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"We don't have time": How imaginaries of urgent energy system change marginalise locally driven pathways

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ABSTRACT

In this empirical study we examine the characteristics of energy systems change for Rwanda envisioned by actors seeking to drive transitions who are based both within and outside the country. We rely on empirical data from interviews ($N = 62$) and observations. We focus on electricity and cooking services as domains which actors including the Rwandan government are seeking to transform. Our study proposes two sociotechnical imaginaries of change. The first envisions rapid, large-scale and private sector-led adoption of externally developed technologies and priorities, aligning with global sustainability agendas. The second envisions a more gradual pathway co-produced by local actors. The first imaginary's dominance has material implications. It frames Rwanda as a recipient of technology from transnational actors, who co-produce the imaginary along with the government. From a critical standpoint, the first imaginary assigns a passive role to users and rural actors while prioritizing transnational actors in urban areas, reproducing coloniality. The second imaginary similarly adheres to modernist ideals of technoscientific advance and economic catch up. Nonetheless, making room for the second imaginary and actors who challenge the first imaginary may avoid transitions in Rwanda inevitably favouring externally developed technologies and knowledges. Promisingly, certain alternative perspectives imagine transitions with characteristics which disturb the coloniality and adherence to modernity perceptible in the two imaginaries. We invite transnational actors to reflect over their participation in the stabilisation and destabilisation of place-specific energy systems change imaginaries. From a policy perspective, we highlight tensions between ambitions to implement rapid energy transformations and to innovate technologies domestically.

1. Introduction

Energy systems are subject to urgent calls for sociotechnical change, accompanied by an array of visions of what this change could or should constitute. Visions of change for a certain location may not originate from this location, and visions of change may have complex spatial footprints [1]. Sociotechnical imaginaries, situated between the Sustainability Transitions and Science and Technology Studies literatures [2,3] are used by scholars to characterize imprecise and contradictory visions of futures. This scholarship has demonstrated how a range of imaginaries may co-exist and are performative, competing for material enactment [4].

This research uses the conceptual frame of sociotechnical imaginaries to characterize visions of change for Rwanda, a country whose government has envisioned rapid and immediate energy systems change [5]. The study presents qualitative interview and observation data

gathered from energy sector actors during 2022. We explore the characteristics and shape of technology innovation and production processes which are envisioned to achieve desirable change related to electricity and cooking. This desired change includes, but is not limited to, achievement of the government's 2024 energy sector targets.

Through this research we seek to address a gap in the literature on sociotechnical imaginaries related to the comparative lack of analyses focused upon lower income countries [6]. In particular, the lack of studies focused upon the contrasting pathways envisioned to deliver desirable futures, and the places and actors who may be empowered or disempowered in these futures [7]. Literature on transitions has noted a tendency to think of users in lower income countries as passive recipients of technological benefits [8] connecting to literature on dependency theory [9]. However, the imagined roles of end users alongside other actors have not yet been explored specifically in imaginaries of change regarding lower income countries. Existing literature

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exploring the roles of users and agency in imaginaries has focused primarily on smart grids in higher income countries [10–12].

Concurrently, research has described how global histories of coloniality and value extraction and repatriation away from the "Global South" shape which places are understood to be wealthy, technologically advanced and knowledgeable [13]. These perspectives raise questions regarding how processes to deliver urgent change are envisioned in lower income country contexts. A small but growing body of scholarship engages with these questions, seeking to understand how relationships of technological dependency may be reinforced or reconfigured by imaginaries in lower income country contexts [14–18]. This constitutes the emerging niche which this research seeks to contribute towards.

Our research aim is therefore to investigate the characteristics of imaginaries emerging from the geographically disparate group of actors seeking to facilitate or implement energy systems change related to Rwanda, with particular focus on how these imaginaries approach agency, location, temporality and directionality. Noting the strong conditioning effect of the government's policy agenda on what happens in Rwanda [19], we use the government's near-term energy sector targets as a starting point from which to characterize imaginaries associated with delivering change.

In doing so, we make both an empirical and theoretical contribution to the literature on sociotechnical imaginaries. First we contribute empirically to the literature by describing how actors envision the drivers of an energy transition and the characteristics of these visions in relation to a specific lower income country, particularly regarding the balance of exogenous and endogenous drivers of change. This is furthermore the first study of sociotechnical imaginaries related to Rwanda's energy system.

Second, we make a theoretical contribution by analysing how temporal framings of urgency combine with a country's unique historical and sociomaterial circumstances; including colonial histories which shape present relationships with transnational actors such as donors and the international private sector. These aspects condition the visions of energy systems change which come to the foreground, coalescing in a preference for futures founded on externally developed technologies. Through this, we connect the literature on sociotechnical imaginaries to theoretical discussion of temporality in transitions [20], as well as to analysis of how some pathways may be discursively shut down [21], meaning only certain pathways are enacted. In our analysis, the observed framing of urgency contributes towards the growing dominance of an imaginary emphasising exogenously driven and rapid change which limits the agency of end users and other actors outside the urban core.

2. Theory

2.1. Sociotechnical imaginaries

Sociotechnical imaginaries have emerged from the Science and Technology Studies (STS) literature to describe and problematize assumptions related to futures [22]. Jasanoff [23] describes them as "collectively held, institutionally stabilized, and publicly performed visions of desirable futures, animated by shared understandings of forms of social life and social order attainable through, and supportive of, advances in science and technology". They have since been broadened to pertain to the past as well as futures [24]. Most critically for this research, they focus attention on the locational, temporal and cultural situatedness of visions, such as nations at a point in time [25,26]. Imaginaries condition, but are also conditioned by, the material infrastructures and assemblages in places [27–29].

Imaginaries scholarship has emphasised how imaginaries can be held collectively at the national level, particularly in how nation-specific scientific or technological projects or agendas reveal collectively imagined visions of life [30]. While not responsible for directions of change,

these imaginaries subtly shape choices around technologies as well as allocation of costs and benefits of transitions within a national context [31]. Rudek [32] in a review of STI research demonstrates how many private visions of individuals coalesce into stabilised STIs via negotiations and coalition building. Powerful actors oriented around national policy agendas relatedly can have a stabilising effect upon imaginaries [33]. Scholars [34,35] nonetheless suggest that this focus on the national scale may be more related to methodological choices than an empirical tendency for imaginaries to stabilise primarily at the national level, encouraging scholars to analyse imaginaries at other scales [see for example [36].

Multiple imaginaries may exist, with some closer to enactment than others – often those connected to material resources and power [37], related to the idea of "controlling imaginations" which materially configure worlds along the lines of colonial modernity [38]. More recent contributions to this literature have contrasted more dominant top-down imaginaries with more diverse counter-hegemonic visions [39–41]. These STIs may enable transformations towards alternative futures, sustain existing regimes or exist outside them [42]. Competing imaginaries offer divergent perspectives on contentious issues which are central to the shape of future systems and life more broadly. Issues explored within energy system-oriented STI scholarship include uses of land [43]; system control and broader national sovereignty [44], degrees of system centralisation and implications for sector workforces [45]; and dealing with system risks and uncertainties [46].

Scholarship of sociotechnical imaginaries which focuses explicitly on lower income country contexts has developed this vein of scholarship, with Mohan & Topp [47] demonstrating how imaginaries of energy systems place contrasting degrees of emphasis on economic growth or ending poverty. Other scholars have demonstrated how powerful actors imagine universalised energy futures for communities, enacted through a focus upon scaling over local participation and ownership [48,49]. Relatedly, Muiderman et al. [50] show how technocratic futures in lower income countries can close down more diverse and regionally oriented worldviews through a reliance on industries based in higher income countries.

This connects imaginaries to literatures investigating the contents of "modernity / coloniality"; described by Oliveira [51] as a homogenizing vision of universal technoscientific knowledge and progress, othering alternatives as "local" or "traditional" [52] and originating from (but no longer limited to) Europe and the USA. Modernity/coloniality are written together to reflect that ongoing coloniality – understood as exploitation, dispossession and destitution - is the essential precondition for modernity. As Oliveira (p.18) writes, "the benefits we associate with modernity are created and maintained by historical, systemic and ongoing processes that are inherently violent and unsustainable", although the "trick of modernity/coloniality is making itself appear benevolently omnipresent, while rendering its violence and unsustainability invisible". Education and knowledge are critical domains within which the implicit hierarchies of modernity are performed, by imbuing some actors and institutions with knowledges considered legitimate within modernity and thus hierarchically arranging anybody else as empty vessels to be filled with knowledge [53].

2.2. Unpacking the contents of sociotechnical imaginaries

We draw upon several concepts to bring analytical richness to the sociotechnical imaginaries we characterize. Agency is a central theme, with particular attention paid to the envisioned role of users in energy systems change [54]. This builds on the work of Ballo [55] who explains how sociotechnical imaginaries of smart grids in Norway envision users primarily as consumers with knowledge deficits and idealise them as "rational resource man" archetypes who benefit from sociotechnical change. The locations associated with processes of energy systems change are also of central interest. Scholars in other domains have examined the implications of imbalanced flows of technology and

capital between places, such as extraction of profit and control by external actors [56,57]. Temporality – particularly the implied pace of change – is another critical area of focus. This builds on STS scholarship which has demonstrated contrasting assumptions around the passage of time and how this conditions the way we conceptualise problems, particularly in relation to technoscientific futurity [58,59]. Finally, we focus on directionality, understood here as the possible directions associated with change [60–62]. Scholars have alleged that discussions of directionality constitute a contested discursive space which imposes constraints and boundaries on possible future systems in terms of their shapes and configurations [63].

3. Empirical context to the case study

3.1. Global sustainability agendas of energy transformation

The 2020s has been described as a critical decade for delivering "a more secure, sustainable and affordable energy system" [64]. International normative commitments such as the Sustainable Development Goals [65] and the Paris Agreement [66] condition the knowledge, technology and finance flows that are perceived to be necessary. Institutions such as the World Bank Group frame the rapid global transfer of the low carbon technologies they perceive to be necessary as a major development opportunity for low- and middle- income countries [67]. Normative and international academic research agendas of "sustainable development" evaluate the economic, environmental or social impact of technologies and natural resource use [68]. Another key pillar of this agenda is the facilitation of finance flows to the places in the world understood to require it, articulated through the language of green [69] or climate [70] finance, the latter often connected to carbon financing mechanisms [71].

In this logic, the priorities of scale, urgency, development and sustainability are mutually interlinked [72]. Some scholars have raised concerns about this international agenda triggering benefits for some actors but costs for others as visions of development and sustainability are inscribed upon places [73]. Many of the private companies operating within East Africa have a transnational footprint. They subsequently mobilise transnational flows of knowledge, capital and technology in relation to regional or global transitions agendas as much as (if not more than) to specific national or local circumstances [74].

3.2. The Rwandan government's vision of energy systems change for Rwanda

Rwanda's current policy and regulatory landscape is oriented towards achieving the government's long term "Vision 2050" [75] to secure standards of life currently associated with higher income countries for all Rwandans. The vision is achieved *through* following a "sustainable path in terms of use and management of natural resources", by halting deforestation (driven largely by demand for cooking fuel) and increasing the share of renewable energy in the power generation mix [76]. In these respects, the Rwandan government's modernist vision is thus relatively typical of many countries balancing economic and social development goals with environmental sustainability. Alongside this focus on transforming the energy system, Rwanda has concurrent plans to become an innovation-led knowledge economy [77] with greater manufacturing capabilities [78] and less reliance on imports [79].

Vision 2050 is enacted in the near-term National Strategy for Transformation 1 for the period 2017–2024 [80], operationalized in the energy sector through the Energy Sector Strategic Plan [81]. This includes the following targets, amongst others:

1. Increase the share of households' access to electricity from 40.5 % in 2017 to 100 % by 2024 i.e. universal electricity access

2. Halve the number of households using traditional cooking technologies to achieve a sustainable balance between supply and demand of biomass from 84 % in 2017 to 42 % in 2024

3. Achieve 52 % of the electricity generation mix from renewable energy sources by 2024

The Rwandan Government is delivering rapid progress against these targets, having fostered a climate of urgent delivery. The number of households accessing electricity has increased to 75 % and biomass usage has reduced to 73 % as of 2023 (see Fig. 1), with data on delivery against the renewable energy target unavailable. Rwanda's expansion of electricity access was the third fastest in Africa and 11th fastest in the world between 2010 and 2020 [82]. Nonetheless, it is considered a matter of concern for officials that progress is behind schedule (see Fig. 1) [83]. New and similarly ambitious targets are expected to be set in 2024, maintaining urgency of desired change [84].

This policy agenda and implied energy future is strongly conditioned by international sustainable development agendas, noting Rwanda's extensive usage of development aid [87,88] and the top-down vision of technological modernisation adopted by the Government of Rwanda for the energy system [89] Following the colonial era and subsequent Genocide in 1994, the ruling party has established close alignment with international donors, having been described as a "star pupil" of the Washington Consensus with a commitment to private sector-led economic development to overcome the divisions of the past [90]. Scholars have alleged that the government's vision is conditioned by the government's close collaboration with the World Bank, who play a role of "unnamed chaperone" orienting the government towards a neoliberal vision of the future [91]. Relatedly, the donor community has supported Rwanda's envisioning of rapid energy systems change with several donor actors having actively helped to plan and deliver various initiatives [92]. Donor and business partnerships today are a reflection of Rwanda's colonial and more recent history, with Belgium, France, Germany, the US and UK key partners [93]. Rwanda's colonial era took place under Germany and then Belgium, France had a close relationship with the governmental regime implicated in the 1994 Genocide, and the US and UK have been key advocates of Rwanda's reconstruction and economic liberalisation post-Genocide [94,95].

This does not mean that the Rwandan Government must do what donors tell them. Rwanda's political context and public debate is dominated by the ruling party in government [96–98]. Whilst Rwanda receives large volumes of finance from donors, it has also been noted to show a high degree of independence from donor attempts to shape energy sector policy direction, which scholars have argued connects to an ongoing sense of donor responsibility for their countries' colonial complicity or inaction in the 1994 genocide [99]. The government's internationalist and modernist vision to align with global sustainable development agendas is understood to stem from the country's top-down leadership structure, who see development partners as useful actors to help deliver their vision [100].

3.3. Energy market and governance context in Rwanda

The energy and electricity market in Rwanda is governed primarily by the state-owned holding company Rwanda Energy Group (REG) and its implementing arms Energy Development Corporation Limited (EDCL) and Energy Utility Corporation Limited (EUCL). REG receives its mandate from MININFRA following a pyramidal governance structure directly up to the President [101] and is responsible both for grid expansion (through EDCL) and maintenance (through EUCL); as well as EDCL setting the terms of engagement for private and non-governmental actors participating in the market on- or off-grid.

In order to achieve the 2024 targets, EDCL designate areas as "on-grid zones" or "off-grid zones" within which implementing actors such as private developers are able to sell and operate certain off-grid technologies or systems [102]. The ratio between – and location of – these
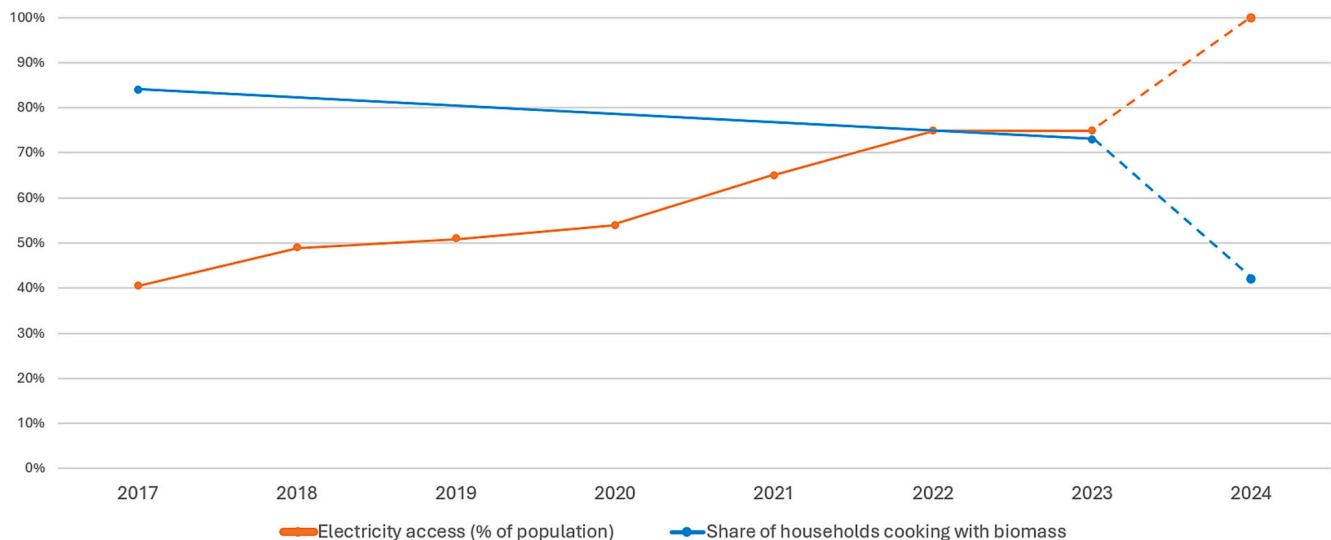
Fig. 1. Progress delivered against selected energy system targets [85,86] illustrating the urgent framing of the policy landscape. Dotted line represents the required target pathway, solid line represents actual progress.

zones has changed over time but in 2022 at the time of data collection was scheduled for 88.9 % zoned for the grid zone, 1.3 % for microgrid and 9.7 % for off grid solar home systems (SHSs) [103]. This represents a notable increase in the areas projected to be on-grid, up from 48 % targeted in the original 2018 ESSP [104]. Private sector actors can participate in grid-connected generation as Independent Power Producers [105] who sell power to EUCL. EUCL subsequently have a monopoly over the transmission, distribution and sale of grid electricity as well as setting the tariff [106].

Eighty nine percent of Rwanda's energy is from domestic and imported biomass (a large proportion of which is for cooking), with the remainder coming from imported oil and domestic hydropower [107]. Alongside Rwanda's import of fuel, the Rwandan energy sector is also seen as an attractive place for foreign companies offering energy technologies; typified by the US Department of Commerce's explanation to US companies that "there are many opportunities for [US based] firms providing innovative and affordable transmission and distribution systems and equipment" [108].

3.4. Financing energy systems change

In 2022, REG articulated the remaining progress towards achieving the 2024 target of 100 % electricity access as a $667 m funding gap to be filled [109]. Finance providers in Rwanda are therefore strongly oriented towards the delivery of the government's targets [110]. The key donor-funding programme of recent years for off-grid has been the World Bank's Rwanda Renewable Energy Fund (REF) results-based financing-programme [111], a $50 m initiative managed by Rwanda Development Bank (BRD) offering loans and subsidies to qualifying companies who in turn offer subsidised technologies to end users [112]. The programme directly supports the government's 2024 access targets, expected to conclude disbursements in 2024 [113]. EnDev's results-based financing scheme for mini-grids specifically aligned with the government's target timelines, similarly concluded in 2024 [114].

Progress towards the 2024 biomass reduction target related to cooking is directly supported by the World Bank's Clean Cooking Results-Based Financing scheme [115,116]. This scheme is structured in a similar manner to the REF programme, with sale of various stoves designs subsidised via grants. Whilst most funding programmes at the time of data collection were oriented around subsidised distribution, an exception is EnDev's Cooking Energy Business Growth Fund (CEBGF) which seeks out local businesses developing innovative cooking solutions [117].

Beyond these initiatives, analysis of funding flows [118] into the small-scale renewable energy market in Rwanda shows that most funders are international concessional finance providers such as higher income country governments, philanthropic foundations and impact investors. Furthermore, this analysis notes that investment from international sources is concentrated into a small number of multinational companies active in Rwanda, with local companies reportedly lacking the requisite systems and fundraising experience to land internationally sourced capital.

4. Material and methods

4.1. Research design and scope

Sociotechnical imaginaries scholarship to date has been critiqued for often overemphasising expert discourses, falsely considering them to be more widely representative [119]. In this study, we did not set out to characterize imaginaries which represent the entire nation of Rwanda. Rather, we sought to characterize the imaginaries stemming from the transnational set of comparatively wealthy and privileged actors who present themselves, or each other, as agents of change *for* Rwanda.

We therefore selected semi-structured interviews and observation of these actors as the primary research methods to gather data. The interview design was informed by questions central to the lead author's wider PhD research project, centered on understanding the characteristics of sociotechnical change; namely who is understood to drive it, where it happens and what it is understood to lead to. This analysis is focused specifically on processes of change related to electricity and cooking services at a household level, given their central role in the Rwandan Government's 2024 energy sector targets (described in Section 3). This focus was explained to respondents prior to interview. This delimits the analysis to directions of imaginaries which involve these technologies. It is therefore possible that other more anti-hegemonic visions of energy systems change which do not relate either to either electricity or cooking are excluded from analysis.

To provide empirical context of how the policy landscape may condition the change pathways envisioned to reach these goals, we read government documents pertaining to energy systems change, including the Vision 2050 [120]; the National Strategy for Transformation 1 [121]; the Energy Sector Strategic Plan [122]; and the Science, Technology and Innovation Policy [123].

For identifying interviewees, we adopted "purposive sampling" as method as opposing to seeking a systematic surveying of the entire

Rwandan energy sector [124]. This approach was selected since the sector is dynamic, with new entrants joining and others leaving, for example international private sector actors departing the Rwandan market at the conclusion of subsidy schemes. Thus we sought to capture a broad set of actors at a specific point in time who position themselves as helping to implement systemic change in Rwanda's energy sector (rather than - for example - simply maintaining existing infrastructure as an engineer may do; or only adopting technologies individually, as certain kinds of user may do). Respondents were thus identified as appropriate for interview if they claimed to be somehow contributing towards energy systems change in Rwanda. This could be in publicly available materials, in the accounts of others describing them, or in our initial Whatsapp, telephone or email exchanges. We began identifying respondents through the authors' networks, boosted by the involvement of the lead author in the University of Rwanda's "Innovation Week" in Kigali which involved many energy sector actors [125]. We then "snowballed" in a purposive direction by asking respondents to recommend other organisations whose activities they understood to *somehow* be affecting change related to the government's 2024 targets.

Respondents would typically share details of others whom they saw as relevant to delivering change related to electricity and cooking. If a respondent only mentioned an actor in passing as being relevant to change, this actor was nonetheless sought out for interview. There is nonetheless a risk of bias towards informants with similar positions and perspectives, potentially overlooking grassroots initiatives distant from the network of comparatively wealthy and privileged energy sector actors concentrated in Kigali.

The empirical scope covers both rural and urban areas, noting that value chains and innovation processes for technologies are sited in both urban and rural locations. Furthermore, this scope accounts for the fact that different actors site different forms of activity in different locations. For example some actors may frame rural areas purely as locations of technology distribution with innovation in urban areas, whereas others may see rural areas as sites of innovation.

In writing of colonial modernity and connecting the empirical data to this idea, we do not position ourselves as separate and able to perceive coloniality with the clarity of an "eagle eye" perspective. Rather we write as "worm eye's view" insiders who are complicit with, existing within and conditioned by colonial modernity [126]. We furthermore acknowledge that this academic article is itself an actant [127] reproducing aspects of coloniality in knowledge systems (related to the people and places understood to generate knowledge on others).

4.2. Research methods

We use semi-structured interviews as our primary research method. Face-to-face interviews ($N = 62$) were conducted by the lead author between February and April 2022, with the majority of these taking place in Kigali, Rwanda. Outside of Kigali, interviews and observation were conducted in Musanze, Bugesera and Gatsibo Districts in Northern and Eastern Provinces respectively. In total, the lead author engaged with 69 respondents from 39 different organisations. The interview guide can be found in "Supplementary Material". We began interviews by asking respondents to orient themselves in relation to the government's 2024 energy sector targets (for further detail see Section 3.2); as well as other future visions of transformative change which respondents aligned themselves with, such as their organisation's ambitions to scale or help implement the Sustainable Development Goals. This allowed categorisation of respondents as either change implementers or facilitators, or a combination of both. Respondents then described the activities and processes by themselves or others which they understood to either be currently driving desirable change or having the potential to do so. This enabled us to build a picture of where different actors envision change as originating from and why.

Table 1 below provides a summary of those interviewed for the study. Each interview is numbered and categorised as "change

implementer" (CI), "change facilitator" (CF) or "change implementer-facilitator" (CFI). CIs and CFs are those actors whose self-described primary role is either *implementing* energy systems change in Rwanda, or alternatively *facilitating* change such that another actor fulfils the role of implementation. Some facilitators additionally refer to a mandate to directly implement change, such as by developing and distributing technology themselves, and they did not indicate any hierarchy between their role as facilitator or implementer, in which case they are categorised as CFIs. This information is derived directly from the interview.

All respondents are anonymized. Interviews were conducted in English. While no respondents voiced concern about language, discussions may have unfolded differently in Kinyarwanda and with a different interviewer.

We contextualize this interview data with observation of innovation processes and implementer-user interactions, with observation taking place within the same period of February – April 2022. Following interview, several respondents identified as "Change implementers" were accompanied by the lead author to observe how they engaged with users and undertook technology innovation and fabrication, such as cookstove production at a local factory. This helped to illustrate logics of change within imaginaries. Four occasions of implementer-user interactions with four different entities were observed on visits by the lead author to either existing or prospective sites of energy service delivery outside of Kigali. These visits involved negotiations and design discussions between implementers and users regarding prospective energy services, as well as installation, production and distribution. Further detail can be found in Table 1.

4.3. Analysing the data to characterize the two sociotechnical imaginaries

The interview and observation data was subsequently coded qualitatively using the software Nvivo. This coding followed an inductive approach [128] in which codes and themes were inferred from the data, guided by the broad research interest in how change is understood. Through this process, we identified several core themes associated with processes of change and which respondents' perspectives differed by. These were locations and actors described as driving change, possible directions of change and pace of change, as well as envisioned differences between what happens in the past, present and possible future. Across these categories, respondents offered perspectives both on what they felt was desirable and what concerned them as being problematic or missing, as well as how they oriented themselves towards the government's targets. At this point, we referred to the literature in these domains, mapping our data to literature on spatial aspects of innovation, agency, directionality and temporality.

Grouping the coded data by locations of innovation demonstrated two contrasting visions of possible change pathways (i.e. one associated more with locations external to Rwanda, and the other more domestic) which connected to other characteristics of change, such as the envisioned actors involved and directions. We subsequently utilised the concept of STIs to make sense of our analysis. We then tested this characterisation in informal follow-up discussions with several respondents and between the author team. While the imaginaries are derived primarily from the interviews, observation helped to validate how both imaginaries could be enacted. For example we understand our observation of an automated distribution booth for a much-hyped technology designed entirely outside Rwanda to be an enactment of the first imaginary. By contrast, we understand our observation of intensive and open-ended engagement with users in the early stages of a technology design process to enact the second imaginary.

Since we did not find that specific technologies consistently associate with specific imaginaries, we characterize the imaginaries as associated with a range of technological configurations. For example the first imaginary of urgent technology import relates to both solar home systems and cooking technologies.

These imaginaries co-exist and overlap across categories of entity

Table 1
Summary of interview respondents.

Entity Type	Description (anonymised where necessary)	Orientation towards energy systems change in Rwanda	# of entities and respondents interviewed	Seniority of respondents	Observation activities undertaken following interview
Government Ministry	Ministry of Infrastructure (MININFRA) - Ministry responsible for a particular aspect of government around infrastructure, which includes the mandate for energy.	Change facilitator	1 entity 1 respondent	Senior staff	n/a
Government department	Subsidiaries of national government responsible for different aspects of government. Specific departments interviewed are: • Rwanda Environment Management Authority (REMA) • National Council for Science and Technology (NCST) • Rwanda Standards Board (RSB) • Rwanda Utilities Regulatory Authority (RURA) • National Industrial Research and Development Agency (NIRDA) • Rwanda Development Board (RDB)	Change facilitator	6 entities 8 respondents	Mid-level staff	n/a
Professional Association	Industry group representing sectoral interests in Rwanda.	Change facilitator	1 entity 1 respondent	Mid-level staff	n/a
Government-owned holding company	Rwanda Energy Group (REG), a government-owned holding company responsible for the import, export, procurement, generation, transmission, distribution and sale of electricity in Rwanda.	Change facilitator-implementer	1 entity 1 respondent	Mid-level staff	n/a
Government-owned holding company subsidiary	Energy Development Corporation Limited (EDCL) and Energy Utility Corporation Limited (EUCL), subsidiaries of REG responsible for implementation.	Change facilitator-implementer	2 entities 3 respondents	Mid-level to senior staff	n/a
District government	Sub-national government responsible for implementing government policy.	Change facilitator-implementer	1 entity 2 respondents	Mid-level staff and senior politician	n/a
Educational Institution	Government educational and research institution with focus on technical training and innovation.	Change facilitator-implementer	1 entity 5 respondents	Students along with junior to senior teaching staff	• Observation of educational institution's mechanical workshops and classroom environment with student and staff's presentations of their projects focused on energy.
International Finance Institution	Organisation with international mandate to finance change processes in member countries.	Change facilitator-implementer	1 entity 1 respondent	Senior staff	n/a
Intergovernmental Organisation	Organisation with international mandate to support change processes in member countries.	Change facilitator-implementer	2 entities 3 respondents	Mid-level to senior staff	n/a
Donor-Funded Agency or Program	Partnerships or programmes with presence in Rwanda funded by donor country governments.	Change facilitator-implementer	3 entities 9 respondents	Mid-level to senior staff	n/a
National Finance institution	Funding bodies affiliated with national government with mandate to finance change.	Change facilitator-implementer	2 entities 3 respondents	Mid-level staff	n/a
Private company, head office outside Rwanda	Companies working on energy headquartered outside Rwanda. All respondents interviewed based in Rwanda, a mix of Rwandan nationals and foreigners. All of the head offices are in Europe, America or China and most are significantly larger than the locally headquartered companies, with operations in several countries.	Change implementer	7 entities 17 respondents	Junior-level to senior staff including members of leadership team	• Observation of interactions at a transnational company's demonstration center which advertised an energy technology designed outside Rwanda. • Observation of a company's warehouse for imported technologies and distribution center. • Observation of a company distributing technologies to users. • Observation of a company's scoping visits to energy users as part of their design process.
Private company, head office within Rwanda	Companies working on energy, headquartered in Rwanda. Respondents from one company were a mix of Rwandan and foreign staff, all other companies composed entirely of Rwandan staff to respondents' knowledge. These companies are smaller	Change implementer	6 entities 9 respondents	Mid-level to senior staff including members of leadership team	• Observation of a factory's operations which fabricates domestically designed technologies • Observation of a company installing technologies for users.

Table 1 (*continued*)

Entity Type	Description (anonymised where necessary)	Orientation towards energy systems change in Rwanda	# of entities and respondents interviewed	Seniority of respondents	Observation activities undertaken following interview
	than the internationally headquartered companies and have operations in Rwanda only, although many have ambitions to scale up to the region or globally.				• Observation of a company's scoping visits to energy users as part of their design process.
Non-Profit organisation, head office outside Rwanda	Organisations conducting activities with a social or environmental mandate, headquartered outside Rwanda.	Change implementer	3 entities 5 respondents	Mid-level to senior staff including members of leadership team	n/a
Non-Profit organisation, head office in Rwanda	Organisations conducting activities with a social or environmental mandate, headquartered in Rwanda.	Change implementer	3 entities 3 respondents	Mid-level to senior staff including leadership	• Observation of a Non-Profit Organisation's routine visit to the villages they support to check usage of technologies which they have distributed to users.

and respondents, even within an organisation. The binary distinction between imaginaries is a scholarly construction which is inferred from the heterogeneity of the rich empirical data. We do not propose that these visions are mutually exclusive or are the only imaginaries of energy systems change related to Rwanda. Rather that these are the two contrasting imaginaries envisioned by a diverse set of transnational actors working in relation to the Rwandan energy sector. These two imaginaries are notable since they are perceptibly stabilised by actors and policy agendas to differing extents [129]. The first imaginary is stabilised by transnational private sector actors and governmental policy programmes targeting rapid energy systems transformation. By contrast, the secondary imaginary is stabilised to a lesser extent by domestically headquartered organisations and policy programmes targeting economic emergence and innovation capabilities.

5. Results

In this section, we first describe the material technological configurations which these imaginaries are associated with, followed by the imaginaries which we derive from the interview and observation data. We conclude the results section by describing temporal dynamics and relations of dominance between the imaginaries.

5.1. Technologies associated with the imaginaries

The technological configurations which respondents are working with at present, or intend to work with, can be roughly split into two categories. These are technologies related to electricity services; and technologies and fuels related to heating services. Technologies related to electricity services include direct current (DC) powered solar home systems (SHSs), decentralized alternating current (AC) power solutions and larger grid-scale capacity additions. SHSs – a key technology for many respondents – are small-scale independent systems (typically less than 100 W) which vary in capacity and application from lighting only to a combination of lighting, phone charging, radio and TVs for example. All of the decentralized AC technologies described by respondents utilise solar power, such as minigrids or solar powered water pumping. Additions to Rwanda's electricity generation capacity described by respondents include technologies such as hydro and fuels such as methane gas and peat, although only one of the organisations categorised as a CI was working on grid-connected electricity generation.

Technologies and fuels related to heating services include improved biomass and bioethanol cooking devices, electric cooking devices, fuels for cooking and solar water heaters. Improved cooking devices developed and distributed by respondents include various stove designs for different fuels such as wood, briquettes, pellets and bioethanol. Several actors were also working on electric cooking devices powered either by AC or DC power, although none of these stoves were widely available to users at the time of interview. Other actors were working on developing and distributing fuels for stoves. Finally, some actors interviewed are in the process of designing solar-powered water heaters.

5.2. Sociotechnical imaginaries of energy systems change in Rwanda

Two imaginaries envision different pathways for *how* to transform Rwanda's energy system in relation to electricity and cooking. The first imaginary envisions an urgent, private sector- and technology import-led pathway. By contrast, the second imaginary envisions a more gradual and domestically co-produced pathway. The key details and differences between them are summarized in Table 2. The locations seen to be generative of change diverge between the imaginaries, leading to two fundamentally different approaches to how Rwanda's energy future might be reached. These pathways imply different actors, temporalities and directions of change.

The first imaginary prescribes a feasible vision of change. This imaginary is stabilised [130] by its alignment with the urgency of the government's energy sector targets, as well as its alignment with the government's preference for maintaining control over a highly centralised national energy market. Additionally, it serves the interests of transnational private sector actors who benefit from an import-led pathway. This first imaginary of change allows these actors to gain legitimacy as central to energy systems change in the country, despite the fact that many of them are relatively new or transient entrants to the Rwandan market. This is achieved through framing Rwanda as a market within which to rapidly sell imported technologies, thus enabling these actors to help deliver the government's immediate 2024 energy sector targets. Stabilisation of the imaginary amongst this transnational group leads to the envisioned passivity of Rwandan users, since product innovation processes take place elsewhere within international networks of operations, reproducing relations of dependency between places [131]. This marriage of urgency and the import of readymade solutions is exemplified by CI12 explaining how they "don't have time" to undertake more locally grounded innovation processes.

By contrast, the second imaginary is collectively held and stabilised primarily amongst the locally headquartered private sector and NGO community, in connection to local research institutions, with these actors referencing each other. The second imaginary provides a means for these actors to gain legitimacy as central to energy systems change rather than the first imaginary's foregrounding of the transnational private sector. The collective of actors holding this imaginary position it as delivering on the Rwandan Government's desire for the country to become an innovation-led knowledge economy, as well as delivering solutions which better respond to the contextually specific needs of users.

Table 2

Summary of characteristics for two stylised sociotechnical imaginaries of energy systems change in Rwanda.

Characteristics of imaginary	Imaginary 1: Urgent, private sector-led and imported pathway	Imaginary 2: Gradual and domestically coproduced pathway
Approach to agency in change	- International finance-enabled private sector as principle agents of change - Private sector has knowledge of user needs and effective business models - Users are primarily consumers whose main demand is keeping costs low - Rural energy users require education to understand benefits of solutions - Users gain agency via empowerment from technology acceptance - Adoption can be boosted by user legitimators e.g. neighbours	- Users coproduce change alongside the private sector and local research and education institutions - Users can instigate change and may design or produce hardware - User needs are complex, related to their daily lives and preferences - Sees technologies which have been designed outside Rwanda as being likely to marginalise the precise needs of end users
Approach to locations of change	- Countries outside envisioned to be generative of useful and often preferable hardware - Needs assessment is the principle activity taking place within Rwanda - This includes some business model customisation e.g. Pay-As-You-Go - Kigali a critical location which connects actors to international finance and technology and also provides a base for remote monitoring of activities	- Rwanda is generative of useful but overlooked hardware innovations - Testing and tinkering with hardware also useful, with customisation effectively creating Rwandese innovations which are fit for context - Localised manufacture of solutions can drive localised benefits - Rural locations can be centers of innovation as much as Kigali
Approach to temporality	- Speed and urgency of delivery as critical, matching the urgency demanded by external funding sources targeting sustainable development - Rwanda needs to keep up with international pace of technological change - Organisations must pivot towards rapidly scalable and standardised projects, with rapid expansion to other countries a key priority - Energy sector workers move out of rural areas and towards Kigali	- The realities and challenges associated with working on energy in Rwanda mean a gradual and perhaps incremental pace of change - Longstanding local companies holding knowledge need to be central - Disconnected to urgency demanded by external funding sources targeting sustainable development; in fact, external funding seen to disincentivise local innovation by de-emphasising context
Approach to directionality	- Environmental sustainability understood on a global level, particularly the benefits associated with forest protection which are framed as universal - Economic catch-up and leapfrogging carbon intensive growth also critical - Energy systems change both enables and is enabled by a digitalised future - A privatized and liberalised market is a key ingredient to desirable change - Change processes should deliver quantifiably large impacts	- Environmental sustainability understood on a localised level i.e. using local resources responsibly for local benefit (even fossil resources) - Domestic energy security is a key priority, including reaching a more balanced import-export ratio related to energy technology and fuel - Change processes may not always deliver quantifiably large impacts

5.3. Imaginary 1: Urgent, private sector-led and imported pathway

5.3.1. Locations of change

Within this imaginary, places outside Rwanda design and manufacture the hardware associated with energy systems change. Different respondents through their responses locate these activities in Europe, India, China, or the US, with CI23 describing their company's European Head Engineer as "the heart and soul of the company" and CI18 explaining that their R&D took place in India; the only aspect which may sometimes (but not always) happen in Rwanda is testing. One can sense amongst respondents a *preference* for more Rwandan hardware; but a perception that this is not possible in the present or near future. This means that for CI9 "there is a difference [between] the end user and the [European] lab. So, the lab guys have their job to do, and the end users, they will be the ones to benefit".

The precise external locations associated with change vary between actors, but they often (not exclusively) relate to the organisational history of the actor in question, and their overseas networks. For example, a cookstove company founded in India emphasised the importance of their company's R&D capabilities in India; a company which originated from a student-led project at Imperial College London emphasised the significance of their UK-based design processes, and a Chinese hardware retailer emphasised their connections with Chinese companies innovating solar PV. For some actors this also extended to capital landing, with two UK headquartered implementers locating their fundraising efforts in the UK (noting the significance of London as a finance center) alongside much of their R&D activity.

Rather than hardware or software innovation, identification and

deployment of technologies from elsewhere along with business model innovation and pricing analysis are envisioned as the central aspects of energy systems change which take place *within* in Rwanda. CFI7 explains how they search for innovations across the world which might be deployable in Rwanda. CFI6 explains that they see Pay-As-You-Go business models as the biggest recent innovation in energy but perceives this innovation as originating from elsewhere in the East African Community. CI10 relatedly explains that a key innovation activity *within* Rwanda is finetuning their business model to access carbon finance, subsidizing the cost of their Europe-designed cookstove. CI8's entity has already perfected their business model for accessing carbon finance in the Kenyan "market" and thus see no need for amending the product of business model for the "Rwandan market", other than finding a carbon finance-subsidised sales price which is acceptable for consumers.

A final locational aspect to note is the focus on change processes *within* Kigali. The focus on tapping international resources, many of whom are present in Kigali, foregrounds the city as the centre for financial and business model innovations along with technology-enabled oversight of elsewhere. CFI1, based at a funding agency, explained that most of their time is spent in Kigali, with only occasional visits to projects. Discussing their future plans for expansion into serving rural areas in multiple countries, CI2 remarked "It's so difficult to get to these [rural] areas. And that's just in Rwanda, which is tiny. You go to Zambia for example, [to] Mozambique; huge, huge countries. [But] you can have one person monitoring a load of places remotely. It's so much cheaper. It's almost always systems […] still within the country, [but] in the capital city for example, rather than having someone in the field".

5.3.2. Agency in change

Within this sociotechnical imaginary, the private sector is understood to be central to change. Users are thus envisioned as "demand" or "need" with relatively limited agency in the *process* of attaining these services. CI5 and CI8 describe users as concerned primarily with cost and convenience in relation to their own purchasing power, understood through the government's Ubudehe income categorisation of the population from highest to lowest. Their preferences are thus knowable by an external implementer, predictable and governed by bounded rationality. Multiple respondents such as CFI2, CFI17, CI4, CI24 and CI26 understand users to have knowledge deficiencies related to energy technologies resulting from limited education, further limiting their agency. This leads CFI12 to applaud user-legitimators who adopt first and act as examples to their neighbours who follow suite. Education consequently becomes a means of addressing low demand or non-acceptance for respondents such as CF6 and CI4, who remarked "People in Kigali have got the idea…but people in the rural areas still don't understand the benefits of using electric hot plates, or other components that will reduce the use of biomass. So, it's mostly about educating these people".

The desired role of users in energy systems change is thus envisioned as passively accepting but enjoying the future benefits of services, often envisioned by respondents as an entrepreneurial stimulus linked to narratives of "productive use of energy". For example CI26 explains that "any day spent without energy, for that woman in the rural area, is a wasted opportunity for the income [the woman] would have generated". In this imaginary, the user shows flexibility by adjusting their lives to the new technology and enjoys agency as a result of - as opposed to *during* - the innovation process. CI8 in fact regaled a negative story in which a product developed in close conjunction with users "ended up too expensive for what the customers actually *need* [....] Every time we asked them [if they wanted] features, I think customers just said: yes!".

5.3.3. Temporality

Within this sociotechnical imaginary, Respondents such as CI4, CI11, CF8 and CFI6 connect their own efforts to rapidly drive change with the urgency of achieving of the government's 2024 targets, which the donor community is strongly committed to supporting. For example CI11 frame their own business prospects as benefiting from the urgency of the 2024 targets, explaining "even with exponential growth, you cannot achieve those targets in two or three years. But then we move to the next target [....] It really does help in conversations with potential funders, when you can show what we are trying to do is in alignment with what the government is trying to achieve", further noting that the funders supporting the government's urgent agenda are typically European and American. On the facilitator side, CFI1 remarked that the 2024 electrification targets have created a huge perceived funding gap to be filled, which all of the "traditional" lending and granting agencies have pivoted towards.

This sense of urgency also favours businesses who present rapidly scalable business and flexible business models to fit these demands for immediate results. This is reflected in CI2, whose company was perceptibly pivoting away from smaller bespoke projects for which they "don't have time". Their business was pivoting towards a modular, standardised and scalable business model which can more rapidly scale to different locations. Another employee, CI4, explained that "I'm still based in [a village], because that's where the pilot of the work was done. But as we are moving into other districts now, I feel the urge to move to Kigali as the central point because it'd be easy to talk to other partners like [a key change facilitator], and as well as moving to other districts as well easily". This temporal aspect ties to location. As things scale up, there is less time to engage with individual users, meaning they move towards the urban centre. As CI4 explains, "It's a small team now, the community is not that big. It's easy for you to go around and talk to them. It'll be harder having 10,000 people, walking around and talking to them".

This sense of fast-paced change stems not only from the national policy context, but also connects to the global scale, in connection to both rapid technological change and urgent demands for sustainability. Regarding the former, CF8 explains the importance of Rwanda being aligned with and able to benefit from globally cutting edge innovations; here, the urgency of the imaginary stems both from the government's target and the fear of Rwanda being left behind in global technological progress. Regarding the latter, international carbon and climate finance is available for businesses operating in Rwanda who can demonstrate that their operations help to rapidly deliver progress against these goals. This funding domain tends to favour internationally headquartered organisations over locally headquartered ones [132]. CI11 explained that the carbon price is now comparatively high, which enables them to subsidise their externally-developed cookstove technology and fuel to a cost which undercuts the Rwandan market, enabling expansion. Similarly, CI10 explained that they had "quite a lot of momentum, both domestically and abroad [for] our solution; we check a lot of impact boxes, especially the climate box. I'm hopeful about the general increase in urgency among populations across the globe for low carbon solutions…I think time is on our [business's] side".

5.3.4. Directionality

Within this sociotechnical imaginary, processes of change are expected to result in transformative and quantifiable impacts on Rwandan energy production and consumption, with CI10 and CI8 both targeting dominance of their respective domains. There is a strong normative association with globalised narratives of environmental sustainability: particularly sustainable energy for all, avoiding biomass and fossil fuel consumption and reducing deforestation, such as by CI7, CI3, CI2 and CI5. These activities help Rwanda "catch up" economically while avoiding a carbon intensive development trajectory. These envisioned outcomes of sustainability appear well received by international financiers, with CI2 remarking "In general, they [the financiers] are interested in providing energy access. I think they like us because we are alternating current and we're renewable". Connected to locations of change, CFI2's focus on environmental sustainability leads them to *import* final products to Rwanda rather than to design and manufacture locally (which would require them to use raw materials they perceive to be damaging).

A digitized, privatized, liberalised market emphasising competition and the ability to rapidly scale both from and to Rwanda is envisioned to be a key pathway to sustainability, with private sector actors who are furthest ahead in automation expected to prevail. CI27 speak favourably of the sector moving towards a more market-oriented approach. Relatedly, CI2 sees their usage of UK-developed automated systems to be a key driver of competitive advantage for them, remarking "We're trying to do this economically and sustainably, but at the same time, we are a little bit neoliberal and we'd rather just economically outcompete them because we think that's a stronger argument". CI18 explained proudly how their fuel distribution system (planned in future to also offer non-energy products) is automated via digital payment and CI4 emphasises their entity's plans to "digitize everything" as a core business proposition, including "how people get to buy components, how people get to use them, how people get to monitor the electricity they use". CF2 outlines a related vision in which Rwanda catches up with places elsewhere by importing technologies perceived to be advanced; "we cannot start with cutting edge technologies by ourselves; we don't have the resources, we don't have the expertise. So let people bring it in [....] eventually after 10 years, we'll be used to the technology".

5.4. Imaginary 2: Gradual and domestically coproduced pathway

5.4.1. Locations of change

Respondents place emphasis on hardware development happening *within* Rwanda in this imaginary. This includes respondents emphasising cookstove designs developed and now manufactured within Rwanda, as well as education institutions experimenting with integrated stove and

SHS designs. From the facilitator side, CF2 explains that "innovation indicators are not really accurate, at least not in Africa. A lot of inventions are actually taking place; the fact that they haven't filed for patent doesn't mean that there's no innovation". Testing and tinkering with products *within* Rwanda is seen as critically important. CFI21, CF2 and CI27 explain how they study energy research and technologies from the UK, America and China, but then develop bespoke versions for Rwanda. CI9 even left their previous employer, a European headquartered cookstove company, due to their unwillingness to adjust designs despite user complaints.

Within this imaginary, both fuels and products are produced within Rwanda, with CI9 and CI20 connecting local product manufacture to Rwanda's economic growth. This connects to a preference for change pathways oriented around usage of locally available resources, rather than pathways which align with what is globally considered sustainable (as in the first imaginary). Several respondents including CI22 and CFI21 subsequently approve of peat, hydro, methane gas and geothermal for power generation, due to their local abundance; that "instead of waiting [for the grid] to just expand out of Kigali, you use what you have nearby". CI9 and CI29 both explain with pride that their innovations utilise locally produced cooking fuels.

Within Rwanda, emphasis is placed on activities situated outside the urban centre of Kigali. Put simply by CI1, "The real Rwanda is outside Kigali" – echoing sentiments by CI10 and CI19. Related to this, CI21 remarked that when their primarily Kigali-based Rwandan staff began distributing SHSs to rural low-income users, they were "lost" and went through a challenging learning process. CI1 inverts perceptions of villages as resistant to change by emphasising the long-term commitment to problem-solving and the capabilities of the rural communities they work with. In contrast with the first imaginary's logic (that the challenges of poor rural populations are addressed by actors based in Kigali or internationally), CFI20 - an entrepreneur based at an education institution in rural Rwanda - described their future hopes related to their biodigester design which creates biogas from food rather than animal waste. This was driven by them seeing "what is happening in Kigali"; i.e. the huge consumption of food and potentially waste. Here, the rurally based innovator solves the city's problems.

5.4.2. Agency in change

Users are envisioned as active agents of change, closest to user-producer archetypes [133], alongside the private sector as co-producers. Their entrepreneurial and problem-solving spirit is central to the co-production of energy systems change, as opposed to being framed more as an outcome in the first imaginary. Users' practices and preferences are shaped not only by cost concerns but also by locally specific and changing considerations meaning they should be involved in design. For example CI26 places emphasis on accounting for the heterogeneity of user cooking preferences.

CI3 explains how their interactions with users ideally begin; "They [a user] have an idea for a business that they'd like to run. And then they'll come and say, how can you help me with this?", citing an example of a daytime tariff agreement which they co-designed with a customer which turned out to be "an efficient solution for both parties." CFI21 even explains how they have been helping communities to solve their own problems by working with them to design efficient cookstoves which they can construct themselves. Conversely, several respondents such as CI7, CFI3 and CI23 strongly critiqued technologies currently available in Rwanda which respondents see as designed based on external influences rather than user needs. CFI3 explains that "you see all these developers from the Netherlands come in with these really shiny stoves, so that you could do phone charging, you can do […] all kinds of things. But they are not adapted to the reality".

Local entities such as research institutions are envisioned as key agents in localizing processes of change, alongside users and the private sector. CI27, CF4, CF6 and CF8 all emphasise the role of local research institutions in building human capacity and helping to develop or contextualize innovations, particularly the University of Rwanda, Integrated Polytechnic Regional Colleges (IPRCs) and Technical and Vocational Education and Trainings (TVETs). For example, CFI17, from a local government perspective, explains that "Innovation comes from IPRCs. Their students who are trained to do improved cooking stoves… they are helpful in the district".

5.4.3. Temporality

This imaginary is characterized by a slower pace of change accompanied, as emphasised by CF7 and CFI19, by *learning*. CI4 describes the frustrating but necessary pace at which their company sources equipment for bespoke projects. This slower pace of change thus establishes a disconnect from the 2024 targets. While not altogether rejecting the targets, temporalities of progress are heterogeneous. This is reflected by CI19's explanation that "considering [our] own [company's] speed, I think we're trying our best [to deliver the targets]. We cannot tell that this is good or bad".

This slower pace of change connects to concern about the funding connected to rapid change which is central to the first imaginary. CI19, working for a small Rwandan-owned company trying to grow and innovate, explains that "Everything needs time. We cannot blame the [lack of] finances because finance also grows with people trusting your business, they invest or also they will bring you customers", going on to comment that "increasing dramatically the [supply of] finance [could] also make the business fail" and concluding that "we can start small". Complementing this, CI7 cautions that fixed duration donor-funded projects create time pressures which lead to a preference by those involved for imported solutions over domestic innovation, explaining "Donor money tells you 'You have funding for three years, you have two years to implement'; you will never experience the real innovation". CI27 describes the plight of two local companies, explaining that "Those guys have been struggling for a very long [time]. It's an example of people who need to be encouraged… I believe that sometimes big funding comes with opportunistic companies. No problem; the market is wide, but I think there should be a certain balance allowing these [local] guys to grow as well. There are longstanding local players with a lot of market experience".

This connects to CI27's broader concern about Rwanda's future if it remains reliant on short- and fixed-term donor funding; a concern manifest in CFI8's description of an international private sector actor immediately leaving the refugee camp project they distributed SHSs to, as soon as their contracted funding ended. Related to this, multiple actors express concerns about the e-waste generated by the rapid surge towards the targets. There is a fear that equipment subsidised by climate finance may break or become redundant after 2024 – raising questions about the localised environmental effects of top-down sustainability agendas.

Visions of scale up are still present, with CI19 optimistically imagining that his company "will incorporate with different countries…and hopefully, maybe tomorrow, you'll see me in [your] hometown". In this future-oriented statement, homegrown technologies and proximity to users (which CI19 emphasise in the present) start to fade out of view. However, unlike in the first imaginary, in the future Rwandan businesses become regional or even global technology producers as opposed to primarily technology importers or consumers.

5.4.4. Directionality

Both facilitators and implementers emphasise a pathway of domestic innovation-driven economic development. The emphasis on the preference for local fuels and technology as opposed to reliance on imports connects to longer term visions of domestic energy security for Rwanda for CI7, CI22, CI30, CF7, CF8 and CFI21. Furthermore, this links to a strongly localised understanding of environmental sustainability. If Rwanda can utilise the resources it has, this is understood to mean a cleaner future. CF4 implies and CFI21 explicitly states that achievement of Rwanda's 2024 targets is predicated on use of local resources. CI29,

when questioned on why they designed their hybrid electricity and cooking solution, explained that they wanted to stop local deforestation by using a specific locally available material (volcanic rock). Like CI14, they connect stopping local deforestation directly to reducing climate change and the increasingly heavy rains locally. Whilst the potential climate change impact of this logic could be debated, within the imaginary there is the potential to connect wicked global problems such as climate change to localization of problem solving and material sourcing.

5.5. Temporal dynamics and relations of dominance between the imaginaries

The temporal characteristics of the imaginaries – as described by respondents - create relations of dominance between them. Most notably, the first imaginary provides a pathway forward to achieving the 2024 targets which can be taken *immediately*. This path can also be taken by some respondents whose responses connect to both imaginaries. For example, tensions can be detected in the responses of CI27 and CI9 between an abstract ideal future state of domestic solution development and adoption of externally funded and designed solutions which they see as the most practical short term pathway forward. The second imaginary can thus be temporally embedded within the first. This implicit chronology gives priority and instrumental potential to the first imaginary; the second imaginary could be invoked as abstract future to legitimize the present enactment of the first.

Some entities and respondents are also in transition from one sociotechnical imaginary to the other. CI4's responses, for example, connect to both imaginaries. Their retrospective accounts of positive change processes fit the second imaginary: the pace is slow, users are heavily involved and processes are locally embedded. When discussing their present and future plans, their remarks fit the first imaginary. This is embodied in the respondent literally planning to move residence from a village where they have piloted projects towards Kigali. In these accounts, whether the second imaginary is longed for as an unattainable idealized future or left behind as the past, the first imaginary presides over the second as a feasible near-term pathway forward.

6. Discussion

The first imaginary is a closer fit to the current Rwandan policy landscape than the second. The imaginary temporally aligns with - and is stabilised by - the government's energy policy agenda. Their agenda utilises various international finance pools [134] to attract the international private sector to distribute energy technologies in support of their targets. The literature notes how policy agendas can have a galvanising effect on sets of actors and networks whose visions cohere around a stabilised STI

[135]. In this case, internationally headquartered organisations cohere around a vision of Rwanda as an attractive place to distribute externally developed technologies at climate finance-subsidised prices.

The first imaginary is also stabilised by the government's preference for control over the country's energy market and transition pathway. The highly centralised market structure – operationalized by REG and regulated by RURA and RSB – enables the government to specify the exact categories and even designs of technologies (such as solar home systems and cookstoves) which are eligible for the subsidy schemes financed by the World Bank and other donors. These schemes in turn shape the technologies which are used and the futures which are enacted. Concurrently, the imaginary provides a pathway towards the achievement of the government's modernist vision of development, founded on the availability and use of digital technologies [136,137] and led by a liberalised private sector [138]. Here, comparisons can be drawn to the work of Rudek & Huang [139] which demonstrates how the Taiwanese government's practices align with a dominant STI oriented around green technological modernity in comparison with more community-oriented alternatives.

The first imaginary's propensity to "close down" [140] the second can be understood through literature problematising the concept of urgency as well as the politics of knowledge. Critical scholars of STS and transformations towards sustainability have noted that a focus on urgency can narrow problem framings – which they caution can risk mistakes and overlooking other possibilities and effects, such as e-waste footprints [141]. Urgent problem framings tend to favour breakthrough technologies as opposed to more complex and systemic change [142]. Relatedly, viewed through Haraway's lens of knowledge politics [143], locally situated knowledge systems which might foster innovations are delegitimised by the first imaginary in favour of globalised and desituated knowledge systems [144]. In this specific case, locally situated knowledges are delegitimized through valorisation of external sustainability knowledges and technologies associated with rapid scale up, implying that rural users must be educated rather than collaborated with or learned from.

This is not to suggest that the Rwandan government dismisses the second imaginary. Rather, simply that different expectations and practices enact different imaginaries and that the Rwandan Government appears to enact and stabilise the first imaginary of energy systems change more than the second. A tension exists between the government's focus on delivering rapid energy targets and its objectives to become a knowledge economy with manufacturing capabilities, which most clearly plays out in the contrasting directionalities of the two imaginaries. This reflects a tension between Rwanda's competing ambitions to drive participatory home-grown initiatives and entrepreneurship alongside a strongly top-down vision of change. Critical scholars have claimed that the Rwandan government has on occasion utilised participatory initiatives more to help implement the government's developmental policy agenda than to deliver material empowerment and self-determination [145]. Relatedly, others have claimed that despite the government's stated preference for a longer-term vision of Rwanda as a technology producer, manufacturing and production is dominated by a combination of internationally headquartered companies and a small number of companies with close links to the ruling party, with limited opportunities for others [146]. It follows that the first imaginary of change matches the urgency and preference for control of the government better by envisioning agency, participation in innovation and economic empowerment for Rwandan people more as an abstract future benefit stemming *from* energy access rather than a driver of it.

It would be analytically dubious – and perhaps problematic given the author team's positionality – to critique the government's current delivery logic, based on its objective of rapid energy systems change and its understandable willingness to leverage international value chains and capital to improve the lives of Rwandan people. This paper does not offer such a critique.

Our critique instead pertains to the way in which this first imaginary of change reproduces relations of colonial modernity by empowering transnational actors and valorising hierarchical and globalised knowledges. The donor-financed schemes utilised to enact the first imaginary favour technology providers who are well networked into global sustainability agendas (with demonstrable alignment with the SDGs considered a key asset) and who can rapidly deploy technologies at the vast scale which these subsidy schemes require. Critically, transnational technology providers are better positioned to meet these criteria than their purely "local" Rwandan equivalents. These implied actor roles, along with disseminating technologies *from* the urban core of Kigali via the Ubudehe categories, enables the government to maintain control over change pathways, in line with its top-down pyramidal structure of governance [147].

The consequent framing of end users as passive recipients requiring rather than possessing knowledge [148] reproduces coloniality, particularly given the considerably more agential and profitable role envisioned for transnational actors within futures of "green modernity" [149], echoing the colonial relations of past eras. Nonetheless, it is these transitions configurations which enable the government to garner praise

from the likes of Sustainable Energy Access for All [150] and the World Bank, with the latter describing Rwanda as an exemplary energy transition case due to the strong involvement of the private sector and free flow of global capital [151]. This implicitly reinforces these globalist agendas and institutions as the arbiters of which systems change processes can be considered successful, based on underlying market-oriented criteria. In sociomaterial terms, this implies a continuation of economic dependence on external countries [152].

Implementing the second imaginary offers a contrasting pathway forward. This pathway could lead to a greater share of technology value chains being based within Rwanda than is the case today, with domestic innovation, manufacturing or assembly activities all likely to drive benefits for the Rwanda economy. Nonetheless, the second imaginary still adheres to modernist ideals of technoscientific advance and economic catch up with higher income countries. The government's industrial policy envisions a highly modernist future in line with the second imaginary in which Rwanda becomes a globally competitive exporter of technologies [153]. Both imaginaries of change fundamentally seek to lay pathways towards a vision of modernity. However they are motivated by different sets of private sector actors seeking to gain competitive advantage.

Furthermore, some of those actors who challenge the first imaginary diverge away from explicitly modernist agendas of change. Engaging with and nurturing these examples may offer fertile ground for possibilities beyond the "green modernity" evident within both imaginaries and its associated coloniality [154]. Such examples include those actors who emphasise more gradual paces of change motivated by care over rapid profit-driven scale up, those treating rural users as knowledgeable agents with autonomy; and those imagining what "sustainable" futures can mean bottom-up rather than from globalised agendas.

7. Conclusion

This article has described the characteristics of energy systems change envisioned by actors implementing change in - or *for* - Rwanda. We have characterized two sociotechnical imaginaries of change and highlighted their differences and interactions. The first imaginary is stabilised to a greater extent through a combination of global sustainable development agendas, enacted through policy mechanisms such as carbon markets, along with governmental objectives and preferences for energy market control. This shapes the political economy of energy systems change in Rwanda, laying a pathway to connect Rwanda and potentially other comparable places to global circuits of capital and external accumulation [155–158].

Beyond an academic contribution, this research has implications for policy and practice. It is of particular relevance for internationally headquartered companies and institutions seeking to implement systems change in specific places, such as in Rwanda. Such change implementers can reflect on their own complicity in the stabilisation or destabilisation of different energy systems change imaginaries and colonial modernity more broadly. What narratives of change do their actions enact or suppress? What possibilities might they stifle by retailing heavily subsidised technologies for brief periods, and what kinds of historic sociomaterial relations might their actions reproduce? How might their organisation's logic frame different places as generators or recipients of knowledge and innovation?

Participation by an implementing actor in a specific country's energy transition is always political, through the stabilisation of certain imaginaries and the destabilisation or delegitimization of others. Recognising this, it would perhaps be appropriate for transnational actors to recognise multiple possible change pathways for Rwanda, at the very least making room for open, bottom-up and locally-led visions of change by conceptualising problems, designing technology, or dispatching finance differently. This is particularly relevant for international actors whose mandate to implement change in Rwanda stems more from their legitimacy within global agendas of sustainable development (for example

by leveraging international carbon finance flows) than from their spatial proximity to (and familiarity with) Rwandan energy users. These probing and perhaps provocative reflections should not lead to disengagement; rather they warmly invite these actors to sit with the problem and reflect, rather than reverting to strategies to fix superficially framed problems in the name of wealth, power or validation [159].

We urge caution in assuming the contextually specific details of Rwanda's imaginaries translate elsewhere. Nonetheless, we believe careful comparisons can be made with other relational encounters between specific locations and those who envision change for them, including within higher income countries. It may be particularly fruitful to compare this case with encounters between globalised or nation state-oriented framings of change narrowly emphasising urgency and scale and more pluriversal framings of change gesturing beyond colonial modernity.

CRediT authorship contribution statement

Declaration of competing interest

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

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.erss.2024.103888.

Data availability

Data will be made available on request.

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