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TIME to Change: Rethinking Humanitarian Energy Access

Benjamin L. Robinson [a,*], Mike J. Clifford [a], Sarah Jewitt [b]

[a] University of Nottingham, Faculty of Engineering, University Park, Nottingham NG7 2RD, UK
[b] University of Nottingham, School of Geography, University Park, Nottingham NG7 2RD, UK

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ABSTRACT

Achieving Sustainable Development Goal 7 - universal access to affordable, reliable and modern energy services by 2030 – represents a considerable challenge. Currently, 40% of the global population do not have access to sustainable energy sources, and instead rely on burning biomass to satisfy their energy needs. Despite a long history of energy technology for poverty-alleviation initiatives across the globe, many interventions fail at persuading end-users to continue using these technologies beyond an initial adoption phase. Whilst many champion sustainable energy solutions, most evaluation approaches do not consider long term sustained use. As a result, many end-user-orientated energy solutions, such as Improved Cookstoves (ICS), fall out of use once project partners depart. These failures are often due to emphasis on ever-more-complex technologies rather than social methodologies such as understanding end-user priorities and the complex contextual barriers to sustained use.

In this paper, we present a novel interdisciplinary formative and evaluative implementation or delivery model, the qualitative Technology Implementation Model for Energy (TIME), for practitioners and policymakers. TIME focuses on refining three core areas of energy technology implementation; to rethink how impact is defined, to understand differences between practitioner perception and end-user reality, and to champion a co-produced approach with all key stakeholders in the energy system. TIME is the first energy implementation model to blend Social Enterprise, Appropriate Technology, Water, Hygiene and Sanitation behavioural change models as well as International Development planning tools whilst advocating an approach centred around co-production, ownership, use of resources and equality.

1. Introduction

The launch of the United Nations Sustainable Development Goals (SDG) [1] created a unified approach for International Development agendas across all participating UN countries. This new roadmap of 17 goals to achieve a "Sustainable Future for All by 2030" [1] championed the eradication of poverty and hunger, reduced inequalities, access to education, and climate action to reduce the global carbon emissions as well as SDG7 – Sustainable Energy for All. SDG7 "ensures access to affordable, reliable, sustainable and modern energy for all" [1] and champions three core elements: increasing energy access, enabling the energy transition and increasing energy efficiency. Yet, despite this roadmap to a sustainable future, in 2021, 40% of the global population does not have access to clean fuels and technologies for cooking [2]. These 2.6 billion people are exposed to household air pollution daily which results in a number of irreversible respiratory health issues responsible for up to 4 million deaths per year with 20% of these being children under the age of 5 [2]. These issues are especially relevant in the context of COVID-19, where underlying respiratory issues are one of the distinguishing factors between life and death [3]. This prompts the question; how can practitioners and policymakers better utilise improved energy technologies to achieve SDG7?

Energy technology implementation, or delivery, is historically an understudied element of the improved energy access literature. Researchers, development practitioners and regional, national and international policymakers often focus on technical performance rather than the complex socio-cultural, environmental and financial context of implementation which results in the disenfranchisement of technology end-user preferences. Whilst there is an emerging literature on energy delivery models, as outlined by Bisaga and To [4], these often focus on overcoming the financial barriers to adoption rather than taking a formative and evaluative systems approach to overcoming the complex socio-cultural, environmental and financing factors that act as barriers to adoption and sustained use of improved energy technologies. The

* Corresponding author.
E-mail address: benjamin.robinson@nottingham.ac.uk (B.L. Robinson).

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literature is littered with examples of energy technologies such as improved cookstoves, solar panels, biogas units and even traditional diesel generators seeing initial adoption, but no long term use due to usability issues, maintenance, finance, and social acceptability, to name just a few [5–9]. As an example, in the case of Improved Cookstoves (ICS) this has resulted in increasing complexity and cost but not adoption rates [10]. Often, the limited usability of ICS and the lack of alignment with contextual cooking practices results in the user 'backsliding' [11] or retuning to traditional technologies such as a three stone fire. The misalignment of priorities between energy technology researchers/developers and technology end-users is often created by these two processes being conducted on opposite sides of the globe with many end-users living in low-income environments whilst researchers/technology developers do not.

Methods of identifying contextual factors in energy access discourse are focussed on either large-scale quantitative surveys or detailed portraits of lived experience through qualitative research methods. Quantitative methods focus on national or regional scale trends through large data sets, which cannot identify specific contextual factors associated with the lived experience of technology end-users. Previous work by the authors of this paper showed that these contextual factors vary throughout space and time in Nepal and require an understanding of end-user lived experiences [5,12–14]. However, quantitative surveys can be conducted without direct contact with users and at low cost through readily available Government Surveys, such as the Household Survey in Nepal [15] or more general Demographic and Health Surveys [16] which can provide a COVID-19 safe approach to data collection. Qualitative research methods [17] use tools such as semi-structured interviews which require direct contact with users and investment for researchers in developing interview skills, direct contact with end-users, time, and translation. However, qualitative research methods can provide deeper insights into end-user behaviours resulting in a more comprehensive understanding of specific contextual barriers. Yet, despite a growing body of literature identifying these contextual barriers [18–20], a research gap still remains around the formative process of integrating these contextual factors into the implementation of improved energy technologies and the evaluation of these processes. However, other sectors focused on environmental health issues, such as the Water, Sanitation and Hygiene sector have reacted by transitioning to a 'software' orientated approach rather than continuing to champion 'hardware' approaches focused on technical development [18]. Given the capital investment of modifying the technical outputs of an energy technology and the logistical challenge of producing an individual product for each context, focusing on integrating these complex contextual factors at the implementation stage also increases the cost effectiveness of improved energy programs, in addition to the core benefit of increasing the probability of the sustained use of a poverty-alleviating technology.

In this paper we present the novel interdisciplinary Technology Implementation Model for Energy (TIME) which was developed from four key literature groups: appropriate technology (AT), social enterprise (SE), water, sanitation and hygiene behavioural change models (WASH BCM) and international development planning tools. This interdisciplinary approach extracts core themes and structures from these literature groups to both develop TIME, and further discourse around improved energy access. Additionally, TIME provides a novel formative and evaluative practitioner and policymaker orientated approach to energy technology implementation for poverty-alleviation that seeks to facilitate the integration of complex socio-cultural, environmental and financial contextual factors into the implementation of energy technologies. We achieve this by championing a co-produced approach with all key stakeholders, redefining metric-based impact, and deconstructing the differences between practitioner expectations and end-user reality. Whilst this paper provides the theoretical background, the practical application of TIME in the Nepalese biomass ICS market is presented by Robinson et al. [13].

The structure of this paper is as follows: in Section two we outline the methodological approach to developing TIME which has both theoretical and practical foundations. Section three outlines the results of the literature search and discusses the themes identified from this process as well as introducing TIME and defining core elements. Section four considers the implications of TIME in terms of the theory-practice paradigm, the role of co-production in improved energy access, the impact of perspective and perception, changing focuses from adoption to sustained use and a number of methodological limitations. The final section, Section five, brings together these findings to conclude the paper.

2. Methods

2.1. Literature review groups

We identified four literature groups that had the potential to synthesise into a novel methodology that could integrate the complex contextual factors often cited as the central barriers to the adoption and sustained use of poverty-alleviating energy technologies. It was important for this methodology to be inclusive of market orientated solutions, to understand the behavioural change of technology end-users, and how this behaviour could be influenced by a range of key energy stakeholders. Improved energy access programs are often focussed on impact metrics such as the number of technologies implemented, rather than understanding the behavioural drivers of technology adoption, which we term a values-driven approach. In this paper we look to promote this values-driven approach to improved energy access drawing on literature from AT, SE, WASH BCMs and international development planning tools.

2.1.1. Appropriate technology

Established by Schumacher [21], **AT** focuses on the design of the technology itself from a technical engineering perspective. Recent interpretations of AT echo many of the 10 core principles [22] developed by Schumacher [21] referring to a de-centralised, product centred approach where low-cost, small-scale, easy to construct technologies are of central importance. However, the modern interpretations also stress the importance of the process being operated by, or in conjunction with, individuals from the targeted community co-producing outcomes together [23–26]. Other modern interpretations, such as Grieve [27], state that the introduction of labour-intensive technologies have gone out of fashion, suggesting capacity building exercises coupled with AT solutions provide a more successful method for technology adoption, creating a multi-level interventions rather than the product centred approach of Schumacher.

2.1.2. Social enterprise

Alter [28] provides a generally accepted definition of **SE**, "a revenue-generating activity founded to create positive social impact while operating with reference to a financial bottom line". The core principles of SE [29] are derived from Muhammad Yunus's field tests for micro-loans in rural Bangladesh in the early 1970s [30]. A number of **Social Enterprise tools** build upon these founding principles to formulate and evaluate a range of social enterprises. Social Return on Investment (SORI) [31] and the Social Enterprise Balanced Scorecard [32,33] are planning and evaluation tools which map the strategic process, linking inputs, outputs, outcomes and impacts from a number of perspectives (stakeholder, financial, internal process perspective and resource allocation).

2.1.3. Water, sanitation and hygiene behavioural change models

The **WASH BCM** literature leans towards a more "software" based approach rather than the "hardware" approach favoured by most stakeholders in the energy sector who often prioritise improved efficiencies over social methodologies. There has also been significant focus on behavioural determinants linked to opportunity, ability and motivation which have parallels with factors affecting adoption and sustained use in the energy sector as supported by Sesan et al. [34] in their analysis of improved cookstove and WASH sector synergies. WASH BCMs add value to this research enabling researchers to better understand the drivers of end-user behavioural change when adopting and continuously using a poverty-alleviating technology.

2.1.4. International development planning tools

International Development Planning tools, such as LogFrames [35,36], Theory of Change [37,38] and the Market Map [39,40] provide established and proven methodologies in the poverty-alleviation sector (brief explanations of these tools are provided in Section 3.1). Nevertheless, they have significant limitations in identifying complex contextual barriers to sustained use that TIME looks to overcome.

2.2. Conceptualisation of TIME

Findings from the literature review informed the development of the initial theoretical framework, which was presented to two study groups before being finalised as TIME. These study groups included five Global Challenge Research Fund primary investigators [41] and stakeholders in Practical Action Nepal's program on Results Based Financing for Improved Cookstove Market Chain Strengthening [13]. The Global Challenge Research fund primary investigator semi-structured interviews were conducted between October and December 2019 and participants were identified by a systematic review [42,43] of 882 projects (representing 824,742,658 GBP) based upon a number of inclusion/exclusion criteria such as, receiving zero funding, SDG7 (Energy) Alignment, Technology AND/OR Enterprise. These criteria were designed to quickly reduce the number of projects with 12 matches identified. These projects were further reduced to 5 by removing projects of a similar nature or that were not directly relevant to the low-income energy topic. Nuclear energy projects, for example, were not included.

The Practical Action project looked to develop a market for Improved Cook Stoves (ICS) in Province 3 and Gandaki Province of rural Nepal which is situated 200 km west of Kathmandu, in the mid-hills of the Himalayas (1500-2500 m altitude). The program sought to offer increased customer choice by building the capacity of market chain actors, strengthening support services and facilitating an enabling environment for the purchase of ICS. Demand and supply side incentives were provided to end-users and private sector actors as well as a range of behavioural change campaigns directed at increasing awareness of the benefits of ICS. Between January and April 2020, the lead author conducted 31 semi-structured interviews and a number of informal interviews with a range of key stakeholders across the key stakeholder groups presented in Section 3.2. The findings of this study in the context of results based financing are presented by Robinson et al. [13]. In this paper we recognise this practical application of TIME to be central in developing the data collection and analysis methodology as well as the framework structure. This process of framework evolution is discussed in more detail by Robinson [41]. In addition to the two study groups, this paper builds upon previous research by the authors using the Market Map Model to map the Nepalese biomass ICS sector [39] and developing Institutional Cooking Solutions in Nepal [14] to integrate learnings from this process into a new theoretical framework.

3. Results

3.1. Identification of literature themes

This method of combining or blending a number of established approaches echoes Owen et al. [44] with the Responsible Innovation framework and Dreibelbis et al. [45] in developing the Integrated Behavioural Model for Water, Sanitation and Hygiene (IBM-WASH). In this section, we identify a number of overarching themes which lays the foundation for Section 3.2 where we discuss how these translate into the four core factors (Co-Production, Ownership, Utilisation, Equality) that define the structure and methodology of TIME.

We derived these factors from the SE and AT core principles set out by the founders of both movements, Yunus and Webber [29] and Schumacher [21] as well as the other literature groups mentioned in Section 2. For example, we built upon definitions of utilisation from AT principle 9 (technical flexibility), AT principle 6 (utilisation of processes on organisational, personal and societal levels) and AT principle 8 (educational flexibility to modify tools to best utilise local understanding) [22]. This flexibility with regards to context ensures local needs are suitably met. Estrella et al. [46] suggest this process is difficult and as a result “needs to be integrated as part of project activities”.

In addition, we draw from IBM-WASH, which synthesises eight other health orientated behavioural change models which aim to promote concepts of ownership, co-production and equality. In addition to engaging directly with the habitual level of behavioural change (key to facilitating ownership) not seen in other frameworks, it aims to “transcend the individual level” [45] by capturing interactions between behaviour change influences from different levels and dimensions. We also built on SaniFOAM [47], a model synthesised by IBM-WASH, which presents a capability-oriented approach, asking if end-users have the opportunity/ability/motivation to sufficiently change their habitual behavioural patterns. But whilst this approach integrates end-user preferences, the technologies being implemented have often already been deemed ‘good’ for the user group, rather than actual need being established prior to implementation. Understanding and reacting to actual energy needs is critical to co-producing energy programs.

We also chose to focus on three International Development Planning Tools, the logframe [36], Theory of Change [38] and the Market Map [48] due to their prevalence in existing International Development sector practice. These tools have evolved from similar roots with the limitations of LogFrames leading to the creation of the Theory of Change, or theory of action which considers the internal process of change [36] by interrogating assumptions and expectations central to the co-production of outcomes. These three models are thus complimentary and often used together. Additionally, the market map provides a useful framework to build inter-geographical comparisons between contextually different enabling environments as well as to identify broader barriers to energy technology uptake, promote inter-country learning, enhance monitoring approaches and integrate end-user feedback into the future development of improved energy technologies [40,49]. However, often these development practitioner frameworks promote participation but keep core decision processes centralised due to funding constraints. This does not give technology end-users a participatory role in the creation of inputs, activities, outputs, outcomes or impacts. The TIME framework looks to overcome the limitations of these tools by synthesising specific elements from the SE, AT and WASH BCM literatures previously identified.

3.2. Technology implementation model for energy

TIME synthesises the themes identified in Section 3.1. which were reviewed through the two study groups as mentioned in Section 2. TIME's hybrid structure blends causal pathways and matrixes resulting in two distinct elements, the Strategic Planning Element (SPE) and the enabling environment matrix (EEM) (Fig. 1). The relationship between these two elements occurs through the engagement sub-factor and is reflective (or cyclical) as information obtained in the SPE can inform the EEM and vice-versa. Matrices allow the exploration of complex multi-level relationships (as in IBM-WASH) rather than causal pathways which present linear steps to technology adoption (as in Theory of Change). Matrices are the most common structure in the models analysed throughout this paper due to their ability to conduct multi-level analysis such as in the SORI and IBM-WASH. Causal pathways are less

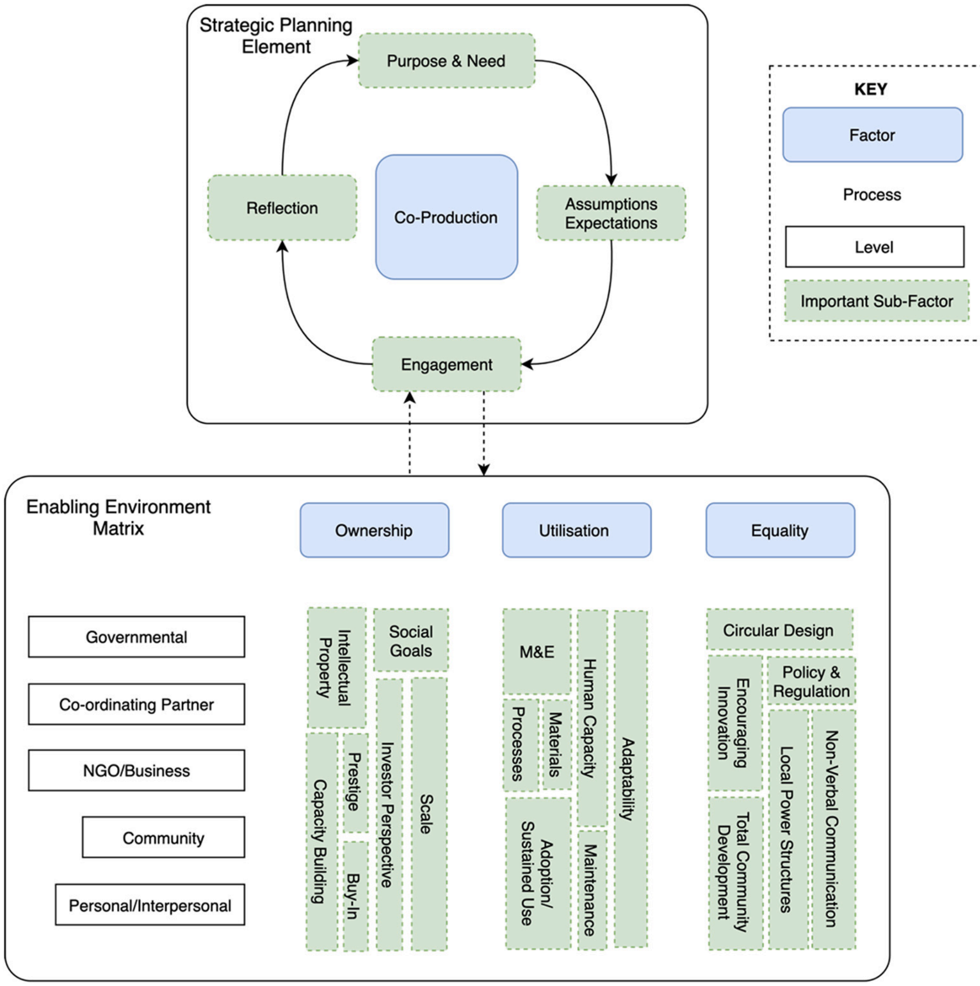

Fig. 1. Technology implementation model for energy (TIME).

common as presenting complex contextual relationships between levels and factors is more difficult. Hybrid structures are also less common, for example, SORI [31] uses a causal pathway for the overall structure of the analysis but uses matrices when considering the individual steps such as the impact map.

The SPE contains four causally linked sub-factors (Purpose & Need, Assumptions & Expectations, Engagement, Reflection) contextualised through the lens of co-production. This lens considers not only what the end-user adds but what the other key stakeholders can add to the end users as one key stakeholder does not drive the process; it is a collaboration between all key stakeholders. This takes inspiration from how the LogFrame is designed "to demonstrate how parts of a program fit together, neatly and logically, and how a series of program activities will lead to a specific set of program objectives" [36], whilst overcoming its shortcoming of failing to capture the complex behavioural processes that occur both between key stakeholders and by end-users. The EEM expands the engagement sub-factor to define the roles and responsibilities of each Key Stakeholder Group (KSG) (Governmental, Co-ordinating Partner, NGO/Business, Community, Personal/Interpersonal) as well as their interactions in the context of three factors, identified from our key literature groups, which are central to influencing behavioural change: Ownership, Utilisation (People & Systems and Material Resources), Equality. The results (or perceptions) of each KSG are individually mapped onto the EEM resulting in 5 EEM perspectives, highlighting any misalignment of priorities resulting in a redefinition of role. This not only highlights discrepancies in role but also shows how the KSG interacted with one another through overlap in the EEM perspectives. This element is inspired by the Theory of Change which provides a robust method to identify linkages between factors and levels; facilitating better co-developed understandings of change by enabling "stakeholders to present and test their theories and assumptions about why and how impact may occur" [38] and mitigating the shortcomings of the LogFrame tool. When combined with the visual mapping mechanisms used for the presentation of results, this produces a powerful tool accessible to development practitioners and policymakers and capable of elucidating complex issues associated with behaviour change; the importance of which is emphasised by Dreibelbis et al. [45].

3.2.1. *Strategic planning element*

Within the SPE the **Co-Production** factor pushes policymakers and practitioners to co-design, co-create and collaborate the Purpose & Need, Assumptions & Expectations, Engagement and Reflective sub-factors with all KSGs. This results in all key stakeholders from end-users to government officials having an equal voice in the strategic direction of any project or policy.

The **Purpose & Need** sub-factor looks to capture the barriers to technology adoption and sustained use from each KSG perspective and align these barriers with the purpose of the project. This establishment of actual need (as opposed to the perception of need) is of central importance as this need often evolves through space and time as the relationship between end-user and technology develops. By understanding the actual energy needs of end-users, as opposed to the perception of need, when proposing energy solutions, the user of TIME can more effectively shape the resulting engagement strategies around ownership, utilisation and equality.

The **Assumptions & Expectations sub-**factor explores the difference between coordinating partner assumptions and end-user/other KSG expectations. Traditionally, the disconnect between the end-user and the implementing organisations priorities results from assumptions made with little understanding of the expectations and associated complex contextual issues felt by the end-users. Identifying these assumptions (what is known, what is not, prepared for unknown unknowns) then becomes central to the strategic planning process. A common assumption, for example, is that ICS users only use one type of cookstove as stated in the linear Energy Ladder Model [50]. This sub-factor looks to also mitigate the failure of many approaches to integrate end-users' perspectives, including the Market Map which values end-users as customers but not as participants in the market mapping process. This results in a top-down view of a value chain with equal attention not given to the demand and supply elements. With its efforts to include socio-cultural, financial and environmental factors from the perspective of the end-user, not practitioner, TIME seeks to avoid this top-down approach.

Core to any successful energy technology implementation is the **Engagement** strategy, or the methods chosen to take the technology from testing into the field. This sub-factor is captured and elaborated through the EEM.

The final SPE sub-factor, **Reflection**, echoes the Responsible Research and Innovation (RRI) framework [51,52] where researchers are encouraged to reflect and act upon the continual research learning process. The reflection sub-factor also arises from the understanding that no implementation model is perfect, continuous improvement is needed especially given the spaciotemporal variations in the contextual environment [53]. The act of reflection can redirect incorrect assumptions or a confusing purpose back to accurately represent end-user/other KSG needs. This reflective element, as championed by RRI, is not often seen in existing energy access approaches due to the short-term nature of funding systems. TIME looks to build this factor into the core project processes so that reflective practice can continue after the completion of funding.

These four sub-factors elaborate on the Focus element of SaniFOAM whilst also reflecting the bottom-up approaches presented in the participatory literature surrounding WASH interventions. As argued by Sesan et al. [34] there is a need to focus on end-user priorities rather than blindly implementing benefit-laden technologies. By communicating with technology end-users and understanding what really matters, interventions are designed to directly address user needs – a theme throughout SORI. This, hopefully, results in the adoption and sustained use [54] of poverty-alleviating technologies.

3.2.2. Enabling environment matrix

Contained within the EEM, **Ownership** is defined as the user buying into the technology through a carefully constructed program promoting sustained use resulting in the user feeling part of the design and/or implementation process. This feeds into the multi-dimensional nature of technology use when engaging with the maintenance of technology over time (driven by a feeling of ownership). The Reach, Efficacy, Adoption, Implementation, Maintenance (RE-AIM) framework [55] directly highlights this dimension as core to the adoption and sustained use of technology. Whilst wider behavioural WASH models tend to focus on the behavioural determinants, TIME looks to echo IBM-WASH's focus on both the software and hardware elements of improved energy access when considering Ownership.

The **Utilisation** of local resources, people and/or materials captures both the energy technology itself and the surrounding local value chain or systems. This focus both reduces the environmental impact of materials traveling large distances but also utilises local systems, such as manufacturers and distributors, in an effort to stimulate local micro-economies, employ local people, get user buy-in, facilitate effective maintenance, and create local ownership of processes and technologies resulting in sustainability of use. This takes inspiration from the SE and AT, though instead of focusing on technical development we are focusing on human centred interventions.

Financial, Environmental and Social Sustainability are central to promoting **Equality** throughout the planning and implementation processes. This factor ensures that co-produced values or the perception of those values are equitable and just for all across the entire project cycle. This stretches from design, implementation, evaluation to the methods of communication in an effort to include all segments encompassed by community living. There will be no discrimination based upon race, caste, language, religion or nationality. The equality factor also looks to break down traditional (and often hidden) colonial power structures of international development initiatives by valuing all KSG equally [56,57].

The Levels or Key Stakeholder groups contained within the EEM include Government, Co-ordinating Partner, NGO/Business, Community, Personal/Interpersonal. The **Government** level includes local, regional and national governments or power structures responsible for determining, implementing and regulating governance and policy in the focus country. The **Co-ordinating Partner** is responsible for project facilitation, planning and knowledge exchange. Usually this would also include providing funding or facilitating funding between the other key stakeholder groups. The **NGO/Business** level captures the formal in-country organisations involved in the design, development and implementation of energy technologies. This includes, but is not limited to; suppliers, manufactures, distributors, consultants, local NGOs and other value chain actors. The Community and Personal/Interpersonal level broadly mirror these levels in IBM-WASH. The **Community** level includes “the physical and social environment in which individuals are nested” [45]. We also extend this to include informal organisations that have the ability to influence community level decision making. The **Personal/Interpersonal** level represents, “age, gender, individual cognitive factors, and attitudes towards the product, hardware, or behaviour” [45] as well as interactions between individual community members. The EEM sub-factors presented in Fig. 1 give examples of the data generated from the two study groups. It's important to note that these sub-factors can exist across multiple levels and that they are subject to change depending on implementation context.

4. Discussion

4.1. The theory – practice paradigm

In line with the evidence-based approach of Dreibelbis et al. [45] in the WASH sector, we seek to champion a method which strengthens the theoretical foundation of formative and evaluative approaches to energy technology implementation through the practical application of TIME. We acknowledge the value of deriving this implementation model from theory and practice. The application of TIME in a real world context, and its earlier variations to two study groups, resulted in significant structural and methodological changes as shown in more detail by Robinson [41]. For example, the primary investigator interviews refined the relationship between the four SPE sub-factors, integrated a societal level into the expectation/assumptions sub-factor, integrated habitual use into the personal levels as well as defining the cyclical relationship between the SPE and the EEM. The application to Practical Action Nepal's project resulted in further groupings of behavioural determinants, mapping of barriers to enablers through the purpose -> assumptions -> engagement -> reflection elements. The utilisation sub-factors were also re-named to more accurately capture key roles and interactions of stakeholder groups and link the EEM to the SPE through the engagement sub-factor. This process also facilitated the development of semi-structured interview questions as well as the qualitative codebooks that framed the data analysis.

In addition to strengthening the theory with practice, the practical application of TIME also allowed practitioners and policymakers to provide direct feedback on the usability of TIME as well as, in the case of Practical Action in Nepal, an opportunity for the lead author to train practitioners on the use of TIME. This resulted in identifying a number of limitations discussed in Section 4.2.4 and providing a practitioner perspective on the best way to implement TIME. Whilst this process of theoretical strengthening added significant value to TIME, it must be acknowledged that we intend for, and encourage, other researchers and practitioners who use TIME to further iterate the model beyond how it is presented here.

4.2. TIME to change

4.2.1. A co-produced approach to energy technology implementation

A long history of energy technology implementation in low-income environments has resulted in varied and diverse strategies to increase end-user demand and create value sustainable chains through incentivising supply and demand side actors. These strategies have revolved around environmental, educational, safety and health goals yet the complex contextual barriers often seem to be the determining factor in success. This paper proposes a new system wide approach, similar to IBM-WASH's “transcending the individual level” [45], where the technology end-users not only partake in the development of the implementation strategy but are seen as equitable co-producers central to sustainable change. Traditionally implementation models are either top-down or bottom-up driven, with the decision-making process either at the top or bottom, with the implementing partner or the end-user. This system devalues the contribution of one or more key stakeholder groups. TIME proposes a system where all key stakeholder groups co-produce the implementation strategy. For example, as shown by Robinson et al. [13] in the Nepalese context, this meant that from the Government perspective, policy must take into account complex contextual factors faced by end-users and focus on developing project goals around key stakeholder group strengths. However, this co-produced strategy is reliant on a fair and open communication methodology where no key stakeholder groups have decision making power over another which can be challenging as traditionally one partner holds the financial power. Whilst we recognise the power of TIME as a formative and evaluative tool, it may then be best implemented by a third party when used as an evaluative tool to ensure the equitability of process.

4.2.2. Practitioner perception Vs end-user reality

The multi-level strategy of the SPE and EEM highlights the difference between key stakeholder group perceptions and the realities of technology end-users. As shown by the results of the Practical Action project presented by Robinson et al. [13], these differences between perceptions and reality can have a significant impact on project outcomes. This highlights the importance of KSGs identifying actual end-user need rather than the assumption of need. As the problem of misaligning assumptions is not exclusive to improved energy technologies, this element of TIME has application across many International Development programs that are traditionally top-down led in theoretically imagined realities with little contextual understanding. Whilst distinguishing between perceptions and reality has additional time requirements, this paper recommends that all technology-based poverty alleviation projects conduct this process to easily highlight shortcomings and possible areas of future failure.

4.2.3. Rethinking impact

TIME challenges traditional quantitative measures of success in energy access projects and encourages a shift to values-driven success through the four core factors: co-production, ownership, utilisation and equality. Quantitative measures focused on adoption rather than sustained use can misrepresent success to funders and implementation partners. In Practical Action's project [13] this led to many ICS being purchased but not used due to a lack of monitoring, training on use and post-purchase support. Additionally, a focus on values rather than metrics of success results in flexibility around the scale of application of TIME, echoing SORI which effectively grows in scale for specific applications. Whilst more challenging to quantify results through this qualitative method, by modifying the definition of impact from adoption to sustained use it helps to promote lasting behavioural change by end-users. However, this change in impact definition also requires the funding and implementing partners to understand the complex socio-cultural, environmental and financial contextual factors, such as the use of multiple energy technologies concurrently [50], and the role that improved energy technologies have in the behavioural change process.

4.2.4. Limitations of TIME

Despite the strengths of the TIME presented in this paper, there are a number of limitations and areas for future work. Given TIME's qualitative methods it would be difficult to produce country wide hypotheses as the approach is designed to develop place-specific contextual learnings. In addition, the highly contextualised nature of qualitative research can make it difficult to replicate results leading to problems of generalisation and a lack of transparency. In addition to the qualitative methods limitations there are also a number of limitations when applying this theoretical framework to real-world situations. TIME relies on the openness of technology-end users/interview participants due to its values, rather than metrics driven, nature. This could result in distorted results if there is not an open, honest relationship between interviewing teams and interviewees. Given the context driven nature of TIME, specific methodological limitations are going to be context specific and difficult to predict before implementation.

The impact of COVID-19 highlights the human centred nature of this research. The ability to travel to the contextual setting is key in effectively mapping the sector or sub-sector of focus. Without the ability to physically experience the contextual factors, many insights are lost. This either requires a change in the focus of TIME or more detailed training of field-based practitioners to conduct this research. However, given the heavy theoretical background, without training TIME could be difficult to effectively implement for practitioners. Additionally, given the detailed methodological steps required to adequately understand the complex contextual factors as well as the roles and interactions of key stakeholder groups, practitioners and policymakers would be required to invest project funds (or time) to implement TIME. As stated throughout this paper, the process would increase the chances of programmatic success, however given the inflexibility of the International Development sector around adopting new methodological processes, the investment requirement may be a significant limitation for TIME.

5. Conclusion

TIME builds upon themes and concepts from a range of existing literature groups to dive deeper into the mechanisms of behavioural change around the co-production of improved energy technology and its sustained use. We build upon the matrix based multi-level approach of IBM-WASH [45], RE-AIM [55], the Market Map [48], International Development planning tools such as logframes and theory of change [36], as well as existing philosophies of appropriate technology design [21] and social enterprise [58]. These literature groups all contribute to our novel practitioner and policymaker orientated model of working set against the existing implementation models in the energy access literature which focus on metrics driven approaches that can result in adoption but limited sustained use of improved energy technologies.

In this paper, we champion the view that alleviating poverty through technological implementation is a multi-dimensional, multi-stakeholder process and thus requires a solution that solves multiple issues simultaneously. We achieve this by redefining three core values of improved energy technology implementation that can be applied to a range of contextual environments: to rethink how impact is defined, to understand differences between practitioner perception and end-user reality, and to champion a co-produced approach with all key stakeholders in the energy value chain or system.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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