Energy Research & Social Science 42 (2018) 23–33

Contents lists available at ScienceDirect

Energy Research & Social Science

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

Original research article

From cookstove acquisition to cooking transition: Framing the behavioural aspects of cookstove interventions

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ARTICLE INFO

Keywords:
Behaviour change
Cooking energy
Energy transition
Household air pollution

ABSTRACT

A clean cooking energy transition necessitates effortful behaviour changes by cooks, financial decision makers, and other family members. A new inter-disciplinary CI-CHANGE model, rooted in technology adoption and behaviour change literature, provides an integrated framework to study the transition process. It provides new testable hypotheses on the *how* and *why* of the transition process using behavioural constructs such as perceptions and habits. In contrast, the current approach is to examine socio-demographic conditions and market/technology characteristics to identify- '*who*' are likely to move away from solid fuels and '*under what conditions*'. CI-CHANGE combines elements of the Transtheoretical Model (health behaviour change psychology), Theory of Planned Behaviour (social psychology), and the Unified Theory of Acceptance and Use of Technology (information systems research) to identify & prioritize intervention focus areas. Such framing highlights three key gaps in the current approach. First, based on process factor conditions of target audience, differential intervention strategies are necessary; second, post-sales interventions are required to support complex and effortful endeavor of accepting a new technology while fighting the old habit of traditional cooking; and third, entire transition process is fragile due to seasonal changes and no-cost reversal to solid fuels. Hence, long-term monitoring should back any intervention-specific climate/health gain projections.

1. Introduction

Nearly 2.7 billion people globally depend on solid unprocessed biomass (firewood, cattle dung and agricultural residue), and coal as their primary cooking fuel [1]. These fuels are generally burnt indoors in inefficient traditional cookstoves (TCS), namely three-stone fires & mud stoves, resulting in "kitchen smoke" [2]. The "mid-range economic value" of the negative consequences for health [3], environment [4] and societal development from global usage of TCS is estimated to be $123 billion per year [5].

Governments and civil society in developing countries along with international actors have promoted both transition technologies that make solid fuels burn in a *cleaner* manner such as "improved" cookstoves (ICS) as well as truly *clean* cooking solutions (CCS)- modern fuels, such as liquefied petroleum gas (LPG), electricity, biogas, and ethanol [6,7]. Only the most advanced ICS technologies seem to have the potential to provide the purported triple benefits (health, environment, social development) across a diverse range of local fuels, though it has not been consistently demonstrated in real-world conditions [8,9]. This is particularly true in terms of lowering household air pollution (HAP) linked health risks [6,10]. Hence, there is growing interest in intervention strategies that enable and motivate TCS households to *leap-frog* to CCS technologies [11]. The general term "intervention" is used throughout to describe "*any legislation, regulation, policy, program, project activity, or event*" that encourages a particular action [12].

Some developing nations like Brazil, Ecuador or Indonesia with high urbanization with concomitant economic development and high CCS subsidy achieved success in displacing TCS as the primary cooking fuel. Urbanization leads to modernity as well as lower access to solid fuels, while economic development allows governments to provide higher levels of CCS subsidies, raising incomes to afford commercial fuels as well as increasing the opportunity cost of solid fuel gathering [1,13–15]. Urban households are more likely to move away from solid fuels as they have higher monetary costs of solid fuels or higher opportunity costs of time & effort, relatively stronger perception of fuel scarcity, and more likely to have access to electricity which "*spurs people to a greater acceptance of modernity*" [16].

However, in countries like India and Kenya with a large number of poor rural communities, CCS (as well as ICS) have not been used

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https://doi.org/10.1016/j.erss.2018.02.015
Received 23 November 2017; Received in revised form 19 February 2018; Accepted 21 February 2018
2214-6296/

consistently, sufficiently or correctly enough to displace TCS as the primary cooking solution [8,14,17,18]. Empirical evidence suggests that rural population with better access to solid fuel (compared to urban areas) prefer to spend their meager and irregular cash income (often derived from seasonal agricultural work) on other priorities where free alternatives are not available [19]. This may be especially true when the opportunity cost of time-savings from fuel switch in form of cash income is low [20]. For example, even the richest 10% of India's rural households (most with access to LPG) continue to depend on solid fuels to meet more than 50% of their cooking energy demand [10]; this phenomenon is known as cooking technology stacking [21,22]. Failure to achieve a successful, stable & long-term transition from TCS to CCS in rural, poor communities with striking public health, societal and environmental consequences poses a major development and multi-disciplinary research challenge in modern times [23].

The purpose of this paper is to examine the clean cooking energy transition through the lens of behaviour change occurring at the individual and household level. Section 2 lays out the multiple, complex behaviour changes that family members have to go through when CCS replaces TCS as the primary cooking fuel in a household (desired output). Two broad knowledge gaps in literature related to how and why of transition and audience segmentation, from an implementation perspective, are then identified in Section 3. In Section 4, the guiding principles and approaches to the creation of the framework are discussed. In Section 5, the inter-disciplinary transition framework CI-CHANGE to study cooking energy transitions is presented that details hypotheses around the 'how' and 'why' of the transition process. Section 6 deals with the utility of the framework in providing new potential insights about the transition and how it should be studied. Section 7 discusses the shortcomings and future research areas to test and improve this framework.

2. Cooking energy transition as a behaviour change challenge

Why should clean cooking energy transition process be viewed through the lens of behaviour change? Irrespective of the technology options, implementation strategy choices or geographical contexts, a successful household-level transition essentially involves undertaking new behavioural actions and ceasing old behavioural actions by three key individual(s) or group(s) within a household [24,25]. One, the cook (s) (almost exclusively women in target households) may have to change the type of food being cooked as some CCS models can be ill-suited to prepare all types of traditional food (ex. when the size of the traditional bread is bigger than the burner size) [26,27]. Further, fire-power and pot size differences between TCS and fixed-dimension CCS may alter cooking styles (e.g. requiring more attention to food as it cooks) or how what quantity of food can be prepared at one time [19,28]. Moreover, the cook's behaviour can also directly influence the health outcome metrics such as personal exposure level depending on where they cook and how they enhance ventilation [29].

Two, other household members (including children) may find real or perceived changes in the size, texture, taste, and flavor of food cooked in CCS that influence the familiarity or desirability of the meal [19]. The spatial behaviour of other family members in the household (near or away from the kitchen) during the cooking period also moderates the health impact of CCS interventions [25].

Three, the financial decision-maker(s) (often senior male members in target households) have to reallocate current consumption expenses and savings decisions, especially in cash-lean seasons, to cover significant expenses on regular fuel purchase and occasional CCS purchase/repair cost [19,30]. While the cook would have an important role in the decision-making process, the male members may have veto power [31]. However, in some cases, time/effort savings from CCS usage may lead to additional income generation to offset the expenses [32]. Further, male household members may also become responsible to arrange for transport of CCS (in case of LPG) from far-off supply point if door-step delivery is not available [14].

Thus, the "bundle" of behavioural actions by key individuals- cooks, financial decision-makers, and other family members can be viewed as the 'clean cooking energy transition'. It not only includes actions that lead to regular, consistent and sufficient usage of CCS [33] but also actions that can maximize the impact of such usage, especially from a health perspective [25]. Here, the 'desired behaviour change' at household level necessarily involves a multitude of relatively new, complex and effortful behavioural actions to be undertaken by the cook (s), financial decision-maker(s) and other household members at an individual level. Technology options, intervention strategy choices and geographical contexts would obviously promote or hinder these actions, but irrespective of these choices/contexts, behaviour changes are integral and in a way, demonstrative of the transition process.

Surprisingly, while behaviour change plays such an important part in the transition process [25], there are only sporadic mentions of behavioural aspects such as the role of habits [34], individual perceptions & knowledge [8,14], and motivation [30] to achieve the transition process. In most of the fifty plus CCS interventions that claimed to use 'behaviour change techniques[1]' (BCT), "their implementation as part an established behaviour change model or framework appeared to be rare" [25] with notable exceptions [30]. BCT strategies were primarily aimed at social marketing for uptake (purchase/acceptance) of CCS by undertaking interventions for information sharing, subsidies, and marketing by local community organizations with a focus on "willingness to pay" [25,35]. There are not many studies or even theoretical frameworks that explore 'willingness to use' CCS in lieu of TCS over the long term from behaviour change perspective. Hence, the "evidence gap" related to the behavioural aspects of transition merits urgent research attention [36].

Hereafter, we use the word key individuals to refer to primary cook (s), financial decision-maker(s) and other household members who possibly have direct or indirect veto power over CCS usage in the household kitchen. Also, the clean cooking energy transition would be referred to as transition for conciseness unless specified otherwise. Further, the terms 'transition' or 'desired behaviour change' would imply, unless specified otherwise, switching from TCS (old behaviour) to CCS (new behaviour) as the primary cooking fuel and maximization of its impact through other behavioural actions.

3. Knowledge gaps in transition literature

The transition process has been primarily framed in the cookstove literature as a technology-centric issue about the identification of a multitude of factors that encourage or discourage technology acquisition/uptake (purchase or acceptance) and usage of ICS or CCS [19,37]. Alternatively, it is also framed from a product-centric outlook as a consumer demand (ex. affordability) and supply (ex. lack of after sales support) issue that requires "cross-cutting enablers" (ex. quality standards and testing infrastructure) [5]. Notably, most past research is on ICS; studies on clean, modern fuels like LPG are much more limited [14].

Further, recent systematic reviews [8,14,38,39] have identified anywhere from eighteen to thirty-one such socio-economic, demographic and fuel-specific factors that influence the transition process. These factors "*operate on a spectrum: if factors are present or satisfactory they act as enablers; conversely, if absent or unsatisfactory, they act as barriers*" [14]. These include price of competing fuels [15] or ease of access to non-monetized fuel [20], high initial cost of CCS [40], volatility of LPG price linked to global oil markets [14], low irregular family income to pay for regular fuel expenses [15], infrastructure for reliability and accessibility of fuel supply [41], individual perceptions about

[1] Defined as an "*active component within a clean cooking intervention that helps produce behaviour change to improve human and/or environmental impact*" [25].

safety [42], limited usefulness/specificity of applications, i.e. not able to perform space-heating and all local cooking tasks that TCS can perform [19], lack of awareness about TCS ills and CCS benefits [38] and gender driven intra-household decision-making conflicts [19].

Sporadic attempts have also been made (in line with our approach) to integrate theoretical insights from diverse fields to study cooking energy transition. Some studies [12,34,43,44] have proposed conceptual frameworks related to household energy transitions drawn from theoretical constructs primarily from economic theories, behavioural economics, and innovation-diffusion literature. Review of these empirical studies, systematic reviews and inter-disciplinary frameworks related to cooking energy transitions, suggest two broad knowledge gaps from the perspective of implementers/practitioners aiming to change the situation at the ground.

First, the mechanisms to prioritize the multitude of socio-economic determinants, product-specific factors and decision environment attributes that matter for cooking energy transition are not clear [12,14,38,44]. This exhaustive list of identified factors (sometimes up to thirty-one factors) cut across policy, markets and technology [14] and are often not ranked by degree of importance or precedence [22], making them of limited utility for real-world intervention planning. In practice, implementation practitioners with limited resources (both in terms of personnel and dollars) cannot simultaneously address all these factors to achieve the intended changes within a project period, typically spanning a few months or years.

Even when some studies using 'revealed preference' methods or related economic models have attempted to quantify the relative importance of the factors, it is framed around two narrow questions that don't solve the field challenges. One, 'who' are more likely to adopt CCS which examines the socio-economic characteristics of households such as income, education, and size [38,44]. For example, high income, educated female-headed urban households from communities that are not socially marginalized are more likely to adopt CCS [38]. It does not help guide efforts that target low income, uneducated male-headed rural households (a demography far more likely to find in typical energy-poor communities) in socially marginalized communities. Two, 'under what circumstances' people are more likely to adopt CCS which examines the decision environment, such as whether there is local market for alternative fuels, availability of electricity, awareness about health & environmental problems of using TCS, and if wood is purchased and at what price [38,44]. Generally, CCS programme implementers have more control on some of these aspects such as awareness creation [35] while other factors can be either out-of-control (e.g. electricity access) or are not amenable in the short term (e.g. market price of alternative fuels).

Second, though past studies have warned against "one-size-fits-all" approach- "*a common feature of many failed interventions in the past*" [45], there is no clear guidelines on target audience segmentation for ICE and other intervention strategies. It is a particularly important issue due to three levels of targeting- region, community, and household. While the regional difference in culture, habits & taste [46] are generally considered for ICS selection, CCS interventions are generally planned at the national level (due to nature of government subsidies associated with them) [14]. Further, there is no guidance on how to design interventions when household level attributes (e.g. family size, income) within a target community have significant inter-household variation [47]. Moreover, there are markedly different behaviours, needs and requirements within a household based on socially sanctioned gender dynamics related to norms, values, roles, and behaviour [36]. The basis for segmentation and how to approach the segmented audience are important questions that are key knowledge gaps from a practitioner perspective.

Finally, it is useful to have well-validated theories in this inter-disciplinary domain that can act as frameworks to generate testable hypotheses and then evaluate and aggregate individual empirical results [48] from geographical/socio-cultural/economically diverse areas across Africa, South America, and Asia. For example, there is contradictory reporting on the role of some factors, such as whether messaging around health and environmental concerns influence positively [44] or do not matter [19] for desired outcomes, and whether household size act as an enabler or barrier to clean fuel choice [38]. Yet, this "complex multi-sectoral" process of clean cooking transitions with its wide-ranging implications for development, gender equity, the environment and public health is studied in a somewhat arbitrary manner [23,25,48]. Hence, our "*empirical understanding of the drivers of this transition* [is] *very limited*" [49].

4. Principles and approaches

4.1. Guiding principles

The proposed framework to study transition aims to address the aforementioned critiques/gaps in existing literature to improve our "empirical understanding" of the process. A new theoretical should provide new insights in the form of testable hypotheses while being consistent with known empirical results [50]. We focus on the black-box problem, namely that even though the multitude of household cooking energy choice determinants (inputs) and the consequences in terms of energy transition success or failures (outputs) are identified, how they interact or dominate over each other during the transition is mostly unknown. As suggested by Heclo, "*understanding is best advanced, not* [just] *by giving priority to one or another type of variable, but by concentration on the interrelationships of ideas, interests, and institutions. The 'action,' so to speak, is at the intersection*" [51]. So, two new aspects of the transition process are explored in this framework: 'how' do households move through the transition process and 'why' some individuals are able to make the transition and others are not.

A useful framework would consist of key theoretical constructs borrowed from different domains to generate testable hypotheses around transition related to the key aforementioned questions of "how" and "why". Priority is given to well-tested theories that have addressed similar questions about behaviour change. The authors included research domains that have studied either household technology specific behaviour choices related to acceptance and usage (e.g. how usage decisions are shaped by technology attributes) or individual self-regulatory behaviour change (e.g. how habits are formed and changed). The underlying assumption is that in absence of any comprehensive theoretically rooted theories on the cooking energy transition process, it is worthwhile to test important adoption/behaviour theories that have been used across different domains. Broadly, for consistency and validity purpose, the framework should conform to (i.e. not be inconsistent with) our understanding of input factors of 'who' is more likely to succeed and 'under what conditions' based on empirical evidence. An important aspect related to studying the transition process- *which* specific intervention strategies can fast-track the transition process- is not covered under this framework and left to future research.

4.2. Objective conditions vs. behavioural constructs

The existing literature mostly uses objective indicators spanning technology characteristics, regulatory regimes, market conditions and demographic factors to explain 'why' of the cooking energy choices [38,44,52]; 'knowledge and perceptions' are sometimes added to this list [14]. However, behavioural sciences literature suggest that human decision choices are influenced by *impressions* of reality driven by effortless and associative perceptions and intuitions [53,54]. The worldview that people hold and the action that they take is often distorted by heuristics, biases, anomalies, mood and past habits [54–56]. For example, awareness generation (information, communication, education-ICE) campaigns are considered as an important factor in the decision environment [35]. However, miscommunication on either side can create negative perceptions [57] while the absence of trust by the community in the messengers can reduce the impact of messaging [35]. In this framing, ICE communication messages, channels and actors (objective measures) should logically increase favourability and the probability of a transition, but it is the (subjective) perceptions formed as a result of these ICE activities that determine whether they have the intended effect.

Critiques may argue that it is a semantics issue as there would be obvious overlaps, such as low-income households (economic condition) would likely not find 'value for money' (perception) in switching to a commercial fuel. Or, an older cook (age) would be more used (habit strength) to use TCS [19]. They may also argue that as the studies have accounted for actual cooking behaviour/verbal survey responses, the role of perceptions is already accounted for. The authors' view is that behavioural constructs (perceptions/habits) derived from objective conditions are more immediate to explain and predict the transition process. For example, the cookstove literature finds that education has a positive effect on the probability of a household moving away from TCS [8,14,38]. The linkage has been described as follows: "*increasing opportunity costs of fuel collection time at higher levels of education and the increased level of awareness of the negative effects of wood and charcoal use on health*" [16]. It suggests that perceptions around opportunity cost and awareness levels are influenced by education. As education (measured by a degree or level of literacy) cannot guarantee higher opportunity cost or enhanced awareness level, it is more useful to assess the proximate (immediate) factors that lead to the decision-making process such as perceptions of health risks of using TCS. Under this framing, an individual's perceptions about (availability of and accessibility to) subsidy (behavioural construct) are more relevant to his/her decision-making compared to the written policies on subsidy (objective conditions).

In case of divergence between subjective perceptions and objective measures, perceptions matter more during the actual behavioural action [58,59]. For example, LPG is generally considered by experts as a safe fuel [5], but during our fieldwork in India, we found that when there was one recent accident, almost no household in an entire village considered it to be safe. Moreover, numerous behaviour change studies have demonstrated that reflex action/muscle memory related to habits can counter the impact of objective factors such as knowledge and awareness in actual performance of behavioural action [60,61] that has led to knowledge-action gap across different domains [62,63].

Reverting back to the analogy of a black box, the objective conditions can be labeled as *input* factors and the behavioural constructs of perceptions and habits are *process* factors to explain transition that exist within that black box. In this paper, behavioural constructs such as attitudes (driven by individual perceptions about objective conditions related to technology, demography, market, laws, and geography) and habits (driven by repeated behaviour in similar settings) would be used to explain the transition process. So, in contrast to traditional scholarship that focuses on factors such as *income* and *age of cook* to explain the transition, the transition factors would be behavioural constructs such subjective perceptions of whether there is '*value for money*' and the strength of the *habit* of using TCS. Hence, rather than assuming an overlap of input and process factors, it is more prudent to capture the perceptions (process factor). For example, '*am I too old to learn a new technology*' may be more relevant and an immediate predictor of actual transition levels (output) than the more distant *age* parameter (input factor). In other words, we hypothesize that the effect of objective measures (income, education etc.) on behaviour is mediated via the subjective perceptions (also known as the self-sufficiency assumption in Theory of Planned Behaviour) [64].

Further, rather than focus on the prioritization of objective factors [38,44,52], the framework would focus on the prioritization of the behavioural constructs. As a simplistic example to explain the role of prioritization of process factors, the aim is to create a model, which can quantitatively compare whether the perceived capacity deficiency or perceived safety concerns is a bigger concern. It can help decide whether an information campaign should focus on generating awareness about the ease of cooking or on alleviating safety concerns when resource constraints won't allow multiple campaigns.

4.3. Literature review beyond traditional knowledge domains

While theories and models from energy economics and related domains in economics have been primarily used to study the uptake of CCS [44,52], the authors have widened the search to include insights from two different but overlapping research areas. First, technology adoption research deals with behavioural interactions directly related to acceptance and usage of a new technology, which is influenced to a large extent by the characteristics of the technology [52]. For example, the extent to which a cook has to modify the current cooking practices would depend on the new stove's firepower [65]. This technology-human interaction has been covered by both technology adoption literature (micro-perspective on change when studied at individual/household scale) or innovation diffusion literature (macro-perspective on the spread of innovation over time at the population scale) [66]. Of the two, it is the micro-level perspective that is most suited to understanding CCS as an innovation adopted by households. We broadly view uptake and usage of CCS as an innovation, even when it is a known & aspirational technology like LPG [67], because it would be a "novel idea" [66] for the target household to actually use CCS for cooking in lieu of traditional solid fuels. Our literature review suggested that information systems (e.g. online banking) [68], and education technology (e.g. new pedagogy) [66] research have both studied technology adoption extensively. Journals in the field of management research [69] and decision sciences [70] have also published work related to technology adoption.

Second is research relevant to changes in age-old cooking habits, adjustment to perceived change in taste of food or reprioritization of financial behaviour (household budget) to pay for CCS [25,71]. Such self-regulatory individual behaviour changes are indirect but essential for the technology adoption to be successful and have been extensively studied in the fields of behavioural economics [53], psychotherapy [72], social psychology [73] and health (behaviour) psychology [74], and applications in the fields of financial behaviour [75] and tourism [76].

A review of these fields reaffirmed Prochaska's views that many disciplines suffer from "*too many theories and too few data to evaluate them*" [50]. A recent study identified 89 theories just around behaviour and behaviour change [77]. Hence, while short-listing theories, importance (citation, contribution to other theories) and generalization (application to diverse domains) were important criteria. Most importantly, any theory that directly addressed the questions that are being asked about 'how' and 'why' of a behaviour change process were further studied.

5. CI-CHANGE behaviour change framework

5.1. CI-CHANGE: theories and behavioural constructs

A new inter-disciplinary conceptual framework (Fig. 1) named CI-CHANGE is proposed to compensate for the lack of cookstove specific behaviour change frameworks as well as to address the aforementioned critiques and gaps in existing literature. It proposes that conscious (behaviour) change necessary for clean cooking energy transition is driven by intention [73]. The intention is influenced by (perceived) control, (past) habits, attitude and (perceived) **n**orms [78]. Based on the literature review, expert interactions and our judgment based on combined field experience of over two decades, the authors decided to use the transtheoretical model-TTM (stages of change model) [79] from health behaviour change psychology to hypothesize 'how' clean cooking energy transition process happens. Then, the theory of planned behaviour- TPB (reasoned action approach) [73] from social

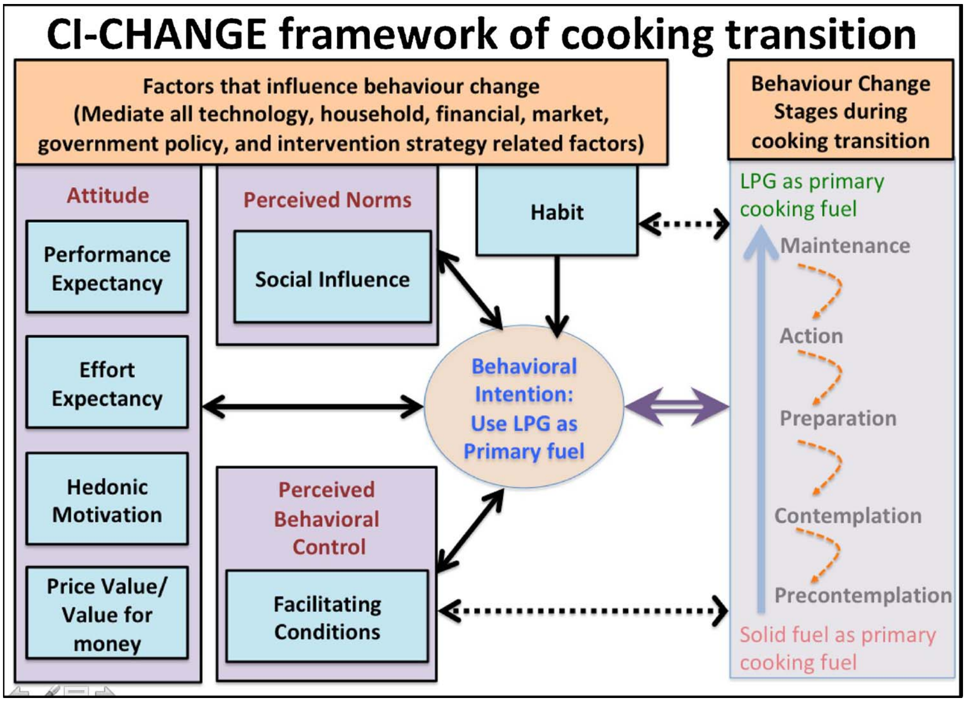

Fig. 1. A conceptual framework CI-CHANGE of behaviour change as a vehicle for cooking energy transition (theoretical constructs presented are explained in the text); where (behaviour) **C**hange is driven by **I**ntention, which in turn is influenced by (perceived) **C**ontrol, (past) **H**abits, **A**ttitude and (perceived) **N**orms, as a **G**eneral [cooking] **E**nergy transition framework. (For interpretation of the references to color in the text, the reader is referred to the web version of this article.)

psychology was added to develop a mechanism to identify and prioritize the key 'process factors' that provide insights on the 'why' aspect. Finally, the Unified Theory of Acceptance and Use of Technology (UTAUT-2) for consumer technologies from the information systems domain is used to expand upon TPB's 'why' conceptualization to make the framework more appropriate for technology adoption (acceptance and usage) related behaviour change [78]. Finally, the linkage between UTAUT-2 constructs (detailed 'why' related to technology adoption) with the empirical evidence around *'who'* and *'under what conditions'* related to cooking energy transition is established. A brief discussion on how these theories complement each other to answer the 'how' and 'why' questions are detailed in Section 5.5.

While this cooking behaviour change model would be expected to apply across a range of interventions spanning different clean cooking fuels (electricity, LPG, etc.), socio-economic contexts (e.g. South Asia, Latin America, Sub-Saharan Africa) and implementation modes (e.g. donor-driven, corporate, government programmes), we have used the Indian government's LPG programme as an example to make the discussion less abstract and more readable. India's *Ujjwala* initiative is a landmark energy access initiative that has enabled 32 million poor women to access subsidized LPG within 20 months since its launch. Under *Ujjwala*, half of the upfront total capital cost (stove, first cylinder/bottle of 14.2 kg LPG, accessories, and administrative costs total ~50 USD) required for a new connection is waived off while the balance amount can be availed as an interest-free loan [80]. So, the desired transition is framed as moving away from the current practice of using solid fuels as primary or exclusive fuel to making LPG as the primary cooking fuel (Fig. 1 blue arrow in the box on the right).

5.2. Delineation of the stages of change

Prochaska's Transtheoretical Model (TTM) is the most cited theoretical framework in health behaviour psychology to explain, predict, motivate, and intervene on behaviour changes across diverse domains such as smoking cessation [81] and sustainable transportation [82]. TTM introduces the idea that a transition from an existing behaviour (i.e. solid fuels as primary cooking fuel) to the desired behaviour (i.e. LPG as the primary option) is not a single event but rather a five-stage temporal process that is gradual and iterative in nature, i.e. individuals can go both forward (along the blue arrow) and backward (orange arrows) during the transition process [79]. Considering the transition from solid fuels to LPG (as primary cooking fuel) as an example of behaviour change, the five stages would be: (1) Precontemplation: Key individuals hold a neutral or negative opinion about using LPG as primary cooking fuel in the near future and are unlikely to have an LPG connection; (2) Contemplation: Key individuals have positive opinions about LPG but don't have an LPG connection yet as they grapple with the pros and cons of such a change; (3) Preparation: Households have an LPG connection (either old connection with minimal usage or new connection) and key individuals express intention/plan to use it as their primary fuel in the immediate future but it is currently not used as primary cooking fuel; (4) Action: Key individuals make efforts to use LPG regularly as the primary fuel and usage is significant enough to have an effect on health outcomes; however, any change in environment (e.g. price increase) would likely bring them back to the preparation stage; (5) Maintenance: LPG is regularly used as the primary fuel out of habit and key individuals are now so used to LPG that they would advocate its continued use as primary fuel even in face of obstacles (e.g. supply disruption) [81,83]. In many TTM studies, especially for smoking cessation, this is considered to occur roughly six months after the Action Stage [81]. These stages based on process factors can be used for target audience segmentation for cookstove interventions.

Here it should be noted that the TTM framework, often applied to pro-health behaviours, views that "not all modification of behaviour count as an action. An individual must attain a criterion that scientists and professionals agree are sufficient to reduce the risk of the disease" [84]. So, in order to count as "action", the user needs to undertake the "desired" behaviour changes that entail sufficient LPG usage in order to significantly reduce the health risks significantly. Due to the supra-linear relationship between reduction in health risk and replacement of TCS [3], such health gains would be possible only when LPG is used as primary cooking fuel [85]. So, stacked users who use CCS intermittently would not qualify to be categorized as part of the "action stage" and would remain in the "preparation" stage. However, we recognize that the accrual of other social and environmental benefits from LPG usage is more proportional in nature and can be realized even at lower levels of usage.

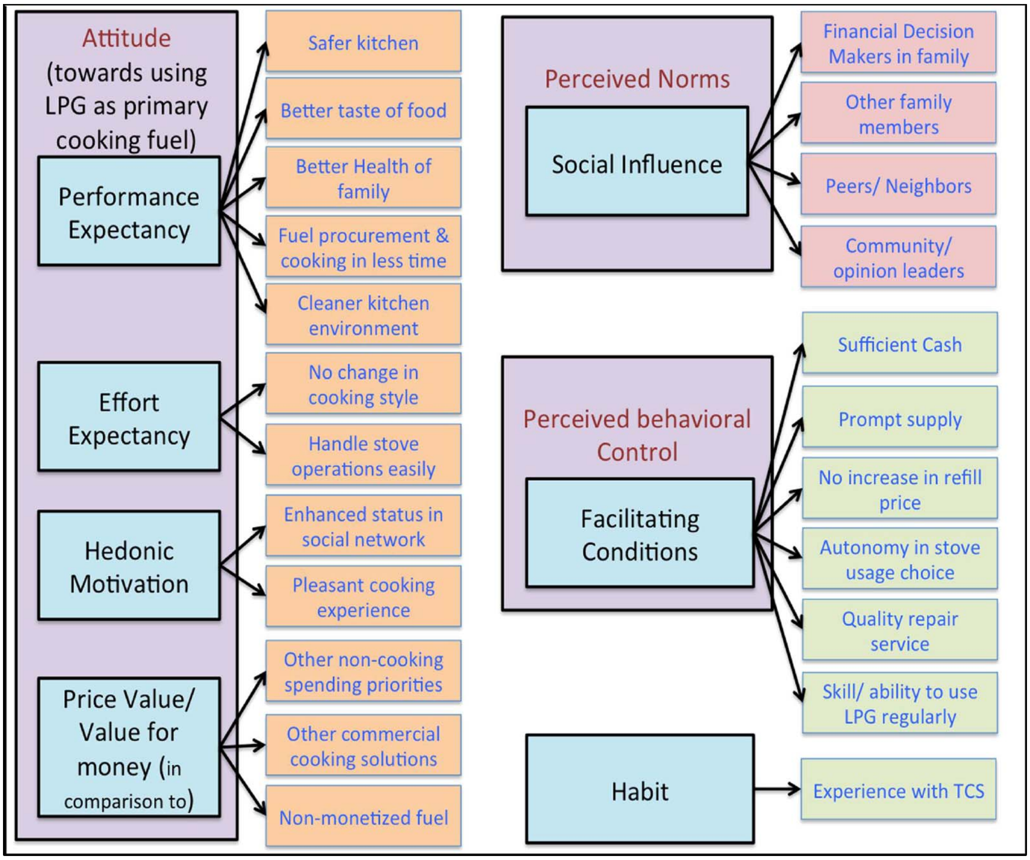

Fig. 2. Integration of cooking energy transition input factors based on published literature to process factors (CHAN) identified in the CI-CHANGE framework by authors. While there would be obvious overlaps, process factors are more immediate and relevant to the formation of behavioural intent. (For interpretation of the references to color in the text, the reader is referred to the web version of this article.)

5.3. Identification of the key process variables for change

TTM helps categorize the behaviour change journey and postulates strategies to progress through the stages based on focusing differentially on stage-dependent pros vs. cons of change and increasing self-efficacy as drivers of change [86]. However, it has been criticized for "*failing to specify the precise variables involved in shifting from one stage to another*" [87], i.e. factors influencing key individuals' behaviour change that leads to progression through stages. Fishbein and Ajzen's social psychology Theory of Planned Behaviour (also known as the Reasoned Action Approach) helps explain the effort by an individual towards behaviour change. It states that "behaviour is performed not automatically or mindlessly but follows reasonably and consistently" from three behavioural constructs [88]. These constructs contribute to strengthening, or weakening an individual's intention to perform the target/desired behaviour; the effect of all other factors are hypothesized to mediate via TPB [64]. First, attitude is the product of the strength of the attitudinal belief that performing a behaviour will lead to a particular outcome (ex. likely/unlikely increase in social status from using LPG) and the level of desirability (ex. increase in social status is good/bad) of the particular outcome [88]. Second, perceived norms are determined by the strength of the normative beliefs weighted by the motivation to comply [88]. It includes both injunctive (perception of what others would say about using LPG) and descriptive (perceptions of others cooking habits) norms. Third, perceived behavioural control (PBC) is determined by a person's subjective probability that a control factor is present (ex. fuel supply reliability would be high/low), weighted by the power of each control factor (availability of reliable fuel supply is very important/does not matter) [73]. Some researchers consider that TTM's self-efficacy is about personal control (confidence in own ability to maintain the desired behaviour in a difficult situation) while TPB's PBC is viewed as external control, where the situation is difficult because of a "*lack of opportunities or resources in the environment*" [87]. However, in this paper, control beliefs are considered similar to self-efficacy and include beliefs about personal, technological and environmental factors that can help or impede their attempts to carry out the desired behaviour in relevant situations [73,89].

5.4. Addition of household technology specificity to the process factors

TPB states that users generally consider five to eight salient beliefs [73]. However, TPB does not help identify the particular beliefs (process factors) relevant for technology adoption necessary to incorporate the specific input factors that systemic reviews of the cookstove literature have identified as influencing behaviour (e.g. age, gender, local environment, household economics, and culture) [8,14,38,39]. The Unified Theory of Acceptance and Use of Technology (UTAUT-2) is an established theory in information systems (IS) research to explain individual (consumer level) 'adoption' of IS products/services like computers and the internet [78]. UTAUT-2 specifically focuses on seven predictors of behavioural intention (process factors) to accept and use a technology that likely matters the most from the user's perspective [68].

Considering CCS such as LPG as the consumer technology in question, the seven predictors would be: (1) Performance expectancy is the belief that using LPG would result in process gains (e.g. less time to cook) and/or output gains (e.g. cook more food with similar efforts); (2) Effort expectancy is the ease or difficulty of using a new technology such as LPG, often in comparison to the old/baseline technology like TCS; (3) Social influence is based on whether other influential actors believe a user should adopt LPG; however we adopt TPB's more expansive definition that also includes descriptive norms; (4) Facilitating conditions are favorable environmental factors such as reliability of LPG refill supply that could support/not impede their use of the technology; (5) Hedonic motivation describes the pleasure user (cook) derives from using LPG, which can simply be lack of eye irritation that happens when LPG is used instead of TCS; (6) Price value is trade-off of benefits/advantages to cost/dis-advantages of transition to LPG; and (7) Habit is the automatic repeated behaviour (of using TCS) impedes adoption of a new technology like LPG [68,78]. This last factor is important as critiques of TPB have identified 'past behaviour' as important drivers of both intentions and observed behaviour [64,90].

Most of the objective input factors identified empirically in the cookstove literature [8,14,38,39] can be incorporated into the conceptual framework (Fig. 2). All the process factors (blue squares) from UTAUT-2 are derived from perceptions of the reality/conditions based input factors (ochre yellow, pink and green rectangles). So, a behavioural construct like 'effort expectancy' captures perceptions about the technology's capacity to deliver similar quantity, taste, and texture of food; mishandling of the technology can also create a divergence between perception and reality.

We extend TPB's sufficiency assumption that the effect of all other biological (age), social (education), environmental (abundance of solid fuel), economic (family income), and cultural (head of household/key financial decision-maker) influences are hypothesized to be mediated by the TPB constructs [64] to also include UTAUT's construct of habit. For example, the cognitive tradeoff between the (non-monetary) perceived benefits of technology use and the monetary cost for using them in form of 'price value' [78] would be different between key individuals from high and low-income households. Again, greater the age, more experience a cook would have with TCS (considering a typical target household where TCS is exclusively used) [19]. As habit is developed by the experience of repeatedly performing a behavioural action [60,61], age (input factor) influences behaviour in our proposed conceptual framework via habit (process factor).

5.5. Inter-linkage of these theoretical constructs

TTM helps explain the 'how' of the behaviour change journey and postulates audience segmentation strategies based on focusing differentially on stage-dependent pros vs. cons of change and increasing self-efficacy [90]. While TTM can help identify a list of pros and cons (factors) for a given behaviour through focus groups, experts and a review of literature, TPB provides value addition to the list of factors in two ways. One, TPB introduces three categories for items under that list- attitude, norms and behavioural control. This categorization and ability to distinguish between attitudes, norms and behavioural control is critical for then designing interventions that address specific types of pro and con factors. Two, the mathematical model of TPN captures two aspects for each category compared to TTM's unidimensional uniform approach. For example, PBC captures the "relevance" of a control factor and "belief intensity" related to the presence of the control factor, while attitude captures both the strength of the attitudinal belief that performing a behaviour will lead to a particular outcome and the level of desirability of the particular outcome. In contrast, TTM only assesses "importance" of a given attitude or control related pro or con while making decisions.

In the proposed model, TPB could explain the 'why'- the effort (or, lack of it) and the underlying intention by an individual to change their cooking energy behaviour [73]. Through the expectancy-value model and similar concepts, it is possible to quantify and prioritize specific aspects (e.g. social norms related to opinion leaders, attitude towards safety) users consider as most important as well as how favourably or unfavourably CCS usage is perceived with respect to a given aspect. The authors view the predictor strength/weakness numbers (in TPB) to be conceptually similar to the pros and cons of decisional balance (in TTM) but more detailed, useful, and practical to apply. The behavioural intention to perform the desired behaviour improves as people move from precontemplation to maintenance stage. Someone at the preparation stage would have more positive predictor values (as per expectancy-value model) as compared to someone in the precontemplation stage. For this person to move to the action stage, interventions have to target the weak predictors.

While TPB states that users generally consider belief strength/feasibility and corresponding attribute evaluation/desirability for 5–8 salient beliefs [73] for any generic behaviour, those beliefs related to technology adoption would be more relevant for the problem at hand. UTAUT-2 helps identify and narrow down those salient and accessible beliefs that determine attitude (TPB construct) and its utility has been demonstrated in other technology domains. Moreover, as UTAUT-2 introduces the new construct of habit, it addresses a major critique that TPB fails to account for past repeat behaviour [64]. Also, UTAUT-2 itself already borrows from more generalizable theories such as TPB and social cognitive theory [78] and its constructs can easily be matched to those of TPB.

The three models, therefore, form a nested framework. The existing set of input factors identified in the cookstove literature can be linked to process factors in the UTAUT-2 model. Those technology-specific process factors can be tested empirically with TPB to explain the behavioural intentions of an individual. The intention levels calculated from the mathematical models of TPB can be differentiated according to the TTM stage of the individual.

6. Utility of CI-CHANGE framework

Application of the CI-CHANGE model advances theoretical knowledge by attempting to link three domain-specific theories in two novel ways. First, we propose an integration of TPB and TTM in a novel manner as "*behavioural intentions would be relatively negative in precontemplators, and progressively more positive in contemplators, preparators, actors, and maintainers, respectively*" [87]. We hypothesize that changes in the TPB variables- attitude, perceived norms and perceived behavioural control- scores can be considered as inputs to the two-step behaviour change process (formation of intent followed by behavioural action). This would then lead to changes in the TTM variables of self-efficacy, and perceived pros & cons of changing behaviour and, therefore, progression through the stages. Second, UTAUT-2 helps identify four salient/accessible constructs in the domain of consumer technology that influences the TPB constructs of attitude. These are performance expectancy, effort expectancy, hedonic motivation and price value. UTAUT-2 also aligns with the other two TPB constructs of norms (social influence) and behavioural control (facilitating conditions) while adding value to TPB by the addition of the role of habits.

The framework also provides three key benefits related to better understanding of transition process: 1) Existing knowledge about clean cooking adoption can be integrated and contextualized using this conceptual framework in order to propose an integrated picture of the transition process including identification & prioritization of key process determinants; 2) It provides a consistent method to generate testable hypothesis about acquisition and usage of new cooking technologies and fuels; 3) It can provide guidance regarding stage-specific actions that can be undertaken to increase uptake and usage of LPG. Below we present three implications of the conceptual framework and associated research efforts required to test the validity of the framework.

6.1. Design interventions through audience segmentation by stage of change

Based on studies across a wide range of human behaviours, TTM proponents advocate for a "stage paradigm", where interventions should be "*matched to each individual's stage of change*" to be more effective [79]. For example, awareness campaigns on benefits of the target behaviour are generally effective in increasing the pros (positively influence decisional balance) during early stage of transition, they are not as effective for the later stages of transition where factors that reduce the cons (e.g. stimulus control) play a more decisive role [83].

This staged behaviour change process fits well with another conceptualization in behaviour science that advocates that three types of behavioural actions- of different durations and different levels of familiarity have different salient determinants and underlying mechanisms [91]. Applying it to the problem at hand, the transition process involves the one-time, unfamiliar *dot* (new LPG purchase to enter preparation stage), short-term unfamiliar *span* (new behaviour during user trials in initial period that spans the action stage) and long-term familiar *path* behaviour (effortful span behaviour turning into the spontaneous habit over time in the maintenance stage).

On similar lines, some CCS researchers have identified these three steps as "acceptance, initial use, and sustained use", primarily driven by empirical observations but bereft of any theoretical grounding [22]. However, the authors have not been able to find any published cookstove literature that clearly identified salient determinants of the desired dot, span, and path behaviour separately. They have clubbed dot with span ("acquisition and initial use" as adoption) [39] or clubbed span with path (mixing short-term usage with long-term usage as "usage") [33] or clubbed together dot, span and path ("uptake") [8]. For example, while capital cost of CCS is widely considered as an important factor [14], its importance at action stage (once the stove is purchased) would be much less than when progressing to preparation stage. So, from the perspective of an intervention planner, it is far more useful to have the already identified exhaustive list of factors categorized by stage-wise saliency. Such research would then inform intervention planning for differentiated strategies to promote uptake, initial usage, and sustained usage, or in TTM parlance, progress from precontemplation to preparation, preparation to action, and action to maintenance stage.

6.2. Need for post-sales interventions to break past habits

The TTM literature repeatedly stresses the iterative and gradual characteristics of behaviour change during a transition and highlights the fragility of the process, wherein stages are "both stable and open to change" [79]. One of the key unanticipated difficulties in the uptake of LPG is that of breaking old habits (TCS usage) to perform new behaviours (CCS usage) in the context of voluntary behaviour, i.e. there are no laws to enforce the desired behaviour in the action stage [61]. For any experienced TCS user, past repetition of old behaviour in a stable kitchen environment has resulted in a well-formed habit of TCS usage. Generally, habit is measured as the extent to which an individual believes the behaviour to be automatic [78] or the activity 'kicks in' automatically when exposed to familiar 'stimulus' cues [61]. In such cases, primary TCS usage would be prompted automatically by situational cues, as a result of cue-behaviour associations learned from past performance [60]. Hence, new CCS customers would struggle in the transition process as every instance of new behaviour would necessitate mental struggle to fight old habit that entails primary TCS usage [34]. Habit automaticity would be evident in the lack of conscious intention (e.g. use TCS without thinking), minimal awareness (quickly, easily, with little effort, and in parallel with other behaviours) and lack of control (difficult to avoid cooking with TCS) [61]. It would have to be countermanded by conscious, deliberative efforts, which can be taxing on the brain at times [53]. So, uptake of CCS does not automatically guarantee CCS usage, i.e. progress from preparation to action stage is a complex and effortful process. Hence, users should get the "*support they need to learn how to use the stove*" to progress to the action stage (regular LPG usage as primary cooking fuel) as the learning curve for desired behaviour change in early days of usage is intense and can be challenging for average users [92].

Yet, most intervention studies are focused on initial sales with scant attention to post-sales challenges [25,37]. Even research around clean cooking transitions tend to be cross-sectional and only examine initial acquisition (sales or uptake) or at best, short-term use; hence, long-term/sustained usage challenges are not well understood [14]. However, in recent years there is widespread acceptance about the importance of long-term consistent and sustained usage of CCS [33].

6.3. Long-term monitoring for reliable impact assessment

TPB literature suggests that we should expect a feedback loop in behaviour change process such that "*when a behaviour is carried out, it can result in unanticipated positive or negative consequences, it can elicit favorable or unfavorable reactions from others, and it can reveal unanticipated difficulties or facilitating factors*" [73]. New behaviours are much less stable (varying over the course of the year) and unlikely to be permanent (over device lifetime and then repeat purchase) in the case of clean cooking energy transition for two reasons. First, there are seasonal variations in energy demands (mud stove provides add-on space-heating in winter) [19], fuel access (surplus crop residue during crop harvest season) [22], food preferences (seasonal grains and vegetables), change in cooking location (cooking indoors during rainy season) [93], and cash-flows [37]. This variation can create temporary negative "individual perceptions and knowledge" [8,14] or, in TTM parlance, increase the cons of using CCS round the year. New cooking fuel purchase behaviour during a cash-rich season may seem less attractive during the cash-lean season and may lead to a reversion to old behaviours [19]. Feedback from earlier experiences (paying for LPG refill in cash-lean season and cutting back on other expenses) is likely to change the person's "*behavioural, normative, and control beliefs and thus affect future intentions and actions*" [73]. Second, switching back to the old option (TCS) is easy as it "*can be constructed for little or no cost and with minimal technical skill*" quickly [19]. Hence, the temptation to "go back" to the old behaviour would always remain high in the face of any disruptive/unexpected change in the external environment (ex. fuel supply delays), technology features (ex. stove breakdown) or household characteristics (ex. increase in family size) [34,61,79]. Hence, unless interventions can monitor to confirm household behaviour at maintenance stage, any projections of health and climate benefits based on initial or short-term usage tracking would not be grounded in reality.

7. Challenges and way forward

While this multidisciplinary conceptual framework to study cooking energy transition should provide useful insights to tackle the urgent problem of HAP, we foresee at least four major limitations or risks that future work needs to address.

First, as CI-CHANGE does not explicitly deal with which intervention strategies could fast-track the transition process, two key insights from literature review related to intervention planning are excluded. One, it excludes the COM-B (Capability, Opportunity, Motivation, Behaviour) model [94] or its close variants such as the theoretical domains framework [95] and the 'opportunity, ability, and motivation framework' [30]. Two, the ten processes of change in TTM, which have received "the most empirical support" compared to the segmentation based on the five stages of change [79] are not included. In both cases, the experiential and behavioural processes of change are more relevant for determining the specifics of an intervention rather than prioritization of process factors (drivers/barriers) at a given stage. If the input based approach is about the "who" and our approach is about the "how" and "why", these approaches are more about the "which" interventions are more suitable. It represents the next stage of work once practioners understand the behavioural priorities of their potential target audience using the CI-CHANGE framework.

Second, none of the three theories have been tested in the cooking energy domain. This is true of all major health behaviour change theories. Though tested thousands of times for other health-relevant behaviours, they have never been tested to address cooking behaviour despite massive health implications. Application into this new domain poses two risks related to the scope of these theories. One, TTM and TPB have been applied most often to explain and guide behaviour changes related to addictive behaviour such as smoking and alcohol abuse. Obviously, the psychological challenges of combating addiction are expected to be different from any cooking energy transition. For example, affordability plays a major role in cooking energy choices in ways that are not the case for addiction. However, there is precedence for applying TTM and TPB to non-addictive behaviours such as pain management, bullying, domestic violence, and readiness for adoption of health behaviours like regular mammography [73,96,97]. There does not appear to be anything inherent in this domain that would indicate TTM and TPB could not be applied equally well. Two, application of these theories to the main socio-demographic target of CCS interventions – rural low-income populations in developing countries – is limited at best. These theories have been tested with primarily urban, well-off educated population [68]. However, again there is no inherent reason to believe it would not apply to developing country low-income populations. TTM has been successfully tested with low-income individuals in industrialized economies, such as low-income Hispanic women in community health clinics in the USA [98,99]. Field-tests of these theories by the authors are currently underway and will provide guidance on how well the theories perform and modifications that would need to be made when applied more widely.

Three, these three theories primarily deal with individual & self-regulatory behaviour while in our framework the main indicator of behaviour change is the household-level usage of CCS. It is possible that key individuals who influence cooking decisions in a household are heterogeneous with different motives and priorities. For example, the priority for the wife (cook), husband and children could be fast cooking, low cost and tasty food respectively [19]. If such key individuals within a household are in different stages of change, their alignment with the household behaviour indicator and the practicality (from a resource perspective) to introducing the stage-specific behaviour change interventions requires more research. This is very different from more homogenous group settings used in the psychology domain to effect behaviour change where targets are employees [68] or smokers who wish to quit [79]. However, there are already notable exceptions, such as a TTM study that targeted parents and children (entities with different motivation triggers) within the same household [100]. In our initial field tests, we study the primary cook's perception while capturing the perceptions of other key individuals in the injunctive norms of salient referents [73]. However, it should be a priority for future research in this area to study best practices to manage conflicting priorities of household members in interventions with limited resources.

Four, these theories have been widely critiqued even where widely applied such as in smartphone-based healthcare for UTAUT-2 [101], or addiction research for TTM [102] & TPB [64]. Entire special issues of journals have been dedicated to promote and refute proposals on whether to "retire" the theory of planned behaviour-TPB [64] and should the transtheoretical model (TTM) be put to "rest" [86]. While there are critiques, the approach here is to use dominant theories in a field despite being aware of their limitations (known devil), instead of selecting novel untested theories (unknown angel) with no sense of the extent of their validity, reliability and consistency issues. Even the critiques admit that there are at present no well-tested alternatives with more consistent findings [64]. It may well be the case that any parsimonious behaviour change theory that is tested rigorously in diverse settings would come up with mixed evidence and inability to fully account for the full spectrum of variance observable in human intention and behaviour [103]. The fact that these theories are considered as "standard" [64] and continuously tested implies a level of general acceptance to scholars across domains. So, testing them to study the cooking energy transition will also help in furthering the ongoing methodological debates regarding these theories. Successful application of the theories in new contexts and for a different set of behaviour changes that are centered on technological change may counter some of those critiques. Conversely, issues in applying the theories will further highlight needed modifications and limitations of the theories.

These challenges demonstrate the complexity of the problem at hand, which has even been described as more difficult than 'rocket science' [104]. The authors believe that this model, for all its potential risks and shortcomings, provides a useful and novel direction to study this age-old problem. Behaviour change is key to the transition process and the proposed integration of key behaviour change theories leads to three new untested hypotheses and under-explored research/implementation agendas. First, the salient factors identified in the literature will differ in their impact based on the specific stage of an individual or household's behaviour change process. Second, post-sales interventions would be most effective in moving individuals or households to the action or maintenance stage when they incorporate those stage-specific factors. Third, shifts in behaviour can only be identified and explained when both stove usage patterns and associated perceptions are tracked over long timeframes.

Acknowledgment

The authors acknowledge support from the Wall Solutions Initiative provided by the Peter Wall Institute for Advanced Studies and the Collaborative Research and Training Experience Atmospheric Aerosol Program at the University of British Columbia.

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