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Challenging perceptions of socio-cultural rejection of a taboo technology: Narratives of imagined transitions to domestic toilet-linked biogas in India

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ABSTRACT

Domestic toilet-linked anaerobic digesters (TLADs) recycle organic waste materials, including human excreta (HE), into a clean gaseous fuel and fertiliser product. Socio-cultural resistance is often used to explain local resistance towards TLADs due to the use of HE as a feedstock. However, through qualitative investigation utilising in-depth semi-structured interviews with potential TLAD users in Assam, India, the use of socio-cultural rejection to describe resistance towards TLADs was found to have homogenised local voices and framed them as resistant to technological change whilst ignoring diversity within groups. The narratives revealed resistance to be diverse and related to an individual's place, personal and social identity. Resistance to TLADs results from both socio-cultural as well as socio-technical concerns and is also potentially negotiable. Adoption of TLADs could be facilitated through opportunities such as technology demonstration, social group adoption and a greater perceived necessity. Inefficiencies in Assam's biogas implementation programme have been potentially overlooked due to too much attention being placed on household decision making and generalising socio-cultural resistance across the state. If TLADs are to be disseminated within Assam, authorities must work with communities and employees of the biogas programme to more widely renegotiate social norms around HE as a resource and not a waste product. More generally Assam's biogas programme is ineffectively identifying households with a need and motivation for domestic biogas and we recommend revaluating the use of local contacts to identify households eligible for the national subsidy as well as the bias towards households with large numbers of cattle.

1. Introduction

Biogas is a renewable, gaseous fuel generated during the decomposition of organic materials in the absence of oxygen through a process called anaerobic digestion [1–3]. Domestic biogas, generated from common household waste streams such as animal dung, mainly cow or pig dung, along with food waste, agricultural waste, and in some cases, human excreta (HE) [4–6], can replace or reduce the use of polluting fuels for cooking such as wood, crop wastes and dung in open fires and inefficient stoves. These polluting fuels and practices are estimated to be used by 2.6 billion people globally, predominantly in low and middle-income countries [7]. Their use can lead to high levels of indoor air pollution and is estimated to cause up to four million premature deaths from associated illnesses [7].

Abbreviations: TLAD, toilet-linked anaerobic digester; DFAD, dung-fed anaerobic digester; HE, human excreta.

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In addition to biogas, domestic anaerobic digesters also produce a liquid by-product called slurry that can be used as a plant fertiliser. The process of anaerobic digestion converts the nutrients in the feedstock into a form more readily available to plants [8]. Domestic digesters do not produce adequate biogas for a family's needs from only household HE, so HE is co-digested with other feedstocks [9]. When a household toilet is connected households can benefit from an improved sanitation system and increased biogas production [4,8,10,11]. Inadequate sanitation is estimated to cause 432,000 diarrhoeal-related deaths annually and is linked to the transmission of many water-borne and bacterial diseases such as cholera, hepatitis A, typhoid and polio [12]. The run-off from open defecation (OD) and poorly managed sanitation facilities also pollute surface and ground water [13,14]. Circular sanitation systems have gained attention in recent decades due to their ability to safely manage HE as well as return nutrients to agricultural soils [15]. There is a risk that anaerobic systems do not remove all pathogens; however, users can be trained to safely handle and treat slurry, such as through composting techniques with other organic materials and drying [16,17]. Many countries across Asia, Africa and Latin America have implemented national household biogas programmes over the last fifty years [18,19]. Programmes in Nepal, China and Vietnam have included additional financial incentives for households if they connect their household toilet so human excreta is co-digested with other feedstock [4,11,20].

In India, the nationwide domestic biogas programme began in the early 1980s and is still in continuation today [21,22]. Its main objectives are to: provide clean cooking fuels and reduce the drudgery of women who predominantly collect the firewood and cook over smoky hearths; provide organic fertiliser and reduce dependency on chemical fertilisers; and improve sanitation in rural areas [23]. It is estimated that to date around 5 million domestic biogas units have been installed [24]. However, sustainable implementation of the domestic biogas programme has been inconsistent with post installation functionality rates reportedly anywhere from 40 to 100 % [21,25]. This is not isolated within India and a wide range of reasons for why there can be unsustainable uptake of domestic biogas have been identified globally [19,26–30]. Many of these issues are technical and include poor construction and technical difficulties [31], unsubstantial or absent follow-up services and lack of training [2,29]. Globally, resistance can also arise due to socio-cultural reasons such as the rejection and apprehension of using of HE and animal dung derived products [32–34], handling of waste materials, and preferences towards fuels such as Liquid Petroleum Gas (LPG) that have more social status [35,36]. The use of HE as a feedstock has led to concerns around the safety of the biogas and fertiliser as well as the risk of social stigma due to associated social taboos [27,32,37,38].

Despite an additional subsidy offered for households that connect a household toilet by the Indian government [22] from early on in the programme [39,40], there are very few reports of successful adoption in contrast to the more prolific reports of socio-cultural resistance and rejection [27,33,41]. In places where there is socio-cultural resistance towards toilet-linked anaerobic digesters (TLADs) it is often described as an insurmountable barrier and used as a blanket term to describe local resistance [27,33,41–44]. Socio-cultural resistance towards TLADs in India is largely unexplored or challenged within research despite the heterogeneity of Indian society and the fact that there are some examples of successful uptake within India [6,39,45], and more in other Asian country contexts [4,9,11,20].

The hegemonic western and colonial approach to technological development leaves little space for working with diverse communities or cultural values [46]. Often, the technology becomes the main focus of a development initiative and, when users or local people demonstrate resistance towards it, the responsibility is placed on them. Little attention is given to understanding the wider context and reasons for resistance [47,48]. For example, in the Global North, local actors that resist technological development have been labelled as having a "Not in My Back Yard" (NIMBY) attitude defined as "*An attitude ascribed to persons who object to the siting of something they regard as detrimental or hazardous in their own neighbourhood, while by implication raising no such objections to similar developments elsewhere*" [49]. This assignment of a simple term to describe a complex paradigm is relatable to the use of socio-cultural rejection, a term more commonly used in Global South contexts. The use of NIMBYism has been criticised for delegitimising local opposition, obscuring the actual causes of opposition by 'othering' local actors and pejoratively simplifying their concerns into unjustified and selfish resistance [49,50]. This narrative has pitted the science community against irrational users [51] and been used to dismiss indigenous and local emotional and psychological connections with the land and way of life [52].

People's lived and told experiences [53] have provided insight into and helped reframe the dominant understanding of NIMBY opposition [54,55]. These narratives are critical in both understanding and driving transitions to new technologies, and subsequently are becoming a more common research method in energy and sustainable transitions research [54]. Narratives have revealed that local resistance towards new technologies can originate from emotional attachments to personal and place identities, misunderstanding of the technology, lack of trust in the developers, negative past experiences and lack of perceived benefits among many others [56–58]. Narratives have helped explain the gap between people's pro-environmental attitudes in contrast to their personal unsustainable practices and unwillingness to change [59]. This is important when it comes to sanitation or recycled products, which are considered environmentally beneficial but also taboo and accompanied by disgust reactions [60,61]. For example, waste-to-energy facilities recycle and valorise household waste streams but are often perceived as a stigmatised technology. Acceptance of stigmatised technologies near to where people live has been problematic. People have explained that they have concerns around smells and adverse effects on health as well as negative impacts on property values, and overall, they believe stigmatised technologies oppose how they envision their local environment developing [62].

Assam is the largest state in the North East of India [63] where agriculture and livestock farming play a significant role in the economy [64,65] suggesting ample biogas feedstock available. However, out of the 6.4 million households in Assam [66] approximately 2.16 % (138.5 thousand) households have installed domestic biogas [24] and more broadly, only 42.1 % of the population use clean fuels for cooking [67]. In 2020/2021 the national biogas programme had a target of building 3400 domestic biogas digesters of all types, not specifically TLADs, in Assam [68] and approximately only 12 % were constructed [24]. It is therefore important to explore perceptions of biogas technology in the area to understand why biogas is not benefiting more households.

Specifically, our objectives were to determine: 1) perceptions of the challenges and benefits that TLADs and their products and services can offer users; 2) the origins and nature of socio-cultural resistance towards TLADs; 3) the motivations and drivers for changing attitudes towards TLADs and how potential pathways to adoption could develop and 4) to obtain a contextual overview of how Assam's biogas programme is supporting sustainable uptake of biogas technology and the connection of household toilets.

Here, we hypothesise that the use of socio-cultural rejection when describing failed adoption of TLADs is masking the complex and diverse reasons that underpin local resistance. In this study, we thematically analyse the narratives of potential adopters of TLADs in Assam, India, to better understand local socio-cultural perceptions towards TLADs. We look for relationships between attitudes towards TLADs and willingness to adopt the technology as well as how potential users describe personal and social-norms and their impact on decision making. We collectively analyse narratives to search for commonalities as well as contradictions between and within them, to make sense of how pathways might develop to adoption of TLADs. This study is the first to enrich a better understanding of the way socio-cultural resistance towards TLADs can be understood in a heterogeneous Indian context.

2. Background

2.1. Biogas in India and Assam

The promotion of domestic biogas in India is now managed under a programme called The New National Biogas and Organic Manure Programme (NNBOMP), which is run by the Ministry of New and Renewable Energy (MNRE). Subsidies and financial assistance are provided by the MRNE, centrally through a top-down model [27] and assigned to each state [68]. The State Nodal Agency (SNA) for each state oversees organising construction, training and maintenance and subsidy allocation along with Khadi and Village Industries Commission, who have promoted biogas for rural development since the 1960s [39], and Biogas Development and Training Centres. The SNA is managed differently in each state, in Assam it is run from the Department of Environment and Forests whereas in neighbouring state Meghalaya for example, it is managed within the Meghalaya Non-conventional & Rural Energy Development Agency.

Despite the additional subsidy provided for household toilet connections, numbers of TLADs in India are unknown but assumed to be low due to reports of socio-cultural resistance. There are few successful TLAD adoption case studies researched within India [6,69] however, one successful case study is in Gujarat [45,70] where a dairy cooperative and partners invested significant effort into sensitising users over time with the aim of improving local sanitation and biogas outputs [45]. Many of the beneficiaries overcame initial resistance and later adopted TLADs. In neighbouring country Nepal, where approximately 79 % of nationwide domestic biogas users have connected their toilets [71], long term engagement was required to achieve this level of acceptance [9,11,72].

The products and services that are offered to users of TLADs can be divided across the sectors of energy, fertiliser and waste management/sanitation and all have their own market competition. LPG and kerosene are clean cooking fuels subsidised and available in the public distribution system. However, these programmes are criticised for reasons including; not reaching vulnerable households and rural areas; failing to result in long term use; and being vulnerable to fraud among others [73,74]. Despite these challenges, the use of clean cooking fuels has increased from 25.1 % to 42.1 % between 2015/16 and 2019/20 in Assam [67]. Chemical fertilisers are also subsidised in India [75,76] although there have been efforts made to encourage chemical fertiliser sellers to co-market compost generated from municipal waste to help clean-up cities and replenish soil carbon [77]. The Swachh Bharat Mission (SBM) has increased household use of improved sanitation facilities across India with Assam's coverage increasing from 49 % to 68.6 % between 2015/16 and 2019/20 [67]. Biogas toilets are also promoted in the SBM information [78] but the predominant design that is promoted, installed and subsidised across India, is the basic pit latrine. Pit latrines only capture HE without containing and treating it and therefore HE is often still reaching the environment and waterways [14,79]. There is also evidence that the SBM is not resulting in long-term behaviour change and some areas that have been declared OD free are still engaging in OD [60]. Consequently, the Indian government are promoting and subsidising competing technological solutions through a top-down system [74]. How these alternative products and services are integrated with the biogas programme will likely affect perceptions, and uptake, of TLADs [27,74].

2.2. Assam cultural, geographical and political context

In order to benefit from biogas technology, households often must have land, cattle dung and/or other feedstock, as well as the financial means to invest in one [27,33,80]. Attainment of these criteria is influenced by a household's demographics, geographical location as well as access to national and state policies that can support households in attaining them. Assam is considered one the least developed states in India despite its high biodiversity and forest wealth, as well as mineral and oil reserves, and tea production and tourism. Land ownership, which facilitates access to services such as bank loans and agricultural policies [81], is inequitably distributed in contemporary Assam due to a legacy of colonial policies [82]. Twenty percent of the people hold about 70 % of the total cultivable [65].

Rural development policies from central government have sporadically reached Assam. During colonial rule the north east states of India were segregated from the rest of ‘mainland’ India and treated as separate. After independence it is thought that to some degree this gap between the north east and central policy was sustained [83]. Colonial rule left India facing severe food shortages and so quickly strengthening the agricultural sector was made a priority. During the 1960's the government invested in agricultural development during a period called The Green Revolution. The investment increased the overall wealth and productivity of India's agricultural industry but, nevertheless, Assam scores very low on green revolution indicators such as fertiliser consumption, machinery use and accelerated growth [84]. Minimum support price (MSP) is set and paid for by central government to ensure that farmers will make a minimum price on specific crops to protect them from market fluctuations. However, farmers in Assam were found to have very little awareness of MSP or where to sell their crops compared to other states that sell a large amount of crops at MSP prices and plan planting on these guaranteed prices [85].

The dairy sector in India is important in helping to alleviate poverty and inequality as the livestock population is more equitably distributed than the land [81]. In a 2013 survey, Assam along with Punjab, had the greatest number of households reporting a major source of income from self-employment livestock farming [64]. However, unlike other states involved in dairying, Assam has small dairy cooperatives [86]. Dairy cooperatives are successful in supporting dairying by providing animal welfare, organisation, product valorisation [81,87] and even, in the case of Gujarat, adoption of biogas including TLADs [45].

The handling and reuse of HE in India is associated with cultural taboos. The dominant religion in India, Hinduism, has a caste system of social hierarchy rooted in purity and pollution and linked to traditional occupations [88–91]. The undertaking of polluting jobs such as sanitation work has historically been forced on one of the lowest caste groups known as Dalits. Some people of higher castes will prevent Dalits from entering their homes and will not accept some food or water from them to avoid pollution [92]. In India, group membership and social status can ensure access to resources such as energy, land and water, in part due to higher castes often having higher paying professions and social status [93]. Access to a variety of energy technologies in Hindu contexts have been found to favour higher castes [33,94,95]. In Assam, local village contacts, often high caste Hindu males, were found to decide who receives subsidies for biogas and so allocation, rather than simply being about eligibility criteria, is often based on social networks [33]. Using local social networks to distribute energy technologies can exclude households with lower socio-economic status from accessing them [94,96]. Cultural taboos could significantly affect adoption of TLADs where adoption might result in negative socio-political consequences [91], for example, adopters of TLADs can take on a social cost if their social contacts are reluctant to visit their household or are hesitant to eat food cooked with the gas [38]. Adopting a TLAD could reduce or reinforce lower socio-economic status for a household due to association with sanitation work and ritual pollution [97].

Religion and culture are not analytical categories [98,99] and thus socio-cultural resistance towards the reuse of HE is likely to be diverse. However, there is surprisingly little information on what socio-cultural resistance is, how diverse it is and how it can influence decision making around the adoption of HE recycled products like TLADs in various contexts. There is a need to better understand the diversity of socio-cultural resistance towards TLADs within India.

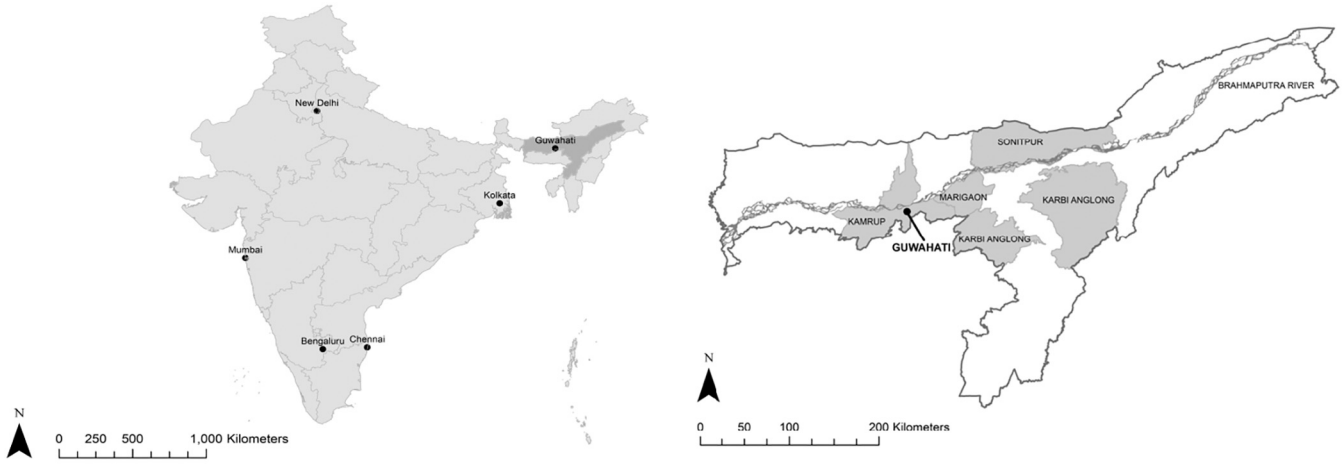

Fig. 1. a) Map of India with the state of Assam highlighted in dark grey b) map of Assam showing the Brahmaputra river and the districts included in this study adapted from [102].

3. Methodology

3.1. Case study location and context

Fieldwork was conducted across 13 rural or peri-urban villages in four districts (Sonitpur, Kamrup, Morigaon and Karbi Anglong) of Assam, (Fig. 1). Table 1 compares Assam to the rest of India across a number of household indicators taken from the latest 2015/2016 full National Family Health Survey of India [100]. Assam is just below the all-India average for electrification but has a 20 % higher average for solid fuel wood used for cooking and it is close to the all-India averages for improved sanitation and drinking water sources. Assam is below the all-India average in terms of wealth. Assam has almost three times the average Muslim population of the all-India average and subsequently less people that identify as Hindu. The Brahmaputra valley was selected for the majority of the data collection because the fertile lands support many people in agricultural pursuits, making them suitable candidates for domestic biogas due to the availability of feedstock and use for the slurry fertiliser. There is also a large population of dairy farmers who have dung-fed anaerobic digesters (DFADs), without toilet connections, and who are therefore familiar with biogas technology and Assam's biogas programme. Karbi Anglong is not within the Brahmaputra valley but was included to add the perspectives from a scheduled tribe (ST) district [101]. STs are protected groups and have a low representation as biogas owners in India despite the additional subsidies for ST and scheduled caste groups [22,80].

Table 1
Household indicators taken from the 2015/2016 National Family Health Survey Assam vs National India average.

Household indicator	Assam (%)	India average (%)
With electricity	78.2	88.2
Improved source of drinking water[a]	83.8	89.9
With an improved sanitation facility[b]	47.7	48.4
Using solid fuel for cooking	74.2	54.7
Living in lowest wealth quintile	24.4	20
Living in highest wealth quintile	6.1	20
Hindu	63.8	81.4
Muslim	32.5	12.5
Christian	3.3	2.7
Sikh	0	1.6
Neo-Buddhist	0.2	1
Jain	0	0.2
Other	0	0.5

[a] Piped water into dwelling/yard/plot, piped to neighbour, public tap/standpipe, tube well or borehole, protected dug well, protected spring, rainwater, tanker truck, cart with small tank, bottled water, community water filtration plant.

[b] Flush to piped sewer system, flush to septic tank, flush to pit latrine, flush to don't know where, ventilated improved pit (VIP)/biogas latrine, pit latrine with slab, twin pit/composting toilet, which is not shared with any other household. This indicator does not denote access to toilet facility.

3.2. Data collection

Data for this study was conducted in February 2020–January 2021. Due to the explorative nature of the research questions, in-depth semi-structured interviews with 40 participants from different households were used as the main data collection method to obtain detailed narratives of perceptions of, and intentions around, adopting TLADs. The questions were kept necessarily broad to allow participants to narrate thoughts, feelings and experiences of a socio-cultural or technical nature when they thought relevant. The interview guides included open ended questions on the following topics: experiences of DFADs including how the biogas and slurry are used; perceptions of TLADs; what could make TLADs more acceptable; and experiences and knowledge of the NNBOMP biogas programme.

The study villages were selected based on their characterisation as rural, accessible by road and having a mixture of households that had and or did not have domestic biogas. Convenience sampling using a door-knock campaign was employed [103,104]. Interviewers approached different typologies of households to ensure both male and female participants of various ages and religious backgrounds were interviewed. Fieldwork was assisted by local gate keepers and translators who both facilitated as well as limited access to households, due to their personal socio-cultural backgrounds, but were invaluable in having in-depth conversations with participants and contextualising the socio-cultural dynamics of the various villages. Of the 40 participants 14 were female and 26 were male and 62.5 % owned or had once owned a DFAD (broken or decommissioned) and none had a TLAD. Hindu's compromised 82.5 % of the sample and of these 28 were Nepali and 5 were from a ST. Three participants were Muslim, three were Christians (two Adivasi [101]) one was a Buddhist and the age of participants ranged from 19 to 68 years of age. One participant was also a trained biogas technician.

To answer research objective 4 a secondary data set (data set 2), was used to supplement the first (data set 1). Data set 2 was collected in 2013 and consists of 60 semi-structured interviews with owners of functional and non-functional DFADs and an interview with the Senior Officer of the SNA. Participants were asked about their experience and satisfaction around usage and non-usage of DFADs. A full methodology for data collection can be found in Raha et al. [33]. The two data sets were used

to evaluate how well the NNBOMP supports people in 1) adopting and accepting TLADs and 2) sustainably adopting and using DFADs.

The majority of the data collection for both data sets was conducted in the Brahmaputra valley where historically many Nepali Hindus settled due its suitability for cattle rearing [105]. Nepali Hindus thus make up 70 % of data set 1 and 100 % of data set 2.

3.3. Analysis

The interviews for data set 1 were conducted and recorded in Assamese, Nepali and Karbi and transcribed into English for narrative analysis using NVivo 12 software. For the basis of this study it was understood that 1) people construct and internalise narratives to make sense of their lives, 2) these autobiographical narratives have enough meaning to be told to others as accounts, and 3) these narrative accounts can be analysed for content themes [106]. Thus, thematic narrative analysis was applied where the aim was to extract themes within the narratives [53]. The identified themes were taken from the explicit surface meanings of the data rather than looking beyond what was told. The analysis aimed to find commonalities and contradictions within and between narratives to make sense of how participants explain their decision to accept or reject a TLAD or could be convinced to adopt one at another time. The hypothesis was that socio-cultural resistance would be found to be inadequate in describing and explaining users' resistance to TLADs and that it would not be a finite barrier to adoption. This hypothesis was used to shape the research questions and the interview guides to prompt users to explain socio-cultural resistance in detail. Thus, the research questions were initially used to guide the thematic narrative analysis and to reduce researcher bias, open coding of the data was subsequently applied to identify emerging themes beyond the research questions. Because the interviews were semi-structured and the aim of the study was to collect qualitative perceptions of TLADs and not to create generalisable results, it was not considered appropriate to base analysis on any quantification of results. However, numbers of participants that agreed with a theme have been used occasionally in the results when it was appropriate to draw attention to and contextualise a particular finding. All participants gave consent to participate. Ethical approval was obtained from the University of Stirling General University Ethics Board before commencement of fieldwork.

Data set 2 was translated from Hindi into English for thematic analysis using NVivo 12 software. Braun and Clarke's [107] phases of thematic analysis were followed and the identified themes were taken from the explicit surface meanings of the data. Research objective 4 was used to guide the initial coding followed by open coding to remove researcher bias. The lead researcher discussed the identified themes as well as the narrative themes from data set 1 with the lead researcher who collected data set 2 to ensure both researchers agreed with common themes that had come out of the data and that it accurately represented what the participants had discussed.

One limitation of the study is that remote villages not easily accessible by road are not represented due to logistical challenges. Additionally, Hindus are over-represented due to their numerical dominance in the study villages, experience and knowledge of DFADs and willingness to participate. Other religious groups were less represented although more Muslim households were approached by interviewers but declined when they learnt the interviews were about biogas. Further research should investigate why some Muslims households did not want to speak about biogas. Additionally, perceptions of TLADs and attitudes towards adopting one could have been misinterpreted from participant responses due to the topic being of a very personal nature, and intertwined with locally specific socio-cultural norms. Longer interview time frames and focus groups may produce more nuanced narratives and interpretations due to greater opportunities for participants reflect and discuss TLADs.

Table 2
Participant distribution of data set 1.

District	Village	Number of participants	Brief description of village context
Sonitpur	Village 1	10	Villages are located in close proximity to each other. Villages are predominantly Hindu.
	Village 2	5	
	Village 3	3	
Morigaon	Village 4	15	Most households in Village 4 had DFADs due to cattle rearing being a large source of income, with an active local dairy co-op. Village was predominantly Hindu.
Karbi Anglong	Village 5	3	Villages are in a Scheduled Tribe district. Villages more culturally diverse compared to the villages in Sonitpur and Morigaon. Cattle ownership was much lower.
	Village 6	4	

4. Results and discussion

4.1. Summary of perceptions of TLADs - positive, undecided and negative

To obtain an initial overview of perceptions, participants were thematically categorised as either having overarching positive (indicated they would adopt or consider adopting with some identified challenges), negative (indicated they would never adopt or use a TLAD) or undecided (neither positive nor negative) perceptions and are presented in Table 3 by demographic group. This was done only to gauge diversity of perceptions towards TLADs, the numbers are not statistically significant or intended to represent demographic groups. Participants were not universally opposed to TLAD adoption and socio-cultural resistance cannot be accurately used to explain local resistance to TLADs. Within this qualitative study, perceptions of TLADs are not related to the gender, age or religion of the participants nor to the highest educational attainment of the household. Belonging to a high Hindu caste was similarly not linked to attitudes towards TLADs as perceptions were almost evenly split between positive and negative. Although generalisations cannot be made the table suggests older participants could have more positive perceptions of TLADs, which is the opposite of other literature on TLAD adoption it and should be investigated further [9,16].

Table 3
Responses (positive, negative or undecided) by demographics from data set 1.

Response	Male %	Female %	Age group 19–30 %	Age group 31–50 %	Age group 51+ %	Hindu %	Other religions (Muslim, Christian and Buddhist)[a] %
Positive	42	43	33	33	50	42	43
Negative	42	50	44	44	45	45	43
Undecided	15	7	22	22	5	12	14
Total number of participants (/40)	26	14	9	9	22	33	7

[a] Although the results in this table were not used for generalisation Muslim, Christian and Buddhist responses were not presented separately due to small samples from each group.

4.2. Perceived socio-technical benefits and challenges around TLAD adoption and use of excreta derived biogas and bio-fertiliser

Literature has shown that adoption, or transitions, to sustainable technologies and practices are inherently socio-technical because they involve alterations to technology, policy, markets, user practices and cultural meaning, among others [108]. As literature on TLADs is relatively sparse, with socio-cultural rejection often cited as a main adoption barrier, participant perceptions of TLADs in this study were broken down and organised into socio-cultural, socio-technical and technical benefits and challenges, and are presented in Table 4. This provided a basis to better understand the origins of people's perceptions of, and resistance towards TLADs that is expanded on within this section. Although the number of participants with overall negative or positive perceptions of TLADs were similar, altogether participants perceived a greater number of challenges than benefits. Convincing people that the benefits of TLADs outweigh the challenges [9,109], as with transitions to other products and practices that recycle HE, will require a significant amount of sensitisation over time [45,110,111].

Table 4
Summary of participants perceived benefits and challenges of toilet-linked anaerobic digesters specifically to the toilet connection and not general to biogas technology, listed in order of most discussed[a].

Perceived benefits to uptake/adoption	Perceived challenges to uptake/adoption
Technical	Technical
• Improved sanitation and cleanliness • Disease containment (perception that diseases will exit in the gas) • Economical (utilising waste, no separate toilet, save on LPG cost) • Increased biogas production • Improved fertiliser (more nutrients) • Additional source of biogas if cow dung becomes scarce	• Toilet connection is unnecessary as there is adequate cow dung available • HE is not available in sufficient quantity to produce enough biogas for a household • Additional cost of connecting a toilet is not worth it • Existing sanitation/toilet is preferred • Lack of available space • LPG is easy to obtain
Socio-technical	Socio-technical
• Labour reduction as toilets will not have to be emptied and cleaned out • Less odour than from existing sanitation/toilet facility • Maintaining and cleaning a TLAD compared to existing toilets will be better work for sweepers[b] • Environmental benefits • Referring to urban centres (not rural) TLADs would be useful cleaning up large amounts of HE	• Concerns that the kitchen and food will smell and taste like the toilet and agricultural fields will be full of HE • Visually and physically connects the toilet with the kitchen which leads to socio-technical concerns • Not suitable for rural areas due to social norms and risk of social exclusion, availability of cow dung and low concentrations of HE compared to urban settings • Maintaining and cleaning TLAD would be a problem as it is considered dirty work • Touching the slurry will be a problem • Eating food cooked on biogas made from TLAD biogas is ritually and physically polluting/dirty • Unsure of benefits due to lack of experience with TLADs • HE perceived as a waste • Not perceived as modern and other more practical options will be available in the future
Social	Social
• None given	• TLADs oppose religious practices and sentiment and will not be accepted in conservative society • Risk of social exclusion and judgement • Older generation will not accept them • Reluctance to be the initial adopters due to risk of social exclusion and perception that it will take a long time for TLADs to be accepted • It is a crime/against customs to mix HE with cow dung • Younger gen will not want to do the hard work they will want LPG or other alternatives

[a] Responses were considered (i) technical when reasons given were only in regard to the technical workings or practicality of the TLAD, (ii) socio-technical when reasons were due to interrelated socio-cultural and technical reasons e.g. concerns that the biogas is dirty to cook on (socio-cultural) because it will smell like toilet (technical) and (iii) socio-cultural when reasons given were only of a social and cultural nature.

[b] Sweeper is a pejorative name for Dalit sanitation workers. The practice has been banned in India but is still apparent and the term still widely used among participants.

No social benefits associated with TLAD adoption were given suggesting that there is no perceived social value in adopting a TLAD. This is in contrast to TLAD adopters in Nepal, who discussed how shameful it was to practice OD and how improved their situation is now [9]. All participants in this study had a sanitation solution that may explain why no one perceived social value in adopting a TLAD. Many participants discussed how increasing environmental pressures could pressure them to adopt TLADs in the future. However, no one expressed positive perceptions towards TLADs based on a perceived environmental good or associated positive emotions with adopting an environmentally beneficial technology [112]. Many participants did not see the benefits of attaching the toilet in terms of improved sanitation, and no one gave scientific explanations around containment of pathogens or how TLADs are better than pit latrines or septic tanks. Some people agreed that having a TLAD that does not require emptying would be a benefit, but most were happy with their sanitation solution and means of emptying it, which for many was calling a sweeper [2]. Many people did not perceive benefits in the form of increased nutrients in the slurry and biogas output when the quantity of HE that a family produces will be small. Education around the importance of sanitation that extends beyond capture to safe containment and treatment could be lacking in the area. Further research could confirm if households that want an improved sanitation system, have large family groups using the household toilet and/or lower numbers of cattle, perceive more benefits in adopting TLADs.

4.3. Origins and nature of socio-cultural resistance towards the use of human excreta derived biogas and fertiliser

Analysis of the narratives revealed that socio-cultural resistance can be better understood when it is differentiated into socio-cultural and socio-technical resistance. Socio-cultural resistance can be understood as resistance to the adoption of TLADs that arises due to the opposition of personal and social, cultural norms independent of technical and practical knowledge. Socio-technical resistance can be understood as resistance that arises due to concerns around social consequences that are based on or reinforced by concerns people had about the technical aspects of a TLAD.

4.3.1. Narratives of socio-cultural resistance

4.3.1.1. Personal and place-based identity. The adoption of TLADs challenged people's personal and place-based identities and three themes within both were identified. For personal resistance: 1) Personal resistance due to TLADs opposing personal norms; 2) resistance due to TLADs opposing social norms of the group someone belongs to and 3) resistance due to threat of social sanctions from the wider community. For place-based resistance: 1) resistance based on not wanting a TLAD in their home; 2) resistance based on the feeling that TLADs do not belong

[2] Sweeper is a pejorative name for Dalit sanitation workers. The practice has been banned in India but is still apparent and the term still widely used among participants.

Fig. 2. Participant quotes around socio-cultural rejection towards toilet-linked anaerobic digesters arranged on a scale that highlights the difference between personal and local resistance compared to group or national resistance.

in their village or villages in general and 3) resistance due to national place identity and feelings that TLADs are not within Indian behaviours or values. Fig. 2 contextualises this analysis by placing participant narratives on a scale between personal and local resistance to group and national resistance, respectively. Identity can be a strong motivating factor for why people reject technologies and practices [55,56], such as rejection of toilets in preference for OD [60]. Identities that translate into beliefs that TLADs do not belong to certain places or people will have strong implications for dissemination. Biogas programmes might have more success disseminating TLADs if they work with communities to renegotiate personal and place-based identities around what is seen as waste and what has value more broadly [60,113], rather than narrowly addressing only TLADs.

4.3.1.2. Narratives of difference –Other places and people. Many participants believed that TLAD adoption would be acceptable for other people and in other places, such as urban centres. They argued that more HE is available in urban centres, urban dwellers are often educated to a higher level and benefit from less social pressure through increased anonymity compared to village dwellers. Participants are aware that social norms influencing their decision making are related to the context.

> *"In urban areas no one cares from where the gas is coming in someone's home"*
>
> (M 42 Hindu 203)

> *"I think the urban society might use it. They are more educated as compared to village people"*
>
> (M 34 Hindu 008)

Their awareness of the fluidity of social-norms suggests there is potential for renegotiation of what is acceptable in rural villages and personal places of residence. Alternatively, rural Assam might not have conditions that incentivise people to adopt TLADs. Due to the close association many participants had with Nepal some drew direct comparisons between Assam and Nepal, geographically and culturally. It was argued that villages in Nepal are more congested with houses built closer together so there is less space for separate sanitation facilities as well as less cattle per household, which they believe make TLADs more of a necessity in Nepal. One participant added that they believe that Nepal has a more flexible culture because many of them migrate abroad for work. Additionally in Nepal, due to topography, access to LPG in rural areas is often limited [47]. TLAD adoption in Assam could be more successful in specific contexts; perhaps where LPG is harder to access or there is demand for sanitation facilities.

4.3.1.3. Knowledge – never enough or too much. Analysis of the narratives revealed diverse preferences for knowledge about TLADs and the different ways knowledge can influence perceptions of TLADs. For some people, socio-cultural resistance was unnegotiable, no matter what they learn about TLAD benefits they would never accept them.

> *"We go for Ganga bath [according to Hindu beliefs taking a dip in the river Ganga washes away your sins], but the river has been [physically] polluted, we can even see with our eyes... but there is something in our heart. [A belief] … that the water of the river is pure, it is different. The point that you are making about the [technical benefits of TLADs] today's generation may accept it….definitely people might benefit. But for me I will never accept it"*
>
> (M 69 Hindu 304)

For these people resistance originates from a social and or religious code of conduct that goes beyond understandings of physical cleanliness and technical understanding [114]. This is why technical knowledge of TLADs would not convince them to adopt one. Participants from all religious demographics articulated it would be perceived as a sin to use the TLAD biogas and that it would go against ritual customs.

> *"It's unacceptable [to use TLAD biogas] for both us and for ritual, I think it would be a sin for us to cook a ritual meal"*
>
> (F 62 Buddhist 101)

> *"The Hindu people do not want to mix those things (HE and cow dung). They believe it as a crime. That's why people don't build one"*
>
> (M 54 Hindu 207)

For others, an absence of knowledge would increase acceptance of TLADs. Their resistance towards TLADs was around the wilful participation of having one in their home or being aware they were eating food cooked on HE derived biogas.

> ***Participant:*** *"No I will not [like] to [eat at someone's home] if I come to know it is cooked with TLAD gas.*
>
> ***Interviewer:*** *"What if you don't know?"*

Participant: *"Then it's not a problem"*

(M 19 Hindu 403)

Similarly, some studies have found that the more information people have about products derived from recycled waste streams, such as wastewater or plastic bottles, the more deterred they are from using them [61,115,116]. Large scale anaerobic digestion that does not advertise that its products are derived from HE [91,116], or commercially markets it by reframing the narrative [51] might have more success in specific contexts.

4.3.1.4. Religion and religiosity – and the diversity within. Religiosity, defined as the intensity of an individual's faith [117,118], specifically around purity and pollution practices, was related to resistance towards TLADs. Participants whose responses suggested a more orthodox approach to ideas of purity saw TLADs as directly opposing religious sentiments. Whereas others, who identified with the same religion, could imagine TLADs existing alongside religious practices.

"Everyone will say the same that since we pray Namaz and do the Roja (religious fasting). If we use the TLAD it will be impure and the prayers and fasting will not be valid"

(F 35 Muslim 308)

"Even I pray Namaz, no I don't think it will be a problem. Even LPG is made from dirty things… all gas is the same"

(F 40 Muslim 306)

A person's religiosity, within many religious groups, can both create feelings of protection over the environment, as well as indifference [117,119–121]. Many cultures and religions have rules and practices around purity and pollution [122]. However, there are few studies that make the distinction between diverse interpretations of religiosity or its influence on attitudes specifically towards circular economy practices [91,113,121], especially around the reuse of HE. Specifically, the intensity of someone's beliefs around purity and pollution and how they influence acceptance or rejection of TLADs should be investigated in more detail. A better understanding of this relationship may facilitate working with cultural groups and provide knowledge for how religious institutions can help renegotiate what is a waste and what has value. For example, in Bhutan a Buddhist leader inspired an increase in waste reduction and recycling behaviours of citizens, when government initiatives did not [113].

4.3.2. Narratives of socio-technical resistance

4.3.2.1. Negative socio-technical imaginaries. The most common concerns people had can be found in Table 2 under socio-technical challenges. Socio-technical resistance towards TLADs arose due to a lack of understanding of how a TLAD would work in practice that resulted in resistance due to decisions being made on negative imagined scenarios.

"There might be a miss-conception that the [slurry] will be full of HE and the entire field will be full of it. Even I feared that somehow, we can see the toilet waste coming out of the [TLAD]… Also, I was the first [to get a DFAD] in the village and even I had the fear of people talking about [my DFAD] badly. If I would have seen [a TLAD] installed earlier, I might have installed one in my home. But since I was the first [to get a DFAD] it was difficult. People even asked us if our food smells of gobar [cow dung] … But now everyone uses it [now they understand that the biogas and slurry are not like gobar anymore and so would not be like HE if they had a TLAD]"

(F 60+ Hindu 211)

This particular participant was deterred from adopting a TLAD both because of a fear of people talking about them and that their technical concerns would materialise. In this instance socio-cultural rejection is one aspect of the final decision not to adopt a TLAD but was reinforced by a lack of understanding of how TLADs work. Negative socio-technical imaginings due to a lack of knowledge or experience is a common reason for resistance to many technologies and practices that can be overcome with learned experience [9,50,111,123,124].

Some of the technical concerns people had such as slurry touching edible parts of crops and the smell of biogas could be warranted. The slurry can contain pathogens dangerous to human health [125,126] and biogas made from any feedstock contains sulphur dioxide, which can be odorous as well as harmful [127]. These concerns could be addressed with sensitisation and training. However, even if a user can operate a TLAD safely they may still risk social consequences [38] if their community is not knowledgeable. Biogas programmes focussed on TLAD adoption could work best targeting and sensitising whole communities [111,128].

4.4. Motivations and drivers for changing attitudes to TLAD that could forge pathways to adoption

Potential pathways to adoption based on different initial attitudes to TLADs were thematically identified and are: 1) people that had positive perceptions of TLADs and decision making not dependent on social approval said they would adopt a TLAD; 2) people that had socio-cultural and or socio-technical resistance to TLADs said they might adopt one if certain conditions were met; and 3) people that said they would not adopt a TLAD no matter what circumstances changed. These identified non/pathways are illustrated in Fig. 3 and expanded upon in the following section.

4.4.1. Leaders or risk takers – people with positive perceptions of TLADs

People with leadership and/or risk-taking personalities could be catalysts for community adoption of TLADs in Assam [9,51]. These participants had overall positive perceptions of TLADs in addition to decision making independent of social approval. They either perceived enough benefits from a TLAD that the risk of social rejection did not matter, or it was not a concern for them. Some also expected that once they had installed a TLAD others in their community might follow once they saw the benefits. These potential leaders of TLAD adoption understand that they could create pathways to wider adoption of TLADs and believe that any social sanctions placed on them would not last forever.

"Maybe some of them will not like it in the beginning. But if I get the opportunity then I will use it. Also, once the other people see that the fuel is benefitting me then they will also start using it"

(F 40 Muslim 306)

Evidence from Nepal, where people with risk-taking personalities did catalyse adoption of TLADs in their communities supports, this potential pathway to adoption of TLADs in Assam [9]. However, using socially determined community leaders to disseminate technologies can risk accentuating existing inequalities [91,94].

4.4.2. Conditions or contexts that would motivate users to overcome resistance to TLADs – people with negative or undecided perceptions of TLADs

Three potential pathways to adoption of TLADs for people with negative or undecided perceptions of TLADs were identified. Participants reflected on what factors have shaped their current perception of TLADs and how this could change. The reflective narratives adds evidence that resistance towards HE derived products is not driven by users and consumers with irrational resistance [129].

4.4.2.1. Demonstration of TLADs – Increased familiarity (linked to disgust). Some people felt they could not make decisions around TLAD adoption without first using one. Additionally, more people might adopt TLADs in Assam with opportunities to see or trial one. This is because

disgust reactions could become eliminated, or less influential on decision making, as the perceived benefits of TLADs, learned through familiarisation, overpower them [51]. Knowledge and experience have been identified as two important factors related to technology adoption [109] and disgust has been recognised as a learned behaviour that can change [130,131]. Participants reflected that they might only feel disgusted because they are not familiar with TLADs and with familiarisation they might not feel disgusted anymore. Disgust or hesitation was related to something unknown and threatening [111]:

> *"I will feel dirty, I guess. Because I have never seen a TLAD or eaten any food cooked with TLAD biogas. It will be a new experience. So, I think I will feel disgusting"*
>
> (M 19 Hindu 402)

> *"In the beginning I will feel disgusting and dirty. But as time flows, I will be accustomed to handle it [slurry from TLAD]"*
>
> (M 55 Hindu 205)

Importantly, initial disgust reactions towards TLADs cannot be used to determine a person's final intention to adopt or reject a TLAD [111]. This is supported by other examples of when the opportunity to trial or observe HE derived products, including from TLADs [9], has led to increased acceptance. In Uganda the adoption of human urine as a fertiliser was expedited through group change and opportunities to observe the benefits [111], and farmers in Malawi indicated greater acceptance of HE derived compost after being shown samples [124].

Although participants articulated that opportunities for trialling a TLAD would increase their acceptance, some also expressed that the less they know the better. These are conflicting pathways to adoption and could depend on other factors and warrants further investigation.

4.4.2.2. TLADs become normalised within social norms. If TLADs became a social-norm they could be perceived as less disgusting and more people might adopt them. Disgust reactions are hypothesised to originate largely as a response to prevent contact with foreigners or people acting in non-normative ways [122,131]. With the social exclusion of sanitation workers in Hindu societies, and wider Indian culture, people might feel less risk in adopting a TLAD if it happened in groups [131].

> *"Toilet is something which we all feel disgusting. And gas from it….. ummm… I don't think I will prefer it now. If someday everyone is using it then I might become accustomed with it and start using it… It is kind of psychology. If everyone uses it then it becomes a kind of tradition"*
>
> (M 19 Hindu 403)

Although it is commonly assumed that people gravitate to social groups they already identify with, people can also become more like the group over time [132]. What participants in this study have described is that within a community structure individuals could redefine their identities around what is acceptable and what is not [9,51]. In Nepal TLAD use has become normalised but many users had personal restrictions around how the biogas and fertiliser could be used based on where they felt comfortable doing so. Individual norms were still influencing behaviour but the community's equilibrium had shifted so that TLADs are acceptable [9]. Assam might have more success disseminating TLADs if the programme works with whole communities and not single households.

4.4.2.3. Necessity. Feelings of necessity such as a perceived scarcity of resources could encourage people to adopt TLADs. Participants explained that if they lacked access to other fuels or cow dung for their DFADs then they would have no choice but to use a TLAD. TLADs may be more suited to contexts that create a greater perceived necessity for

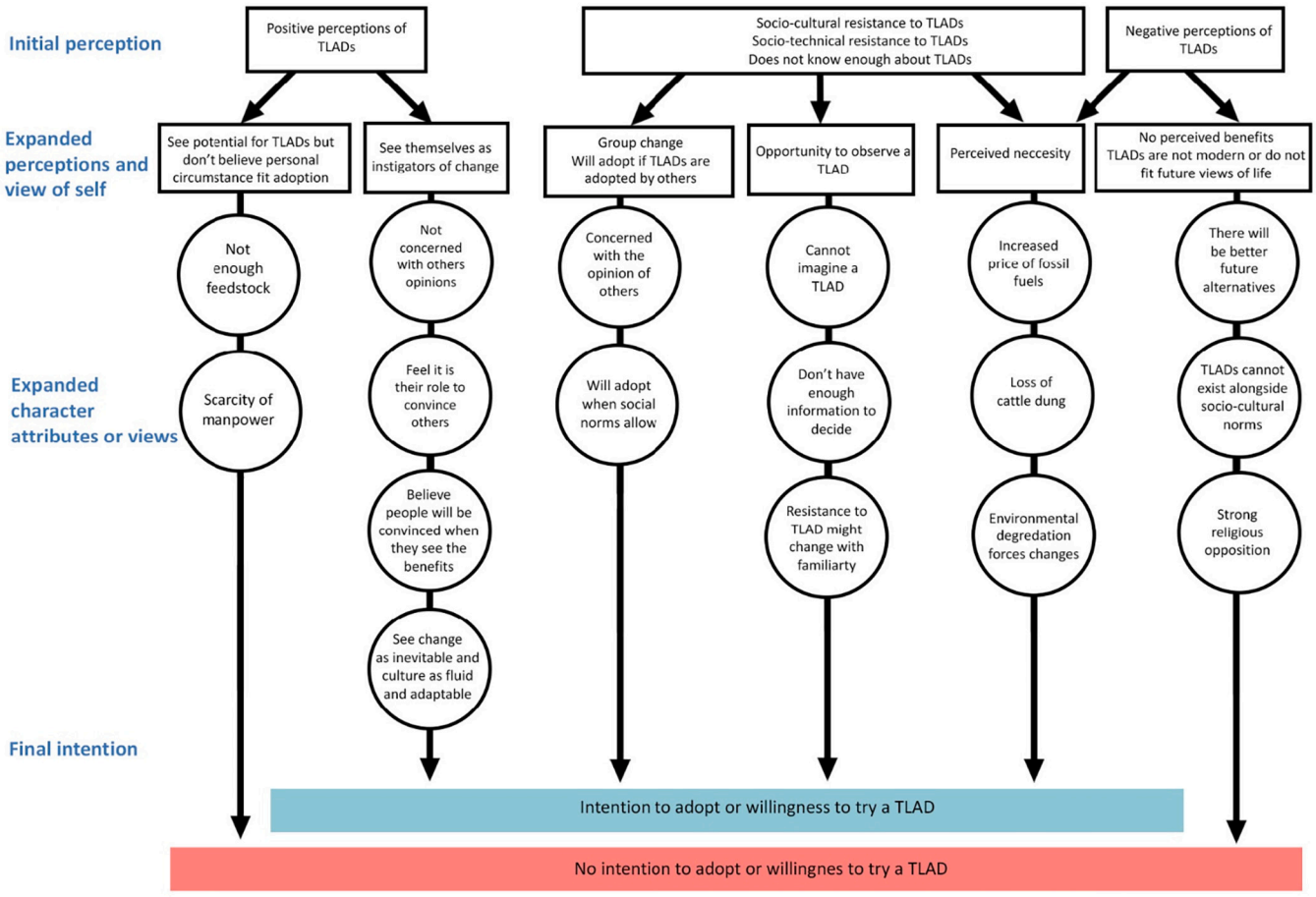

Fig. 3. Illustrates the potential pathways to a participant either intending to adopt or no intention to adopt that were identified during analysis.

TLAD products and services [25]. Alternatively, the promotion and subsidisation of alternative energy, fertiliser and sanitation solutions within the state might be contributing to perceptions that TLADs are not needed [27]. Better coordination between programmes along with promotion of TLADs might encourage people to consider them as an option. Although, experience of water scarcity drove some people to accept water recycled from waste water [129], but for others it did not [130]. Further research is required to determine when feelings of necessity or scarcity translate into a willingness to adopt TLADs.

> *"If situation demands it then I have to accept [a TLAD]. But in my present scenario, I will not have it"*
>
> (M 34 Hindu 008)

> *"If the LPG price rises too high, then we shall use a TLAD connected to our gobar gas as we wouldn't be left with any other options. Such circumstances will compel us to do so!"*
>
> (M 64 Hindu 303)

With the high consumers predominantly from the Global North causing most environmental issues it is unethical to use environmental pressures to motivate lower-income households and convince them of a necessity to adopt biogas when they can add time, labour and social burdens to people's lives. If people adopt TLADs it must be in their best interests.

4.5. How Assam's biogas programme engages with communities to support sustainable uptake of biogas technology and the connection of toilets

4.5.1. NNBOMP engagement with users around TLAD adoption

The potential pathways to TLAD adoption identified in this study have not been understood or considered in Assam's biogas implementation plan. Most participants who were asked had heard of TLADs, but only one participant had been offered one and very few knew of the additional subsidies for TLADs. No one had had the opportunity to observe a TLAD except a few participants who had visited Nepal. These experiences did not result in adoption of TLADs in Assam, which would suggest that local demonstration is necessary [133]. There was no evidence that potential users had been engaged with or supported in adopting TLADs. The NNBOMP states that the SNA and other state implementing actors should work with the SBM and sanitation schemes to identify eligible households for TLADs [22]. The target for TLAD installation in Assam between the years 2020/2021 is three hundred units [68], this commitment to TLAD installation does not seem to be embodied at the state level of implementation, at least in these study areas.

The absence and low awareness of TLADs could be a result of a negative or dismissive attitudes towards TLADs from biogas programme actors. Both the SNA officer and local biogas technician, who are gatekeepers to knowledge of biogas technology, had dismissive attitudes towards TLADs. The technician said that he has discussed it with people but added that *"we don't use that [TLAD] here in [village]"* and the SNA officer articulated, making assumptions of diverse groups, that people in Assam would not agree to link their toilets with DFADs because of religious and cultural reasons [33]. Personal resistance of government officials in India towards the reuse of HE in agriculture has been found to be higher than those of small holder farmers and a potential barrier to wider institutional change [134]. Renegotiation of how eligible households for the programme are identified as well as programmes of sensitisation and training for staff in addition to users is recommended.

4.5.2. Effectiveness of the NNBOMP state implementation in supporting sustainable adoption of biogas technology – the wider context of domestic biogas adoption in Assam

The NNBOMP objectives that encompass energy, fertiliser and sanitary benefits for users are not being fully utilised by biogas users in Assam. Many households were only utilising the biogas and not the slurry [33] and none were utilising the sanitary benefits of connecting a toilet. Additionally, many of the participants were not optimally using their DFADs. Some were confident conducting small repairs, optimising biogas through feedstock management and knowledgeable on how best to apply the slurry. However, others were not optimising biogas production and were discarding the slurry or using it incorrectly by drying it in the full sun, which causes nutrient loss due to evaporation [135]. A participant who had tried vermi-composting, suggested by the NNBOMP as a method to treat and valorise the slurry that uses earthworms to compost it [22,136], explained that it is a lot of additional work and without a market to sell it they lack incentive. There was also variability in the amount of cooking hours a household reported compared to how many cows they had determining how much cow dung they feed their biogas a day [33]. The variability shows that having cattle and a DFAD does not guarantee sustainable adoption [27,137], and installation of biogas technology does not mean people will automatically use it to its full capacity, or know how to.

There is a lack of commitment into activities beyond construction that would facilitate users in optimally using biogas technology. There was a lack of, and spatial inequality found in, post installation support. All DFADs in Napaam and Amolapam were non-functional because either no one was available for repairs, or users had sold their cows and decommissioned the DFADs due to lack of feedstock. Almost all other users of DFADs reported working DFADs and that there was a skilled person available for repairs. Napaam and Amolapam are a four-hour drive from the SNA in Guwahati, whereas all other villages (except those in Karbi Anglong) are within 1–2 h. The distance of users from the urban centres or biogas offices could be associated with the biogas programme efficacy, although a participant in Karbi Anglong reported receiving post installation follow up, which is positive. There was a lack of training around slurry valorisation and utilisation as well as around how to optimise biogas output. Many reported that they do not obtain enough biogas in colder winter months, where feeding of the biogas plants must be increased to boost biogas production. Many of the households had enough cattle dung available to increase feeding but were not doing so, which indicates lack of training and or incentive.

Ineffective targeting of biogas users in Assam could be contributing to inefficient use of the biogas technology. In Assam as well as other states, cattle ownership is required to be eligible for biogas subsidies [27,33]. However, owning many cattle suggests a higher income, which would mean greater access to alternative products resulting in less motivation for running a DFAD. This could explain why not all households with more cattle were getting significantly more biogas a day or able to last the winter without using LPG.

> *"Certainly, people who have a good income will not go for gobar gas [DFADs]. They will find other, easier alternatives. They will go and buy LPG. It completely depends on the person's scarcity of money"*
>
> (F 54 Hindu 209)

Biogas ownership favours higher socio-economic households across all of India [80]. The NNBOMP offers additional subsidies for lower socio-economic groups (ST and SC groups [22]). However, offering subsidies to households with cattle is perhaps an oversight of Assam's programme in achieving this objective. Some of the lower socio-economic households in the study villages kept pigs, which require less land to farm compared to cattle [64,138]. Pig dung is a common feedstock for DFADs in Vietnam and China [5,20]. The NNBOMP policy literature refers to the technology as 'cattle dung based biogas plants' [22] and the online form households use to express interest in applying to the scheme asks how many cattle a household has (Buffaloes and cows) and not other livestock [139]. To more effectively reach lower socio-economic households and work with diversity in the state the programme should be made more accessible for households that keep pigs. Assam not only has the highest number of households deriving a major source of income from livestock farming of all India's states, but the highest numbers of ST and SC households doing so [64]. There is

much higher potential for biogas adoption in Assam, especially by lower socio-economic households than is currently being achieved. Additionally, the use of local contacts to select programme beneficiaries, which introduces social bias, will not be effective in identifying the suitable adopter households.

5. Conclusions and recommendations

This study provides a better understanding of what socio-cultural resistance towards TLADs is, how pathways to adoption might evolve, as well as how the state implementation of the NNBOMP could become more effective and work better with cultural diversity.

Analysis of the narratives revealed that socio-cultural resistance is sometimes independent of an individual's technical understanding of TLADs as well as more socio-technical, where resistance is related to knowledge of TLADs. Resistance was also related to how orthodox someone's beliefs are around purity and pollution practices and how dependent their decision-making is on social approval. Resistance towards TLADs could be overcome if people are provided with opportunities to observe or trial a TLAD, if TLADs became a social norm and if circumstances changed so TLADs are perceived as a necessity. Many people perceived TLADs as unnecessary due to the small amounts of HE a household produces compared to cattle dung, as well as the availability of alternative products and services.

This study has opened up several opportunities for future research and suggestions for policy development. While a main finding from this study is that perceptions of TLADs and potential pathways to adoption within demographic groups or across communities cannot be generalised, for practicality, some generalisations within a biogas programme's approach must be made. We recommend that future research investigations aim to obtain a better understanding of the adoption pathways that can develop in communities and when to apply certain approaches to target villages. More empirical research should investigate if demonstration of TLADs and using village leaders or risk-takers as catalysts for wider community adoption are effective pathways to adoption, and if facilitating whole communities to adopt TLADs can remove some of the social barriers to adoption in Assam. Research should also focus on the influence that access to services, i.e. LPG and or sanitation facilities, has on TLAD adoption. Moreover, larger sample sizes should be obtained to gather more diverse perceptions from religious, caste and age groups. Specifically investigating how the younger generation perceive TLADs and differences in generational opinions should be a priority as policy approaches may have to change over time.

Narratives in this study revealed that people are aware that their perceptions towards recycling HE and TLADs are potentially negotiable and related to feelings of identity. Thus, more broadly, research investigations should aim to better understand the fluidity of social norms around recycling HE in regards to place and personal identities. This could facilitate better engagement with potential adopters of TLADs as well as other technologies and practices that recycle HE. More broadly working with people to renegotiate seeing HE as a resource and not a waste product might have better results, rather than specifically focussing on the promotion of TLADs [60].

We recommend that the NNBOMP in Assam improves how it identifies biogas adopter households through needs assessments, and works with diverse local groups to overcome resistance towards TLADs. A re-evaluation of the use of local contacts to identify households eligible for the subsidy as well as the condition, or the bias towards households that have high numbers of cattle is suggested. Lower socio-economic households could benefit more from biogas but often have less cattle or keep pigs [64]. Moreover, some stakeholders within the programme were found to have negative perceptions towards TLADs therefore education of stakeholders within the NNBOMP on the benefits of toilet connections is recommended. Without commitment from state authorities to promote and support users adopting TLADs, the additional subsidies offered by the central NNBOMP for toilet connections are obsolete [140]. Additionally, a better commitment to offering post installation services and training to domestic biogas users is essential. Some households were not using biogas technology optimally even if they had enough feedstock, and many others wanted to keep their biogas functioning but did not have a technician available locally to help them to do so.

Finally, we recommend that the state integrates the biogas programme with other programmes, such as the SBM, to work with users within specific local contexts, to assess which energy and fertiliser products as well as sanitation and waste management solutions are best for a household [141].

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.

Data availability

Data will be made available on request.

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