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Role of product standards in the acceleration of the Indian energy transition: The case of the Indian off-grid solar sector

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ABSTRACT

This article considers the role of product standards in the acceleration of the Indian energy transition. It argues that standard-setting plays a crucial role in shaping interactions between national regulators and stakeholders of the off-grid solar sector. Thirty-three expert interviews were scrutinised in a narrative analysis. Product standards are assessed in the context of an emerging Indian off-grid solar sector. The study found that there are two different frameworks for product standards, that standard adherence played a significant role in accessing government programmes, and that the establishment of product standards in the off-grid solar sector was driven by international stakeholders. By applying a narrative analysis, two central narratives on the governance of the Indian off-grid solar sector have been found. The paper concludes that diverging product standards frameworks due to increasing politicisation of energy access governance impact the acceleration of the Indian energy transition.

1. Introduction

Achieving sustainable energy access for all by 2030 creates a significant challenge for the governance of sustainable technologies in the Global South. On the one hand, energy access is crucial for economic development, and on the other hand current energy access pathways contribute to the climate crisis. The ongoing COVID-19 health crisis further amplified the need to address the energy access gap [1]. The magnitude of this challenge is significant, as there were still 789 million people without access to modern energy in 2018 [2]. Here, India has been an example for attempts to accelerate energy transitions through the recently completed SAUBHAGYA scheme (Pradhan Mantri Sahaj Bijli Har Ghar Yojana, which translates as 'Prime Minister's scheme for easy electricity to each household' [3]) and the Jawaharlal Nehru National Solar Mission (JNNSM), which is set to introduce a 100-GW solar energy generation capacity by 2022 into the Indian energy system. While both programmes have been successful in connecting millions of people to more sustainable energy access through the power grid, 64 million Indians still lack access to modern energy [2].

The politics involved in the Indian energy transition play a crucial role in achieving sustainable energy for all. Earlier literature looked at politics involved in electrification programmes through renewable energy in India [4–6]. Studies on energy access for the rural poor showed that clientelism and political promises to the electorate to provide energy access played an important role [7–10]. The political economy literature offers studies on the diffusion of solar [6,11–13]. Here, the viability of off-grid energy access as part of electrification efforts for the rural poor was investigated [8,14]. It was found that in an Indian off-grid solar (OGS) sector, actors pursued strategies of engagement or disengagement with the government [15–17].

What has been so far little understood is how product standards contribute to or mitigate political contestation in the Indian energy transition. Product standards are often regarded as neutral in technology governance as they 'specify acceptable performance criteria along dimensions such as functional levels, efficiency, health and safety' [18]. Earlier studies on OGS markets in African countries showed that product standards intended to protect local markets can disadvantage poor consumers relying on OGS systems [19]. This can be due to the complexity of such product standards and amount to a socio-technical 'black box' [20]. This study argues that competing interests of stakeholders favouring the power grid

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or off-grid companies [21] shape the way in which product standards are applied in the appraisal of OGS systems in India [22]. However, the number of publications considering the role of product standards in energy transitions in terms of global production and trade is limited [23–26].

Therefore, this study sets out to further disentangle the 'black box' of product standards in the Indian energy transition by studying the OGS sector. It provides insight into the political nature of standard-setting and contestation in the Indian energy transition. The study applies a narrative analysis [27–29] of expert interviews conducted with public and private stakeholders of the OGS sector in India. The following two research questions guided the inquiry:

RQ1: How is contestation articulated in the Indian energy transition, and what can be learnt from the Indian OGS case?
RQ2: Which role do product standards play? Do they allow to mitigate or entrench contestation?

The remainder of this article is organised as follows. The following sections provide background information on the Indian OGS sector and product standards based on grey and academic literature. Section 2 introduces the method applied to analyse the expert interviews and describes the data. Section 3 elaborates the theoretical framework. Section 4 presents the main findings and identifies two central narratives to understand contestation and the role of product standards. Section 5 discusses the findings in the context of the Indian OGS and political economy literature.

1.1. Background: the Indian off-grid solar sector and product standards

The number of households with experience in using off-grid solar systems grew significantly in the last ten years. While only one million households worldwide had experience with such systems in 2010, that number had grown to 73 million households worldwide by 2018. Because of the lack and unreliability of grid connections, a potential customer base exists of nearly 2.2 billion people worldwide [30]. In 2016, annual global sales amounted to approximately 8.1 million systems, and in 2018 this figure was 7.6 million [31]. India is one of the largest markets for off-grid solar systems; between 2016 and 2018, 2.7 million off-grid solar systems were sold annually by members of the Global Off-Grid Lighting Association (GOGLA) [31]. The scope of the analysis was limited to the OGS lantern and Solar Home System (SHS) market segments. This means in this study picoPV systems of 0.5–10 W peak (Wp) output. Such systems can power small lanterns up to lighting a household. The study also covers plug-and-play and open market components SHS providing 11 Wp and higher. OGS systems consist of a photovoltaic (PV) module, battery, lights, inverter, wiring, and appliances (e.g. fans, tv or radio sets) [32].

Since 2010, India had been a key off-grid solar market. It is served by a growing number of companies adhering to the international product standard introduced by Lighting Global, a programme of the World Bank and International Finance Cooperation (IFC). Although off-grid solar systems are cost-competitive in their market segment, the availability of support from global and national institutions played a significant role in driving the market's development [30]. Small-scale productive applications are playing an increasing role in the market. Also, government programmes such as KUSUM scheme, which aims to provide farmers with 1.75 million subsidised solar water pumps until 2024, shape the market [2].

In contrast to markets in sub-Saharan Africa, the Indian market was dominated by cash payments for solar systems. In India, demonetization gave a boost to digital payments for OGS systems in urban and peri urban OGS markets. Here, companies such as SIMPA Networks were able to profit from the demand for PAYGo payment plans. This was due to the high penetration of ICT-related infrastructure and services [33]. However, in rural areas there were only limited options for digital payments available through pilot projects [34]. Reasons for this asymmetry included the related risk of credit default compared to urban markets, the overall difficult access to consumer finance in rural areas, and the strict regulation of the financial service sector in India [32]. Therefore, cash sales continue to play a central role in rural areas [31]. However, the recent emergence of new digital payment platforms such as KPay and the buy in of French energy company ENGIE in SIMPA Networks show that this might change in the future.

Today, multiple stakeholders are involved in the Indian OGS sector. They can be categorised into global institutions, national institutions, cross-cutting and local institutions (companies, industry associations and so forth), and civil society organisations [35]. Global institutions include the aforementioned Lighting Global programme. Furthermore, the International Electrotechnical Commission (IEC) is a global institution for the regulation of product quality standards. Other global institutions include international networks such as Power for All, the Collaborative Labelling and Appliance Standards Program (CLASP), and the International Solar Alliance (ISA). National institutions such as donor agencies (UK Department for International Development [DfID] or the German Corporation for International Cooperation [GIZ]) have supported experimentation with off-grid solar technology at the local level.

In India, institutions such as the Indian Bureau of Standards and Ministry of New and Renewable Energy (MNRE), nodal state agencies, and distribution companies play vital regulatory roles. Cross-cutting institutions include companies such as d.light, Green Light Planet, and SELCO as well as the business associations GOGLA and the Clean Energy Access Network (CLEAN). Civil society organisations include research bodies such as the Energy and Resource Institute (TERI), environmental NGOs such as the Council on Energy, Environment and Water (CEEW), as well as foundations such as Shakti [32,36].

1.2. Product standards in the Indian OGS sector

In the early 2000s, international stakeholders began to develop a global product standard for off-grid solar to decrease production cost and increase comparability of systems. The shared concern for product standards within this sector led various PV producers, lending institutions (e.g. the World Bank), and governmental and private organisations to this step [37]. In 2013, the Lighting Global programme together with the US Department of Energy established the Lighting Global Quality Test Methodology as the world product quality standard for off-grid lighting products at the International Electrotechnical Commission (IEC). At the technical level, the initiative is supported by the Schatz Energy Research Center; test labs in Africa, Asia, and the United States; and CLASP. This shift towards a harmonised international standard reflected concern about vulnerabilities of production networks due to growing international trade and short product lifespans [37].

The international efforts to standardise OGS systems were not translated into a harmonised Indian standard for the OGS sector. Stakeholders of the OGS sector criticised that Indian standard-setting practices had been undertaken in an ad-hoc manner [38]. Due to the lack of setting and enforcing an appropriate standard, there was little control on substandard systems entering the Indian off-grid market [39]. Therefore, stakeholders called on the government to allow for 'accreditation of participating companies,

setting and enforcing standards, verification of installations, and monitoring of system performance' [39]. These tasks should be taken on by independent bodies such as the Bureau of Energy Efficiency (BEE) or the Bureau of Indian Standards (BIS) [39].

Today, there is an international standard (IEC TS 62257-9-5) and the Indian standard (IS 16476) administered by the MNRE in close cooperation with the Indian Bureau of Standards (IBS). The two standards diverge in design aspects of the systems, testing procedures, and scope. The international standard covers pico Photovoltaic products up to 10 W (Solar lanterns, task lights, etc.) and solar home system kits from 10 W to 350 W. In comparison, the Indian standard is only designed to cover solar lanterns with separate photovoltaic modules from 0.3 W to 5 W. In addition, the Indian standard focusses on a specific type of solar lantern that provides uniform illuminance at all angles around the base of the lantern. This difference can create ambiguity in testing procedures, and regulatory ambiguity for a broad range of off-grid solar systems common in Indian markets, but not following these specifications.[1]

Adherence to product standard requirements can play a role in accessing representative bodies such as industry associations. A study on the DRE sector by CEEW, an Indian NGO, indicated that less focus was given by Indian off-grid alliances to technology aspects, whereas six 'overseas alliances' in the sector addressed such concerns [40]. The Global Off-Grid Lighting Association (GOGLA) has a stronger definition of standard adherence where members are 'expected to ensure that their products meet at least internationally agreed minimum standards' [41]. According to the Lighting Global Programme website, 176 products of 49 manufacturers[2] are quality-verified in accordance with this standard. In contrast to GOGLA's strong reference to the international standard, the Indian industry body CLEAN provided a weaker definition where it 'is important to certify the DRE technologies and applications to ensure good products are provided to the consumers. The enterprises have largely agreed to have authoritative bodies to certify their products' [42]. CLEAN is an Indian industry body with 104 members, of which 41 were manufacturing or distributing OGS systems [43].

Furthermore, product standard adherence can play a role in competing for tenders in public sector energy access programmes. In 2012, the MNRE clarified standards and testing for JNNSM by stating that 'imported complete PV systems' were excluded from the scheme; however, the 'use of imported components of a complete PV system would be permitted, subject to adequate disclosure and compliance to specified quality norms and standards' [44]. The numbers confirm that public procurement is an attractive market segment: GOGLA members sold 2.7 million off-grid solar systems annually between 2016 and 2018 [31], whereas by March 2020 the JNNSM alone aimed to install 300,000 solar streetlights and distribute 2,500,000 solar study lamps [45].

1.3. Academic literature on the Indian energy transition and product standards

The academic literature found that contestation in the Indian energy transition is the result of domestic and international dynamics. From a policy perspective, the emergence of solar was seen as the result of external factors such as international reputation and cooperation and internal factors of domestic politics [5]. Electricity market liberalisation promoted in the Electricity Act of 2003 contributed to an increase of private sector engagement in renewable energy [28,46]. However, the lack of long-term strategies had a negative influence on the development of domestic solar panel production in India [6]. Recent literature showed that due to conflicts over land use and resistance against large-scale solar parcs in India [47], improved planning of energy transitions in India is necessary to make energy access inclusive [13].

The roots of contestation in the Indian energy transition can be traced back to longstanding political visions of economic development in India. Atul Kohli proposed understanding economic development in India as unfolding in a 'fragmented multi-class state' and identified two political visions. In short, *one* vision can be related to state-led economic development and centralisation, whereas a *second* vision pursues decentralisation with the goal of poverty alleviation at the cost of a relative decline in centralised state structures [48]. Studies on electrification in India showed that such competing visions also influenced the governance of the energy sector. Here, contestation arose on the question of stronger central- or state-government control and the role of the private sector in the energy sector [7,9]. With the Electricity Act of 2003 the electricity sector in one sense 'more closely approximated early planners' visions of a centrally controlled and coordinated sector' but in another sense 'had moved further away from the early nationalist vision' because of the increasing role of the private sector [7].

In this contested energy system, OGS systems were either a stopgap solution until the grid arrives or a more permanent alternative to the grid for rural and peri-urban India. OGS technology was considered a viable solution in rural areas with a possible benefit on social justice and economic development [49]. Therefore, OGS emerged as an alternative pathway to electrification in India's rural areas, where grid extension made less economic sense [8]. Contestation was found to also run through the OGS sector, where two groups of OGS companies emerged. One favoured strategical engagement with the government, and the other preferred the government to keep out of the market [15,17]. Therefore, better policy coordination between addressing the needs of the OGS sector was seen as an important improvement [14,21].

Three needs concerning the governance of product standards were identified in the literature that required better policy coordination. A first need is to improve implementation processes of off-grid energy projects [49]; a second need is to enforce standards on OGS components as part of a complete system [22]; and a third need is to standardise key components such as batteries, for example in accordance with current environmental standards [16]. It was argued that the Indian government was not doing enough about lagging standards and specifications for solar technologies related to such needs, which made it hard to keep pace with OGS industry innovation worldwide [15].

Several studies offer insights about the role of standards in energy transitions. The political economy literature argued that standards can promote economic efficiency and trade, address concerns on the social and ecological dimensions of trade, help to switch from the low to the high road of competitiveness, and point to new forms of global governance [50,51]. A development state and governance literature discussed the role of standards in industrial development driven by the 'development state' [48,52], the role as part of a 'shadow of hierarchy' [53] in transnational governance arrangements [54], or in private transnational sustainability governance [55,56]. The sustainability and energy transitions literature argued that standards offer normative directionality on sustainability for public and private actors [57–60].

Political economy literature offers explanations for the roles of product standards that can be applied to the Indian energy transition. Product standards can be the outcome of 'hybrid authority'

[1] Based on Interview 14.

[2] Lighting Global Website, accessed 31 March 2021: https://www.lightingglobal.org/about/our-impact/.

[61], where actors bridge a regulatory gap by interacting with crowded spaces of domestic governance that can be inconsistent but still very relevant [62]. Standards can play the role of a gate keeper, create import barriers, and act as a 'sine qua non' condition to access global markets or as a local product quality requirement. In their 'gate keeper' role, they contribute to market development [24,63] and can be critical to the management of risks for lead firms [64,65]. They can furthermore create 'entry barriers' by defining product quality in difference to other standards [26,66,67]. As a 'sine qua non' condition to access the world market, they link local networks to global know-how [24,68] through industrial upgrading strategies [69,70]. However, the role of product standards as a minimum quality requirement often is undercut by substantial grey and counterfeit markets to gain a competitive advantage [71].

2. Materials and methods

A growing body of literature applies narrative and discourse analysis to understand policy processes and contestation in energy transitions. Approaches that were pursued include discourse, frame, and narrative analysis [72]. Narrative policy analysis investigates stories with a beginning, middle, and end. They articulate certain scenarios and arguments and help to deal with uncertainty and complexity in policy planning. They allow all involved stakeholders to stabilise their assumptions in situations with many unknowns, high interdependence, and limited agreement on the way forward [27].

Qualitative expert interview data was used to identify stories that reflect on contestation and product standards in the case of the OGS sector. Expert interviews offer sufficient flexibility to the interviewer and the interview partners to understand ranges of aspects and articulate perceptions of complex processes and the 'reconstruction of knowledge stocks' [73]. Experts are understood as holders of 'privileged knowledge assets' in the context of their 'responsibility for problem solutions' [73]. Types of organisations that were interviewed included:

- Indian companies such as SELCO or SIMPA networks
- International companies such as d.light or Green Light Planet
- International organisations such as UNDP, World Bank
- Research institutions and NGOs such as TERI or CEEW

The questionnaire was semi-structured and designed to explore a combination of opinion, value and knowledge questions. Patton suggested that the combination of opinion, knowledge and values questions are particularly helpful to understand what experts think about issues and their intentions and expectations. A semi-structured design was chosen, as it allows for a structured exchange on topics, processes, and dynamics in the OGS sector and flexibility to follow up on specific points emerging in the interview situation [74].

The interview guide (see Appendix 2) was designed to identify stories expressing issue perception and expectations. Interviews were organised in three blocks, where a first block covered aspects of production, a second block aspects of regulation, and a third block aspects of the broader perception of off-grid solar technology. As suggested by Bogner et al. [74] a topical interview guide allows to systematically investigate exclusive knowledge stocks held by experts. Based on the expertise of interview partners, additional questions were added to the questionnaire either based on previous research or as part of the interview. Specific questions included: 'Which key challenges do you see for the Indian off-grid solar market?' 'In your opinion, which role do product standards play in the Indian context?' 'In your opinion, how does internationalisation affect your company?' Interviews had a duration between 20 and 90 min.

The timeframe covered by qualitative data includes field research in Hong Kong and Shenzhen in 2016 and 2018, and in New Delhi, India, in 2017 and 2019. As suggested by Yin [75], longitudinal study designs allow to 'cover trends over an elongated period of time, following a developmental course of interest'. As will be further discussed in section 3, a longitudinal design allows to better understand how developmental blueprints [27] in policy planning impact contestation in energy transitions. The timeframe allows an identification of shifts in perceptions and the continued existence of stories. Such stories were found to be consistent in the observed timeframe. China was chosen because of its role as production hub for off-grid solar systems. India was chosen as it is the biggest market for OGS systems. Thirty-three semi-structured expert interviews were conducted. Appendix 1 summarises the conducted interviews. A snowball technique was applied to identify interview partners. Fig. 1 summarises demographic details of the interview partners.

The expert interviews were coded in NVivo 12 and sampling aimed for a maximum variety of different experts on the Indian OGS sector. Coding of the interviews adhered to a combination of descriptive and axial coding strategies [76] in NVivo 12. Sampling aimed at including a variety of experts from firms and international and national institutions involved in the Indian OGS sector. The sampling strategy has aimed for a maximum variation of interviewed experts to capture shared and divergent stories on the OGS sector and the Indian energy transition.

Several limitations were considered in the process of conducting this study. Related to the interview method, limitations can arise from incomplete knowledge stocks, misremembering of factual knowledge, or non-acceptance of the interviewer as quasi-expert [74]. This was mitigated through desk research on grey and academic literature presented in the background section and the presentation of the research results to expert communities at two workshops and a conference. Regarding scope, careful consideration was given to the specificities of the selected case by systematically scrutinising the gathered evidence as suggested by Yin [75]. Interviews focussed on private sector experts, which might limit the extent to which the study represents narratives held by public sector experts. During field research and analysis, cultural differences in using language played a role in understanding the stories presented in the interviews [77]. This was mitigated through four in-country research stays and presentation of results to expert communities.

3. Theory section

Based on the literature review, the study considers three roles of product standards in the OGS sector referring to contestation in the Indian energy transition. This section defines how contestation is investigated and contextualises narrative analysis in the Indian energy transition. In addition, it situates roles of product standards in narratives on the Indian energy transition.

Contestation is understood along two dimensions, relations between the state and OGS sector and within the OGS sector. State-OGS sector relations were found to have a need for improved planning of energy transitions in India to make energy access inclusive [8,13]. This was argued to be done through improved policy coordination between grid extension and the OGS sector to leave no one behind [14,21]. Looking at relations within the OGS sector, the literature pointed towards two independent markets where relations are structured by degree of internationalisation and degree of engagement with the government [15,17]. The adoption of new technologies such as PAYGo repayment plans [33] and 'smart grids' [78] further differentiates stakeholders.

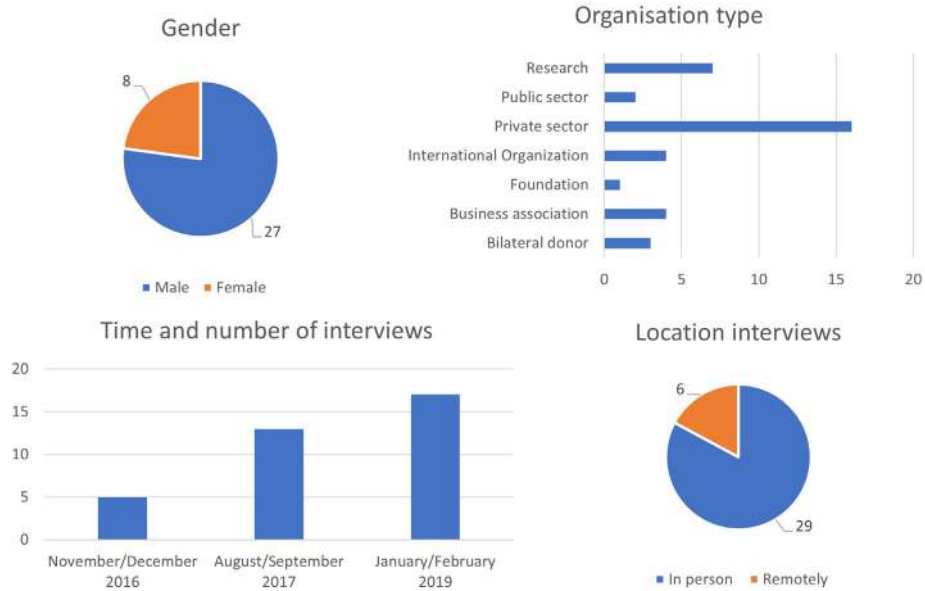

Fig. 1. Demographic details; N = 35.

Based on earlier research on the Indian energy transition, a narrative analysis is conducted. Narratives are defined as 'story with a temporal sequence of events which lays out a problem, its causes and consequences and typically makes arguments for possible solutions to the problem' [29]. Such narratives can have a clear purpose and are therefore not neutral but 'strategically designed to influence the policy preferences of the target audience and narratives usually express a stance on policy issues' [29]. As suggested by Mohan and Topp, narrative analysis is applied to understand narratives as a 'communicative tool' in the context of perceptions on product standards in the off-grid solar sector.

Earlier research argued that the failure of field blueprints serves to increase the appeal of a narrative explaining uncertainty [27]. In the Indian energy transition, Mohan and Topp identified two policy narratives: 'Energy for development – economic growth and energy security' and 'Energy for all' [29]. The first narrative has a stronger focus on centralisation in a power grid that is capable of powering industrial development. The second narrative is more focussed on enabling energy access for households in urban, peri-urban, or rural settings. Mohan and Topp argue that 'narratives of energy access for equitable sustainable development proposed by civil society and certain private actors clash with hegemonic ideas of modernisation, industrial growth and economic prosperity, to be achieved through universal grid connectivity and a mammoth build-up of large-scale energy infrastructure' [29].

The remainder of this section defines the role of product standards applied in the analysis. A first role evolves between 'neutral' gate keeping and active setting of entry barriers. Such roles might align with a narrative of 'economic development' in the Indian energy transition. In their 'neutral' gate keeper role, product standards can contribute to market development [24,63] and can be critical to the management of risks for lead firms [64,65]. In a more activist role, product standards can act as 'entry barriers' to protect infant industries [26,66,67].

A second role of product standards is to act as a 'sine qua non' condition for entering world markets or localising international knowledge. As a minimum requirement, this role might align with a narrative of 'energy for all'. Here, an export-oriented and a knowledge-oriented role are distinguished. An export-oriented perspective highlights the development of innovative technology and international competition to solve energy poverty [15]. A knowledge-oriented perspective argues that adherence to international standards is a 'sine qua non' condition of linking local networks to global know-how [24,68] and therefore localising international best practices [79].

A third role of standards can be related to bridging regulatory gaps to address three needs in standardising OGS systems. This is understood as a technocratic bridging of regulatory gaps, which aims to align with SDG 7. Therefore, it is closer to the narrative 'energy for all'. A first need is to improve implementation processes of off-grid energy projects [49], a second need is to enforce standards on OGS components as part of a complete system [22], and a third need is to standardise key components such as batteries, for example in accordance with current environmental standards [16]. Here, private and public governance bridges a regulatory gap by interacting with 'crowded spaces' where 'domestic governance is often uneven and inconsistent but is rarely irrelevant' [62]. Such hybrid authority is a 'non-conventional form of power and regulation' exercised through standards [61].

4. Results

4.1. Contestation: A 'tale of two markets' and 'government the almighty'

A first narrative of a 'tale of two markets' reconstructs contestation between stakeholders of the OGS sector in a subsidy- and private sector–driven market. Two markets were distinguished, one driven by government subsidies and the other a private sector–driven market. They represent two different worlds, where one group of local companies sells through government subsidy programmes or through government tenders. They adhere to the local standard set by the MNRE and IBS. A private sector–driven market, on the other hand, adhered to the standards by the IEC. Such companies developed their own sales channels in India. In the private sector–driven market, there is limited government involvement.[3]

[3] Interview 5, 14, 15.

Manufacturers in the private sector–driven market are to a high degree internationalised. Here, stakeholders included bilateral and multilateral donors, who provided access to resources, expertise, data, and spaces for exchange for both Indian and international manufacturers.[4] A central dynamic was the globalisation of production in the OGS sector, which was enabled by the financial crisis in 2008/2009. By making use of productive overcapacities in the crisis of 2008/2009 and the available manufacturing quality in the Chinese electronics sector, manufacturers were able to establish major production hubs for OGS systems in southern China. While the Indian manufacturing ecosystem was seen as suboptimal, the Indian market was attractive for such international manufacturers due to its size, but also as it figured as a test case for their technology and the marketisation of OGS systems. The Indian market was considered as a strategic choice in the internationalisation strategy of international manufacturers. Internationalisation strategies were found to be driven by the conviction that market forces can be harnessed for social change.[5]

Local manufacturers in the subsidies-driven market did not scale their sales beyond regional markets. In the absence of a clear business case in the energy access market, larger corporations did not engage in scaling the market. A related factor was that no clear market linkages between rural and urban areas were established to benefit from productive use powered by OGS systems.[6] Also, manufacturers were seen as working in silos, due to the lack of organisation within the sector through representative bodies and spaces for exchange, which held back Indian stakeholders.[7] At the same time, Indian institutions helped manufacturers through government-run programmes and collaboration with bilateral donors. This included the development of open access innovations by Indian institutions for Indian companies, who were encouraged to enter the OGS sector.[8] With the increasing competition of international manufacturers, Indian manufacturers turned toward government tenders in their business strategy.[9] Subsidies play an important role in this market.[10]

The internationalisation of the private sector–driven market was considered as a problem for the Indian manufacturers. Here, international manufacturers were distinguished in two groups, one being Chinese manufacturers who were competing on lower prices and lower quality, and other international manufacturers competing on quality and some affordable entry-level systems, such as d.light or Green Light Planet. Chinese manufacturers were seen to take on a large market share by 2014–15. Due to the increasing competition by Chinese manufacturers in the entry-level product segment, Indian and other international companies shifted towards solar home systems (SHS) or solar microgrids.[11]

Several reasons for increasing contestation in relations between a subsidy- and private sector-driven market were identified. After a period of liberalising the energy sector through the Electricity Act of 2003, protectionism increased as the government sought to improve domestic technology capabilities and endorsed on-grid solar energy access through initiatives such as 'Make in India'. Thus, after an initial period with some focus on off-grid energy access, government resources for OGS were reduced.[12] In addition, policy was seen to move faster than the private sector and able to adapt, for example when it comes to solar panel manufacturing.[13] Here, Indian manufacturing was considered as lacking the ability to compete with the solar PV manufacturing base in China.[14] In addition, shocks caused by demonetization in 2016–17 had a big impact on the OGS sector, as it led to a shortage of cash in rural areas for several months, which impacted the entire rural market.[15]

The second narrative, 'government the almighty', brings together stories on the government as regulator of the OGS sector. The off-grid solar sector was seen as receiving little government support. In addition, short-term thinking in election cycles was seen as a reason for little success in electrifying rural areas. Politicians engaged in 'flip flopping' by not defining long-term goals and introducing different programmes that tried to achieve the same thing, but without coherent success. Also, definitions of energy access were found to be contested. For example, the SAUBHAGYA electrification scheme was for a long time based on a 10% access target for Indian villages.[16]

Relations between the OGS sector and Indian regulator were strained due to missing recognition of the OGS sector. This was articulated as the (central) government being too far away or 'not listening'.[17] This included notions of creating an uneven playing field through subsidies or by setting policy priorities without consulting all actors of the private sector. Energy access was seen as a political top-down decision process, where the government is looking for grid extension through big programmes such as SAUBHAGYA Scheme and the National Solar Mission. This limits the role of off-grid solar as it was not seen as fulfilling the requirement of providing cheap energy through the power grid. In addition, the government was seen to focus on quantitative goals, because not keeping the political promise of 24/7 grid access was bad for reputation with the electorate.[18]

This led to criticism of government policies that were introducing barriers for international OGS manufacturers. Such policies included tariff barriers on solar imports related to the 'Make in India' initiative, and the focus on grid extension through SAUBHAGYA scheme and the NSM. As part of the 'Make in India' initiative the government aimed to localise solar panel and equipment manufacturing. To this end, import tariffs on solar panel imports from China and Malaysia were introduced, which impacted OGS manufacturers and their ability to provide affordable systems. Another point of criticism was related to subsidised OGS systems provided through public procurement programmes.[19] While the NSM earlier offered some support to OGS manufacturers, this changed with the decision to focus on electrification on the grid and the planning of larger scale solar parcs. The perception was that the government's policy left gaps where OGS companies needed to step in to enable energy access, when grid extension did not make economic sense.[20]

4.2. The three roles of product standards in the Indian OGS sector

This section discusses three roles of product standards in the Indian OGS sector (Table 1). In the observed timeframe, companies adhered to either the international or the IBS standard. It has to be added that an IBS standard was early on in place and competed

[4] Interview 13, 22.
[5] Interview 1, 26, 29, 31, 32, 33.
[6] Interview 2,3,8,13.
[7] Interview 1,2,14,29.
[8] Interview 2.
[9] Interview 2.
[10] Interview 2, 3, 5.
[11] Interview 2.
[12] Interview 1, 2.
[13] Interview 1, 4, 7, 14, 25, 29.
[14] Interview 1, 3, 13, 29.
[15] Interview 14, 29.
[16] Interview 1, 7, 13, 22, 25.
[17] Interview 2.
[18] Interview 1, 2, 5, 6, 7, 13, 14.
[19] Interview 1, 3, 5, 7.
[20] Interview 2, 3, 7, 8, 10, 13.

Table 1
Narratives and roles in the governance of the off-grid solar sector through product standards.

	Protectionist 'Gate Keeper'	Neoliberal: in between access to world markets and establishing local-global knowledge networks	Technocratic bridge builder
Narrative 1: 'Government the almighty'	Government as gatekeeper preferring other technology configuration: The government focusses on economic development and electrification on the grid.	The government as indecisive gatekeeper: The central government leaves rural areas and poverty alleviation to international stakeholders and the Indian private sector.	Opening Indian markets to global production: The central government is engaged to translate international regulation into national regulation. Private regulatory authority is underpinned in non-publicly regulated areas to bridge the regulatory gap.
Narrative 2: 'Tale of two markets'	Government as gatekeeper of a publicly subsidised market: Technical barriers to access public electrification programmes are set up through product standards.	Leaning towards technocratic bridge builder: Stakeholders delimit a private market from central government interference through product standards in the absence of central government regulation.	'Transnational hybrid authority': International stakeholders enabling private regulatory authority over a private sector-driven market.

Author's conception.

with the international standard.[21] Leading manufacturers such as d.light or Green Light Planet were adhering to the international standard. Most of the Indian manufacturers who were not meeting this standard adhered to the standard set by the MNRE and the IBS.[22]

A 'gate keeping' role was strongly focussed on setting up barriers through protectionist policies. It was argued that it allowed to take local conditions for OGS systems in India into account and offered a framework where Indian manufacturers were able to compete despite their lower quality OGS systems. Also, Indian standards were seen to create a protective space for developing manufacturing capacities. Indian stakeholders expressed concerns about the quality of imported systems from China, especially referring to the third group of Chinese manufacturers competing on price at lower quality. These manufacturers not adhering to the IBS or IEC standard were 'flooding' the Indian market with cheap systems, particularly in areas close to the border.[23]

As a 'sine qua non' condition to access world markets, product standards were referred to as gateway to exports and winning consumer trust. The omnipresence of the international standard in other developing countries was seen as beneficial for South–South technology transfer. Flexibility was highlighted as important in order to adapt the standard to local conditions in the Global South. Intercomparability of systems was seen as beneficial in understanding competition in the market and also to have benchmarks for finding the right partners in manufacturing, for example in China. It was also considered as an advantage in communicating towards consumers, due to the many levels of quality in the Indian market. Disadvantages were seen in the cost of adhering to the standard and the resources necessary to achieve quality requirements for Indian companies. The government was considered as harming market development and innovation by setting standards for OGS too 'low' or focussing on standardising aspects that make it harder to compete in the world market. Therefore, the Indian standard in this perspective was seen as holding companies back, as it did not require manufacturers to innovate in order to meet the international standard.[24]

When addressing a technocratic role comparability of standards and gaps in local regulation were highlighted. Comparability referred to moving towards a harmonised standard that was applicable in different contexts and comparable test methods. The ambiguity in the two markets was highlighted and seen as two different worlds going their own ways. This was reflected in standards as the Indian government focussed on its own standards, while the private sector and especially leading manufacturers focussed on the international standard. Product standards were considered in terms of their flexibility both in how they are governed and which benchmark they set. Stories highlighted support for development and adherence to the international standard and focus on the private sector–driven market in India. Here, a unified standard was seen as benefiting both consumers and the internationalisation of companies as it allowed for increased comparability of OGS systems.[25]

Overall, several patterns of solutions were found to bridge regulatory gaps. Technological solutions constitute a first pattern with the introduction of AC/DC conversion to enable grid and off-grid technology compatibility. A second pattern evolved around inserting Indian manufacturing capabilities into global value chains of renewable energy and appliances. Here, Indian market players should add value along the global value chain in the right segments (e.g., development of efficient appliances for productive use). A third pattern focussed on repositioning OGS as backup technology to weak grid infrastructure with frequent brown or blackouts. A fourth pattern argued for a level playing field with clear guidance by the government on the role of OGS technology and other off-grid technologies as well as guidance on how and to which standard to adhere in the Indian market. Lastly, a fifth pattern focussed on increasing lobbying activities and speaking with an industry voice of international and local manufacturers towards investors and the government through industry bodies.[26]

5. Discussion

The two narratives presented in the previous section expanded earlier findings on contestation in the Indian energy transition. Earlier findings showed that 'narratives of energy access for equitable sustainable development proposed by civil society and certain private actors clash with hegemonic ideas of modernisation, industrial growth and economic prosperity, to be achieved through universal grid connectivity and a mammoth build-up of large-scale energy infrastructure' [29]. This study extended this finding by showing how hegemonic ideas clash with ideas of equitable

[21] Interview 15, 16, 25.
[22] Interview 2.
[23] Interview 2, 7, 8.
[24] Interview 10, 13, 14, 15, 29.
[25] Interview 2, 7, 10, 13, 14, 15,16, 22, 25.
[26] Interview 1, 2, 7, 10, 13, 14, 15, 25, 29.

sustainable development in the case of the Indian OGS sector. It did so by looking at contestation in the relation between the government and the OGS sector and within the OGS sector.

Relations in the OGS sector were referred to in the narrative 'A Tale of Two Markets'. This narrative distinguishes a subsidised market from a private sector market. Stories on the subsidised market reflected earlier findings on 'Energy for development – economic growth and energy security'. Here, the OGS sector played a role as providing stopgap solutions until the grid arrives or where the grid does not make economic sense. Stories on the private sector market reflected earlier findings on 'Energy for all' [29]. In this context, the OGS sector was seen as an independent power provider with a lasting role alongside a weak grid as backup or as a permanent solution where the grid makes no economic sense.

The narrative 'government the almighty' referred to government-sector relations. This relation was found to be fundamental to defining identities in the OGS sector through engagement or non-engagement with the government as a regulator [17]. Related to this aspect was the perception that the government is not listening to all OGS stakeholders as it considers it a stopgap technology not being within scope of the on-grid electrification plan. Also, a lack of acknowledgement of the role as plugging electrification gaps left by the government's electrification policy played a role in this narrative. Threat of shifting government regulation created uncertainty about which standard to adhere to. This included the potential shift towards the Indian standard for adherence and potential competitive disadvantages due to the necessary time and resources to be in accordance with the standard.

A lack in policy coordination and disconnect between the government and the OGS sector was seen as a central issue. Energy access was seen as the result of a top-down decision-making process with diverging policy priorities based on SAUBHAGYA scheme and JNNSM. This was found to be problematic because lagging behind in targets on solar rooftops in JNNSM could have been reached by including OGS systems. Definitions such as the 10% of households threshold in connecting all Indian villages as part of SAUBHAGYA scheme were later changed. Here, improved policy coordination between grid-extension and OGS sector to leave no one behind was seen as a crucial step, as argued in the literature [8,13,14,21].

Product standards were often perceived in their role as setting up barriers to protect domestic production. The Indian product standard leaned towards creating entry barriers for a subsidised market. The findings pointed towards an activist state setting barriers to encourage economic development rather than acting as a 'neutral' gate keeper, an observation found to be consistent with earlier literature [26,66,67]. Such a protectionist role was consistent in both narratives identified in this study and can be related to the narrative of 'Energy for development' as proposed by Mohan and Topp [29]. The government sought to provide a space for developing an Indian OGS sector based on public procurement. This also relates to campaigns such as 'Make in India' which promoted the localisation of manufacturing not only in the OGS sector but across several key industries.

Stories on the international standard as a 'sine qua non' condition varied between its status as a minimum standard to be able to compete in world markets and acting as a means of quality assurance in the Indian market. Findings point towards a stronger connection to the 'Energy for All' narrative [29], where market forces shall allow for an inclusive energy transition. Such a 'sine qua non' condition was earlier found to allow for better risk management of lead firms in global production networks [64,65].

Two groups of manufacturers in the private sector market were distinguished regarding a 'sine qua non' conditionality. A first group of Indian manufacturers pursued the goal of exporting to the wider Global South trying to reach the standard and highlighted aspects such as cost and R&D requirements, frugal innovation as strength of Indian entrepreneurs (water pumping) and increasing flexibility of the international product standard. A second group was found to be in line with the 'Energy for All' narrative, and the aim to assure high quality to the benefit of people living in rural areas. Product standards were attributed a significant role in distinguishing OGS systems from cheaper or low-quality systems in the marketplace. A motivation to aim for higher product standards was to achieve social change in line with SDG 7 and to solve local problems in India. The international product standard sought to accommodate both, a 'sine qua non' role in world markets and in assuring quality of energy access in India.

In overcoming the entrenched positions in government-OGS sector relations, a third technocratic role can be distinguished. Findings showed that shared public and private authority can help to build bridges by interacting with 'crowded spaces' where 'domestic governance is often uneven and inconsistent, but is rarely irrelevant' [62]. This role was found to be more consistent with the 'Energy for All' narrative [29]. Bridging regulatory gaps was found to be temporal and aiming for adherence to international product standards based on the three needs identified in the literature. In this sense regulation amounts to a limited 'hybrid authority' to bridge a regulatory gap by temporarily establishing a transnational regulatory space within a sovereign territory [61].

The study also pointed towards several solutions to mitigate the regulatory impasse. A first solution is to improve energy systems designs, for example by making SHS compatible to use them with the grid as a smart grid infrastructure. Here, OGS technology could be repositioned as backup technology to a weak grid infrastructure with frequent brown or blackouts. A second solution was to improve public-private coordination on setting long-term policy targets for adaptation and mitigation to combat the climate crisis. This solution was related to Indian manufacturers adding value to global value chains in the right segments (e.g., development of efficient appliances for SHS). This also referred to clear guidance by the government on the role of OGS technology and other off-grid technologies as well as guidance on how and to which standard to adhere to in the Indian market. A third solution was seen in better industry coordination on lobbying activities and speaking with an industry voice of international and local manufacturers towards investors and the government through industry bodies.

Considering product standards as a part of the political economy of the Indian energy transition through a narrative analysis had several limitations. It was beyond the scope of this study to consider the testing of standards and the role of labour or environmental standards in the OGS sector. Also, looking at manufacturers adhering to product standards might be only the tip of the iceberg as there is a substantial grey market undercutting such standards to gain a competitive advantage.

6. Conclusion

The Indian energy transition represents an important cornerstone in achieving the Sustainable Development Goal agenda and sustainable energy for all (SDG 7). As this agenda relies on efficient governance of green technologies, the adherence to specific product standards plays a crucial role. In this sense, the findings of the study point towards diverging interests involved in defining the right pathway in the Indian energy transition. Such interests led to diverging product standards which entrenched actors' perceptions of regulation and were seen to considerably shape pathways toward energy access. Therefore, product standards cannot be understood in isolation but should be considered as a relevant field of

contestation between competing interests across scales that refer to specific blueprints of economic development [27,29].

Future research could address how different governments in the Global South interact with a sphere of 'transnational hybrid authority' to govern technology. This could include approaches to open innovation and to better understand the role of new technologies such as digital payment methods (e.g., PAYGo SHS) and how they entrench or mitigate contestation in the Indian energy transition and beyond. Another direction could be to understand interests involved in other technology standards in the context of sanitary installations, urban infrastructure, or food safety. Finally, the growing role of Chinese product standards in the context of global manufacturing deserves further attention.

CRediT authorship contribution statement

Matthias Galan: Conceptualization, Data curation, Formal analysis, Funding acquisition, Investigation, Methodology, Project administration, Resources, Software, Supervision, Validation, Visualization, Writing – original draft, Writing – review & editing.

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Appendix A. Supplementary data

Supplementary data related to this article can be found at https://doi.org/10.1016/j.glt.2021.08.001.

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