager Bakke, a waste-to-power incinerator.

Deep ecology affects everything, from business plans to aesthetics. For the new entrepreneurial generation, carbon neutrality emerged as a business standard. Design-oriented startups mainstreamed a new ecologically-savvy visual culture. Energy plants are

designed as architecturally distinguished sites. One of the forerunners of the new visual culture in energy sector was Amager Bakke, waste-to-power incinerator plant in Copenhagen (Figure 3). The incinerator has a ski slope, its surface does not resemble conventional power plants, and as a curious detail, its chimney will blow a smoke ring every time a tonne of carbon dioxide has been released – a reminder to local residents of keep their extensive carbon footprint to a minimum.

Instead of a global scale, most startups operate locally and regionally. They provide for local needs and solve environmental problems on-site. This is, too, a consequence of new ecological consciousness, as people try to live as locally as possible. As medium-scale political entities, cities are the central political, cultural and economic units in society. Their success depends on how well they succeed in attracting innovative companies. Cities are relatively independent from national regulations. Most cities specialize in particular issues so that some attract businesses from the creative economy, others from the energy sector etc.

A world of neo-carbon startups

The gradual efficiency gains of renewable energy technologies continued throughout early and the mid-21st Century. But where a major frontier of competition for radical startups emerged was the energy storage sector. New companies were pushing with battery technologies, neo-carbon storage solutions, as well as artificial photosynthesis and energy harvesting. The storage market expanded, costs declined and returns increased. This created opportunities for further specialization and also spun off a related services sector, providing items such as customizable storages. In 2050, the storage solutions link across numerous value-chains and clusters where firms interact and generate combined increasing returns.

Penetration of small-scale, local energy solutions are driven by startups' rationalization with characteristics of local energy resources. The energy system is highly decentralised and consumers as prosumers self-produce a major part of their energy. Open data and advancements in industrial ecosystems support utilization of waste streams also in small scale companies. Ubiquitous ICT, advanced automation and smart pricing enable significant volumes of real-time energy trade even between small-scale consumers and producers.

As production is mainly local and regional, and as digitalised "smart solutions" are in wide use, the demands for transport of goods and people have reduced compared to the first decades of 2000. 3D printers have massively entered households, industries, and other

sectors, allowing for a hyperlocal, specialised and efficient production. Smart city concepts enable modular shift of mobility towards public transport, walking and cycling.

Questions emerging from the scenario narrative:

- *What explains the emergence and appeal of startup thinking?*

- *What kinds of capabilities are required from startup companies to perform innovative activities? Why and how would startups endorse the values of peer-to-peer, open collaboration and deep ecological awareness?*

- *What particularities do solar energy startups have compared to other types of startups? What kinds of obstacles might startups or small-and-medium-sized enterprises have to face in order to get where they hope to aim for? What prevents them from stagnating or failing?*

- *How can, and should, the objectives of pioneering and innovative startup companies be supported by the public sector? How can a conducive innovation environment and culture be nurtured?*

- *How does the scenario narrative, with its numerous weak signals and envisioned developments, relate to the startup activities and innovation environment in the case study countries, Kenya and Tanzania?*

In the next section, we begin the scenario-testing by providing a short historical overview on the evolution of the solar photovoltaics niche and markets in Kenya and Tanzania.

3. HISTORY OF SOLAR ENERGY IN KENYA AND TANZANIA

The previous section provided the initial scenario narrative. In turn, this section illustrates a brief history of solar energy in Kenya and Tanzania as a factual contrast to the scenario narrative. It has to be remembered that numerous reasons have been identified that for a considerable time held back the diffusion of solar energy – globally and in East Africa. This section illustrates how still fairly recently, solar energy was primarily perceived as a technology topic, approached from a technical point of view. Only gradually, after persistent efforts during an initial period of over 25-30 years by numerous actors who have been involved in the build-up of the off-grid solar photovoltaics niche in Kenya and Tanzania, a viable market has started to emerge. This section draws heavily on Byrne (2011), as well as Ockwell and Byrne (2016) on Kenya, and Byrne (2013) on Tanzania.

Kenya – promoting the uptake of solar energy since the 1980s

The story of solar photovoltaics in Kenya has been rather well documented, and is typically stated to begin around the 1980s. The concept of 'a solar home system' seems to have been created accidentally around 1984, when a solar photovoltaic lighting system was installed in Karamugi Harambee Secondary School, which is located on the slopes of Mount Kenya[15]. ***Once the installation was complete, it is said, the Headmaster and teachers wanted lighting systems also for their homes*** (Jacobson 2004). This experience stimulated two Americans who were involved in the Karamugi installation – Mark Hankins and Harold Burris – to explore further opportunities with solar photovoltaics (Ockwell and Byrne 2016).

Next, Burris started a solar home systems business in the area near the school, while Hankins looked to get donor-support for other school installations. USAID, the United States development agency, which traditionally has had a strong presence in Kenya, supported installations in three more schools. Again, it was found that people wanted systems in their homes. By 1987, it is estimated that 500 solar home systems were sold through the market, most by Burris' company, and others by the suppliers in Nairobi (Hankins 1990).

[15] Located north of Nairobi, between Embu and Meru, these days in Tharaka Nithi County.

Between the time that Hankins left Kenya in 1987 and returned in 1990, he discovered that the market had grown to an estimated 4 000 solar home systems (Hankins 1990). He soon ***started his own business – Energy Alternatives Africa (EAA) – and began looking to international donors for funds to implement various projects he thought might help strengthen the development of a nascent market*** (Byrne 2011). EAA often successfully won such grant money from donors, and went on to implement a wide range of projects with a range of actors in Kenya, creating interventions in the various 'socio-technical fronts' (Ockwell and Byrne 2016) of this evolving niche. These included advocating for favourable energy policy, building actor-networks, creating and collectivising expectations amongst solar PV actors, experiments with technologies and micro-finance models, helping to formulate PV standards and regulations, learning through market surveys, publishing reports and market information, and training PV technicians. Meanwhile, the solar home systems market continued to grow.

By the late 1990s, powerful development actors had become interested. Starting in 1997, for example, ***the International Finance Corporation (IFC)[16] tried unsuccessfully to implement a USD 5 million market transformation programme*** (IFC 2007). In spite of initial failure, ***they were more successful 10 years later when they began implementing the Lighting Africa project*** to promote solar PV lanterns (Lighting Africa 2008). The solar lantern market has experienced significant growth, and ***continues to attract foreign players as well as to inspire technical and business innovations*** (Rolffs, Ockwell, and Byrne 2015). A solar PV module assembly plant – a joint venture between a Dutch investor and a Kenyan holding company – began operations in Naivasha in 2011, and this supplies PV modules to the entire East African region (Ockwell and Byrne 2016). The perception of the market has begun to change, as both solar lanterns and solar home systems are now flourishing and increasingly widespread. And, finally, Kenya has become a popular target for solar mini-grid projects (Cloke, Mohr, and Brown 2017; Gollwitzer 2017). Micro-Grid operator PowerHive was reported as the first private sector utility to sell electricity to the Kenyan public in 2016[17][18].

[16] International Finance Corporation is the finance and advisory arm of the World Bank, which encourages private-sector development in developing countries.

[17] https://www.cio.co.ke/news/main-story/powerhives-kenyas-first-private-utility-to-sell-electricity/

[18] A number of private operators, such as PowerHive, PowerGen, SolarJoule and SteamaCo, are running micro-grids in Kenya's small, densely populated town centres.

Tanzania – donor-facilitated efforts to develop actor-networks

It is documented that some discussion of solar PV had taken place in Tanzania in the late 1970s (UTAFITI 1978), but there was no substantial effort to introduce the technology until EAA (see above) and the Tanzanian non-governmental organisation called KARADEA won funding to establish a solar training facility in Karagwe in the year 1993 (Kasaizi and Hankins 1992/3; KSTF 2009). This KARADEA Solar Training Facility (KSTF) became an important source of technician training in the East African region. Perhaps 200 technicians received training there over the ensuing ten years or so along with many others who would occupy managerial roles in PV projects across the East African region (Byrne 2011). Interestingly, ***almost no Tanzanian technicians who were trained at KSTF managed to start PV businesses in their country. There was little market activity and practically no funding to help them get started***. EAA, in its part, would only occasionally install community service systems in Tanzania.

In the late 1990s, finally, when the Tanzania Traditional Energy and Environment Development Organisation (TaTEDO), based in Dar es Salaam, won funding from international donors to implement a large solar photovoltaics project, the Tanzanian niche began to evolve (Byrne 2011). ***Its first training workshop, in Dar es Salaam in May 2000, led to the creation of the Tanzania Solar Energy Association (TASEA)***[19]. Membership of TASEA quickly grew as TaTEDO moved to other parts of Tanzania to run further training workshops (e.g. TaTEDO 2000). TaTEDO began to emerge as an important actor in the Tanzanian niche. One important factor was its involvement with Umeme Jua, a Dutch-Tanzanian joint venture, that began to develop a marketing model in the country from around 2001 (Byrne 2011). Partially funded by the Dutch government, Umeme Jua used this support to help it build a network of solar photovoltaics dealers and technicians in several parts of Tanzania.

Simultaneously, four other large projects got underway between 2004 and 2006 in different parts of the country, although each funded by a different donor[20], implementing otherwise fairly similar approaches. ***These projects built extensive actor-networks, collaborated in advocating successfully for the removal of tax on PV equipment, experimented with different solar home systems configurations, raised awareness of solar home systems amongst Tanzanians, solved problems and shared their lessons learned with each other, tested micro-finance models, trained PV technicians, and so on*** (TASEA 2005, Byrne 2011).

[19] This later changed its name to the Tanzania Renewable Energy Association, TAREA (TAREA 2011).
[20] In 2004, UNDP-GEF funded a project in Mwanza District; in 2005, UNEP and Swedish International Development Cooperation Agency - Sida started a project each in different parts of the country; and between 2004 and 2006, the Free Energy Foundation (FEF) piloted its own marketing project (URT et al. 2003; Felten 2008; Byrne 2011).

Over the course of just a few years, the PV market in Tanzania grew from almost nothing to a value of USD 2 million or more in 2008, half of which passed through Umeme Jua. The market has continued its rapid growth. Solar lanterns have been introduced (initially through the action of SolarAid), and solar mini-grids are being installed at an impressive rate.

An evolving off-grid solar market

The evolution of the off-grid solar market can be summarized by distinguishing different stages of market evolution. An industry report (REN 21 2016) distinguishes and describes four stages for Kenya, as illustrated in Figure 4. As has been written above, the first solar photovoltaics pioneers started their activities in the 1980s. The following describes the process from the initial stages, followed by a gradual development of demand and distribution, into increasingly sophisticated business and service models. It has to be also remembered that the cost of solar photovoltaics technology at the time was far more expensive than today.

Figure 4. Overview of off-grid solar market development in Kenya, 1985 to 2016 (REN21 2016. Data: EAC Regional Status Report 2013)

During the 2000s, there have been focused and sustained efforts in product and market development. One factor that has helped a nascent industry to develop has been the exemption of value added tax (VAT) on all solar products (but not services) in Kenya and Tanzania, thanks to the advocacy by the solar niche actors. An ability to operate in a relatively conducive policy environment built confidence in the industry and niche actors, which subsequently has allowed them to make investments for future development, seek external support, and carry the mission of the companies forward. Before the 2010s, barriers to the adoption of solar photovoltaics still included at least: ***1) a financial barrier in terms of affordability, 2) organising service, which consists of a quality product, maintenance and warranty, and 3) lack of communication with the solar photovoltaics system***.

The niche nurturing efforts by Lighting Africa, a joint IFC-World Bank program to accelerate sustainable solutions to energy poverty, seems to have played an important role in the

growth in demand for so-called **'pico-solar products'**[21]. Pico-solar systems signify solar energy systems that can power products and services such as mobile phones, calculators, cameras, music players, and portable electronic devices, or charge batteries. Common to these pico-solar products is that they do not use high amounts of electricity. In areas that do not have electricity, they can prove to be extremely useful in powering a number of small businesses and to be used for other beneficial purposes. Interviews with the solar photovoltaics sector actors confirm that the fall in the price of solar photovoltaics in the 2010s has not gone unnoticed in Kenya and Tanzania, which likely has accelerated the market growth. The uptake of pico-solar products, again using Kenya as an example, is described in Figure 5.

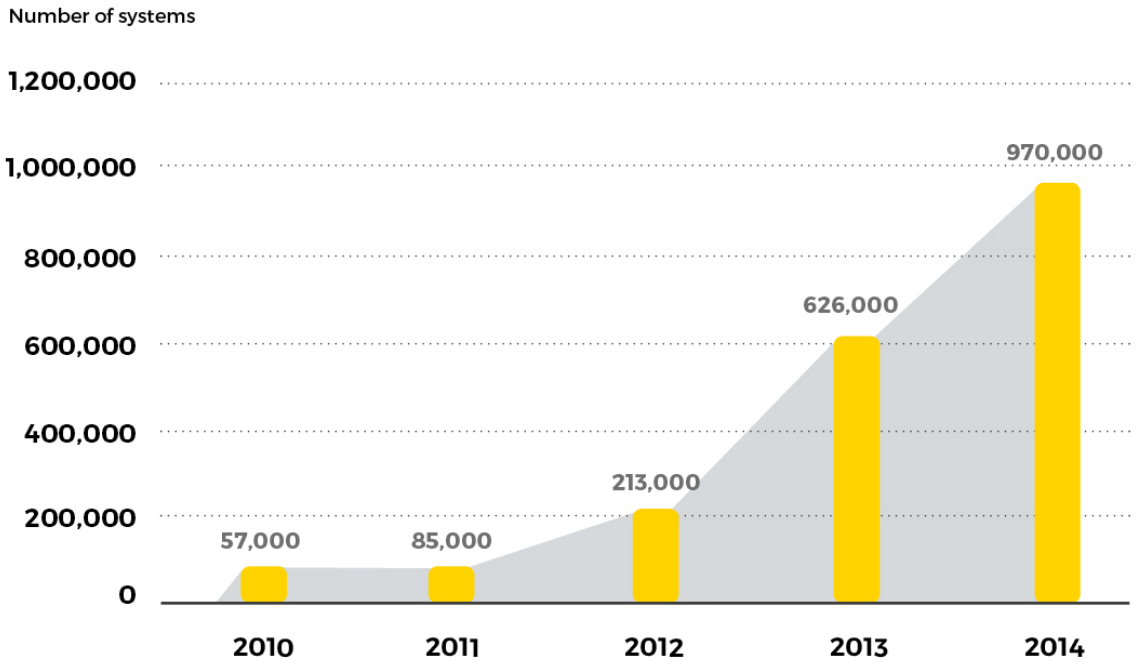

Figure 5. Reported sales of Lighting Global quality-verified pico solar products in Kenya 2010-2014 (REN 21 2016. Data: EAC Regional Status Report 2013, 48).

The introduction of the pay-as-you-go (PAYG) business model marks the most recent stage of the evolution (Rolffs et al. 2015). In a nutshell, ***the PAYG model provides a household with a solar system, and allows the user to pay for solar power on a "pay-as-you-go basis", just like they would do for charging credit and data to their mobile phones***. The primary aim of the solution is to replace household use of kerosene by clean, safe, and renewable power to families with a business model that achieves a cost at about half the cost of the kerosene, without any government subsidies or tariffs[22]. The payments typically take place through

[21] For recent updates on the work of the programme, see e.g. Lighting Africa (2018).
[22] An adoption of solar products or services in households does not necessarily mean that a full substitution effect away from kerosene is achieved.

mobile money, which is now used by the majority of citizens and businesses in Kenya and Tanzania. The evolution of mobile money, which is even integrated with international money and banking services, is well described in Onsongo and Schot (2017). Mobile money, which can be used with any standard mobile phone, including smartphones, allows users to make payments, transfer money and gives access to banking services, essentially enabling financial services even in the most remote and rural parts of the countries.

The emergence of an increasingly market-driven and private sector led approach coincides with a criticism of development aid, and a project-led approach to the diffusion of solar photovoltaics. Stark criticism outlines proven failures in certain aid or philantrophic projects, which justify themselves with 'lifting Africa from poverty' (Leber 2016). The philosophy in the market-driven model to technology adoption is that when people own a system, rather than being handed as "a gift", a product is valued and taken care of. For instance Mobisol, one of the leading solar companies in East Africa, states bluntly that "if you do not own your system, you do not take care of it". Nonetheless, development aid and numerous project-led efforts have over the years enabled important demonstration activities, expedited learning about related problems, and built up local expertise.

All in all, solar panels as products today are hardly a novelty in African countries, but what is noteworthy especially in Kenya and Tanzania as pioneering markets, are the problem-solving activities for improved service delivery, improved affordability and rates of adoption. ***Retrospectively, it may be speculated that without initial experimentation efforts led by civil society and through development cooperation, the present business models perhaps would never have surfaced[23].*** What is noteworthy is the pride taken by many of today's solar companies ***in their business model, positioning themselves as a social business, providing numerous social and environmental benefits.*** Solar energy is today well recognised to improve daily health conditions by eliminating indoor air pollution from kerosene; lighting for reading; reducing CO_2 emissions; and time-savings[24]. Similar developments are emerging also in other East African countries (BNEF and Lighting Global 2016; Bisaga et al. 2017). In sum, as argued by many of the companies, ***mobile technology has allowed the sector "to turn a development challenge into a business challenge"***. The next section turns to the private sector actors, which are presented as case studies.

[23] Furthermore, non-governmental organisations (NGOs), which have played a critical role in the early experimentation and development phase, continue to conduct important advocacy and awareness-raising activities.

[24] A social impact study in Kenya in 2014 claims that an individual saves time up to 2.3 hours per week that was previously spent on travelling in order to purchase kerosene or take a mobile phone for charging. http://www.azuri-technologies.com/what-we-do

4. CASE STUDIES

These case studies have mainly been described through a desk-based review and data available through public sources, and have been complemented by interviews with selected companies, to describe the evolution of the solar photovoltaics space in Kenya and Tanzania. An illustration of these businesses is used to provide some explanations about the drivers and innovations that are shaping the uptake of solar PV in the countries. In addition to the ones described here, several other companies operate in the solar PV space of these countries. The links to the company profiles are provided as footnotes for ease of access to the reader, and a more detailed list of the companies can be found as Appendix 3. When relying on self-proclaimed company information, the reader should remember to exercise certain criticism.

Solinc East Africa – manufacturing panels locally

Figure 6. Solinc, formerly known as Ubbink East Africa, is one of the few local manufacturers of solar photovoltaics. Photo: Solinc website.

"Engineered in Europe, manufactured in Kenya", states Solinc, based in Naivasha, Kenya, northwest of Nairobi[25]. Solinc manufactures solar panels of 20W to 250W, see: Figure 6. The company is also involved in the assembly of solar home kits that consist of a battery, phone charger and LED lights. In 2016, it announced its manufacturing capacity to be at 140 000

[25] www.solinc.co.ke; see also: http://www.ubbink.co.ke/

solar panels per year. The company states that its product range has expanded from solar panels into solar street lighting solutions as well as solar kits. In addition to Kenya, the company has presence in Tanzania and Uganda. In 2016, the company suggested that in Kenya, even in rural areas over 90% of shops already sell their solar product, and that they expect further growth in Tanzania, Uganda, Rwanda, Burundi, the Democratic Republic of Congo (DRC), and South Sudan.

Solinc, which was known as Ubbink East Africa until 2016, proudly states that it has trained its key factory staff in the Netherlands[26]. In a 2016 interview, Solinc's Managing Director Haijo Kuper emphasizes the depth of local involvement, and how out of over 100 people, he was the only 'expatriate'[27]. The company promises quality, service, and value for money, and ***has applied 'kaizen', a Japanese management philosophy that signifies continuous improvement and involvement of all its employees***. They are a member of a Germany-based industry network Centrotec Sustainable AG, under which several companies gather knowledge on "sustainable" solutions such as heating, ventilation, climate control technology, solar thermal, biomass, heat pump technology and co-generation.

In 2009, an initial investment of about $3 million for a joint venture between Dutch based Ubbink B.V. and Kenyan based Largo Investments took place to found Ubbink East Africa. It is noteworthy that Ubbink B.V. was founded in The Netherlands already as long ago as in 1896. ***Ubbink East Africa has been perceived as the first manufacturer of solar panels in the East and Central African region***. They have partnered with Chloride Solar, a battery manufacturer and solar panel distributor. In 2016, a name change was announced from Ubbink East Africa to Solinc East Africa, and the company became majority Kenyan-owned. The company sources components from China, India and Europe to manufacture in Kenya unlike most solar companies in the region, which typically operate by importing ready-made panels from China. Solinc's major competitors are Chinese manufacturers: "The competition is basically 90% Chinese", Kuper publicly stated in 2016[28].

M-KOPA Solar – Kenya's early solar pioneer

M-KOPA Solar (or M-KOPA), which was founded in 2011, sells solar power systems to low-income customers. For a person to become a customer, only a phone number and an ID

[26] https://sibkenya.com/sectors/finance/item/147-solinc
[27] https://www.howwemadeitinafrica.com/manufacturing-solar-panels-east-africa-rising-demand-challenges-remain/
[28] Ibid.

number are needed. M-KOPA Solar then provides a solar kit, with a two-year warranty. consisting of a solar panel, two LED bulbs, an LED flashlight, adaptors for mobile phone charging, a rechargeable radio, and an 8 Watt battery (promised to last at least four years). A control box that has a battery and a SIM card then communicates with the M-KOPA headquarters in Nairobi. A customer makes a down payment using M-Pesa mobile money, and the SIM card then sends a signal that activates the panel-powered battery. Through this communication link, M-KOPA can collect data, and tell when the sun is shining, whether a solar panel has been properly mounted or needs cleaning, for instance (see also: Karjalainen and Heinonen 2017).

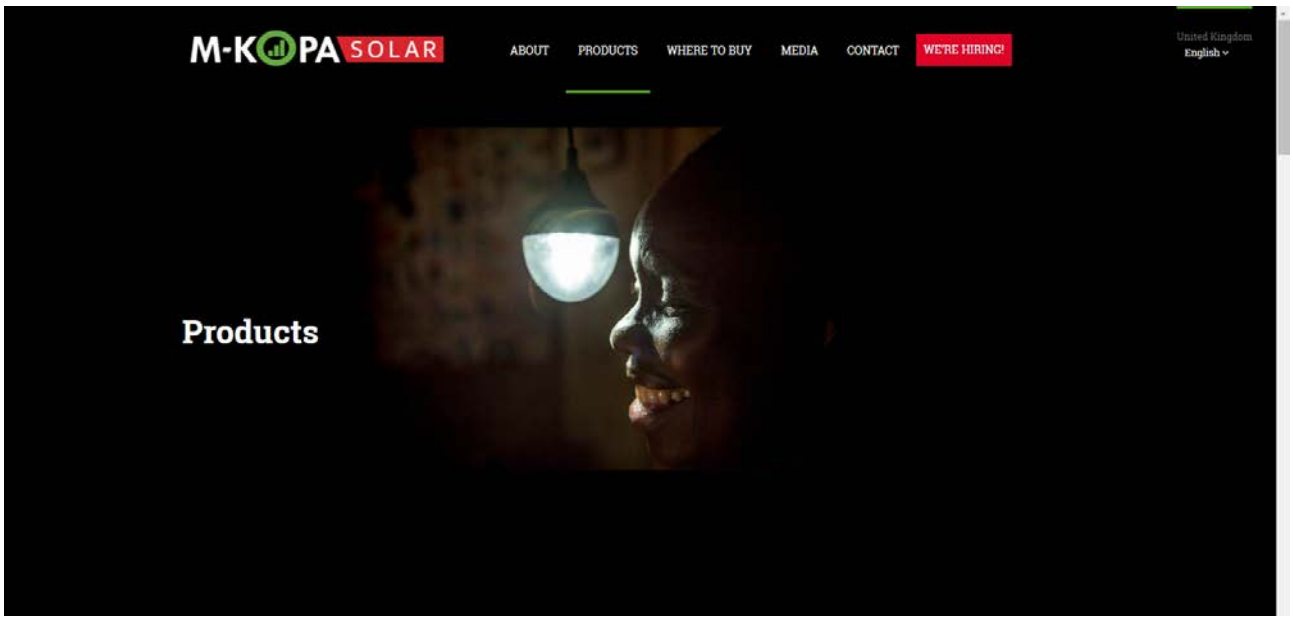

Figure 7. M-KOPA Solar products are sold in Kenya, Tanzania and Uganda. Photo: M-KOPA website.

The key innovation of M-KOPA's solution and business model is the financing model – a winner of numerous international awards and extensively covered in media (Faris 2015). Kopa means "to borrow" in Swahili language. The company has stated that it actually considers itself a finance company, giving the customers collateral and a line of credit. In the financing model, a customer pays only an equivalent of USD 35 upfront, after which (s)he continues to make daily payments in instalments of around 0.45cnt during a sustained period of 12 months. After this time period, the customer becomes the owner of the system. In 2015, it was reported that the repayment rate for the solar system was as high as 93 percent and for secondary products at 98 percent.

In 2009, Jesse Moore and Nick Hughes, left their telecommunications jobs at GSMA Development Fund and Vodafone, respectively, and with banker and micro-finance expert Chad Larson set up M-KOPA Solar. In its inception stage, the company performed extensive user surveys to develop the business model to overcome the high initial cost of solar energy,

a long-standing industry problem. The growth of the company has been remarkable. Since starting operations in 2012, by the end of 2014, M-KOPA provided power to more than 140 000 households in East Africa, in 2015 to 250,000 and in early 2017 already to 400 000 customers. By May 2017, M-KOPA stated to have connected over 500 000 homes to affordable solar power, with 500 new homes being added every day. One of M-KOPA's assets has been its technical, distribution and marketing partnership with Kenya's telecommunications giant Safaricom (initiated by Vodafone)[29]. Its investors include aid agencies, foundations, and venture capitalists.

These days, M-KOPA also provides aftersales through other "green" business models, such as a fuel-efficient stove (to spare charcoal), a bicycle (to cut transportation costs and to provide an ecological transport mode), a rainwater tank, loans to pay for school fees, as well as amenities for entertainment such as access to smartphones, or a 16 inch solar-powered television. The company later introduced a 20 Watt kit, which comes with an extra battery and a small digital television. In 2017, M-KOPA stated to employ about 1 000 people as full time staff, along with 1 500 sales agents on commission, in three East African countries: Kenya, Tanzania and Uganda. ***Several other companies have followed in M-KOPA's footsteps to enter the pay-as-you-go space in Kenya and neighbouring countries.*** The company has been quoted to be earning up to USD 20 million per year, and has since started to licence its technology in other markets, such as Ghana.

Helvetic Solar – Tanzanian entrepreneurial mindset

Helvetic Solar Contractors (HSC) is a Tanzanian solar energy company, which sells solar energy products – solar photovoltaic panels, solar water heaters, battery banks, generators, and back-up units (Figure 8). The company has an affordable Helvetic Solar Kit, targeted to cater for rural customers. They have installed small rooftop solar systems in Tanzania and neighbouring East African countries – Kenya, Uganda, Rwanda and Burundi. The company's clients are stated to include international aid agencies and non-governmental organisations, such as the United Nations and World Vision, as well as the Tanzanian Army. The HSC enterprise has grown into a multi-million dollar company Helvetic Group.

[29] In 2018, Safaricom was owned by Vodafone, the UK multinational in telecommunications, Vodacom, which is Vodafone's South African business, the Kenyan Treasury and retail investors.

Figure 8. Helvetic Solar, spearheaded by CEO Patrick Ngowi, has been one of the local pioneers in the solar energy business in Tanzania.

In 2012–2013, Helvetic Solar Contractors was named as the Fastest Growing and Number One Company in a survey of the Top 100 Mid-Sized Companies in Tanzania by KPMG East Africa. Patrick Ngowi, the CEO of Helvetic Solar Contractors, is a Tanzanian businessman and philanthropist, and has been viewed as one of Africa's pioneer solar energy entrepreneurs. ***Ngowi started his first business at the age of 15 with 50 USD, by selling Chinese-imported mobile phones in Tanzania***. Later, Ngowi had an opportunity to take university studies abroad in China. After graduation, at the age of 22 years, Ngowi then took a loan of 1 800 USD from his mother, and started to export solar products to Tanzania[30]. Ngowi set up a small shop in Arusha, Tanzania, which has since grown. Through solar projects, Ngowi and his companies state to have employed directly 250 people, and an additional over 1 000 people indirectly throughout East Africa. Ngowi was nominated for Africa's Young Person of the Year award by The Future Awards in 2013[31]. In 2016, Ngowi was also named as one of ten Sustainable Development Goals' (SDGs) pioneers by the United Nations Global Compact[32].

[30] https://www.forbes.com/sites/mfonobongnsehe/2013/08/01/the-young-african-millionaire-lighting-up-tanzania/
[31] http://thefutureafrica.com/awards/; The National Mirror, August 15, 2013, p.44-45
[32] https://www.unglobalcompact.org/sdgs/sdgpioneers/2016/patrick-ngowi

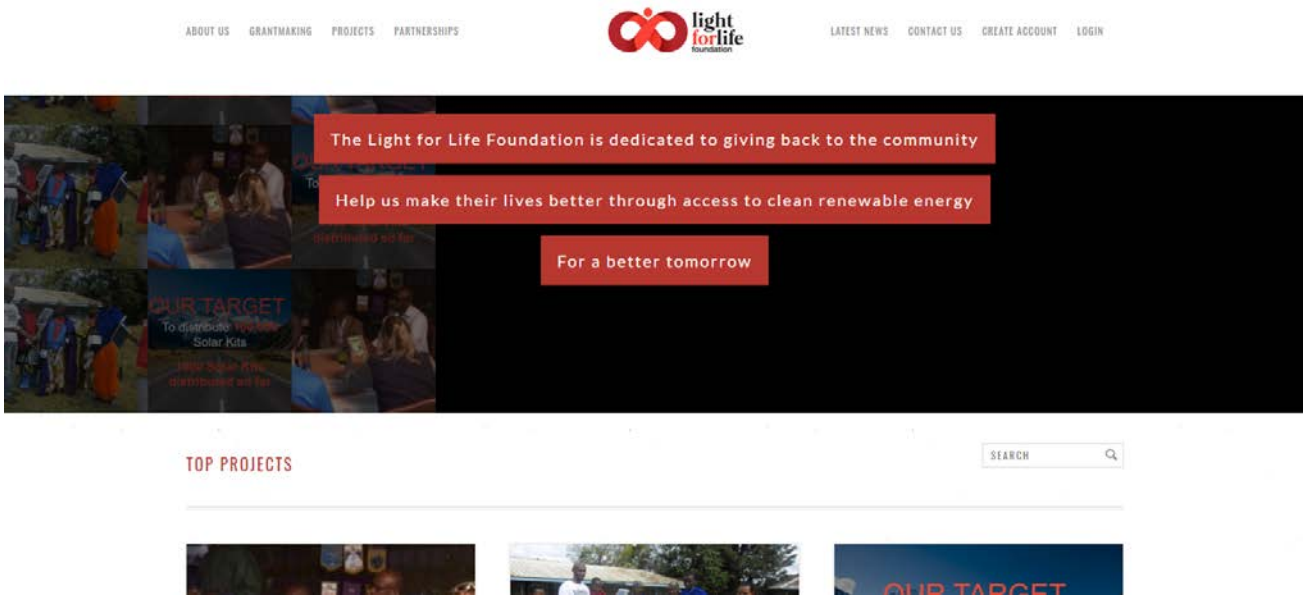

Figure 9. Light for Life Foundation partners with public, private and governmental sectors.

Ngowi is also the founder of Light For Life Foundation, which seeks to increase access to solar energy to women and young people in off-grid communities in Tanzania (Figure 9). Light For Life Foundation's Train-The-Trainer project has aimed to train individuals who will be empowered to go on and train other trainers and uplift their communities. Lower your Carbon Footprint! project aims to work with collaborators in Tanzania to lower their carbon footprints by installing solar water heating systems throughout Tanzanian health sectors. The Gift of Light initiative provides Helvetic Solar Kits to women in off-grid areas in Tanzania by donating solar kits. These initiatives have, among other things, sought to use crowdfunding in their uptake.

Solafrique – a micro-grid operator in Kenya

Solafrique is a company in Kenya, which specializes in the generation, transmission and distribution of electricity from solar micro grids through metering to businesses and home owners in the rural areas. The pilot program for this project is in Kibwezi town, Makueni County. Solafrique has focused in providing alternative energy sources to commercial users who supplement their grid supply with expensive diesel-generated electricity. Solafrique ***finances the micro-grid and enters into a leasing contract or power purchase agreement (PPA) with the user. The user has the option to purchase the micro-grid with Solafrique retained as the operations and maintenance partner***.

The company was started by Lois Gicheru, who mentions to have received an inspiration to found the company during her Bachelor's Degree in Finance and Accounting in Strathmore

University in Nairobi, and she also holds a Certificate in Supply Chain Sustainability from Rutgers University. At the time of her studies, Kenya had ratified Kyoto Protocol (in 2005) and discussions about carbon finance in Kenya were active. This led her to begin research into carbon credits and renewable energy technologies, while writing a research paper on the implementation of Environmental Accounting in Kenya. Gicheru states that ***"she had always known that she would found her own company, but she just did not know on what until that point"***[33]. Her business career would move through stages, founding first a wind energy company, and then powering events with solar energy. This led her to the solar industry, and Gicheru has described how she has had to learn about the industry in-depth, since she did not initially have an energy or technical background and how to combine the technical aspects with her business background.

Figure 10. On the left, Lois Gicheru, CEO of SolAfrique, being awarded in the 2nd Africa-EU Energy Partnership Stakeholder Forum in 2016 (Source: AEEP)

As described in an interview, ***she has been through "learning about watts, working in the energy field, working with the engineers in this field, how to calculate electricity, among many other key details"*** [34]. From these initial efforts, SolAfrique followed. The development of SolAfrique has also advanced through stages of pivoting, abandoning ideas that do not

[33] Research interview quote.
[34] https://www.strathmore.edu/news/alumni-spotlight-lois-gicheru-wins-best-entrepreneurs-award-africa-eu-energy-partnership/

work and tweaking further the company's business model. This has generated increasing interest from customers, investors, and potential partners, and is slowly establishing Solafrique as the energy partner for commercial users in Kenya.

Later on, Gicheru has continued to act in numerous roles in the energy sector, as a Future Energy Leader in the World Energy Council (WEC), Deputy Secretary of the WEC Kenya Member Committee, and was awarded as the Best Entrepreneur in the Young Scientists and Entrepreneurs competition of the 2016 Africa-EU Energy Partnership Stakeholder Forum for SolAfrique's community mini-grid model (Figure 10). She was recognised as an upcoming energy leader during President Obama's 2016 Mandela Washington Fellowship for Young African Leaders, and was a Women in Business Challenge finalist already in 2012[35].

Juabar – applying design principles in Dar es Salaam

Juabar, ('Jua' is Swahili for sunshine), is a company that builds and operates a network of solar charging kiosks in Tanzania. Juabar offers mobile phone charging facilities to people living in off-grid areas. The solar powered kiosks manufactured by the company are fitted with a solar photovoltaics system that can charge up to 20 phones at a time. The solar kiosks are then leased to local entrepreneurs, who offer electricity services to their communities.

Figure 11. Juabar core team at work in Dar es Salaam. Design thinking principles are important also when designing for a business model that caters to the needs of low-income customers.

The idea with the charging kiosk is that as a public kiosk, it attracts customers and provides a physical location for additional business opportunities, such as retail product distribution. A standard solar kiosk has a 50 Watt solar panel, twenty phone charging outlets (34 Ah of 12 V), and a battery storage.

[35] https://www.howwemadeitinafrica.com/how-lois-gicheru-is-moving-kenya-towards-green-energy/

The solar kiosks are also an entrepreneurship opportunity. 'Juapreneurs' pay a monthly fee of TSh 80 000 (equal to around 30 € or 35 USD) to operate the kiosks as franchisees, and are at liberty to set phone charging prices, with most ranging from TSh 300 to TSh 500 (0.10-0.20 € or USD 0.14-0.23) per phone. When the company was leasing out 30 kiosks to Tanzanians, Juabar's entrepreneurs were reported to be earning profits of between $75 and $150 per month. Juabar has used crowdfunding to increase the number of their solar kiosks.

"We are not really a technology company
- it is more about design and implementation."
- Olivia Nava, CEO, Juabar

Figure 12. Juapreneurs. Photo: Juabar.

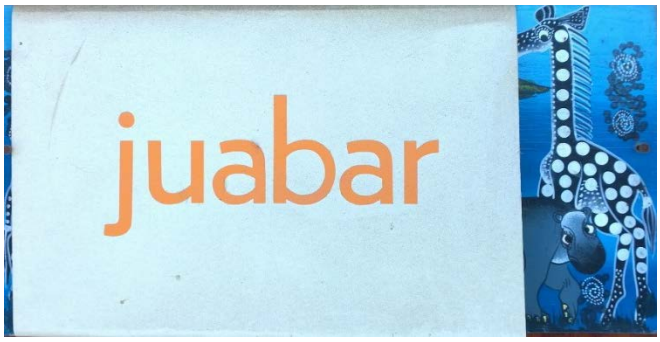

Figure 13. Juabar office is located in Dar es Salaam, Tanzania.

Juabar has described the evolution of their business and how the company is moving to so called Phase Two of their business in the following way: ***"We have started deploying solar-powered media hubs, we still offer phone charging but now offer TV, satellite and solar retail sales. This increases the business opportunity while setting the stage for local access to digital content through our TVs and soon internet."***[36] The company has also partnered with

[36] http://juabar.com/

Ubongo Kids, an educational cartoon to offer children dynamic learning opportunities at the media hubs. Juabar states to be responding to community members' request for digital content and information, while bridging a digital divide, aspiring to bring internet connectivity to rural off-grid Tanzania.

Mobisol – user-led approach and skills academy

Mobisol GmbH is a German-based solar company operating in Kenya, Rwanda and Tanzania. Mobisol combines solar photovoltaics with an affordable payment plan via mobile phone pay-as-you-go system. Client communication is conducted through confidential SMS messages. In a "rent to own" model, after a small initial investment by customers, the running costs are paid off in a 36-month instalment plan via mobile phone payments. ***Mobisol advocates for a comprehensive service plan for three years, which includes a free-of-charge service hotline, remote monitoring technology, and a used battery recycling programme.***

Figure 14. Mobisol Akademie is a training institution that serves local entrepreneurs, contractors and the company staff.

Mobisol has grown substantially since its launch and claims to be now East Africa's largest rent-to-own solar service provider, when measured by capacity installed. Mobisol's solar home systems are available in four sizes: 80, 100, 120 to 200 Wp (Watt peak). The actual system comes with a three-year warranty. The smallest option can light three rooms, powers a radio and charges four mobile phones per day. The largest system can power multiple lights, consumer appliances (e.g. a laptop or a television), a refrigerator and charges up to ten mobile phones simultaneously. Mobisol also offers a "Business out of a Box" feature, which enables entrepreneurs to set-up income generating activities such as barbershops

and phone charging stations.[37] According to media reports, in 2015, Mobisol had 185 permanent employees, and over 200 freelancers in Tanzania.

The Mobisol Akademie is ***a training institution for local entrepreneurs, contractors and the company staff, created to train and equip entrepreneurs working as technicians and sales staff and employees to service customers***[38]. Shortly after market entry in Rwanda in early 2014, the Mobisol Akademie in Nyamata, Rwanda, was established, and a second Akademie was founded in Arusha, Tanzania later that year. Mobisol states that its Akademies are to be established in every project country to provide each location with the same level of knowledge and compliance to the quality standards of the company. The trainings are based on international educational standards and carried out by trained local teaching staff.

In industry interviews, Mobisol founder Thomas Gottschalk says to have travelled the world and returned to his home in Germany with a question - if solar power can power Germany, why can it not power Africa?[39] The company has harnessed design thinking in its innovation process to identify customer needs. As a quickly grown startup, Mobisol has fostered technological solutions, used its employees' skills to improve their business model, while paying attention to their customers' needs and values. ***Mobisol has also invested in awareness creation in communities so that they recognize the benefit of their model***. Mobisol received the Ashden Award 2017, an annual reward for actors promoting sustainable energy solutions in Europe and the developing world[40].

In Tanzania, Mobisol's partners include mobile operator Vodacom and Kakute Ltd, a local company of solar installers, based in Arusha[41]. Mobisol also set office in Rwanda in 2014 and in two years, Mobisol Rwanda connected 10 000 customers. In early 2015, Mobisol reported that it had electrified 35 000 households in East Africa, with 3.5 MW in solar capacity estimated to save 15 500 tons/year of CO_2 emissions. In early 2017, Mobisol stated to have installed over 80 000 solar home systems, with a total capacity of 8.1MWp, in East Africa to provide access to electricity to around 400 000 people. Later in June 2017, Mobisol had installed over 85 000 solar home systems on households and businesses, enabling over 425 000 beneficiaries to access clean, affordable and reliable solar energy. In July 2017, Mobisol strengthened its capital base with a loan, which was granted up to 10 million € from

[37] http://www.plugintheworld.com/mobisol/wp-content/uploads/2014/05/PR-Inauguration-Mobisol-Akademie-Tanzania.pdf
[38] https://www.plugintheworld.com/mobisol/mobisol-akademie/
[39] http://energyaccess.org/news/recent-news/member-spotlight-mobisol/
[40] https://www.ashden.org/winners/mobisol
[41] http://kakute.org/?page_id=128

Finnfund, the Finnish Fund for Industrial Cooperation Ltd., following an already provided senior loan in 2016 to Mobisol's operations.[42] In October 2017, ***Mobisol joined hands with Baobab+, a major solar distributor in West Africa, to bring the PAYG solar model to Côte d'Ivoire (the Ivory Coast)***[43].

Devergy – micro-grids powering rural Tanzania

Devergy, based in Dar es Salaam, Tanzania, provides ***a village-sized energy micro-grid, as an easy to use, plug-and-play electrical service to households and businesses***. The system consists of solar panels, batteries and energy meters, and cables that interconnect the households in a micro-grid. At a basic level, the system can be used for mobile phone charging. The company can add capacity, if more power hungry appliances are used. This way, it can connect the users to lights and appliances such as radios, TVs and refrigerators. Devergy suggests that its system is designed in a way to require no user maintenance and is remotely monitored for faults to ensure the reliability and availability of the service.

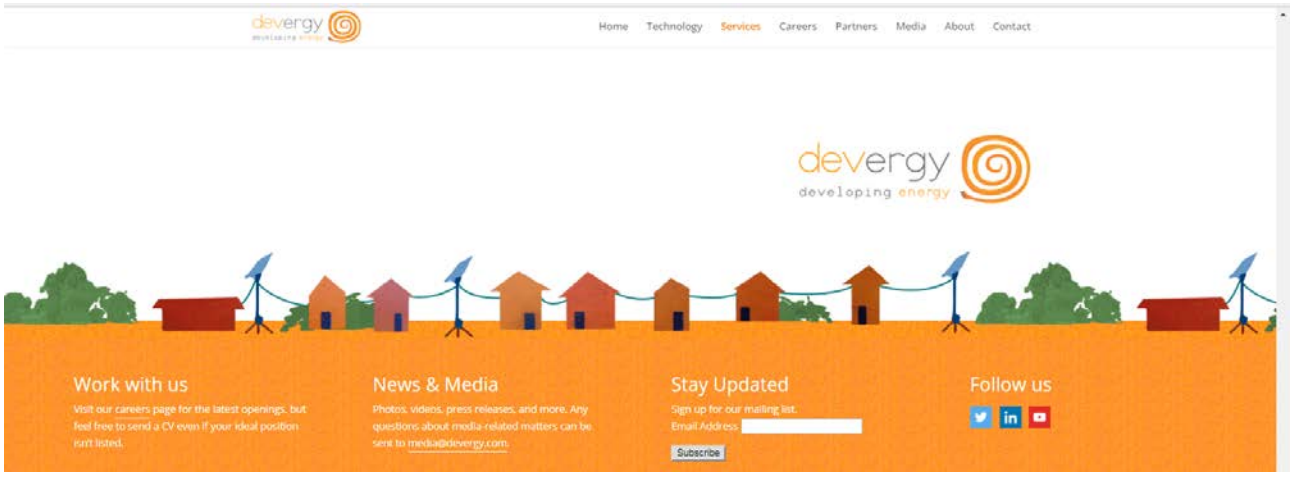

Figure 15. Devergy was founded in 2010 and began operations in 2012. Photo: Devergy website.

In Devergy's model, the installation cost of the micro-grid is largely covered by the company. An energy meter powers the household with a pay-per-use approach. ***Each user tops up their energy account by buying Devergy credit, which is purchased for the same value of mobile phones credit. The customers can pre-pay for their energy bundles via***

[42] https://www.pluginthe world.com/mobisol/2017/07/11/mobisol-secures-additional-substantial-senior-loan-facility-from-finnfund/
[43] https://www.pluginthe world.com/mobisol/2017/10/17/baobab-mobisol-join-hands-to-bring-the-payg-solar-revolution-to-cote-divoire/

mobile money or in person at the village store. The energy is priced lower than the cost of using kerosene for lighting or commercial phone charging. A small connection fee is collected at the time of the first connection. An online video describes the basic approach of the company's model[44].

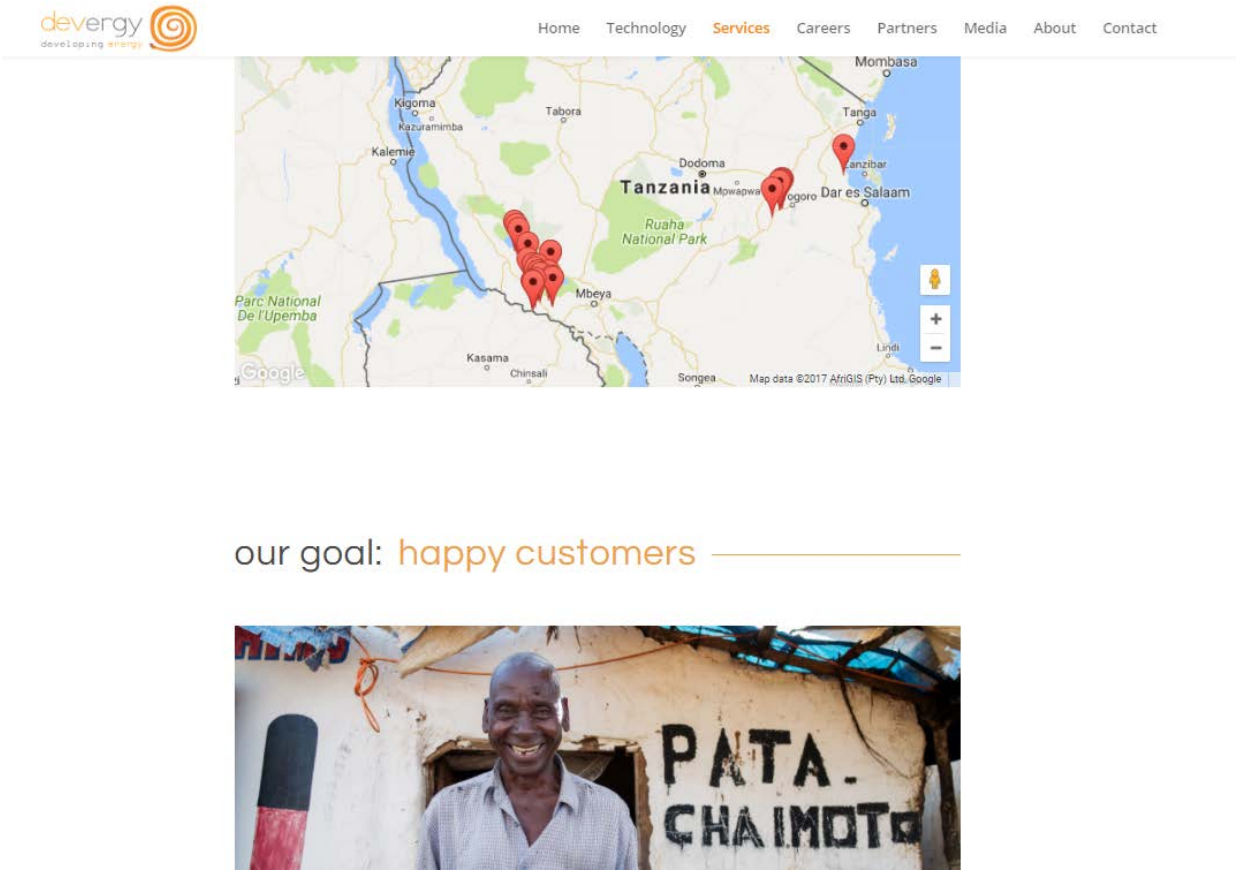

Figure 16. According to Devergy, in Tanzania only about 7% of the country's rural population has access to electricity via the national power grid. Photo: Devergy website.

Devergy reports its story to ***derive from dissatisfaction with purely project-driven aid-delivery models***, which they witnessed in the early 2000s. After graduating from university in 2007, Gianluca Cescon and his friend Fabio De Pascale were backpacking in Guyana. Making their way through small villages, they report to have come across a number of broken solar power projects[45]. The founders thought how financing allocated for development aid could be sustained, but re-channelled in a more sustainable way. The founders then report to have taken multiple trips to study the problem first-hand in African countries.

After an initial, small crowdfunding round in 2010, Gescon moved to Tanzania. The two other partners still continued in the jobs they held at the time. After completing a demonstration project, Devergy has continued to grow to extend operations also to other regions in

[44] http://vimeo.com/57079474
[45] http://tonyloyd.com/098-gianluca-cescon-devergy-solar-micro-smart-grids/

Tanzania. Devergy has received development aid funding and was selected as the Energy & Environment Partnership (EEP) Project of the Year 2014[46]. After starting with six villages in the Bagamoyo and Morogoro districts in Tanzania, with approximately 800 paying customers connected to the Devergy grids, the company has tested its model with two villages in Ghana.

Azuri Technologies – with a machine learning algorithm

Azuri Technologies, headquartered in St John's Innovation Centre, Cambridge, the United Kingdom, is a provider of pay-as-you-go solar systems to rural off-grid communities. The company has staff based in Kenya, Uganda, Ghana, Ethiopia and Tanzania, and altogether presence in 11 countries across sub-Saharan Africa[47]. The company promotes its solar energy system stating it is ***"the first time that a machine-learning algorithm has been used in small domestic solar home systems"***, claiming that its model could mark the next step in intelligent automation.

Figure 17. Azuri's Quad system consists of 10 W solar panel, LED lamps, USB phone-charging, and a digital light switch. Photo: Azuri Technologies.

[46] http://eepafrica.org/eep-project-of-the-year-2014-devergy-tan4019/
[47] http://www.azuri-technologies.com/about-us

In its Quad product, the company's HomeSmart solution ***harnesses artificial intelligence (AI) technology in its solar home system,*** as its machine learning algorithm learns to adjust the brightness of the light according to the customer's average system usage, weather patterns, and how much power is remaining in the battery, as shown in Figure 17 and Figure 18[48]. The service promises 8 hours of clean lighting daily and the opportunity for mobile phone charging at home.

After a small installation fee, the solar home system can be topped up weekly or monthly with a scratch card, SMS, or fully integrated with mobile money services. Azuri offers its services on a pay-as-you-go basis, and after top-ups, ***the user owns the equipment after an estimated 18-month period***. The customer then "pays off" the entire system or can upgrade to a larger model.

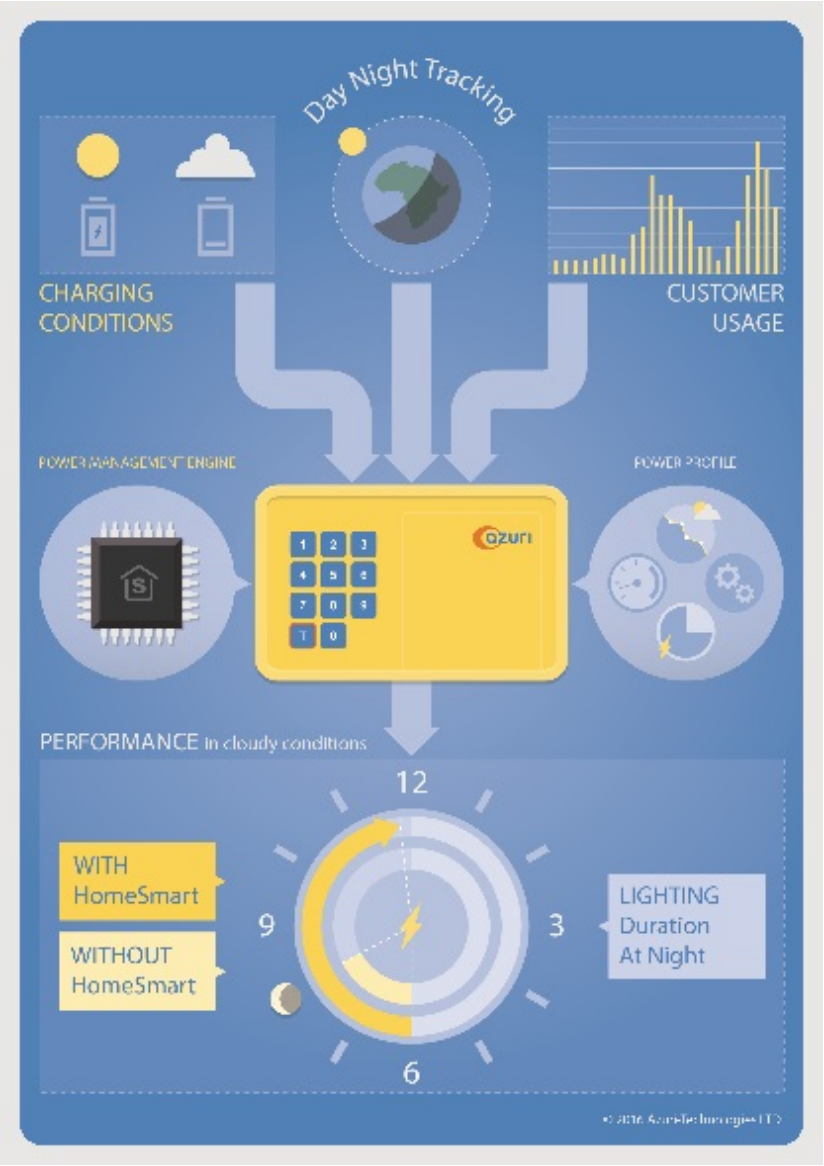

Figure 18. Integrating machine-learning as a form of artificial intelligence (AI). Photo: Azuri Technologies.

The company secured a £1 million working capital loan for four years from Barclays bank. The company has been recognised with industry and technology awards. Azuri Technologies was recognised as a Technology Pioneer by the World Economic Forum (WEF) in 2013, and received the UN climate change award in 2015 United Nations Climate Change Conference COP-21 in Paris[49].

[48] http://www.planetexperts.com/azuri-technologies-fostering-solar-revolution-africa/
[49] http://www.azuri-technologies.com/info-hub/recognition

Strauss Energy – piloting building-integrated solar tiles

Strauss Energy[50], established in 2007, is a local Kenyan firm, which ***seeks to fit solar cells into the functional parts of a construction, such as roofing, glass, pavement, walls, roads, warehouses or stadiums***. Strauss Energy argues that the use of building-integrated photovoltaics (BIPV) is an alternative to installing solar panels, "re-known for superior durability, cost efficiency and aesthetics in comparison to regular solar panels". Its solar-powered roofing tile, which can be customized to a desired colour, ***is designed and made in Kenya, and has been tested and approved by the Kenya Bureau of Standards (KEBS)***. The installation is promised to be "fast and efficient" thanks to a simple, modular design comparable to regular roofing tiles in terms of the ease and overall simplicity. When targeting new houses, solar roofing a three-bedroom house costs between USD 4 000 and USD 5 000, which according to Strauss, is not much higher than the price of a conventional roofing tile. Furthermore, ***homeowners are expected to recoup their money within three years, if they sell excess power back to the grid.***

Figure 19. Strauss Energy differs from the other case studies with its building-integrated solar photovoltaics approach.

In Strauss Energy's model, an interested customer, domestic household, commercial or industrial, has to register their home or building to seek a building-integrated solar photovoltaics instalment. The Strauss team then visits the requested site to assess the energy requirements. The energy requirements are measured against other parameters (size of roof, local climate conditions) to determine the appropriate size and capacity for an installation.

50 http://straussenergy.com/

To prove their concept, the company installed solar roof tiles at a rural school in the Kenya's Central Province. Before the solar tiles, Gaitheri secondary school had no lighting to provide lighting for students in the morning, apart from a diesel generator. They replaced the iron sheets on one building and now produce power up to 250 kW (kilowatts), which is enough to run equipment and machinery at their laboratory[51]. Buyers also have the option to install just enough solar tiles to meet their energy needs. (In the U.S., Tesla introduced a similar business model in 2016, announced to have fit its first solar rooftops in 2017[52], and aimed for its installations to be made available outside the US in 2018[53].)

Strauss Energy founder Angela Nyagah is a Jomo Kenyatta University of Agriculture and Technology (JKUAT) alumni who developed her career working with interior design, architectural firms, Aga Khan Hospital and the United Nations (UN)[54]. Co-founder and CEO Tony Nyagah, directing the company strategy, held senior positions at IBM and the World Bank Group prior to founding the company. Tony Nyagah has 15 years of management experience, and he co-founded a biometrics technology start-up, which grew into annual turnover of USD 250 million in four years. Nyagah holds a Masters in Energy Management and a Bachelors' degree in Structural Engineering. In June 2016, the company won the People's Choice category of the Global Innovation through Science and Technology competition in the Global Entrepreneurship Summit at Silicon Valley, USA.

In Kenya, Strauss Energy has used the facilities of Gearbox Innovation Hub[55]. ***Gearbox, based in Nairobi, is one of the first hardware communities designed for young entrepreneurs to gather to tinker***. In Nairobi, it opened in late 2015 as the first open makerspace for design and rapid prototyping. In autumn 2015, its premises in Ngong Road were already designed and were taken fully into use during 2016. It is a co-working space for entrepreneurs working with materials using 3D printing or targeting new renewable energy based solutions. It aspires to have "a pivotal role in incubating and accelerating innovations its members so as to build the capacity of electronic manufacturing in Kenya through collaboration on projects in a wide range of scales".

[51] http://cleanleap.com/solar-tiles-alternative-traditional-roofing-solutions
[52] https://www.standardmedia.co.ke/business/article/2000226980/kenyan-firm-beat-tesla-to-solar-roofing-tiles ; https://www.tesla.com/fi_FI/solarroof?redirect=no
[53] http://www.wired.co.uk/article/elon-musk-solar-city-roofs
[54] http://straussenergy.com/coo-named-among-the-top-40-under-40-women/
[55] See more at: www.gearbox.co.ke

5. DISCUSSION

This chapter uses the initial Radical Startups 2050 scenario narrative, and 1) after an overview of the initial narrative, re-visits it to examine it in the context of Kenya and Tanzania for similarities and differences. Using theoretical insights and complementary viewpoints from innovation literature 2) innovation capabilities; 3) global innovation networks; 4) innovation ecosystems view; 5) emerging policy considerations; and 6) possible future directions are then further consider and opened up.

Testing the Radical Startups 2050 scenario

Concerning the two scenario axes, the peer-to-peer logic and ecological consciousness, the radical solar energy startups in Kenya and Tanzania have built their business models aligning with the peer-to-peer principles in terms of ***1) the off-grid mindset: a bottom-up view, limitations of a centralised approach, difficulty of expanding the grid, local organising, 2) the payment technology (mobile money platform), and 3) the ICT (machine-to-machine communications and experiments with blockchain, etc.).*** An initial objective of many of the 'radical' startups was to allow low-income customers not connected to the grid to access affordable energy services, and to solve related obstacles. The pay-as-you go model, in principle, is a convergence of decentralized ICTs with renewable energy technologies. Similar visions were already depicted several years ago by the likes of futurist Jeremy Rifkin (2011). Such service models are viewed as an increasingly promising strategy for the further diffusion of solar energy (Bacchetti, Vezzoli, and Landoni 2016).

Many of the pioneers aim to be 'socially conscious' and manifest the principles of social entrepreneurship, capturing the essence of the scenario narrative. Indeed, all entrepreneurs are not driven by financial motives alone. In pushing the sector forward, this made the solar pioneers to be perceived not only as 'heroic', but also 'innovative'. Concerns of improving electricity access, environment, and health form the ethical core of the businesses. In addition, some of the businesses have created complementary social impacts. When customers engage into mobile money payment schemes, households that previously did not have a credit record build one. The largest startups have grown from the initial stage, and create considerable employment benefits, especially in the technician and sales levels. This builds on the idea that it is possible to create a world without poverty by re-directing capitalism to serve humanity's pressing needs (Prahalad and Hart 2002; Yunus 2009, 2011). Gradually, the 'clean' electrification of the African continent is emerging as a

major business opportunity. ***Whether this mixture qualifies for "a deep ecological logic" deserves further study.***

Interestingly enough, the original scenario narrative offers a plausible vision that seems to be materialising, but does not ***explain how the radical startups assume their capabilities for 'radical innovation' in order to design disruptive business models.*** The case study countries are generally perceived to hold a low- or middle-income status, with challenges in educational attainment, which is why the opportunities to perform innovation require careful analysis. The merits and pitfalls of promoting entrepreneurship in a development context are not always carefully articulated (Naudé 2011), and certain reservations have been expressed about the novel developmental vogue (Venot 2016).

Innovation capabilities of pioneer entrepreneurs

Innovation is the creation of new knowledge or new combinations of existing knowledge. Entrepreneurship in itself has been associated with innovation, futures orientation, freedom and self-realization (Drucker 2014, 1985; Fuller and Warren 2006; Heinonen and Ruotsalainen 2012). A pathway from a startup to a growing small- and medium-sized enterprise (SME) – and earning stable revenue – can be a challenging one. In literature, it is generally suggested that most startups initially fail (and hopefully, "as fast and often as possible", to learn and bounce back even stronger).

Previous research has studied solar PV as a physical product and suggests that ***no single place or region these days dominates innovation in the manufacturing of solar photovoltaics*** (Urban, Geall, and Wang 2016; Huang et al. 2016; Baker and Sovacool 2017; Binz and Truffer 2017; Binz, Tang, and Huenteler 2017). However, this view is limited to the extent where innovation is perceived to only concern the solar photovoltaic panel as a physical product, as a technology. Innovation can also refer to novel ideas that better respond to potential users' latent needs and how solar energy is provided to the users, for instance as a service through innovation in the business or financing model. As problem-solving, firm-level innovation, however, is a resource intensive activity. ***Compared to organizing a firm's production and value chain, innovation is highly uncertain, ambiguous and complex***.

Entrepreneurs, nimble startups and small- and medium-sized enterprises (SMEs) catalyse innovation, new ideas (products, services) and practices. According to the innovation diffusion model, only a few are needed to initiate change, and novel solutions may spread, if the circumstances make it possible (Rogers 1962). In practice, an entrepreneur needs an array of competences. A firm's ability to innovate can be viewed through the analytical

concept of **innovation capability** (M. Bell and Figueiredo 2012). It is claimed that innovation capabilities may be acquired through interactive and collective learning (ibid.), and that innovation crucially depends on communication (Benkler 2017). Previous research suggests that startups and SMEs depend on external partners to complement their internal innovation activities (Radziwon and Bogers 2018), and firms in challenging environments primarily depend on international knowledge sources for learning and building innovation capability (Ernst 2002).

It seems, therefore, analytically possible to differentiate solar PV entrepreneurs and companies in Kenya and Tanzania, based on the different aspects and levels of 'innovation' or 'innovative activities' in their work. Some companies operate in the 'innovation frontier' where the latest novelties are adapted. ***It is also possible to distinguish emerging local entrepreneurs in the solar PV niche who are gradually incorporating innovation activities in their business.*** Activities that amount to 'radical innovation' can be distinguished to have had a particularly crucial role in developing the niche. After the pay-as-you go model has spread, a growing number of solar energy companies now operate in that niche, some introducing further, incremental innovations. ***It seems that creative learning processes deserve further study: which solar energy startups perform design thinking activities, where, how, and with whom? What kinds of problem-solving abilities have they used and what will they need in the future? Which limitations do they have in performing innovation?***

The enabling role of global innovation networks

It seems that many innovative solar energy pioneers conduct problem-solving by identifying local issues with a user-centred approach and with design thinking. Many innovative entrepreneurs and startups – from local and international background – refer to the necessity of 'pivoting', tweaking a business model repeatedly, to find out what works in the market and meets customer needs. At the same time, many frontrunners interact internationally (or are by definition established by international actors). M-KOPA Solar was nurtured through determined and patient innovation to understand user needs, backed by international public and private financing, and then went on to establish a partnership with a Kenyan telecommunications giant, Safaricom (Karjalainen and Heinonen 2017). Such factors enabled the emergence of its solution, which later would set several industry benchmarks.

Overall, as illustrated by the case studies, several solar PV pioneers in Kenya and Tanzania have participated in technology competitions, been recognised with innovation awards, and many of their key staff possesses considerable international-level business and

management experience. Support by international grants and loans for piloting and scaling up also seems important. They have received early-stage funding internationally, many from the Energy and Environment Partnership (EEP Southern & East Africa) programme, funded by the governments of Finland, United Kingdom/DFID and Austria[56]. Later on, social impact funds and venture capitalists have also begun to pay growing interest to their activities.

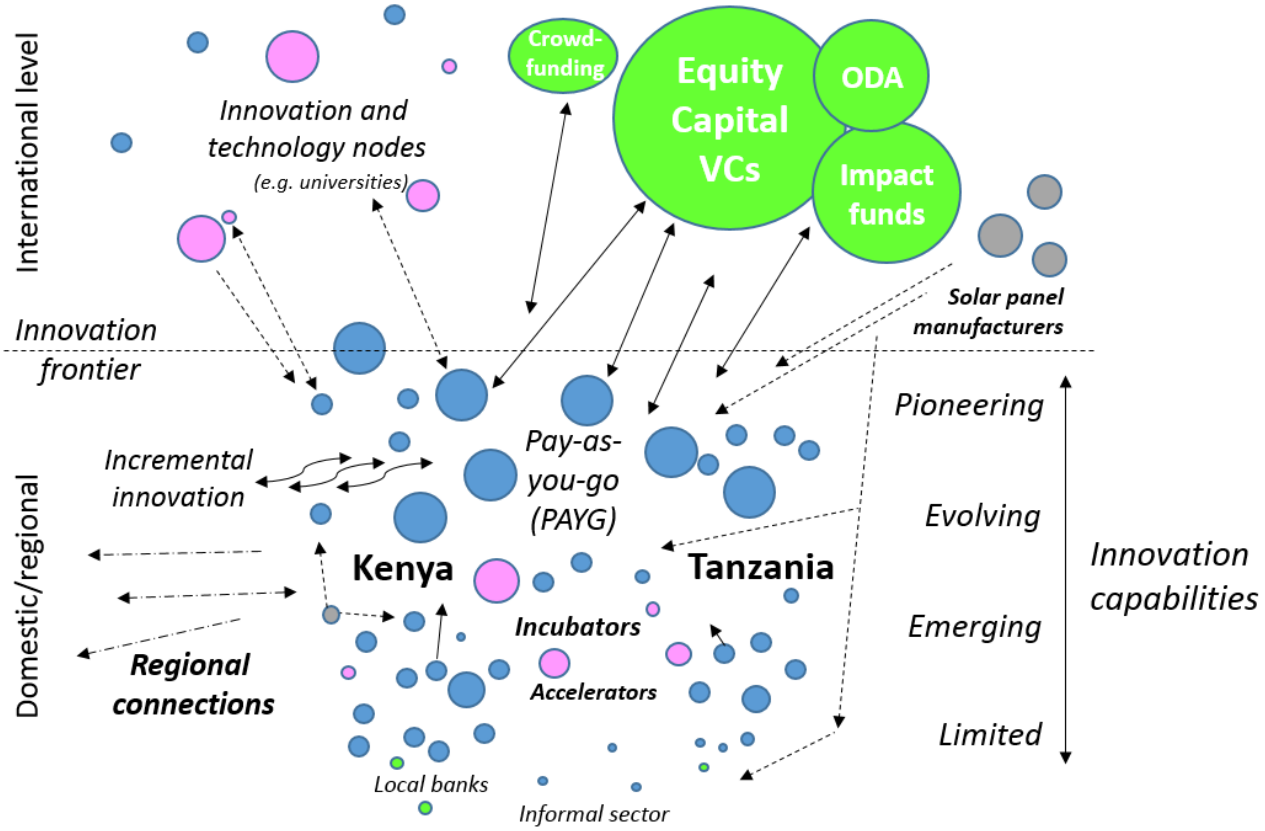

Figure 20. Conceptual map of off-grid solar PV entrepreneurs and companies in Kenya and Tanzania, as part of an innovation ecosystem, with connections to global innovation networks, and other ecosystem actors. (Solar manufacturers are also included in the figure.)

*A **blue dots** depicts a solar energy firm. A **pink dot** represents knowledge actors, such as incubators, accelerators, universities and technology nodes. The **green dots** represent finance actors. The **grey dots** represent (typically foreign) manufacturers. The size of a dot is indicative of the significance of each market/ niche actor.*

ODA = Official development assistance
VCs = Venture capital (providers)

It is therefore possible to aim to conceptualise the solar energy innovation ecosystem through the lens of the actor-networks, knowledge and innovation capabilities that they possess. In Figure 20, a conceptual map represents the solar PV companies in Kenya and Tanzania to illustrate the dynamic nature of their operating environment where they work, and may (or may not) perform innovation activities. The sketch depicts different the local companies as blue dots, and their positioning by their innovation capabilities, with some of

[56] Read more about the EEP Programme: https://eepafrica.org/

them operating right at the innovation frontier, with cutting-edge solutions and technologies. Some of the actors are networked with different local, regional and international actors beyond solar panel manufacturers and importers. Examples of innovation and knowledge actors include other startups, professional networks, universities and research groups; supportive actors include accelerators, incubators, and innovation hubs; and finance actors consist of international donors, crowdfunding platforms, social impact funds, and venture capitalists.

According to Liu (2017), ***innovation is an interwoven layer of a firm's global value creation network and a firm's value creation process, which relies on the interaction between diverse knowledge sources and exploitation of existing knowledge***. Interestingly enough, the significance of global innovation networks (GINs), as "the transfers of intangibles and immaterial assets between countries" (OECD 2017) is only a rather new and rapidly changing phenomenon of analytic interest. The role of global innovation networks has increased with the globalisation of the world economy, and their extension into middle-income countries (Barnard and Chaminade 2012; 2017). One question concerns the extent to which such networks service local entrepreneurs and emerging startups in the beginning of their journey. For instance Abubakar et al. (2019) recognise a lack of theoretical conceptualization and empirical work on how internationalization influences SME-level innovation in LDCs. Our exploratory study suggests that a better understanding of the role of global innovation networks, and their nature at play, could help de-mystify the pre-requisites of 'radicality' or 'capabilities to perform innovation activities' in the solar sector.

From business ecosystems to more local innovation ecosystems?

The solar energy companies have managed to build a stable network to serve their customers, which consists of an ecosystem of distributors, service agents, installers and local entrepreneurs. This has allowed many of the businesses to grow, become more profitable and financially increasingly sustainable (compared for instance to aid projects). Since inception of the Kenyan pay-as-you-go model, competition has emerged in the segment (Rolffs, Ockwell, and Byrne 2015). All in all, the evolution of the niche exemplifies a formation of a business ecosystem.

At the same time when the solar energy niche has formed into an increasingly cohesive shape, the innovation ecosystems of the countries have matured. ***Kenya's startup ecosystem in its early years primarily focused on ICT, technology and product commercialisation***. Ever since, the innovation activities have diversified, as a growing number of co-working spaces, services, people, funds, investors and organizations now exist

(primarily in Nairobi, but also elsewhere in Kenya)[57]. There are visions of social entrepreneurship as the next big thing after the ICT[58]. At the same time, in Dar es Salaam, the nascent tech start-up ecosystem consists of fairly young start-ups, with a limited number of serial entrepreneurs, many of whom are involved with renewable energy technologies (Mulas et al. 2017). ***Arusha, a town in northern Tanzania, has gradually emerged as a hub of solar energy ventures.*** Tanzania, however, starts from a very low technological basis and a weak private sector[59].

The challenge of both Kenya and Tanzania – seems to concern the question on how to upgrade their local innovation ecosystems at a time when the quality of education needs further improvements. The innovation ecosystems in countries such as Kenya and Tanzania, and many of their peers, are still relatively weak. At times, it has been easy to point to too much external reliance[60]. At a micro-level, although this issue would warrant further study, there is a perception that the main aspects of complex problem-solving by the solar startups are conducted by the businesses' core teams, often lead by international professionals. This seems to ***open up a novel dimension to knowledge, technology transfer and innovation debates, namely to the building of local innovation capabilities i.e. skills which perhaps are not as explicit as merely technical, sales, marketing or management know-how***.

Innovation collaboration and emerging policy debates

Increasingly inviting conditions and a growing attention to solar PV globally in the 2010s have invited the private sector to provide PV based solutions and services, and brought about a gradually emerging 'hype' in East Africa. Innovative solutions as an outcome of the private sector involvement and the startup activities may catalyse multiple benefits, but in policy debates, ***there are concerns which suggest that (developing) countries at the moment are not able to capture the full value of innovative activities*** (OECD 2017). This is an important consideration because radical innovation delivers higher value added returns from the nascent industry value chains (Ockwell and Byrne 2016b).

The present dynamics of global innovation networks suggest that they have the potential to catalyse novel solutions, but even more attention needs to be paid to their alignment. Previous research finds a lack of attention to the nature and timing of government and donor support in processes of learning and upgrading local PV industries (Hansen, Pedersen,

[57] For ecosystem descriptions, see also Coetzee 2017 and Mpala 2018.
[58] http://www.businessdailyafrica.com/Social-enterprise-the-next-big-thing/539444-2208914-11uho36z/index.html
[59] http://www.finland.or.tz/public/default.aspx?contentid=336632
[60] http://www.openhealthnews.com/news-clipping/2014-06-10/hype-around-ngo-funded-apps-stifling-africas-innovation

and Nygaard 2015). Local actors still struggle to ensure access to capital, as local banks are timid in providing commercial loans, and more accessible local or international financing could be another tool for leveraging self-sufficiency. ***Most importantly, it is typical that too few know about design-driven entrepreneurship tools, have related training or access to supportive technology***[61]. Targeting niche markets cannot be tackled with generic entrepreneurial advice, typical of government programmes, specific advice and counselling are needed (OM 2013, 13-14). In contrast, design management helps a startup to compete without large investments[62]; to shape their environment, contributing to building a reality and helping in strategic management, when navigating amidst complexity and uncertainty (Moroni et al. 2015).

One option points to more nuanced approaches to stimulating the sectoral innovation ecosystem locally. There are past examples of ***local companies benefiting from international partnerships from high-quality training and network access.*** Already organisations such as Gearbox, Kenya Climate Innovation Centre in Nairobi, Kenya, or BUNI Innovation Hub, which hosts the Energy Change Lab in Dar es Salaam, Tanzania with their networks are playing a role in supporting early stage entrepreneurs' efforts. ***Exploring the role of creativity, design thinking and related principles in such learning processes may further help local entrepreneurs who aspire to create innovative services or to engineer and even manufacture products that suit the local context***. Whether this can happen between firms as 'intra-firm collaboration', can be facilitated by support actors, and/or requires policy guidance is an interesting question (and if so, what kinds of perhaps mutually supportive policies). Entrepreneurship requires enabling policies, measures, enabling systems and institutions, sharp instruments and partnerships to empower innovators (Adesida and Karuri-Sebina 2013). In contrast, the wrong kind of regulation, or too much of it, may stifle innovation. For instance, one-size-fits-all approaches in science, technology and innovation (STI) policies have been a sure recipe to failure (Arocena and Sutz 2012).

Future directions

The companies are disrupting the status quo by not only overcoming the problems of energy access and helping to eliminate kerosene use, but by enabling technology deployment in emerging markets. ***Initial pioneer entrepreneurs or companies are no longer considered the 'crazy ones in the market', solar electricity has rather become reality and***

[61] As highlighted in an industry interview: https://www.huffingtonpost.com/rich-nadworny/women-innovating-africa-m_b_10277960.html

[62] Conventionally, such efforts typically have required advanced capabilities in research & development, innovation and strategic business development.

leading companies are looked up to as those who can make change happen. As solar, wind and other renewables-based energy solutions emerge as increasingly cost-efficient options, one challenge of countries such as Kenya and Tanzania is to reduce the innovation gap to today's technological and innovation forerunners (Karjalainen and Heinonen 2017). As illustrated by Strauss Energy's building-integrated solar photovoltaics, even more innovative locally-based solutions could be emerging (Pearce et al. 2017). ***Many PV pioneers seem to carry training aspects to develop the industry skills further. Ideally, this could over time build grounds for even deeper knowledge accumulation, and provide grounds for further, locally-rooted transformations***.

Especially the pay-as-you-go model, as a financing innovation, has been hailed for unlocking solar energy to low-income households in line with **the Bottom-of-the-Pyramid logic** (Prahalad 2006). Nevertheless, there are suggestions ***that the pay-as-you-go business model still may not yet reach 'the very poorest of the poor'*** (Lighting Global and BNEF 2016). Some even criticize entering into long-term business relationships with low-income households who may struggle to make their ends meet, and have to decide how to prioritize various types of expenditure. Reports from M-KOPA Solar's repayment rates in the early years in its pay-as-you-go scheme are very satisfactory, but this issue may require long-term monitoring. In relation to the revenue streams, a new interesting and a potentially sensitive question concerns a scenario where the operation costs of the pioneering companies improve. ***What will be considered justifiable profit margins, especially as the companies seek to strengthen their market position, compete, and further expand their activities***?

Whilst innovation activities are increasingly presented as intrinsically connected to the processes of development, ***a structural concern deals with the inequalities of income distribution and the access or ability to perform innovation activities***. In geographies with deep-rooted inequalities of access and opportunity, often based on historical conditions, what chances are there for inclusive economic development trajectories, broad-based learning effects and knowledge spill-overs? Achieving economic benefits that are evenly divided intra-country as an integrated part of the innovation trajectory, is likely even more challenging than ensuring that value is retained nationally.

At the same time, technology is developing. Cloud-based management systems allows a solar company's technicians' to optimise the solar system performance and monitor customer status information in real time. According to Bloomberg New Energy Finance (BNEF), digitalisation through sensors, data collection and analytics will drive the energy industry heavily forward, helping home owners with rooftop solar, batteries or electric

vehicles to 'become more autonomous and derive greater value from these assets'[63]. While technology is able to improve the application of solar energy, ***future ethical questions may be related to data collection, storage, data sharing and privacy, when providing and optimising energy solutions*** (Bisaga et al. 2017).

Finally, as novel energy products and services are expected become an increasingly integrated part of the economy, efforts to advance recycling processes should continue. Although at modest numbers now, ***preliminary industry estimates suggest that Africa and Latin America will see expanding volumes of PV waste by 2030***. One option is for materials to be sold onwards in global commodity markets or re-used to produce new solar panels. It is estimated that the raw materials technically recoverable from PV panels could yield a cumulative value of up to USD 450 million (in 2016 terms) by 2030. This would be equivalent to the amount of raw materials that would be needed to produce approximately 60 million new solar panels, or 18 GW of power-generation capacity (IRENA & IEA PVPS 2016; REN21 2017, 71). Collaborative and innovative approaches to design and implement the principles of circular economy in practice can be expected to warrant even further future attention.

[63] http://www.renewableenergyfocus.com/view/46417/market-for-digitalization-in-energy-sector-to-grow-to-64bn-by-2025/

6. CONCLUSIONS

The expectations of solar energy to power Africa's future are heightening. This working paper has drawn on the transformative scenarios constructed during the Neo-Carbon Energy project, and specifically the **Radical Startups 2050** scenario narrative, to think about its relevance in the off-grid solar photovoltaics sector of Kenya and Tanzania. This way, the generic scenarios which were built during foresight work were given a more careful study, and a nuanced consideration of local dynamics. In this working paper, ***the dynamics were illustrated through a historical evolution of the solar niche, the case studies of pioneering companies, and a discussion of related challenges***. The off-grid solar photovoltaics niche of Kenya and Tanzania exemplifies increasingly mature business ecosystems, in the context of a gradual formation of innovation ecosystems in both countries.

Consequently, it seems like a balanced assessment to state that the study confirms the possibility of the particular scenario realisation as an alternative future that could further unfold. The peer-to-peer based operational logic seems to be manifested in the services and technological solutions that the companies provide. It was not, however, assessed in detail to what extent the companies internally structure their daily activities, as an organizational logic, on the values of peer-to-peer. This study also confirms the strong motivation of social entrepreneurship (health; lighting; CO_2 emissions; time-savings[64]; building a credit record; and so forth), but did not study the extent to which profound ecological thinking is an explicit part of the ethos of these innovative companies. If the scenario unfolds further, precise realisation will depend on numerous factors. ***What initiatives should be taken to improve the likelihood of the scenario to be realised in a desirable way?***

The initial scenario emphasized open networks in the startup ecosystem. It did not, however, elaborate these networks or how knowledge is disseminated and shared. The business models and company histories shed light on these dynamics in linkage to 'radicality' and experimentation. Initial niche building and 'external push' responded to a lack of awareness, financing, and loose networks. After the growth of the knowledge and the industry, today, collaboration with international partners seems increasingly imperative in explaining the success of pioneering PV actors. The evolving niche dynamics seem to speak of both collaboration and competition.

[64] A social impact study in Kenya in 2014 claims that an individual saves time up to 2.3 hours per week that was previously spent on travelling in order to purchase kerosene or take a mobile phone for charging. http://www.azuri-technologies.com/what-we-do

The evolution of the innovation space around solar energy has taken place simultaneously with the recent changes in global development policy, and the introduction of Sustainable Development Goals (SDGs). The approach of market-based transformations, as a long-term process where development aid is used as a leveraging tool to catalyse private sector financing, seems to have the potential to overcome some shortcomings of the project-based aid delivery model (reliant on one-off aid based or philantrophy schemes). Policy makers are further seeking to achieve 'sustainable energy for all' objectives through entrepreneurial clean energy technology ventures in developing countries. ***In this task, building local innovation capabilities may deserve even more focused attention, especially in the light of the continued market development.*** Ensuring linkages between local entrepreneurs and innovators with global innovation networks may hasten locally-rooted processes of knowledge transfer. This poses an interesting challenge for national policy design, considering that public expenditure in Kenya and Tanzania is limited, but the state may still wish to further encourage the nurturing of creative and innovation-related 'soft' skills in education and work environments.

An 'idea' that meets a 'social need' advances through several stages. In entrepreneurship, startups initially struggle to make ends meet, and an idea has to be conceptualised by a team that begins to experiment with their idea, shaping it into a business model. Pioneer entrepreneurs and early stage companies have to overcome numerous obstacles before stabilising their business model. They have to conceptualise a solution that is of value, economically feasible, convince customers, attract investors, manage organisational growth, and so on. What is more, moving from a startup to a functional enterprise is not a given – it is a rarity. ***As startups often source ideas from diverse collaborations, the role of global innovation networks seems to deserve further research.***

A challenge for local entrepreneurs may be their initially weaker position to attract suitable financing. In spite of somewhat limited evidence, based on observation, we may speculate of at least the following. Small-scale financing for early stage companies is limited locally. In contrast, many financing instruments and foreign investment tends to cater for rather large concepts and efforts[65]. Apart from certain programmes, ***questions could be raised of the availability of patient financing that is "small enough" to nurture local early stage companies at their initial stages, allowing them to learn and experiment.*** Crowd-funding from internationally-recognised platforms seems like a trending strategy, but perhaps may still not reach all. Local entrepreneurs might lack the connections to global innovation

[65] International development banks as international financial institutions, tend to step in to provide risk guarantees for mainly large-scale projects.

networks (foreign private investors, social impact funds, development actors), to jump to the next level.

If off-grid solar energy is as revolutionary to Africa in the coming decades as mobile telecommunications have been in the 2000s, as hoped by the industry, solar is a large opportunity for entrepreneurs and investors. Niche diversification shows a growing momentum in the provision of solar home systems and a growing push for solar or hybrid mini-grid solutions. In further research, it would be meaningful to study in more detail how innovation and technological capabilities are created, nurtured or transferred by these actors. This could include studying ***what type of inter-firm interactions take place in Kenya and Tanzania and under what conditions, as well as what capacity-building and learning processes, consciously or unconsciously, take place inside the companies***.

In the future, issues concerning data, privacy, structural inequalities, and circular economy (such as battery recycling) may emerge as issues that require increasing attention. Such components could also be integrated into the sectoral innovation ecosystem – ***to deliver increasing value locally in environmental, social and economic terms***. Entrepreneurs and business leaders who are expected "to lay out a clear vision for a sustainable future and shape a new era for business" (UNGC 2017) have to recognise such considerations and processes – like the policy makers shaping their innovation environments.

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APPENDIX 1. Interview data

Kenya interviews	
Renewable energy company	3
Non-governmental	3
Local business association	2
International trade agency	1
Local consultant	3
Foreign innovation actor	1
International energy expert	1
Researcher	1
Local innovation actors	3
Civil society	1
Total	*19*

Kenya futures roundtable/workshop	
Foreign researcher	1
Non-governmental	4
Energy expert	2
Local consultant	3
Business / Industry	6
Local researcher	4
Local business association	2
Total	*22*

Tanzania interviews	
Renewable energy company	6
Researcher	6
Donor representative	2
Energy expert	2
Consultant	1
Government	1
NGO	1
Total	*19*

Tanzania futures workshop	
Business	8
Entrepreneur	3
Non-governmental	2
Business association	2
Student/Individual	5
Total	*20*

International	
Government	1
Consultant	1
Innovation/technology expert	2
Total	*4*

The interviews and futures workshops were conducted between 2015 and 2017.

APPENDIX 2. Innovation in the Business Model Roundtable in EEP Knowledge Exchange Seminar (Kampala, Uganda) October 11, 2017

Innovation is the creation of new knowledge or combining existing knowledge in a novel way. It is an interwoven layer of a firm's value creation. Innovations can be technical, economic, social or cultural. Innovation, new ideas and practices often stem from startups and small- and medium-sized companies (SMEs). Innovation relies on the interaction between diverse knowledge sources and exploiting existing knowledge. Compared to organizing a firm's production and value chain, innovation has been described to be ambiguous, complex and uncertain.

Incremental innovation means small improvements to an existing product or a product line to help maintain or improve a competitive position over time, while a *disruptive* or *radical innovation* is an invention or change that has not been seen before. An example of innovation in renewable energy comes from the solar PV sector: pay-as-you-go is a *finance innovation* that addresses the issue of affordability, with some *technological innovations* ranging from ICT-based mobile banking to machine-to-machine communications.

To learn and share, the roundtable addresses questions such as:

1) What is innovation for our company / organisation?
2) What types of innovation processes are there in place? How to innovate, and with whom?
3) How can a renewable energy company start an innovation process?
4) What challenges should be addressed to ease innovation? What role can EEP or other stakeholders play?

APPENDIX 3. Solar energy companies in Kenya and Tanzania

This serves for illustrative purposes, and is not an exhaustive or an up-to-date list of all solar industry actors. Numerous companies operate in both markets, as can be seen from the list.

Solar energy companies in Kenya	Solar energy companies in Tanzania
Davis & Shirtliff	Zola (M-Power / Off-Grid Electric)
Chloride Exide Kenya Ltd	Azuri Technologies
Sollatek Electronics Kenya Ltd.	RISE Tanzania (Rural Initiative for Solar Electrification)
SolarCentury	Sollatek (Tanzania Service Centre),cf. Power Control Ltd
Barefoot Power	Juabar
Solanterns / REV Renewable Energy Ventures (K) Ltd.	Helvetic Solar Contractors (+Light for Life Foundation)
d.light Limited	d.light Limited
Strauss Energy	Chloride Exide Tanzania
BBOXX	Devergy
Mibawa	JUMEME
M-KOPA Solar	Karibu Solar Power
Powerhive	Power Corner Tanzania
SolarAfrica	BBOXX
SolarKiosk Kenya	Solea AG
KENSEN, Kenya Solar Energy Ltd	Sikubora
Little Sun	Ensol
Brighterlite	Zara Solar
SunTransfer	Rift Valley Energy RVE
Solinc (formerly Ubbink East Africa)	African Solar Designs
Radiant Energy	Rafiki Power
SolAfrique	SolarNow
Azuri Technologies	Solaris Offgrid (Eternum Energy)
Solektra International	Little Sun
SunCulture Kenya Limited	Redavia Tanzania
African Solar Designs	SunCulture (Kenya Limited)
Blackwealth Solar	JamiiPower (startup, no more active?)
Redavia Tanzania (also in Kenya)	SunKing Tanzania (from Greenlight Planet)
Tropical Power Energy Group	JUMEME
Solar Sister	GreenLink (cf. RIWIK)
SunKing Kenya (Greenlight Planet)	Solar Sister
SunnyMoney	SunKing Tanzania(Greenlight Planet)
SkyPower Global	EEG Energy
Steama.Co (formerly access:energy)	E.ON Off Grid Solutions
PowerGen Renewable Energy East Africa Limited	Helios Foundation for Sustainable Development
Stenrich Cycles S.A.R.L. / Off-grid energy (East Africa)	AGLEX
Boma Safi Limited	Mobisol
Kenya Green Supply Ltd	AISE Tanzania
!nspiraFarms Solar Cold Chain Technologies (Enterprise Project Ventures Limited)	JuaWezesha Solar Solutions
Orb Energy Private Limited	Space Engineering Limited
Raj Ushanga House Limited	L's Solution Limited
PowerPoint Systems (E.A) Ltd - Home	Gongali Model Company
Pamoja life	Radiant Energy
Vanoji Technology Inc	Vanoji Technology Inc
Pfoofy Power and Light Limited	Green Solutions Limited
Vulcan Inc.	SolarKiosk Tanzania
Solar Works	TerraProjects (see also JUMEME)
Aquion Energy	Fenix International
Green Energy Africa	EnviroFit
Future Pump	ARTI Energy
SCODE Limited	Kakute Ltd
Fenix International	Rex Energy
EnviroFit	Angaza
Center for Alternative Technologies	
Angaza	

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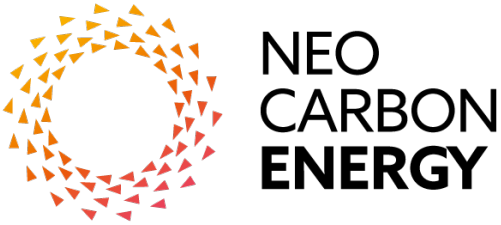

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