

Can Pay-As-You-Go, digitally enabled business models support sustainability transformations in developing countries? Outstanding questions and a theoretical basis for future research

Article (Accepted Version)

Ockwell, David, Atela, Joanes, Mbeva, Kenedy, Chengo, Victoria, Byrne, Rob, Durrant, Rachael, Kasprowikz, Victoria and Ely, Adrian (2019) Can Pay-As-You-Go, digitally enabled business models support sustainability transformations in developing countries? Outstanding questions and a theoretical basis for future research. *Sustainability*, 11 (7). 2105 1-21. ISSN 2071-1050

This version is available from Sussex Research Online: <http://sro.sussex.ac.uk/id/eprint/83022/>

This document is made available in accordance with publisher policies and may differ from the published version or from the version of record. If you wish to cite this item you are advised to consult the publisher's version. Please see the URL above for details on accessing the published version.

Copyright and reuse:

Sussex Research Online is a digital repository of the research output of the University.

Copyright and all moral rights to the version of the paper presented here belong to the individual author(s) and/or other copyright owners. To the extent reasonable and practicable, the material made available in SRO has been checked for eligibility before being made available.

Copies of full text items generally can be reproduced, displayed or performed and given to third parties in any format or medium for personal research or study, educational, or not-for-profit purposes without prior permission or charge, provided that the authors, title and full bibliographic details are credited, a hyperlink and/or URL is given for the original metadata page and the content is not changed in any way.

1 Article

2 **Can Pay-As-You-Go, digitally enabled business**
3 **models support sustainability transformations in**
4 **developing countries? Outstanding questions and a**
5 **theoretical basis for future research**

6 David Ockwell ^{1,*}, Joanes Atela ², Kenedy Mbeva ², Victoria Chengo ², Rob Byrne ³, Rachael
7 Durrant ³, Victoria Kasprowikz ³ and Adrian Ely ³

8 ¹ Department of Geography and ESRC STEPS Centre, School of Global Studies, University of Sussex, UK

9 ² African Centre for Technology Studies (ACTS), ICIPE Duduville Campus, Kasarani, P.O. Box 45917 – 00100,
10 Nairobi - Kenya

11 ³ SPRU (Science Policy Research Unit), Sussex Business School, University of Sussex, UK

12 * Correspondence: d.ockwell@sussex.ac.uk

13 Received: date; Accepted: date; Published: date

14 **Abstract:** This paper examines the rapidly emerging and rapidly changing phenomenon of
15 pay-as-you-go (PAYG) digitally enabled business models, which have had significant early success
16 in providing poor people with access to SDG relevant technologies (e.g. for electricity access, water
17 and sanitation and agricultural irrigation). Data is analysed based on literature review, two
18 stakeholder workshops (or “transformation labs”) and stakeholder interviews (engaging 41
19 stakeholders in total). This demonstrates the existing literature on PAYG is patchy at best, with no
20 comprehensive or longitudinal, and very little theoretically grounded, research to date. The paper
21 contributes to existing research on PAYG and sustainability transformations more broadly in two
22 key ways. Firstly, it articulates a range of questions that remain to be answered in order to
23 understand and deliver against the current and potential contribution of PAYG to effecting
24 sustainability transformations (the latter we define as achieving environmental sustainability and
25 social justice). These questions focus at three levels: national contexts for fostering innovation and
26 technology uptake; the daily lives of poor and marginalised women and men, and; global political
27 economies and value accumulation. Secondly, the paper articulates three areas of theory (based on
28 emerging critical social science research on sustainable energy access) that have potential to
29 support future research that might answer these questions, namely: socio-technical innovation
30 system building; social practice, and; global political economy and value chain analysis. Whilst
31 recognising existing tensions between these three areas of theory, we argue that rapid
32 sustainability transformations demand a level of epistemic pragmatism. Such pragmatism, we
33 argue, can be achieved by situating research using any of the above areas of theory within the
34 broader context of Leach et al.’s (2010) Pathways Approach. This allows for exactly the kind of
35 interdisciplinary approach, based on a commitment to pluralism and the co-production of
36 knowledge, and firmly rooted in a commitment to environmental sustainability and social justice,
37 that the SDGs demand.

38 **Keywords:** Pay-As-You-Go; Digitally Enabled Business Models; Sustainability Transformations;
39 Energy Access; Energy for Development; Sustainable Development Goals
40

41

42

43 1. Introduction

44 SDG7 and accompanying Agenda 2030 goals aim to provide access to sustainable energy for all
45 (SE4ALL) by 2030. This recognises the fundamental need for access to energy for improved
46 economic productivity in many developing countries, energy consumption being tightly coupled to
47 economic growth [2]. It also recognises the human and economic development needs of many poor
48 and marginalised women and men, 1.1 billion of whom currently lack access to electricity [3]. SDG7
49 also recognises the tension with achieving such goals within a carbon constrained world and looks
50 to leverage potential synergies with new, sustainable energy technologies and off-grid energy access
51 in rural, urban and peri-urban contexts. A key problem to date has been finding ways of making
52 access to sustainable energy technologies affordable in contexts characterised by extreme poverty
53 [4]. This issue applies equally to many other SDG-relevant technologies, e.g. technologies for
54 improving agricultural productivity, water pumping and health, as affordable access to new
55 technologies and innovation cuts across multiple SDGs (as does, often, the need for access to
56 electricity).

57
58 No matter how one looks at these problems, a goal such as SE4ALL inevitably requires
59 transformative change at speeds that are, to date, unprecedented. Current analysis, however,
60 suggests we are not on track to achieve the UN's SE4ALL goal [3]. It is no wonder, then, that against
61 this backdrop the recent emergence and rapid proliferation of new, digitally enabled
62 Pay-As-You-Go (PAYG) business models (now colloquially referred to as "PAY-Go" by
63 practitioners), that aim to make access to sustainable technologies affordable to poor people, has
64 captured widespread international donor and press attention. For example, the World Resources
65 Institute (WRI) describes them as a "*one-stop-shop solution*" to the SE4ALL challenge [5] and *The*
66 *Economist* describes them as "*ending energy poverty*" by providing "*power to the powerless*" [6]. Even
67 detailed, financially grounded market analyses tend to talk up the promise of PAYG; for example,
68 the global trade association for mobile operators describes PAYG as the "*perfect example*" of the
69 "*second wave of inclusive digital innovation*" [7, p.4].

70
71 PAYG business models use an innovative combination of mobile banking technologies and
72 machine-to-machine (M2M) technology to facilitate PAYG payment plans that seek to overcome
73 barriers experienced by past micro-finance models, such as high up-front initial costs and lack of
74 integration and availability of technical support [8]. In many instances, these payments either
75 mirror, or are cheaper than, the existing payments customers made for alternative energy sources
76 (e.g. kerosene for lighting and cooking). The machine-to-machine technology also enables providers
77 to switch off the system if customers fail to top-up their payment plans, or if they default (different
78 companies have different definitions of what constitutes "default" – e.g. the anonymous company
79 studied by Barrie and Cruickshank [9] considered customers to have defaulted if they had not added
80 credit to their systems for a four week period). Through this they are providing access to sustainable
81 electricity and other technologies and services (e.g. energy efficient appliances, agricultural
82 irrigation technologies, water and sanitation services [7]) to customers for whom access to such
83 technologies and the services they provide would otherwise be prohibitively expensive.

84
85 Despite their promise, however, PAYG business models are very new and very little critical
86 analysis of their actual and potential implications for delivering against the SDGs has been
87 conducted. As the literature review in section 2 demonstrates, to date only five peer reviewed papers
88 in mainstream academic journals exist on PAYG business models, as well as seven papers in peer
89 reviewed practitioner journals and six detailed professional reports. Having first emerged in Kenya
90 circa 2010 following the widespread success of the MPESA mobile banking system, by 2016 a UC
91 Berkeley study reported 30 PAYG companies operating in 32 countries in the Global South by
92 Alstone et al. [10]. Alstone et al. [10] do not state specifically which countries these are, but a map
93 provided in the report suggests that they include coverage in Central and South America, East, West
94 and Southern Africa and South and South East Asia. The GSMA [7] reports the majority of the

95 market share being focused in East Africa (Kenya, Tanzania, Uganda and Rwanda), with evolving
96 markets present in West Africa (Ghana and Ivory Coast) and South Asia (India). A later report by the
97 GSMA published just eleven months later, lists many more countries as having active PAYG-based
98 companies [11]. Whatever the actual numbers, the differences in this reporting imply the spatial
99 distribution of PAYG activity is evolving rapidly.

100
101 As well as this rapid geographical spread, stakeholder interviews and workshops conducted in
102 support of our analysis below also suggest a proliferation of different types of PAYG business
103 models. Some, for example, provide only PAYG software-based platforms for other companies to
104 use (in whatever application those companies want – from electricity supply and household
105 appliances, to agricultural irrigation and transport), whilst others provide whole-system technology
106 and finance services, from purchase, through maintenance, to end-of-life and recycling. This
107 diversity is also reflected in the PAYG business model being used in multiple other SDG relevant
108 sectors beyond electricity access, where PAYG first began, but with a continued emphasis on
109 providing access to services (e.g. water, sanitation, cooking and irrigation) to poor and marginalised
110 people in rural areas [11, 12], thus emphasising the potential relevance of the PAYG phenomenon
111 across multiple SDGs. As Alstone et al. [10, p.10] put it:

112
113 *“... the PAYG market is incredibly dynamic. New business models appear almost daily, companies pivot
114 and change approaches, funding is raised, and players disappear. This report presents a snapshot of what our
115 team observed during the June and July of 2014. Since then, even our partners have altered their approaches...”*

116
117 Against this backdrop of a dearth of critical, peer reviewed scholarship and the rapidly
118 expanding and metamorphosing shape of the PAYG space in developing countries, we seek in this
119 paper to make two key contributions. Firstly, based on consultation with stakeholders in Kenya the
120 paper articulates a number of critical questions pertaining to the current and potential contribution
121 of PAYG business models to delivering sustainability benefits. Our aim here is to highlight key
122 dimensions to the interaction between PAYG business models and sustainability that are not
123 acknowledged within existing mainstream discourse. Stakeholder consultation is based on
124 seventeen interviews and two stakeholder workshops (or, more specifically, two “transformation
125 labs” – see methodology below) with stakeholders from Kenya and elsewhere in East Africa, where
126 PAYG business models first evolved and where most experience to date has been accrued. The
127 process of stakeholder selection and rationale for different stakeholders’ involvement is described in
128 the methodology below.

129
130 In line with Leach et al. [1], we define sustainability as foregrounding concerns with both
131 environmental sustainability and social justice/inclusivity. Our particular interest is in the
132 intersection between PAYG business models and the myriad ways in which access to energy – and
133 technology and innovation more broadly – are interwoven across the majority of the SDGs. In
134 aligning ourselves with Leach et al.’s work, and in particular their Pathways Approach to analysing
135 sustainability, we adopt the position that any existing or potential “benefits” accrued from PAYG
136 are contingent (both in their definition and their perceived receipt) on the self-constructed needs and
137 aspirations of different stakeholders. We further maintain that these self-constructed needs and
138 aspirations will differ between different actors, e.g. benefits perceived by an economically
139 marginalised woman in a remote rural area will be different from benefits perceived by a policy
140 maker in an intergovernmental development organisation (see Ockwell and Byrne [13] for an
141 application of a Pathways Approach perspective to solar PV for energy access in Kenya). By
142 adopting a methodology that explicitly focuses on eliciting stakeholder perspectives and
143 operationalizing a normative commitment to the co-construction of knowledge, we endeavour to do
144 justice to understanding and responding to the self-constructed nature of ‘sustainability benefits’.

145

146 Having articulated these critical questions regarding the sustainability benefits of PAYG, the
147 paper then seeks to make a second contribution by articulating four areas of conceptual work
148 within the emerging critical social science literature on energy access, and sustainability
149 transformations more broadly, that may be of use in facilitating future, critical research on PAYG
150 and sustainability transformations. Our intention is to facilitate future research focussed on fulfilling
151 two key aims: 1. Understanding in further detail the sustainability benefits (and potential
152 drawbacks) of PAYG, and; 2. Understanding the opportunities and barriers to increasing the
153 contribution of PAYG to sustainability in future. At all times, in line with our definition and position
154 on what constitutes sustainability articulated above, we foreground attention to issues of inclusivity,
155 with a consistent focus on who gains, who loses, how and why; and how this might change in ways
156 that are more inclusive in future [c.f. 14, 15, 16]. In this way we are fundamentally interested in how
157 PAYG business models might contribute to rapid transitions, or “transformations”, in ways that
158 foreground issues of environmental sustainability and social justice and do not underplay the
159 deeply socio-cultural and political nature of transformation [c.f. 17].
160

161 The paper begins with a review of the small existing peer reviewed and grey literature on
162 PAYG business models, before outlining the methodology that underpinned the new data collected
163 for this paper, which is analysed in the subsequent section. The paper then suggests three key levels
164 of analysis and linked areas of relevant theory that constitute a potential basis for progressing future,
165 critical research in this field. A fourth area of theory is also suggested as a means of providing an
166 overarching framework through which research utilising the initial three areas of theory might be
167 coordinated within a normative commitment to pluralism and the co-construction of knowledge.
168

169 To be clear from the outset, we are not claiming that this paper provides a comprehensive
170 answer on the current and potential future impacts of PAYG for sustainability transformations. Nor
171 are we claiming that the conceptual approaches we propose below are the only way in which future
172 research can, or should, be framed. Our hope is, rather, that the ideas and insights herein provide a
173 nuanced basis for critical, but constructive, future research that is grounded in the existing literature
174 on PAYG, the emerging critical, socio-cultural turn in energy access research more broadly [13] and
175 in the perspectives of different stakeholders. In line with many of the stakeholders and
176 commentators active in the PAYG space, we share a normative commitment to delivering against the
177 SDGs and to a vision of sustainability that is both environmentally sound and socially just. Our hope
178 is that this paper can therefore make a small contribution to future research that contributes to
179 realising these commitments.

180 **2. PAYG business models: insights from analyses to date**

181 *2.1 Coverage of existing literature*

182 In this section, we summarise the peer reviewed and grey literature available on PAYG
183 business models to date. As inferred above, the existing literature is at best patchy and a long way
184 from providing any comprehensive overview of what is a rapidly expanding and metamorphosing
185 phenomenon. A literature search using Scopus, Web of Science, Science Direct and Google Scholar,
186 together with direct approaches to authors of some of the papers these searches identified to ask if
187 they were aware of other literature we had missed, resulted in identification of only five articles in
188 mainstream academic journals [8, 9, 12, 18, 19], seven articles in practitioner journals [20-26] and six
189 detailed reports [5, 7, 10, 11, 27, 28]. Of these latter, three were produced by the global mobile
190 operators' key trade association (the GSMA) [7, 11, 27], one by researchers from UC Berkeley based
191 on a study commissioned by the World Bank [10], one by the World Resources Institute [5] and one
192 by an independent think tank, the Consultative Group to Assist the Poor [28]. Whilst not explicitly
193 stated, it is likely that only the UC Berkeley and World Resources Institute reports were subject to
194 peer review (and probably not blind peer review).
195

196 Within this small literature, only three papers attempt to use any kind of theoretical approach in
197 their analysis. Rolffs, Ockwell [8] operationalize a “strategic niche management” perspective from
198 the socio-technical transitions literature. Barrie and Cruickshank [9] operationalize a “diffusions of
199 innovation” theoretical perspective, which originates from the work of rural sociologist Rogers [29].
200 Finally, Bisaga and Parikh [18] speak to the theory of the “energy ladder” from energy access/energy
201 and development research. Bearing in mind that within the social sciences it is theory, built from
202 multiple observations across myriad different contexts, that supposedly allows research to work
203 towards more generalizable insights, this lack of theoretical engagement within the literature to date
204 calls into question the extent to which insights from research on PAYG are in any way generalisable.
205

206 Moreover, the literature to date, including the current paper, is based largely on data from East
207 Africa, with very little on PAYG applications elsewhere in the Global South. There have also been no
208 longitudinal studies conducted to date, making it difficult to comment on the temporal
209 sustainability of any PAYG business models and their attendant costs and benefits, whether
210 financial, social or environmental. As Alstone et al. [10, p.7] put it:

211
212 *“The strength of connected PAYG (and other connectivity-enabled approaches) for supporting reliable,*
213 *adaptive solar energy access will become clearer as the first wave of systems entering the market today age and*
214 *are supported with maintenance, expansion, and replacement.”*
215

216 One other notable characteristic of this emerging literature is the use, in three cases [9, 12, 18], of
217 remote, mobile-enabled data, collated by PAYG companies, on consumer practices, consumer
218 financial risk profiles, and the technological performance of solar home systems and other
219 technologies that PAYG businesses facilitate access to (e.g. battery performance, charging profiles
220 and impacts of weather). In the case of the three aforementioned peer reviewed analyses, this data
221 has facilitated sophisticated analysis that is able to look in detail at the practices of consumers. Some
222 commentators also note that PAYG businesses themselves are using the remote data that PAYG
223 affords them access to in order to generate consumer debt financing risk profiles, as well as
224 discussing the potential need for developing more centralised risk profiles, available to all actors
225 across the sector, in efforts to facilitate the scaling up of PAYG based services [7, 11]. Whilst,
226 however, access to such data does facilitate interesting and insightful analysis (e.g. see our
227 discussion of social practices later in this section), there are nevertheless significant potential ethical
228 issues related to the use of such data; issues that some authors acknowledge [12] and others note as
229 having arisen as salient concerns within focus groups with PAYG users [10].

230 2.2 Dominant focus on technical and financial dimensions

231 As with the majority of the energy and development literature to date, there is a tendency
232 within what literature so far exists on PAYG to privilege a focus on technical and financial issues,
233 with relatively little, or at best implicit, attendance to socio-cultural or broader innovation system
234 related dimensions. Other than passing mention of “enabling environments” regarding the
235 uncertainty around relief of VAT on solar imports [8, 24], or a couple of mentions of the word
236 “politics” without any elaboration [8], consideration of the political or political economy dimensions
237 of PAYG’s contribution to sustainable development is completely absent. This is not to diminish in
238 any way the importance of financial and technical dimensions. Rather it is to highlight, as we expand
239 upon further below, the limitations of such a two-dimensional perspective in underpinning
240 anything close to what might be considered transformational change. Indeed, Rolffs et al.’s [8] core
241 thesis is that, despite PAYG business models being ostensibly financial and technical in nature, it is
242 actually the deep understanding of the social practices of poor and marginalised people in paying
243 for and consuming energy services – which was developed by early pioneers of PAYG through
244 decades of living and working in poor communities – that is fundamental to the early success and
245 potential future growth of PAYG. It is through such understandings, they argue, that these pioneers
246 were able to identify the opportunity to use mobile payments, machine to machine technologies and

247 increasingly cheaper solar PV to construct PAYG payment plans that come close to replicating
248 existing payments for energy (e.g. kerosene) and practices around purchasing mobile air time or
249 using mobile banking technologies.

250

251 Within the analysis of technical-financial dimensions in the existing literature, four issues in
252 particular tend to be emphasised. Firstly, several authors emphasise the benefits of PAYG over
253 traditional micro-finance based approaches [8, 22, 23], particularly when targeting lower income
254 households with access to basic energy services [19]. Secondly, the availability of mobile banking
255 services is discussed by several authors as having implications for the viability of PAYG. Whilst
256 attempts have been made by some businesses to overcome this, for example via the use of scratch
257 cards, these have been plagued by logistical limitations relating to making cards available in remote
258 locations and gathering cash from vendors [24]. Zollmann, Waldron [28] note experimentation with
259 other revenue collection approaches, including cash collection and exchange of mobile airtime for
260 solar credit, but find that such approaches suffer from significantly higher cost and coordination
261 issues than mobile banking based PAYG business models.

262

263 A third issue emphasised in the existing literature refers to the difficulties companies face in
264 raising working capital [5, 10, 19, 26, 28]. This is due to a range of issues, including the need for long
265 repayment terms and foreign currency risks, a lack of data on customer repayment ability/credit
266 ratings, high transaction costs associated with mobile money and a lack of experience and
267 understanding of PAYG business models by commercial banks within countries of operation. The
268 latter has been hypothesised as one reason why most PAYG companies are foreign owned and
269 headquartered [5] (an important issue in relation to questions of how much local companies and
270 countries are benefiting from PAYG, which comes up in the stakeholder consultation and political
271 economy discussion further below). In light of this, it is not surprising that many PAYG companies
272 have originally relied on donor and grant funding for their initial set up [21, 24, 25]. There is likely
273 still a key role for public funding for PAYG businesses, with a strong public good rationale for such
274 investment in providing access to SDG relevant technologies and services (although, learning from
275 Bangladesh, Sanyal, Prins [5] emphasises the need to channel such funding in local currency through
276 local banks to increase national understandings of PAYG).

277

278 The final area of financial and technical issues reported in the literature concerns the high costs
279 and complexities of developing and implementing technology interfaces that can deal with myriad
280 different potential network operator protocols (protocols that are sometimes subject to change [24]),
281 different mobile money platforms, customer interfaces etc. [10, 12, 28] . This is compounded by low
282 levels of digital literacy amongst some consumers that demands simple consumer interfaces [28].
283 These costs can act as market barriers to small operators [12]. Some authors also report issues around
284 highly technical choices regarding the suitability of GSM connectivity, global vs. local networks,
285 embedded SIM options, and so on, thus further emphasising the levels of technical capabilities
286 companies require to work in this space [7].

287 2.3 Socio-cultural dimensions of PAYG

288 Socio-cultural dimensions of the PAYG phenomenon are largely ignored in the literature to
289 date, which is, as developed further below, both concerning and noteworthy given that the first
290 paper on the subject in a mainstream academic journal [i.e. 8] argued that it was an understanding of
291 socio-cultural practices that was fundamental to the early success of PAYG. That said, the existing
292 literature does touch on several relevant issues. The first regards the extent to which PAYG reaches
293 the poorest consumers. Muchunku, Kirsten [19], for example, report some vendors being paid
294 commission based on levels of consumer default, providing a disincentive for vendors to target
295 lower income people. Collings and Munyehirwe [24] also report consumers being of above average
296 wealth within rural populations. That said, Alstone, D. [10] argue that PAYG still represents the best

297 finance model to date for reaching lower income, especially rural populations due to the potential to
298 lower the transaction costs of energy access.

299

300 One key socio-cultural dimension that is almost completely ignored in the literature to date is
301 that of gender (and any other characteristics of potential social exclusion). Nowhere is there any
302 explicit, gender focussed research on the ways in which PAYG might impact positively or negatively
303 on gender relations (an issue discussed in more detail further below). Barrie and Cruickshank [9] do
304 mention gender, noting that their respondents reported women being in charge of payments,
305 leading (they report) to men feeling justified in wanting to keep a solar home system, despite
306 payments being defaulted on. Zollmann et al. [28] also touch on gender, reporting purchase
307 decisions for PAYG as being made by men, despite resistance from their wives whose household
308 budgets are often negatively impacted on by the purchase (including when decisions are made to
309 acquire more assets once the initial solar loan is paid off).

310

311 At multiple points in their detailed analysis, Barrie and Cruickshank [9] mention various other
312 socio-cultural issues. For example, cultural clashes between ideas of possession vs. ownership were
313 observed to make repossession of PAYG equipment in event of default difficult, especially where
314 customers were accustomed to free hand-outs from past development projects. Fluctuations in
315 income and ability to top up payment plans due to the nature of customers' livelihoods were also
316 noted (e.g. agricultural incomes, or highly-mobile market traders – the former also being noted by
317 Bisaga and Parikh [18]). This inflexibility towards seasonal incomes potentially undermines Rolffs et
318 al.'s [8] point on the close match between PAYG payment plans and existing consumer practices
319 around paying for energy. But the idea of increased potential for default is countered by Bisaga et
320 al.'s [12] analysis, where they cite the ability of machine to machine technology to switch off services
321 as serving to decrease possibilities of default. It is not clear whether the business analysed by Barrie
322 and Cruickshank [9] had this capability or not, but it is notable that Bisaga et al.'s [12] sample size
323 was significantly larger than Barrie and Cruickshank's [9] (the former basing their analysis on 20,000
324 active systems vs. the latter's 747).

325

326 Elsewhere in the literature, Bisaga and Parikh [18] explicitly refer to social practice theorists
327 when reporting on observed shifts in social practices once PAYG systems are installed, where
328 consumers are observed to change their practices to mirror the availability of energy in a solar home
329 system. They also note the relevance of the availability of appliances in influencing this. Collings and
330 Munyehirwe's [24] analysis also demonstrates implicit recognition of the relevance of social
331 practices through their emphasis on the similarity between scratch cards for solar and for air time as
332 being a factor that increases ease of use for customers.

333

334 Finally, it is worth noting that the "diffusion of innovations" theory applied by Barrie and
335 Cruickshank [9] does include attending to a notion of the "social". One example of this is their
336 inclusion of the "nature of the social system" as a key analytical variable. But this is then rather
337 crudely described as social systems being either "urban" or "rural", with the implicit assumption of
338 a lack of variability between different socio-cultural attributes within different rural or urban locales.
339 They also acknowledge in their discussion that new innovations being different to existing
340 "practices" can be a key factor mitigating against widespread adoption of a new technology. It is
341 interesting, however, that it is the solar home system that they note as matching existing consumer
342 practices, and not, as in the case of Rolffs et al. [8], the PAYG payment structure.

343 2.4 Innovation systems

344 The final dimension that is acknowledged as important elsewhere in the energy and
345 development literature, but largely ignored in the existing PAYG literature, is innovation systems
346 [e.g. see 30]. Barrie and Cruickshank's [9] analysis does touch on aspects that other authors [e.g. 13]
347 emphasise as important parts of building functioning innovation systems to increase uptake of new,

348 SDG relevant technologies. These include the use of market research and proactive demonstration,
349 promotions and marketing; although the initial boost in sales in Barrie and Cruickshank's [9] study
350 that resulted from such activities was then reflected in subsequent higher default rates, thus
351 questioning the sustainability of such approaches. Their analysis is not, however, explicitly
352 concerned with a systemic perspective on innovation and development, or its socio-technical nature,
353 which we expand upon in Section 5 below.

354

355 Nowhere in the existing literature on PAYG, then, do we see any comprehensive, theoretically
356 grounded analysis of the PAYG sector, even at a single country level (not surprising given the rate at
357 which it is emerging and its increasing diversity), or any longitudinal analysis beyond very short
358 periods of time. In line with the insights from the stakeholder consultation undertaken for this paper
359 (see below) there are clearly a range of critical questions that remain unanswered and which are vital
360 for research to engage with if the potential for PAYG to contribute towards rapid sustainability
361 transformations is to be properly understood and realised in practice. Having set out the key
362 insights from the PAYG literature to date, we now turn to the empirical data collated from
363 stakeholder consultation for the current paper, before setting out some of the key areas of theory that
364 might help to frame future research aimed at better understanding and supporting the existing and
365 potential role of PAYG in underpinning sustainability transformations.

366

367 3. Methodology

368 As the literature review above reveals, the current state of knowledge on the potential for PAYG
369 to facilitate sustainability transformations is currently in its infancy. It is at best geographically patchy,
370 based on a relatively small number of studies over relatively short time-scales. That said, there are
371 clearly several interesting hypotheses beginning to emerge from this literature, for example regarding
372 the nature of innovation, that might serve the needs of low income men and women and the need to
373 understand existing social practices around consuming and paying for energy services, in order to
374 develop effective technical and financial solutions to the energy access issue (responding to SDG7 and
375 the myriad other SDGs which rely on access to clean, reliable energy, or on innovation and technology
376 access more broadly).

377

378 Bearing this in mind, the project upon which this paper is based set out to consult with a
379 cross-section of stakeholders with knowledge and experience of PAYG business models. The aim of
380 the consultation was to elicit key questions and concerns that remain unanswered regarding:

381

- 382 1. The existing and potential contribution of PAYG to sustainability transformations;
- 383 2. Existing and potential barriers to rapidly scaling up PAYG business models, and;
- 384 3. Which socio-technical innovations and governance approaches might hold the key to
385 transforming the PAYG space in ways that lead to more sustainable and inclusive future
386 benefits for all.

387

388 Stakeholder consultation consisted of two different methods, namely transformation labs, or
389 "T-Labs", and semi-structured interviews, each conducted in one of three different phases of data
390 collection. Based on earlier work on "social innovation labs" [31], T-Labs "...are specifically designed
391 to guide transformations in social-ecological systems towards sustainability... [by] include[ing] a set of
392 stakeholders who may have different roles and perspectives, but who have an interest in solving the
393 problem and some ability to provoke change" [32, p.7]. For a full explanation of the background and
394 processes involved in T-Labs, readers are encouraged to consult the practical guide produced by the
395 Pathways Network [32]. In summary, the process involves convening two, subsequent workshops (or
396 "labs"), which move from an initial process of attempting to frame challenges and identifying
397 potential innovators/stakeholders towards developing change strategies and even testing prototypes
398 of interventions. "Prototypes could be new business models, services, or kinds of governance that

399 fundamentally change human-environmental interactions and contribute to changes for a better
 400 future" [32, p.7]. Importantly, the nature of T-Labs and the ways in which the processes evolve is
 401 contingent upon the context specificities of any given issue, whether these contexts pertain to social,
 402 political, economic, technical or environmental considerations. Their emphasis on co-production of
 403 knowledge, via convening a plurality of perspectives and voices, is designed specifically to recognize
 404 and respond to such specificities (and thus aligns T-Labs with this paper's normative commitment to
 405 recognising a plurality of voices and the co-construction of knowledge as necessary for understanding
 406 the nature of sustainability transformations).

407
 408 The type and number of stakeholders that participated in the two T-Labs are summarized in
 409 Tables 1 and 2 (note that private sector participants were all PAYG based businesses, other than one
 410 participant who was a lawyer previously involved in drafting relevant legislation).

411
 412 **Table 1. Stakeholders participating in T-Lab 1**

Type of stakeholder	Number of interviewees
Private sector	6
Public sector	3
Not-for-profit/third sector	2
Research/universities	3
PAYG users	1
Total	15

413

414 **Table 2. Stakeholders participating in T-Lab 2**

Type of stakeholder	Number of interviewees
Private sector	3
Public sector	1
Not-for-profit/third sector	1
Research/universities	9
PAYG users	0
Total	15

415

416 T-Lab 1 focussed on framing existing problems and unanswered questions regarding the existing
 417 and potential contribution of PAYG to sustainability transformations (questions 1 and 2 above). T-Lab
 418 2 focussed on articulating questions and issues that need to be addressed in order to develop solutions
 419 to the issues raised in T-Lab 1 (question 3 above).

420

421 In between T-Labs 1 and 2, several stakeholders, including some of those involved in T-Lab 1 and
 422 other stakeholders contacted via a snowballing approach, were interviewed. Interviews were
 423 conducted in person and by Skype/phone and were semi-structured. The structure was based on
 424 asking the initial opening question of how they perceived PAYG to be contributing to access to
 425 sustainable technologies and the barriers to scaling this contribution up, then using the results of T-Lab
 426 1 to drill down in more detail on the specific issues that had arisen. Additional questions were asked
 427 regarding potential solutions and possible future innovations to increase the contribution of PAYG to
 428 sustainable development, with a view to helping with the framing of the subsequent, solutions
 429 oriented T-Lab 2. Stakeholders participating in T-Lab 1 and the interviews were also asked who they
 430 perceived to be key change makers in the PAYG space in order to inform which stakeholders were
 431 approached to participate in T-Lab 2. The number and type of stakeholders interviewed is summarised
 432 in Table 3. Note that all apart from one private sector interviewee were companies operating around a
 433 PAYG business model. In the case of the interviewees, however, as opposed to the T-Labs, the one
 434 private sector exception was a UK-based telecoms solution company with experience of mobile
 435 network protocols and specialist knowledge and experience of mobile applications in humanitarian
 436 contexts.

437
438
439
440

Table 3. Stakeholders interviewed

Type of stakeholder	Number of interviewees
Private sector	10
Public sector	5
Not-for-profit/third sector	1
Research/universities	1
PAYG users	0
Total	17

441
442
443
444
445
446
447

Four of the participants in T-Lab 1 also took part in T-Lab 2 and 1 participant in T-Lab 2 was also interviewed. This brings the total number and type of stakeholder consulted through the research to 41 (as summarised in Table 4).

Table 4. Total number and type of stakeholders consulted through the project, including via the two T-Labs and seventeen interviews

Type of stakeholder	Number of interviewees
Private sector	19
Public sector	8
Not-for-profit/third sector	3
Research/universities	10
PAYG users	1
Total	41

448
449
450
451
452
453
454
455

The results of the two T-Labs and the interviews were analysed to identify common themes and group different questions, concerns and insights according to these themes (see Section 4). These themes were then compared to emerging themes in the nascent, critical social science literature on energy and sustainable development (see Ockwell, Byrne [30] for a recent review of this literature) to identify any concepts and theories that could usefully provide the basis for future, critical research in this field, with a firm focus on yielding empirical analysis that is able to inform policy and practice in ways that will increase the contribution of PAYG to sustainability transformations (see Section 5).

456
457

4. Results: Critical questions arising from stakeholder consultation regarding the current and potential contribution of PAYG business models to sustainable development

458
459
460
461
462
463
464
465

A key insight to emerge from T-Lab 1 was that the problem space in Kenya and beyond around PAYG is closely associated with diverging interests, views, knowledge and narratives on how to go about leveraging innovations like PAYG to underpin transformational change. T-Lab 1, together with subsequent stakeholder consultation (through the interviews and T-Lab 2) yielded multiple questions, which stakeholders viewed as currently unanswered, but critical to any future reliance on PAYG to achieve sustainability transformations. The questions arising from both T-Labs and the interviews can be grouped under the following four overarching themes:

466
467
468
469
470
471
472
473

1. How do national contexts enable or constrain PAYG business models?

Sub questions under this broader question included: Have the nature and strength of existing national stakeholder networks around key technologies, like solar PV and mobile banking, had significant impacts on the evolution and success of PAYG (and hence been material to the relative success and potential of these business models across different national contexts)? What aspects of national contexts do PAYG businesses perceive as constraining or enabling? What technologies and sectors are PAYG models currently being used for beyond energy? Is there potential for expansion across other technologies and sectors? How would all of this change if new ideas around open source

474 software platforms for PAYG were developed? How would this impact existing PAYG actors? What
 475 role do mobile networks play? Can single mobile network dominance vs. multi network diversity (as
 476 observed to be varying across different E African contexts) explain the relative success of PAYG in
 477 Safaricom dominated Kenya, and is this material to potential for scaling up elsewhere? How do mobile
 478 network protocols enable and constrain PAYG and what needs to change for PAYG models to scale up
 479 internationally?

480

481 **2. In what ways (positive and negative) do PAYG business models intersect with the lived**
 482 **realities of poor and marginalised women and men?**

483 Sub questions under this broader question included: Who currently benefits from PAYG, e.g. is it
 484 the poorest people, women, men, or other categories where social discrimination occurs? And under
 485 what conditions are benefits realised in practice (including different local contexts, different scales and
 486 types of technologies and different structures and foci of different emerging PAYG business models)?
 487 Are financial, productive opportunities being enabled for users; and if so how, where and for whom?

488

489 **3. What is the global political economy of PAYG business models?**

490 Sub questions under this broader question included: Where are benefits being accrued, by whom,
 491 how and why? Are indigenous firms, research organisations, governments and other actors gaining, or
 492 losing? Where is capacity being built and capital being accumulated; is it within countries where
 493 PAYG businesses are operating or elsewhere (particularly bearing in mind most existing companies
 494 are headquartered in the Global North)? How is this influenced by dominant development discourses,
 495 particularly neo-liberal development thinking and the increased emphasis on entrepreneurship and
 496 financialisation, and what is the implication of this for the agency of poor countries and women and
 497 men therein? What does this imply for how benefits of PAYG could be more firmly focussed on the
 498 countries where these business models operate?

499

500 **4. What do the answers to questions 1-3 imply about the potential for PAYG business**
 501 **models to deliver sustainability transformations and how do they contribute to theory**
 502 **building and future research on this issue?**

503 Sub questions under this broader question included: Under what circumstances do which actors
 504 gain and lose, how and why? What are the broader implications of this for thinking about which
 505 sustainable development pathways are implied by which existing or possible future PAYG business
 506 models?

507

508 **5. Discussion: Theoretical pathways for future research and analysis**

509 The questions above focus our attention on **three distinct levels of analysis** with which PAYG
 510 business models intersect:

511

- 512 1. National contexts for fostering innovation, including technology development and uptake.
- 513 2. The daily lives of poor and marginalised women and men.
- 514 3. Global value chains and political economies.

515

516 Based on these three levels, and the broader concern of this paper to consider PAYG within the
 517 context of sustainability transformations, we have identified **three distinct areas of theory** that
 518 could provide useful points of departure for framing future, action-oriented research in this field.
 519 Each of these focuses at the three different levels articulated above and each draws on the nascent,
 520 but rapidly emerging critical, social science based literature on energy and development [30]. They
 521 are:

522

- 523 1. *National innovation systems* theory and recent fusion, in low-income country contexts, with
 524 *socio-technical transitions* thinking.

- 525 2. *Social practice theory*.
526 3. *Global political economy perspectives*.

527

528 Nevertheless, as will become clear, several tensions and areas of disagreement exist between
529 proponents of these different theoretical perspectives. Bearing in mind this paper's overarching
530 concern with the transformative nature of PAYG in relation to achieving sustainable development,
531 this raises a final question that future research in this field will need to grapple with, namely:

532

533 *How might the relative strengths and weaknesses of, and tensions between the three areas of*
534 *theory operationalized below, contribute to a more comprehensive theoretical perspective on the*
535 *potential transformative role of technology and innovation in low-income country contexts?*

536

537 Below we suggest that a fourth, more overarching conceptual perspective, wedded to the
538 importance of interdisciplinary, co-constructed knowledge production might be of use, namely:

539

- 540 4. Leach et al.'s [1] *Pathways Approach*.

541

542 This latter area of theory focuses on the dynamics of, and myriad potential pathways towards,
543 sustainability, with an emphasis on the level of inclusivity and social justice attributed to alternative
544 pathways. Adopting a pragmatic epistemic position, and drawing on existing scholarship that
545 utilises the Pathways Approach, we argue that each of the first three theoretical perspectives above
546 can contribute, in different ways (casting analytical emphasis on different dimensions), to analysis of
547 access to new technologies and innovation for sustainability transformations. But, importantly, this
548 must build on emerging work that operationalizes these theoretical approaches within low-income
549 contexts – contexts which represent stark differences to what Furlong [33] refers to as the “modern
550 infrastructure ideal” that characterizes the empirical realities in the Global North from whence the
551 first three theoretical perspectives above emerged.

552

553 In the sub-sections below we explore the relevance of each of these areas of theory in turn.

554 5.1 *National contexts for fostering innovation, including technology development and uptake*

555 Innovation systems thinking [e.g. 34] provides a useful point of departure for thinking at
556 national, more systemic levels about the dynamics of technology, innovation and development; the
557 same level at which many mainstream commentators, as characterised in section 1 above, tend to
558 focus when discussing the transformative potential of new, PAYG financing and delivery models.
559 The innovation systems literature can be broadly characterised as emphasising the systemic contexts
560 within which the uptake of new technologies and the capacity for innovation has been, and can be,
561 nurtured. Essentially innovation systems refer to the network of actors (e.g. firms, universities,
562 research institutes, government departments, NGOs) within which technology development,
563 transfer and uptake occurs, the strength and nature of the relationships between them, and the
564 institutional environment within which they operate [35]. Empirical analysis in the Innovation
565 Studies literature has demonstrated that national differences in the nature, speed and extent of
566 technological change can be explained by a systemic understanding of the context within which
567 technological change is facilitated, with innovation systems providing the context within which all
568 processes of technology development, transfer and uptake occur [35] - *ergo*, it is these systemic
569 contexts that policy and research aimed at delivering the SDGs ought to focus.

570

571 In many low-income countries, innovation systems are weak, fragmented or non-existent,
572 particularly as concerns new, sustainable technologies. Research could, therefore, usefully focus on
573 understanding the state of existing innovation systems around PAYG in different countries or
574 regions. Questions around what resources different actors lack, or, indeed, what actors different
575 countries lack, and the nature and strength of existing and potential relationships between relevant

576 actors, could be answered. This would provide a fertile basis for directing and maximising the
577 impact of resource investment aimed at building new, or strengthening existing parts of innovation
578 systems that have relevance to PAYG business models, including broader concerns with existing
579 national policy frameworks and governance. Multiple actors would then be able to better target their
580 investments and interventions, including national governments, NGOs, the private sector, donors
581 and inter-governmental actors (the latter two of which stand to make huge investments in
582 technology and innovation around sustainability transformations in the near future as they seek to
583 deliver against the SDGs and international climate change commitments).

584
585 But innovation systems theory focuses at the level of firms, technologies, sectors and national
586 and regional economies – technology users and politics are relatively absent, or at least under
587 emphasised [36]. Based on a detailed historical deconstruction of the success of solar PV in Kenya
588 Ockwell and Byrne [13] demonstrate the potential value of theoretical fusion between innovation
589 systems perspectives and insights from socio-technical transitions thinking [e.g. 37, 38]. The latter
590 casts analytical attention on the ways technology and innovation co-evolve with social practices and
591 broader social institutions, creating dominant socio-technical regimes and path dependency that
592 new niches of sustainable technology use struggle to compete with and influence in new, sustainable
593 directions. Importantly, as several authors have now shown in relation to energy access [e.g. 8, 16,
594 39, 40-42], these socio-technical regimes can look different in remote areas of low-income countries
595 to those studied in the Global North; the latter being the empirical context within which the majority
596 of the socio-technical transitions literature has emerged to date [as analysed, for example, in a recent
597 special issue, see 43, 44]. Nevertheless, as demonstrated by the afore mentioned recent contributions,
598 these low-income contexts are still subject to similar dynamics, where every day practices and
599 powerful economic and political interests align with dominant socio-technical regimes (e.g. in the
600 supply of kerosene for cooking and lighting), or with potentially unsustainable alternatives (e.g.
601 expanding grid connected, coal fired electricity supply), implying continued utility for
602 socio-technical transitions perspectives within low income contexts.

603
604 It is through the fusion between the component foci of these two bodies of theory that Ockwell
605 and Byrne [13] argue we can move forward towards a theoretical perspective that can accommodate
606 a more systemic understanding of technological change, innovation and development, whilst
607 simultaneously attending to the socio-technical nature of such change, and the powerful
608 path-dependency of existing socio-technical regimes of energy consumption (and, in the case of
609 PAYG business models, energy finance – see Rolffs et al. [8]). Based on this premise, Ockwell and
610 Byrne [13] proffer a new, hybrid perspective on how to foster the uptake of new, sustainable
611 technologies based on “*Socio-Technical Innovation System Building*” (something they have taken
612 forward to inform a new policy perspective in the international climate finance field – see Ockwell
613 and Byrne [35]). Whilst acknowledging the utility of Ockwell and Byrne’s [13] synthesised
614 perspective, and the detailed, historical empirical basis upon which they developed it, we would,
615 however, argue that their analysis is left wanting in two key areas. Firstly, they fail to properly
616 attend to social practices at the level of the lived, daily realities of poor and marginalised women and
617 men. Secondly, whilst politics is, to some extent, acknowledged in the idea of socio-technical
618 regimes, their analysis is, by their own admission [both in their 2017 monograph and a recent paper,
619 see 16], left wanting in its attention to politics and, in particular, the powerful political economic
620 dynamics at play.

621 5.2 *The daily lives of poor and marginalised women and men*

622 Prominent social practice theorists have acknowledged socio-technical transitions theory for its
623 explicit theory of social change (something other relevant areas of theory are arguably lacking – see
624 Shove [45]). Nevertheless, social practice theory is arguably much more explicit than socio-technical
625 transitions theory in emphasising the lived realities of the people whom it is assumed will benefit
626 from access to new, sustainable technologies. In the context of low-income countries, it is these lived

627 realities of poor people that arguably must be kept centre field in any research that seeks to
628 contribute to achieving the SDGs. As Shove and Walker [46] convincingly argue, what is remiss in
629 much energy policy research is explicit attention to the central question “what is energy for?” Poor
630 women and men do not want PAYG business models. Nor do they want solar panels or access to the
631 grid. They want, or need, things like being able read at night (and hence need light), or to
632 communicate with others (hence needing to charge mobile phones), or to keep food fresh (hence
633 needing refrigeration).

634
635 A social practice perspective hence allows us to push back against the technological
636 determinism that traditionally characterises analysis of technology and innovation within the
637 development literature [47]. Attention is focussed instead on the energy services poor people want
638 or need (e.g. light, heating, cooling, communications) and, fundamentally, the social practices these
639 services facilitate (e.g. studying or pursuing economic activities after dark, sending money
640 electronically, or communicating with family or business associates). This, in turn, provides the
641 potential for critical interrogation of the extent PAYG business models are, or are not, meeting the
642 self-constructed needs and aspirations of poor people, as well as how the nature of social practices
643 might be changing (or not – for better or for worse) as a result.

644
645 Emphasising self-constructed needs and aspirations also focuses our attention on issues of
646 social discrimination, most obviously including inter- and intra-household gender relations [48, 49],
647 but also issues like income inequality, race, cast etc., that might intersect in different ways with
648 PAYG business models. For example, one PAYG business director interviewed during this research
649 had noticed a difference between whether the man or the women in a household ended up with
650 agency over how electricity is used, based on whether the PAYG payment method was via pre-paid
651 scratch card or mobile enabled bank payments. It is not surprising, then, that several contemporary
652 scholars researching the intersection between gender dynamics and energy access have utilised
653 social practice approaches [41, 50]. This suggests further utility for deepening social practice based
654 research on the intersection between PAYG and the lived realities of poor women and men in
655 relation to gender relations and beyond (e.g. see, for example, emerging work by Cross and
656 colleagues [e.g. 51, 52]).

657 *5.3 Global value chains and political economies*

658 The questions arising from the stakeholder consultation above emphasise how any analysis of
659 PAYG business models and sustainable development would be remiss without explicit
660 consideration of global political economy dynamics. This requires specific attention to who wins,
661 who loses, how and why from PAYG business models globally, particularly as concerns where
662 economic benefits (whether financial or technological capacity building – both of high significance to
663 long term economic development in low-income countries) are being accumulated. It takes us to
664 what Lasswell [53] argued to be the root of any political analysis, i.e., in his words, “who gets what,
665 when, how”.

666
667 Whilst acknowledging the arguments of proponents of socio-technical transitions theory [in
668 particular 54, and 55] that, if done properly, attention to regime and landscape levels of analysis
669 already allows socio-technical transitions scholarship to engage with politics, we nevertheless argue
670 that there is more work to be done on political economy considerations in particular, such that it
671 takes us beyond the boundaries of what socio-technical transitions scholarship has facilitated to
672 date. Indeed, several contemporary scholars have usefully demonstrated how a political economy
673 focus can provide more depth and insight on the specific dimensions, or levels, that socio-technical
674 transitions scholars tend to focus on. This includes work on the political economy of climate change
675 and energy in Kenya, where Newell and Phillips [56] have demonstrated how political economy
676 perspectives can add depth to understanding what transitions scholars would refer to as the
677 “landscape” level of analysis. Byrne et al. [16] have also sought to elaborate on how political

678 economy dynamics shape the building of socio-technical “niches” and their potential to influence
679 socio-technical “regimes”. Furthermore, authors looking across the piste of SDG relevant innovation
680 and development questions, have increasingly begun to emphasise the critical importance of politics
681 and political economy in defining and shaping sustainability transformations [14, 15].
682

683 Bringing these theoretical considerations into the context of the questions and concerns that
684 arose from our stakeholder consultation, stakeholders emphasised that many PAYG businesses are
685 headquartered in Europe. They also raised questions as to the extent to which indigenous companies
686 and innovators are involved in these companies, or could be involved in future, e.g. via explicit
687 collaboration between indigenous innovators and international PAYG businesses, or via potential
688 future innovations around open-source PAYG software platforms. This was seen to raise
689 fundamental questions as to the extent to which low-income countries were able to benefit in the
690 long-term from the presence and activities of PAYG companies, and the extent to which PAYG
691 businesses facilitate value accumulation in the countries within which they operate, with “value”
692 understood broadly as including financial capital, technological capabilities and broader indigenous
693 capacity building. Or, is this another case of capital accumulation in the Global North? Such
694 concerns also emphasise the potential utility of Global Value Chain Analysis [see 57] in facilitating
695 empirical analysis that is able to explicitly analyse where value is being accumulated via PAYG
696 businesses. This also allows us to acknowledge and intersect with critical accounts of financialisation
697 and accumulation in the context of ideas of transformations [e.g. 58, 59].

698 *5.4 Overarching conceptual frameworks, pragmatic, interdisciplinary thinking and transformations towards* 699 *sustainability: The potential utility of the Pathways Approach*

700 As we have argued, the three areas of theory above provide analytical purchase for future
701 research focussed on answering the questions that arose from our stakeholder consultation and do
702 so in ways that are potentially complementary; each attending to specific levels and types of concern
703 that the others are less focussed on. Nevertheless, as we acknowledged at the outset, there also
704 exist key areas of tension between these theories. For example, the analytical fusion between
705 innovation systems and socio-technical transitions thinking attempted by Ockwell and Byrne [13]
706 would likely be viewed as unacceptable to some proponents of each theoretical perspective. The idea
707 of researchers wedded to social practice theory and those wedded to innovation systems theory
708 accepting one another’s ontological and epistemic positions as potentially complementary seems
709 more unlikely still. That said, in the case of political economy theory, examples do exist of scholars
710 that have successfully acknowledged the value of innovation capabilities (a core tenet of innovation
711 systems thinking) in their analysis [see 60]. And, as demonstrated in a recent special issue [see 30], it
712 seems to be increasingly common in the contemporary, critical social science literature on energy
713 access to find examples of scholars using social practice, innovation systems, or political economy
714 theory (the latter also including the work by Newell and Phillips [56] and Byrne et al. [16] mentioned
715 in section 5.3 above) to drill down in more detail on specific aspects of the multi-level perspective
716 [38] that has been so influential in socio-technical transitions thinking.
717

718 Whilst not wishing to belittle in any way the epistemic and ontological concerns that
719 protagonists of these different theoretical positions might raise, we would argue that the rapid
720 transformations demanded to deliver against the SDGs simultaneously demands a level of
721 pragmatism on behalf of the research community. This is in line with calls for inter-disciplinary
722 research that increasingly characterise SDG focussed funding programmes (such as the UK’s
723 controversial Global Challenges Research Fund), as well as international scientific panels like the
724 Intergovernmental Panel on Climate Change. Without wishing to disappear down a rabbit hole on
725 the long-standing debate on the virtues of interdisciplinarity, its drawbacks and the difficulty of
726 achieving it in practice, we end this paper by making a fundamental point pertaining to plurality
727 and diversity. Through this we point towards a body of (what might be described as) “meta-level”
728 thinking and theorising that has potential to convene interdisciplinary research, focussed on

729 transformations towards sustainability, that preserves a critical perspective (with an explicit eye on
730 social justice and environmental sustainability), whilst accommodating a plurality of different
731 research voices from different disciplines and theoretical perspectives.
732

733 With the emergence of the new, critical social science voice in the energy access literature has
734 come empirically grounded critiques of the previously dominant two-dimensional understanding of
735 the problem as being simply one of needing new technology and finance to pay for this. This early
736 framing of the problem resulted in the simultaneous domination of research in this field by the
737 disciplines of engineering and economics [13, 61]. Seeing energy access as a two dimensional
738 problem ignores multiple other dimensions of the problem, including socio-cultural and political
739 dimensions, as well as more systemic perspectives on innovation and the path dependency between
740 social and technical dimensions of socio-technical change, as captured by the various theoretical
741 perspectives reviewed above. But care needs to be taken that proponents of these latter perspectives
742 don't fall into the same trap that many of them have argued energy access research was plagued by
743 in the first place. Each of the critical social science theories that have more recently engaged with the
744 energy access problem emphasise different aspects of the issue. It should therefore not be too great a
745 leap to argue that there may be value in drawing on insights from across the piste of what these
746 different perspectives offer. Simultaneously, whilst seeking to move towards more
747 multi-dimensional, sophisticated understandings of the dynamic interplay between technology,
748 innovation and sustainable development, critical social science scholars ought not dismiss the
749 fundamental role of engineering and economics, alongside socio-cultural and politically focused
750 approaches. This arguably entails a need to work towards perspectives that can draw from multiple
751 disciplines, supporting a more enlightened understanding of the context-specific, values based and
752 deeply political nature [62] of sustainability transformations [63]. Such sentiments are well captured
753 by recent work by Stirling [e.g. 17, 63-65], although it could be argued that Stirling's push back
754 against, for example, socio-technical transitions and socio-ecological systems scholars can itself be
755 characterised as denying the plurality in knowledge production we argue for here (although, of
756 course, Stirling's critique is in fact levelled squarely at the ways in which socio-technical transitions
757 scholars have had a tendency to adopt an overly managerial, techno-deterministic conception of
758 change, which is insufficient to address the socio-cultural and political nature of socially just
759 transformations, thus risking achieving the exact opposite – this therefore places Stirling's work very
760 much in line with the argument that we are attempting to articulate in the current paper).
761

762 In addition, throughout much of the literature on sustainability transformations we observe a
763 commitment to fostering the co-production of knowledge with stakeholders in ways that recognise
764 the plurality of different voices and perspectives on a problem and the value and importance of
765 fostering such diversity in knowledge production. Knowledge co-production is also now explicitly
766 demanded (nominally at least) by many research funders. It seems illogical, therefore, not to be able
767 to apply similar principles of plurality and diversity to the theoretical perspectives that underpin
768 research; why co-produce knowledge with diverse stakeholders if we're not willing to respect the
769 knowledge produced by researchers with different epistemic and ontological perspectives than
770 ourselves?
771

772 The Pathways Approach (developed by Leach et al. [1]) is arguably one theoretical framework
773 that has been able to accommodate different disciplinary voices, whilst simultaneously keeping
774 centre field concerns with the politics of knowledge production and the ways in which this might
775 work for, or against, marginalised people and the environment. It is designed to facilitate exactly the
776 kind of theoretically-grounded, critical, interdisciplinary analysis that this paper argues for. In
777 simple terms, it casts aside the idea of a single, accurate and normatively "good" pathway or route to
778 sustainable development, and emphasises the need to remain open to multiple alternative
779 development pathways that countries and communities might pursue. This is particularly vital in
780 the context of the complex, interrelated challenges resulting from the need to address poverty whilst

781 simultaneously dealing with other (often competing) priorities such as climate change,
782 environmental integrity, job creation, economic growth and social justice. Most fundamentally, the
783 Pathways Approach recognises that who you are shapes how you ‘frame’ – or understand – a
784 problem or opportunity, and that – alongside powerful interests and technological trajectories –
785 these understandings have a tendency to focus on specific development pathways favoured by
786 powerful groups to the neglect of alternative perspectives. Or they might simply represent the
787 received wisdom [66] of donors or government agencies, failing to appreciate the realities of a
788 problem from the perspective of poor households or national firms. For instance, a poor household,
789 a solar home systems vendor, a member of parliament, a multilateral development bank and a
790 multinational PAYG based business might all frame the benefits, costs and risks of PAYG (and the
791 services it provides access to) in different ways. Those various framings will lead to different
792 narratives being told about PAYG’s role in development and different choices being made about the
793 value of PAYG, including where, to whom and via what specific variance of the different business
794 models that are now proliferating such values can be leveraged. These considerations apply equally
795 whether considering PAYG business models for delivering solar lighting in rural villages, or models
796 for brokering international deals with multinational companies for building new, large scale
797 programmes to scale up the use of PAYG for access to different technologies, and their attendant
798 services in different contexts. At all levels, critical questions need to be asked about the distribution
799 of benefits – who gains, who loses, and how can this be changed to better deliver against the
800 self-defined development needs of poor and marginalised people and poor countries more broadly?
801

802 Importantly, in light of our core argument in this paper, the Pathways Approach also
803 emphasises, and has been demonstrated to enable, the use of interdisciplinary research to facilitate
804 such analysis. Drawing on theory and ideas from across a diverse range of disciplines in both the
805 natural and social sciences, the Pathways Approach has been applied across a wide range of
806 different research domains, including: health and disease [67-69]; food and agriculture [70-73];
807 pastoralism [74]; energy and climate change [13]; technology and innovation [75, 76]; urbanisation
808 [77, 78]; water and sanitation [79, 80]; gender equality [81]; and many more besides. This body of
809 work provides support for the potential utility of the Pathways Approach as an overarching
810 framework with which to use different theoretical approaches to examine the kinds of
811 interconnected issues that arose from the stakeholder consultation reported above. Our attention is
812 thus drawn to the dynamics, motivations and outcomes of the various types of PAYG business
813 model, e.g. what assumptions underpin the design of these models? Who are they designed to
814 benefit and how, and to what extent do these assumed benefits play out in practice, particularly over
815 longer time periods? Which models target the poorest households, and what can policy makers/
816 donors do to support these models? Have the successes and failures of PAYG to date been due to
817 technical, social, political or economic issues, or a combination of these? The end point being the
818 support of a broad church of critical research that is specifically geared towards providing the
819 empirical and conceptual basis for understanding how PAYG business models are, or are not,
820 supporting social just, environmentally sustainable outcomes and how their contribution to such
821 goals, as epitomised by the SDGs, might better be supported in future.

822 6. Conclusions

823 To conclude, there has been much hype around the potential of PAYG business models to effect
824 a step change in access to energy (and other SDG relevant services) for poor and marginalised
825 women and men. Given the rapid rate at which these business models are spreading and evolving,
826 and the fascinating story of technological innovation in mobile technologies that (on the face of it)
827 sits behind the PAYG story, such hype is arguably understandable. This is especially so given the
828 need for rapid, transformative change that delivering against the SDGs and other global
829 sustainability goals (e.g. those of the Paris Climate Accord) demands. But, as the results of the
830 stakeholder consultation above demonstrate, it is early days for PAYG business models in terms of
831 our understanding of the extent to which they are delivering, or could deliver meaningful

832 sustainability transformations (defined by a commitment to social justice and environmental
833 sustainability). As we have seen, the published and grey literature on PAYG to date is at best patchy
834 and far from affording any comprehensive, longitudinal and theoretically grounded picture of how
835 PAYG is delivering, or might deliver, against myriad concerns central to achieving sustainability
836 transformations.

837

838 In this paper we have presented three areas of theory (socio-technical innovation system
839 building, social practice and global political economy) that we argue have potential to support
840 critical, action oriented research at the three different levels of concern that arose from our
841 stakeholder consultation (national contexts for fostering innovation, the daily lives of poor and
842 marginalised women and men and global political economies and value accumulation) and the
843 related groups of stakeholder questions that these three fields of theory are able to engage with.
844 Furthermore, we have attempted to make the case for epistemic pluralism in bringing to bear these
845 different theoretical perspectives, perspectives that are often in tension with one another, under the
846 broader, unifying roof of Leach et al.'s [1] Pathways Approach. Through this, we argue, future
847 analysis of PAYG business models will have potential to retain a critical focus on the variegated
848 benefits that accrue to different actors (users, international or indigenous businesses, national
849 economies, governments, women, men etc.), whilst retaining a commitment to use such critical
850 research to inform meaningful change in policy and practice.

851

852 In these ways, this paper has sought to contribute to emerging debates on sustainability
853 transformations, focussing in particular on the new phenomenon of PAYG business models. In
854 particular, the analysis above contributes to the existing literature on PAYG by summarising a range
855 of outstanding questions that stakeholders perceive to be of relevance to understanding the existing
856 and potential contribution of PAYG to sustainability transformations. It has also sought to provide
857 the theoretical bases through which future research might usefully be framed in order to maximise
858 this potential contribution. Transformations towards sustainability and achieving the SDGs
859 demands urgent, far reaching, interdisciplinary research and action. This urgency must be met with
860 respect, diversity and a commitment to pluralism and the co-construction of knowledge (both
861 between knowledge producers and knowledge users, as much as between knowledge producers
862 themselves). Without this, research, policy and practice risks falling prey to the same monolithic,
863 two-dimensional thinking that has plagued the energy access field, and work on technology,
864 innovation and development more broadly, to date. Two dimensional perspectives are not fit for
865 purpose. It is, we would argue, time for change, seasoned with a heavy dose of pragmatism.

866 **Funding:** The authors gratefully acknowledge funding from the ESRC [grant number ES/1021620/1] and the
867 Transformations to Sustainability programme, which is coordinated by the International Social Science Council
868 (ISSC) and funded by the Swedish International Development Cooperation Agency (Sida), and implemented in
869 partnership with the National Research Foundation of South Africa (Grant Number
870 ISSC2015-TKN150224114426).

871 **Conflicts of Interest:** The authors declare no conflict of interest.

872 References

- 873 1. Leach, M., I. Scoones, and A. Stirling, *Dynamic Sustainabilities: Technology, Environment, Social Justice*. 2010,
874 Abingdon: Routledge.
- 875 2. Ockwell, D.G., *Energy and economic growth: grounding our understanding in physical reality*. *Energy Policy*,
876 2008. **36**(12): p. 4600-4604.
- 877 3. IEA, *Energy Access Outlook 2017*. 2017, International Energy Agency: Paris.
- 878 4. Mitra, S. and S. Buluswar, *Universal access to electricity: closing the affordability gap*. *Annual Review of*
879 *Environment and Resources*, 2015. **40**: p. 261-283.
- 880 5. Sanyal, S., et al., *Stimulating Pay-As-You-Go in Kenya and Tanzania: The Role of Development Finance*. 2016,
881 World Resources Institute: Washington DC.
- 882 6. The Economist, *Ending energy poverty: Power to the powerless*, in *The Economist*. 2016.

- 883 7. GSMA, *Mobile for Development Utilities. Lessons from the use of mobile in utility pay-as-you-go models*. 2017,
884 GSMA: Place published not specified.
- 885 8. Rolffs, P., D. Ockwell, and R. Byrne, *Beyond technology and finance: pay-as-you-go sustainable energy access and*
886 *theories of social change*. Environment and Planning A, 2015. **47**(12): p. 2609-2627.
- 887 9. Barrie, J. and H.J. Cruickshank, *Shedding light on the last mile: A study on the diffusion of Pay As You Go Solar*
888 *Home Systems in Central East Africa*. Energy Policy, 2017. **107**: p. 425-436.
- 889 10. Alstone, P., et al., *Off-Grid Power and Connectivity; Pay-As-You-Go Financing and Digital Supply Chains for*
890 *Pico-Solar*. 2015, Lighting Global, World Bank: Washington DC.
- 891 11. GSMA, *Going greenfield with utility pay-as-you-go models: Enabling access to water, sanitation and energy in and*
892 *beyond East Africa*. 2017, GSMA, London.
- 893 12. Bisaga, I., et al., *Scalable off-grid energy services enabled by IoT: A case study of BBOX SMART Solar*. Energy
894 Policy, 2017. **109**: p. 199-207.
- 895 13. Ockwell, D. and R. Byrne, *Sustainable Energy for All: Innovation, Technology and Pro-Poor Green*
896 *Transformations*. 2017, Abingdon: Routledge.
- 897 14. Scoones, I., *The Politics of Sustainability and Development*, in *Annual Review of Environment and Resources*.
898 2016. p. 293-319.
- 899 15. Scoones, I., M. Leach, and P. Newell, eds. *The Politics of Green Transformations*. 2015, Routledge: Abingdon.
- 900 16. Byrne, R., K. Mbeva, and D. Ockwell, *A political economy of niche-building: Neoliberal-developmental encounters*
901 *in photovoltaic electrification in Kenya*. Energy Research & Social Science, 2018. **44**: p. 6-16.
- 902 17. Stirling, A., *Pluralising progress: From integrative transitions to transformative diversity*. Environmental
903 Innovation and Societal Transitions, 2011. **1**: p. 82-88.
- 904 18. Bisaga, I. and P. Parikh, *To climb or not to climb? Investigating energy use behaviour among Solar Home System*
905 *adopters through energy ladder and social practice lens*. Energy Research & Social Science, 2018. **44**: p. 293-303.
- 906 19. Muchunku, C., et al., *Diffusion of solar PV in East Africa: What can be learned from private sector delivery models?*
907 Wiley Interdisciplinary Reviews: Energy and Environment, 2018. **7**(3): p. e282.
- 908 20. Amankwah-Amoah, J., *Solar Energy in Sub-Saharan Africa: The Challenges and Opportunities of Technological*
909 *Leapfrogging*. Thunderbird International Business Review, 2015. **57**(1): p. 15-31.
- 910 21. Goodier, R., *Micro-Power! Making an impact on millions one home at a time*. Appropriate Technology, 2015.
911 **42**(4): p. 26-27.
- 912 22. Groh, S. and H. Taylor, *The role of microfinance in energy access: Changing roles, changing paradigms, and*
913 *future potential*. Enterprise Development and Microfinance, 2015. **26**(4): p. 307-324.
- 914 23. Reichert, P. and U. Trivella, *Increasing energy access: The rise of payas-you-go solar and innovative*
915 *financing partnerships*. Enterprise Development and Microfinance, 2015. **26**(3): p. 248-261.
- 916 24. Collings, S. and A. Munyehirwe, *Pay-as-you-go solar pv in rwanda: Evidence of benefits to users and issues of*
917 *affordability*. Field Actions Science Report, 2016. **2016**(Special Issue 15): p. 94-103.
- 918 25. Wheldon, A., E. Dobbs, and C. Sharma, *15 years of development in access to offgrid renewable electricity: Insights*
919 *from the Ashden awards*. Field Actions Science Report, 2016. **2016**(15): p. 150-159.
- 920 26. von Hülsen, A., T. Huth, and S. Koch, *Village power scaling rural electrification in Uganda*. Field Actions
921 Science Report, 2016. **2016**(Special Issue 15): p. 104-113.
- 922 27. Winiecki, J. and K. Kumar, *Access to Energy via Digital Finance: Overview of Models and Prospects for*
923 *Innovation*. 2014, CGAP: Washington DC.
- 924 28. Zollmann, J., et al., *Escaping Darkness. Understanding Consumer Value in PAYGo Solar*. 2017, CGAP:
925 Washington DC.
- 926 29. Rogers, E.M., *Diffusion of innovations (1st ed.)*. 1962, New York: Free Press of Glencoe.
- 927 30. Ockwell, D., et al., *The uptake and diffusion of solar power in Africa: Socio-cultural and political insights on a*
928 *rapidly emerging socio-technical transition*. Energy Research & Social Science, 2018. **44**: p. 122-129.
- 929 31. Westley, F., et al., *Social Innovation Lab Guide*. 2015, Waterloo Institute for Social Innovation and Resilience:
930 Waterloo, Canada.
- 931 32. Pathways Network, *T-Labs: A Practical Guide - Using Transformation Labs (T-Labs) for innovation in*
932 *social-ecological systems*. 2018, STEPS Centre: Brighton, UK.
- 933 33. Furlong, K., *STS beyond the "modern infrastructure ideal": Extending theory by engaging with infrastructure*
934 *challenges in the South*. Technology in Society, 2014. **38**: p. 139-147.
- 935 34. Freeman, C., *The National System of Innovation in Historical Perspective*. Cambridge Journal of Economics,
936 1997. **19**: p. 5-24.

- 937 35. Ockwell, D. and R. Byrne, *Improving technology transfer through national systems of innovation: climate relevant*
938 *innovation-system builders (CRIBs)*. Climate Policy, 2016. **16**(7): p. 836-854.
- 939 36. Truffer, B., *Challenges for Technological Innovation Systems research: Introduction to a debate*. Environmental
940 Innovation and Societal Transitions, 2015. **16**(Supplement C): p. 65-66.
- 941 37. Kemp, R., J. Schot, and R. Hoogma, *Regime shifts to sustainability through processes of niche formation: the*
942 *approach of strategic niche management*. Technology Analysis and Strategic Management, 1998. **10**: p. 175-
943 196.
- 944 38. Geels, F., *Technological transitions as evolutionary reconfiguration processes: a multi-level perspective and a*
945 *case-study*. Research Policy, 2002. **31**: p. 1257-1274.
- 946 39. Pedersen, M.B. and I. Nygaard, *System building in the Kenyan electrification regime: The case of private solar*
947 *mini-grid development*. Energy Research & Social Science, 2018. **42**: p. 211-223.
- 948 40. Rodríguez-Manotas, J., P.L. Bhamidipati, and J. Haselip, *Getting on the ground: Exploring the determinants of*
949 *utility-scale solar PV in Rwanda*. Energy Research & Social Science, 2018. **42**: p. 70-79.
- 950 41. Ulsrud, K., et al., *Pathways to electricity for all: What makes village-scale solar power successful?* Energy Research
951 & Social Science, 2018. **44**: p. 32-40.
- 952 42. Davies, G., *Clean energy product markets in sub-Saharan Africa: Complex market devices and power asymmetries*.
953 Energy Research & Social Science, 2018. **42**: p. 80-89.
- 954 43. Hansen, U.E., et al., *Sustainability transitions in developing countries: Stocktaking, new contributions and a*
955 *research agenda*. Environmental Science & Policy, 2017.
- 956 44. Wiecek, A.J., *Sustainability transitions in developing countries: Major insights and their implications for*
957 *research and policy*. Environmental Science & Policy, 2017.
- 958 45. Shove, E., *Beyond the ABC: climate change policy and theories of social change*. Environment and Planning A,
959 2010. **42**: p. 1273 - 1285.
- 960 46. Shove, E. and G. Walker, *What Is Energy For? Social Practice and Energy Demand*. Theory, Culture & Society,
961 2014. **31**(5): p. 41-58.
- 962 47. Byrne, R., et al., *Energy Pathways in Low Carbon Development: The Need to Go Beyond Technology Transfer, in*
963 *Low Carbon Technology Transfer: From Rhetoric to Reality*, D. Ockwell and A. Mallett, Editors. 2012,
964 Routledge: Abingdon.
- 965 48. Marshall, M., D. Ockwell, and R. Byrne, *Sustainable Energy for All, or Sustainable Energy for Men? Gender and*
966 *the construction of identity within climate technology entrepreneurship in Kenya*. Progress in Development
967 Studies, 2017. **17**(2): p. 1-25.
- 968 49. Winther, T., et al., *Women's empowerment through electricity access: scoping study and proposal for a framework of*
969 *analysis*. Journal of Development Effectiveness, 2017. **9**(3): p. 389-417.
- 970 50. Winther, T., K. Ulsrud, and A. Saini, *Solar powered electricity access: Implications for women's empowerment in*
971 *rural Kenya*. Energy Research & Social Science, 2018. **44**: p. 61-74.
- 972 51. Pschetz, L., et al., *Understanding situated energy values in rural Kenya*. 2018, DRS. p. 729-746.
- 973 52. Martin, C., et al., *The Lived Experience of Energy and Forced Displacement*. 2018: Practical Action.
- 974 53. Lasswell, H.D., *Politics: Who gets what, when, how*. 1936, New York: P. Smith.
- 975 54. Geels, F., *Regime Resistance against Low-Carbon Transitions: Introducing Politics and Power into the Multi-Level*
976 *Perspective*. Theory Culture & Society, 2014. **31**(5): p. 21-40.
- 977 55. Kern, F., *Engaging with the politics, agency and structures in the technological innovation systems approach*.
978 Environmental Innovation and Societal Transitions, 2015. **16**: p. 67-69.
- 979 56. Newell, P. and J. Phillips, *Neoliberal energy transitions in the South: Kenyan experiences*. Geoforum, 2016. **74**: p.
980 39-48.
- 981 57. Schmitz, H., *Value Chain Analysis for Policy-Makers & Practitioners*. 2005, International Labour Organization:
982 London.
- 983 58. Polanyi, K., *The Great Transformation: The Political and Economic Origins of our Time*. 1980 (1944), Boston:
984 Beacon Press.
- 985 59. Harvey, D., *A Brief History of Neoliberalism*. 2005, Oxford: Oxford Univ. Press.
- 986 60. Phillips, J., K. Das, and P. Newell, *Governance and technology transfer in the Clean Development Mechanism in*
987 *India*. Global Environmental Change, 2013. **23**(6): p. 1594-1604.
- 988 61. Watson, J., et al., *What are the major barriers to increased use of modern energy services among the world's poorest*
989 *people and are interventions to overcome these effective?* CEE Review 11-2004. . 2012, Collaboration for
990 Environmental Evidence. Available at: <http://www.environmentalevidence.org/SRSR11004.html>.

- 991 62. Newell, P., *Trasformismo or transformation? The global political economy of energy transitions*. Review of
992 International Political Economy, 2018: p. 1-24.
- 993 63. Stirling, A., *Emancipating Transformations: From controlling 'the transition' to culturing plural radical progress*,
994 STEPS Working Paper 64. 2014, STEPS Centre: Brighton.
- 995 64. Stirling, A., "Opening Up" and "Closing Down": Power, Participation, and Pluralism in the Social Appraisal of
996 Technology. Science, Technology & Human Values, 2008. **33**(2): p. 262-294.
- 997 65. Stirling, A., *Towards innovation democracy? Participation, responsibility and precaution in the politics of science*
998 *and technology*, STEPS Working Paper 78. 2015, STEPS Centre: Brighton.
- 999 66. Leach, M. and R. Mearns, *The Lie Of The Land. Challenging Received Wisdom On The African Environment*.
1000 1996, Oxford: James Curry.
- 1001 67. Scoones, I., et al., *Pathways to Health and Sustainability*. 2018, Abingdon: Routledge.
- 1002 68. Waldman, L., et al., *Peri-Urbanism in Globalizing India: A Study of Pollution, Health and Community Awareness*.
1003 Int. J. Environ. Res. Public Health, 2017. **14**(9): p. 980.
- 1004 69. Bardosh, K., *One Health. Science, politics and zoonotic disease in Africa*. 2016, Abingdon: Routledge.
- 1005 70. Sumberg, J., *Agronomy for Development: The Politics of Knowledge in Agricultural Research*. 2017, Abingdon:
1006 Routledge.
- 1007 71. Scoones, I., et al., *Pathways to Sustainable Agriculture*. 2017, Abingdon: Routledge.
- 1008 72. Whitfield, S., *Adapting to Climate Uncertainty in African Agriculture. Narratives and knowledge politics*. 2015,
1009 Abingdon: Routledge.
- 1010 73. Sumberg, J. and J. Thompson, *Contested Agronomy: Agricultural Research in a Changing World*. 2012,
1011 Abingdon: Routledge.
- 1012 74. Scoones, I., *Sustainable Livelihoods and Rural Development*. 2015, Warwick: Practical Action Publishing.
- 1013 75. Smith, A., et al., *Grassroots Innovation Movements*. 2016, Abingdon: Routledge.
- 1014 76. Ely, A., Adrian Smith, and Patrick Van Zwanenberg, *Regulating Technology: International Harmonization and*
1015 *Local Realities*. 2011, Abingdon: Routledge.
- 1016 77. Marshall, F. and J. Dolley, *Transformative innovation in peri-urban Asia*. Research Policy, 2018.
- 1017 78. Marshall, F., J. Dolley, and R. Priya, *Transdisciplinary research as transformative space making for sustainability:*
1018 *enhancing propoor transformative agency in periurban contexts*. Ecology and Society, 2018. **23**(3): p. 8.
- 1019 79. Karpouzoglou, T., F. Marshall, and L. Mehta, *Towards a peri-urban political ecology of water quality decline*.
1020 Land Use Policy, 2018.
- 1021 80. Lemos, M.C., et al., *Advancing metrics: models for understanding adaptive capacity and water security*. Current
1022 Opinion in Environmental Sustainability, 2016. **21**: p. 52-57.
- 1023 81. Leach, M., *Gender Equality and Sustainable Development*. 2016, Abingdon: Routledge.
- 1024
- 1025 **Acknowledgments:** The authors gratefully acknowledge the ESRC [grant number ES/I021620/1] for financial
1026 support, as well as the Transformations to Sustainability programme, which is coordinated by the International
1027 Social Science Council (ISSC) and funded by the Swedish International Development Cooperation Agency
1028 (Sida), and implemented in partnership with the National Research Foundation of South Africa (Grant Number
1029 ISSC2015- TKN150224114426).