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Perceived unknowns about gridless water, sanitation and energy services

SEI report
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Cover photo: Solar panels on a house roof in a Berber village in the Anti Atlas mountains of Morocco © Ashley Cooper / Getty

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Contents

Key messages

- **Gridless technological solutions have the potential to expand access to energy, water and sanitation, but progress has been impeded by a lack of understanding of their benefits, challenges and potential trade-offs.**
- **Stakeholders identified barriers to greater use of gridless solutions including regulatory gaps and a lack of information on their compatibility with existing systems.**
- **To expand the uptake of gridless solutions, more attention must be paid to the needs and preferences of potential users, the technological appropriateness of certain options in specific contexts, and issues of social equity and distributional justice.**
- **Better insights are needed about the scalability of certain options and the key factors that underpin successful technological transfer.**
- **Better financial know-how is also needed to help secure investments in innovation and start-ups, and to create commercially viable business models.**

Introduction

The development of "gridless" systems has accelerated in recent years in an attempt to find new ways to provide basic water, sanitation and energy services that can be deployed onsite and operated independently (Olsson & Barquet, 2020). The term "gridless" captures a series of trends in system design. Such trends include scaling shifts in product assembly away from larger, single units to more, smaller units; moving towards industrial manufacturing (pre-manufactured) instead of on-site construction; using standardized design properties (instead of specialized components) to obtain economies of scale; and expanding physical, decentralized network architecture away from single, large systems. Examples of such modular technologies include (but are not limited to) electrical mini grids, solar home systems, stand-alone waste treatment systems, and decentralized desalination plants. They are increasingly seen as valuable complements to grid-based systems.

Yet, despite technological advances and their potential to expand access to needed services, gridless technologies face significant barriers. These barriers surface throughout their life cycle, from research and development to implementation and use, and to products' ultimate disassembly. A host of issues hinders development and upscaling, including regulatory mismatches, inadequate understanding about end users' expectations, and a lack of financing options and sustainable business models (Olsson & Barquet, 2020). The issues vary, depending on the sector and the technology. For gridless electricity, challenges include low electricity demand in rural areas, high payment default rates, and over-optimistic demand projections; these matters have prevented technologies such as mini-grids from reaching scale (Peters et al., 2019). Other gridless energy technologies face major challenges for widespread dissemination. For example, clean cookstoves in many rural areas have failed to catch on in part because of the high costs of technologies, limited availability of fuels, a lack of spare parts to maintain stoves (Agbokey et al., 2019), and a failure to adequately address sociocultural and behavioural issues related to the use of the stoves (Jürisoo et al., 2018; Lambe et al., 2020; Vigolo et al., 2018). Solar home systems also face key challenges that stem from product cost and quality, and unreliable customer service (Girardeau et al., 2021). Decentralized solutions for water and sanitation needs confront yet another set of challenges. Financing and upscaling are a challenge for the tailored systems that are often required. Providers often must invest time and effort working with local communities to create acceptance and ensure buy-in (Andersson et al., 2018).

THE SEI INITIATIVE ON GRIDLESS SOLUTIONS

The initiative aims to explore some of the barriers and opportunities of decentralized solutions using socio-technical lenses. The initiative focuses on questions concerning access to energy, clean water and safe sanitation, and the balance between systems with various degrees of decentralization. The questions from the workshops described in this report will direct some of the scientific research of the initiative, and potentially lead the way for collaborations.

Gridless solutions can be considered to be components of technological innovation systems. These are complex socio-technical systems that aim to promote the development, diffusion and use of a particular technology, while considering technical, institutional, social, economic and organizational factors (Bergek et al., 2008). The central idea is that determinants of technological change are not (only) found in individual organizations, but (also) in the broad societal system in which these organizations are embedded. Therefore, to understand the factors that contribute to, or hinder, the development and diffusion of technological solutions, one must understand the wider system. The features and characteristics of the innovation system must be identified, examined, and supported or corrected (Bergek et al., 2008).

SEI sought to apply this approach to gridless systems, and to identify specific features that might hinder or facilitate their development, assembly, implementation, maintenance, diffusion and disassembly. To this end, SEI brought together a diverse set of actors representing distinct roles operating in the water, sanitation, and energy sectors from throughout the world. These representatives participated in four online workshops to provide feedback on the gaps that confront the adoption and use of gridless technologies in their sectors. This report summarizes their input. It outlines the key issues participants identified that must be resolved to better understand the trade-offs, benefits, challenges, and potential of gridless solutions in the water, sanitation, and energy sectors globally.

Methods

The research team identified workshop participants through a stakeholder mapping exercise, following procedures outlined in Barquet et al. (2021). The exercise was used to identify actors in the gridless water, sanitation and energy sectors. The team mapped relevant stakeholders across Europe, Asia, Africa, North America and South America to address geographical variations in water, sanitation and energy sectors. Efforts were made to ensure representation of distinct groups: public authorities, researchers, funders, and representatives of civil society, non-governmental organizations and the private sector.

The stakeholders were invited to join one of four online workshops (held on 23 and 25 November 2020, for water and sanitation; and on 9 December 2020; and 27 January 2021, for energy). Participants indicated the role they played in the sector by selecting from a list of possible options: funders, managers, end users, innovators, lobbyists, gatekeepers, decision makers, knowledge providers, buyers, service providers, coordinators, and problem brokers (Figure 1).

The online workshops used a large canvas on Google Slides to collect information on two guiding questions:

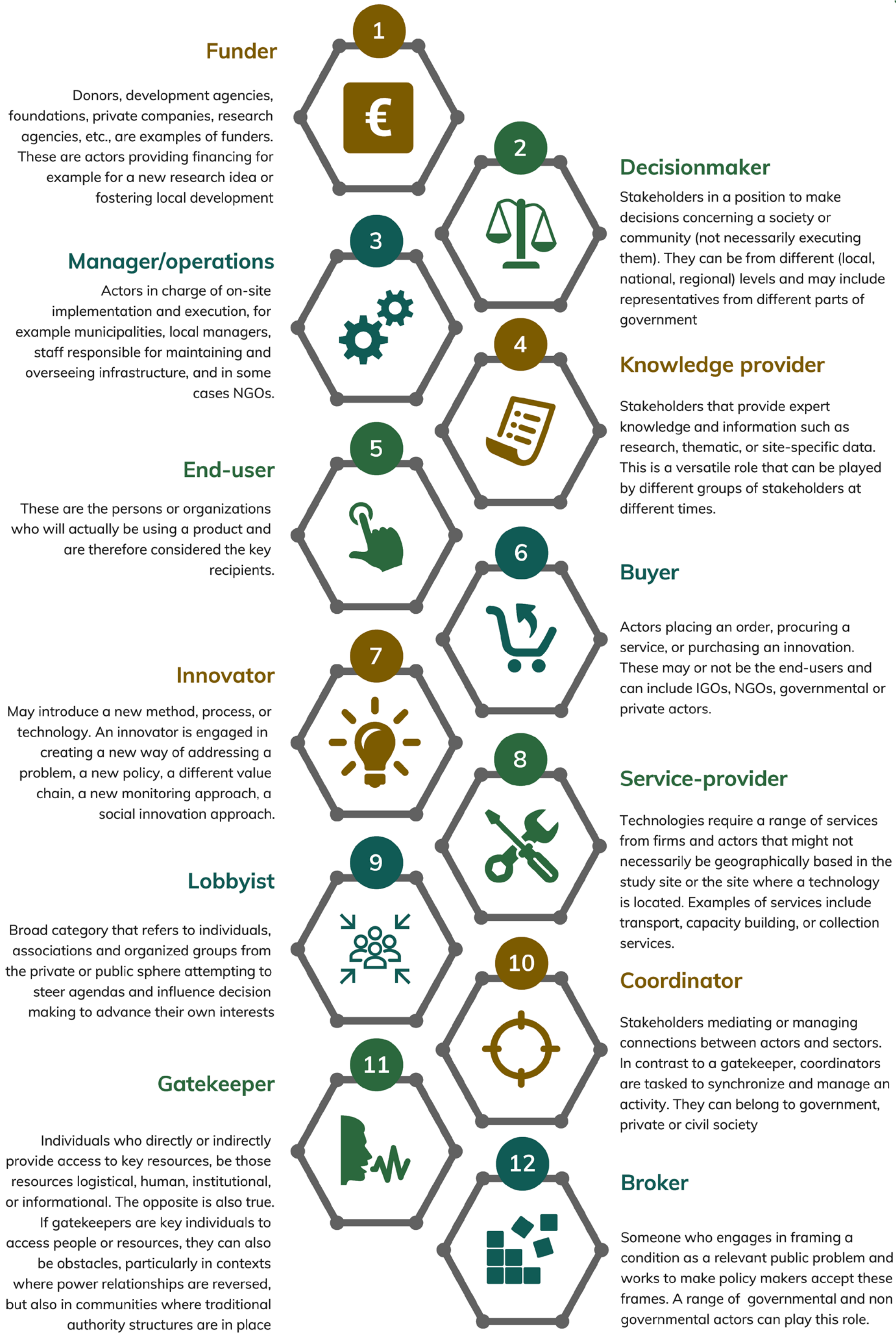
1. What are your main concerns with gridless technological solutions?

2. What questions need to be resolved to understand the applicability of gridless solutions in different contexts?

To trigger systemic thinking guided by the framework of technological innovation systems, we asked these two questions in relation to a seven-step, product-development process. The seven steps are: 1) research and development (R&D), 2) assembly, 3) implementation, 4) maintenance, 5) users and market fit, 6) diffusion, and 7) disassembly. These elements represent the lifetime of a product – from ideation to the end of an intervention.

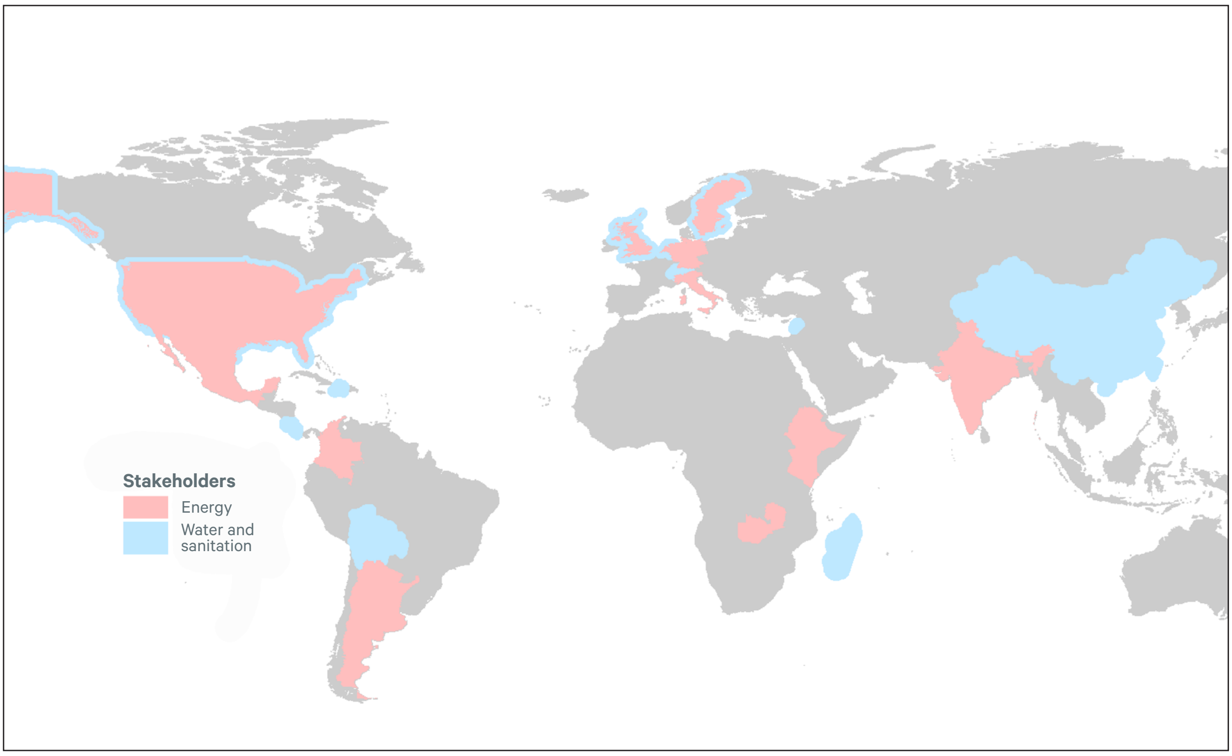
To obtain as many different views as possible from the groups during the structured interactions, we used a “think, write, share” methodology. For each question, participants had 10 minutes to individually write down short responses and place them on the corresponding

Figure 1. Possible stakeholder roles



development stage. Thereafter, participants were asked to comment on a selection of their entries to expand, highlight or clarify their points. The moderator facilitated a round of interventions from all participants before moving onto the second question, which followed the same process. The group spent 20 to 30 minutes on each question. The sessions were recorded and documented by the team. Following the workshops, the collected input was collated (by removing repetition and clarifying points) and sent to the workshop participants for additional comments or validation.

Figure 2 Geographical distribution of workshop participants

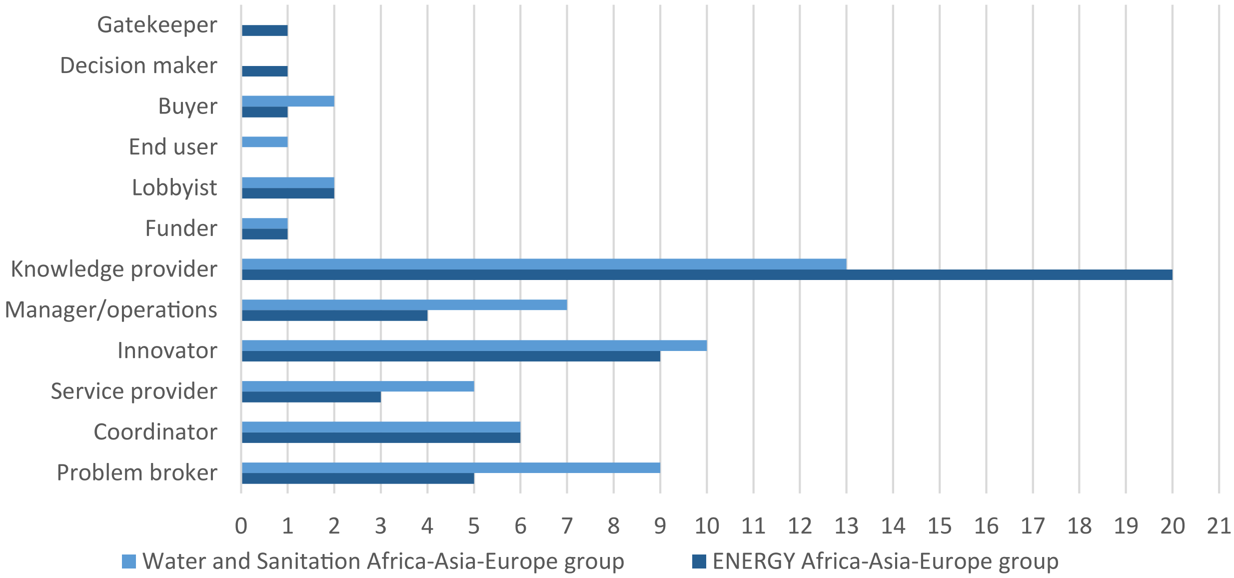


Results

Workshop participants

Of 58 invited stakeholders, 20 attended the water and sanitation workshops. Participants represented 11 countries: Bolivia, China, Costa Rica, Haiti, Lebanon, Madagascar, Netherlands, Sweden, Switzerland, the UK and the US (Figure 2). Participants represented academia (6), the private sector (7), non-governmental organizations (5), stakeholder networks (1) and government (1). Most participants self-identified as knowledge providers, innovators, and problem brokers (Figure 3).

Figure 3: Self-identified roles of stakeholders attending the workshops (51 participants)



For the energy workshops, 28 of 72 invited stakeholders attended. Participants were from 13 countries: Argentina, Colombia, Ethiopia, Germany, India, Italy, Kenya, Mexico, Netherlands, Sweden, the UK, the US and Zambia (Figure 2). Participants represented academia (15), the private sector (6), funders (2), non-governmental organizations (2), intergovernmental organizations (1) and civil society (2).

Perceived knowledge gaps about gridless options for water, sanitation, and energy

We collated perceived knowledge gaps and questions for each stage of product development based on input from the workshops and post-workshop feedback in gridless water and sanitation (Tables 1) and energy sector (Table 2). Gathered questions can serve as a basis for further research or policy engagement.

Table 1. Synthesis of questions identified by stakeholders in gridless water and sanitation sector.

Process development stage	Identified question	Additional comment	Theme
R&D	How does innovation funding influence the development of gridless solutions?	Further investigation is needed regarding influences of funders' interests, governmental attitudes towards novel technologies, institutional learning, and short- and long-term funding options.	Finance
	How can global and domestic R&D funds be structured to incentivize government engagement earlier into the product-development process?		Finance Government
	How can good investment decisions be made? How much should be invested? Where should investments be made?		Finance
	What are the most efficient ways to upscale pilot projects?	Pilot projects are set up to test new technologies, but many projects fade out after the pilot stage, and fail to generate scalable solutions that contribute to sustainable development.	Scalability
Assembly	What are the benefits of scale?	It is challenging to accurately compare prices for gridded and gridless options.	Scalability
	How do the (monetary and non-monetary) costs and benefits of imported and locally developed solutions compare?	Imported and local solutions have different costs and benefits. The accessibility and availability may differ for components and spare parts. Building locally will increase jobs in the sector, whereas importing may provide a more standardized or higher-quality product.	Local solutions
	What regulations could help beneficially shape needed products?	Gridless solutions operate in overlapping and complex policy and regulatory regimes. There are often few incentives for government bodies to change or upgrade regulations. The public sector is not equipped to control or supervise private, gridless initiatives. Governments often need global standards, yet there are few such standards to help guide governments.	Regulations
Implementation	When and why do governments favour gridded solutions?		Governments
	How should upscaling be financed?	Government subsidies/investments favour gridded over gridless options because they are more familiar, and because they may be easier to undertake. Gridded options often do not require the private-property interventions that gridless options tend to entail.	Scalability Finance
	What are the governance systems for gridless solutions?	Regulatory regimes needed by gridless technologies overlap with other policies in complex ways.	Governance
	Who can mitigate the risks of (new) gridless solutions?	Risks in gridless solutions occur at the individual or household level; by contrast, risks in centralized systems are largely held by the provider. Governments appear to be unwilling to assume risks for new technological solutions. Financiers can cover some implementation risks, but not all of them. Who will fill the risk gap?	Risks
	How should the design of technical specifications and regulatory process address issues (such as reusing water) that arise in dry and rainy seasons?		Regulations
	How can one monetize positive social and environmental externalities to help resource recovery to become more financially viable?	The transaction costs of getting value out of waste (e.g., for faecal sludge reuse) could be a barrier.	Finance
	What types of local conditions affect the success of gridless solutions?	Conditions that could have an impact include space and storage capacity; skills available for assembly and maintenance; user preferences and the acceptability of certain technologies; purchasing decisions; and regulatory and legislative gaps.	Success, local conditions

Process development stage	Identified question	Additional comment	Theme
Maintenance	Who are the different actors across gridless systems? What roles do they play? Do these actors understand each other's roles and responsibilities? How can a feeling of responsibility can be increased (for example, through increasing ownership among users and operators)?	There is a lack of awareness of roles and responsibilities among different actors. Those conducting research and development need to have greater awareness about potential end users, for example. There is a need to map the roles to assess responsibilities and ensure resilience in the system.	Actors (links, roles, responsibilities)
	How can innovators expand their vision from focusing almost exclusively on the development of products to focusing on provision of better services?	The current focus is on developing a product, not a service. This leads to poor (or a lack of) maintenance of equipment, and undercuts the sustainability of systems.	User needs Services
	What innovative financing options (such as performance-based contracts, results-based financing) can be used for gridless options?	Innovative mechanisms such as performance-based contracts are missing.	Finance
	How can utilities engage in a hybrid utility model for on-site sanitation? Can sanitation models emulate innovations that are similar to those that connect electricity utilities and solar technologies? What are the related barriers and risks?	The roles of public utility in operation and maintenance stages are shifting responsibilities to the private sector or individual owners. The whole area of operation and management costs should be evaluated before implementation. Such measures must address the lack of incentives for professional service providers; the absence of training and licensing; and the need for payments or subsidies sufficient to cover operating expenses, regular maintenance and asset replenishment.	Governance
	What are the barriers, risks and benefits that users perceive for on-site sludge management?	Concerns about loss of revenues might impact utilities.	User acceptability
Users/Market fit	Who could/should pay for gridless solutions? What issues should be considered in terms of fairness and justice?	Measures should consider the differences between the ability, willingness, and obligation to pay for services to pay for services in public domain.	Finance Equity Distributional justice
	What are users' needs? What is the best approach to meet them?		User needs
	How can gridless solutions be designed to ensure social acceptance and acceptability?	What do users want and need? What problem needs to be solved? What are drivers for behavioural change (e.g., of utilities but also of users)? What behaviour change is demanded of the users?	User acceptability
Diffusion	What are the most effective ways to enhance communication with governments and communities to lead to uptake of new technologies and options? What strategies and communication tools can aid the transfer of technology from concept to use?	Diffusion of a successful technological solution is complex, and one cannot understand the subject from a successful pilot project conducted in one context only. Long-term involvement of local groups during transference of technology is often needed.	Technology transfer
	How can one design good monitoring and performance benchmarking for gridless solutions? How can common metrics be devised?	There is a lack of good monitoring and performance benchmarking of gridless solutions in the public sector. Higher- performance technologies are often not valued due to excessive cost of monitoring.	Monitoring
	How can regulatory systems for monitoring, quality control, and accreditation of companies be devised to enhance (rather than block) diffusion?		Regulations
	What are the most appropriate management schemes?	Examples include design-build-operate schemes and delegated management with output-based payments.	Management
	What steps can be taken to assure successful transfer from financiers/project implementors to local managers and users?		User acceptability Technology transfer
Disassembly	What are disassembly requirements in post-disaster situations? How do these differ from those for other public investments?	Who is responsible for waste disposal and recycling costs?	Disassembly in post-disaster context
	What are the impacts of disassembly processes?	In the humanitarian field and particularly in situations requiring an immediate response, single-use items are often preferred to long-lived items.	Disassembly impacts
Cross-cutting questions	What are gridless solutions? How are they different from decentralized or sanitation systems that are not connected to sewers? Is there a need for a new term? Do gridless options include "hybrid" systems?	Clear definitions could help improve communication with decision makers.	Full spectrum of gridless options
R&D	How does innovation funding influence the development of gridless solutions?	Further investigation is needed regarding influences of funders' interests, governmental attitudes towards novel technologies, institutional learning, and short- and long-term funding options.	Finance
	How can global and domestic R&D funds be structured to incentivize government engagement earlier into the product development process?		Finance Government
	How can good investment decisions be made? How much should be invested? Where should investments be made?		Finance
	What are the most efficient ways to upscale pilot projects?	Pilot projects are set up to test new technologies, but many projects fade out after the pilot stage, and fail to generate scalable solutions that contribute to sustainable development.	Scalability

Process development stage	Identified question	Additional comment	Theme
Assembly	What are the benefits of scale?	It is challenging to accurately compare prices for gridded and gridless options.	Scalability
	How do the (monetary and non-monetary) costs and benefits of imported and locally developed solutions compare?	Imported and local solutions have different costs and benefits. The accessibility and availability may differ for components and spare parts. Building locally will increase jobs in the sector whereas importing may provide a more standardized or higher-quality product.	Local solutions
	What regulations could help beneficially shape needed products?	Gridless solutions operate in overlapping and complex policy and regulatory regimes. There are often few incentives for government bodies to change or upgrade regulations. The public sector is not equipped to control or supervise private gridless initiatives. Governments often need global standards, yet there are few such standards to help guide governments.	Regulations
Implementation	When and why do governments favour gridded solutions?		Governments
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	What types of local conditions affect the success of gridless solutions?	Conditions that could have an impact include space and storage capacity; skills available for assembly and maintenance; user preferences and the acceptability of certain technologies; purchasing decisions; and regulatory and legislative gaps.	Success, local conditions
Maintenance	Who are the different actors across gridless systems? What roles do they play? Do these actors understand each other's roles and responsibilities? How can a feeling of responsibility can be increased (for example, through increasing ownership among users and operators)?	There is a lack of awareness of roles and responsibilities among different actors. Those conducting research and development need to have greater awareness about potential end users, for example. There is a need to map the roles to assess responsibilities and ensure resilience in the system.	Actors (links, roles, responsibilities)
	How can innovators expand their vision from focusing almost exclusively on the development of products to focusing on provision of better services?	The current focus is on developing a product, not a service. This leads to poor (or a lack of) maintenance of equipment, and undercuts the sustainability of systems.	User needs Services
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Diffusion	What are the most effective ways to enhance communication with governments and communities to lead to uptake of new technologies and options? What strategies and communication tools can aid the transfer of technology from concept to use?	Diffusion of a successful technological solution is complex, and one cannot understand the subject from a successful pilot project conducted in one context only. Long-term involvement of local groups during transference of technology is often needed.	Technology transfer
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	How can regulatory systems for monitoring, quality control, and accreditation of companies be devised to enhance (rather than block) diffusion?		Regulations
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Cross-cutting questions	What are gridless solutions? How are they different from decentralized or sanitation systems that are not connected to sewers? Is there a need for a new term? Do gridless options include "hybrid" systems?	Clear definitions could help improve communication with decision makers.	Full spectrum of gridless options

Table 2. Synthesis of questions identified by stakeholders in gridless energy sector.

Process development stage	Identified question	Additional comment	Theme
R&D	What can be done to build consumer confidence in national standards for gridless technologies?	Each country has minimum standards for technology / equipment.	Regulations Standards
	Which mechanisms can be used to inform users about the products?	Users may be illiterate, or they may not understand written instructions or labels.	User awareness
	How can developers ensure that all users' needs are met?	A distinction is needed between the needs of men and women, particularly in the context of cooking.	Social equity
	Should designs primarily seek to generate tailored solutions to suit individual contexts, or to products intended to suit all contexts?	Decentralized solutions often lack economies of scale. Multi-market targeting could improve their financial viability.	Scalability
	How can user needs be integrated at the innovation stage?		User needs

Process development stage	Identified question	Additional comment	Theme
Assembly	What can be done to ensure that technologies are compatible with the needs of different socioeconomic groups?	Greater socio-economic inclusivity is needed for wider uptake of gridless technologies. There are concerns that only certain socio-economic groups are prioritized.	Social equity
	How can products be designed to facilitate in-country manufacturing?	Local engagement and local empowerment are important.	Manufacturing capacity
	Can training be provided to facilitate the local manufacturing of the solution?		Skills and training
	When should cheaper or more effective solutions be imported, and when, instead, should the generation of local jobs be the priority?	There is a need to examine the trade-offs between the costs and values of imported options and locally produced alternatives.	Trade-offs Employment
Implementation	How can the needs of the users be better understood?	There is currently too much focus on product-driven research over demand-driven research. Some actors have knowledge of needs, but this knowledge does not always reach solution providers. How can this gap be bridged?	User needs
	What triggers behaviour change in technology adoption?	User needs and preferences in adoption require greater study. These issues connect to user and market fit.	User behaviour
	What business capacity is required for distributing gridless energy?	.	Business capacity
	Which business models work for different sectors?		Appropriate business models
	How can solutions that allow for self-management be implemented?	For gridless technologies, when is institutional centralization more appropriate over decentralization? What circumstances allow for different degrees of institutional decentralization?	Sustainable business models
Maintenance	How should regulatory and financial measures link gridded and gridless systems?		Systems compatibility
	What are the skills among the local workforce? Can local people receive training to work with gridless technologies?	A challenge concerns the level of skills of people in the regions in which technologies are deployed. Technologies (such as mini-grids) that may be useful in remote areas may require extensive training and skills that may be beyond existing levels of education and skills of local people.	Skills and training
	What provisions are in place for long-term maintenance of the system?	Concerns extend well beyond installation. New products must run for many years. This is often forgotten when designing business plans, and it is not an activity that is usually covered in R&D grants.	Maintenance
	How are rights of users guaranteed during the maintenance of the project?		Users' rights
Users/market fit	Which delivery models are most useful for gridless solutions in the agriculture sector?		Appropriate delivery models
	How will the gridless solutions interact with the grid? How does the gridless business model integrate with existing grids?		Systems compatibility
Diffusion	How can gridless technological options ensure last-mile access?		Last-mile access Social equity
	Which users should receive subsidies? Should subsidies be targeted to low-income users?	Systems must be devised to continuously check who receives subsidies.	Social equity
	What can be done to bring down costs to make solutions more scalable?		Scalability
	How can revenue be generated from local users?	This is important for scale. If the service improves the standard of living, local people should be willing and able to pay for the services.	Scalability
Disassembly	What are the impacts on health and the environment from the various technologies?		Health and environmental impacts

Process development stage	Identified question	Additional comment	Theme
Cross-cutting issues	How do centralized policies for gridless solutions play out in peripheral areas?		Local context
	How can new, gridless solutions empower stakeholders?	Gridless options represent the start of a new paradigm. They represent an opportunity to undertake an urgently needed transformation of current development processes.	Empowerment
	What can be done to foster a sense of community ownership to spur good use of technologies?		Ownership

Discussion

Key gaps in the gridless water and sanitation sector

Overall, perceived gaps in the gridless water and sanitation sector focused mostly on the financial aspects at different product-development stages. A particular concern emerged regarding the role of governments in implementation and diffusion, and the roles that governance can and should play in addressing users' needs.

Key knowledge gaps that were identified at each stage are as follows:

- **R&D:** finding ways to generate finance; understanding how to make solutions scalable; linking finance, innovation, and upscaling.
- **Assembly:** addressing scalability; creating locally appropriate solutions; crafting beneficial regulations.
- **Implementation:** determining the appropriateness of different governance measures; addressing mitigation of risk; examining the local conditions needed for success.
- **Maintenance:** mapping the actor landscape; acquiring better understanding of actor's roles and responsibilities, and how these interact; understanding user needs and the acceptability of different technologies; finding financial and governance models to maintain and sustain services.
- **Market fit:** understanding user needs; understanding the acceptability of certain technologies; addressing matters of equity and distributional justice.
- **Diffusion:** understanding how to assure successful technological transfer; expanding knowledge about good monitoring and performance; and improving clarity regarding the role of regulations and different management mechanisms.
- **Disassembly:** addressing environmental impacts of products at the end of their life cycle.

Key gaps in the gridless energy sector

In general, stakeholders highlighted gaps related to skills and training needed to implement and serve gridless energy applications; ways to generate and maintain local employment and local manufacturing capacity; and business capacity required for establish viable gridless markets. Questions about how to ensure social justice, equity, and empowerment in the delivery of gridless solutions were also prominent in discussions.

Key knowledge gaps that were identified at each stage are as follows:

- **R&D:** ensuring that standards and regulations for gridless energy solutions are in place; striking a balance between meeting the needs of individual users and developing scalable solutions that are widely applicable.
- **Assembly:** understanding how local employment, skills and training can be supported through gridless solutions; finding ways for technologies to stimulate local manufacturing and employment.
- **Implementation:** understanding user behaviour; selecting appropriate and sustainable business models to deliver the solutions.
- **Maintenance:** generating compatibility between gridded and gridless energy systems in terms of finance and regulation; understanding how local skills can be channelled into gridless maintenance systems.
- **Market fit:** understanding users' needs and perceptions; understanding how gridded and gridless business models can be linked; thinking about ways to make these systems more compatible.
- **Diffusion:** addressing social equity issues in terms of ensuring "last-mile" access for hard-to-reach communities; targeting subsidies to support the groups that need services and financial support the most; addressing scalability issues that are linked to the need to generate revenue from local users.
- **Disassembly:** understanding the potential health and environmental impacts associated with gridless energy systems at their end of their productive life.

Shared gaps across the sectors

Several overlapping gaps emerged among the energy and water and sanitation sectors. Prominent topics of discussion concerned gaps in regulations, and issues about compatibility between gridded and gridless systems. Other mutual areas of concern include understanding user needs and preferences; determining the appropriateness of technologies; and addressing issues of social equity, fairness, and distributional justice. Stakeholders expressed concerns about the limited knowledge of the factors that make solutions scalable, and the ingredients that underpin successful transfer from innovative product to use on the ground. Representatives expressed concern about the need for greater know-how on financing and marketing issues – including securing funding for innovations, finding investment sources, and creating commercially viable business models. Another key issue discussed concerns product maintenance, particularly before markets have been established. Both groups of stakeholders also highlighted a lack of understanding of the benefits of localized solutions, and the need to better understand local needs in specific context.

Implications

Results from the workshops highlight the many and varied knowledge gaps that stakeholders perceive to be holding back gridless technologies. These gaps primarily relate to the broader societal systems in which technologies and processes must be embedded. The questions highlighted by stakeholders support the claim on the causes of project failures – these questions do not necessarily relate to technological performance; they rather refer to a lack of clarity related to actors' roles and responsibilities, system functions beyond technical efficiency, and to the features of the innovation system and how it impacts the solutions that are being implemented (Murphy, 2001).

Using the lens of technological innovation systems, we note several key knowledge gaps at different levels of the gridless system. A lack of knowledge on how to understand and incorporate

user needs and user behaviour into the design and delivery of gridless solutions is a recurring theme. Questions continue to surface on the role of government regulations for supporting the development and diffusion of gridless technologies. Providing subsidies to facilitate last-mile access, and ensuring standards for new products and services are also critical issues. These system functions could be seen as particularly critical for the successful scale-up of gridless technologies in resource-poor settings and where solutions target marginalized communities.

Another key theme concerns the compatibility of gridded and gridless technologies in many respects – at various systems levels, including government regulations, business models, finance and impact on users. Indeed, many of the gaps outlined by stakeholders seem to relate to the stages beyond the innovation process. A systems perspective is clearly required to work out how the various technical, institutional, social, economic, and organizational factors can best be aligned to ensure systems compatibility.

It was useful to think about issues that arise in specific product-development steps to flag gaps in current innovation practices. For example, product testing increasingly emphasizes the need for test beds in the actual contexts in which they will be used; however, testing at present rarely includes efforts to explore longer-term aspects related to maintenance and the local chains necessary to provide services. As a result, many technically feasible technologies fail because of unrealistic maintenance requirements in the contexts in which they are applied. At the same time, this narrow view of testing innovations fails to raise the important issue of the local employment opportunities that can arise by training and hiring local people to provide longer-term maintenance service.

Relatively few stakeholders had reflected on matters related to disassembly. This may be an area that needs further regulatory attention. In addition, disassembly may present an untapped business opportunity. Recycling laws have led to new businesses for collecting, processing, repurposing, and selling recycled products. Similarly, requirements for overseeing the disassembly of water and sanitation and energy products could lead to new local value chains based on service provision.

Limitations

The list of gaps in understanding of gridless technologies is biased by the composition of the participant group and our introductory framework. Nevertheless, the insights from the stakeholders provide a useful starting point to brainstorm about important but under-researched or unaddressed issues. More systematic effort must be undertaken to collate and highlight knowledge gaps in future to be able to address them.

Concluding remarks and ways forward

Ignoring or oversimplifying social and cultural relationships existing in the implementation context may lead to failure of innovative solutions (Murphy, 2001; Tigabu et al., 2015). The gaps highlighted by stakeholders confirm that contextual aspects remain unexplored, even though they are the crux of major challenges facing innovators of water, sanitation and energy technologies today. Innovators must keep in mind local conditions, user needs, the accessibility of potential solutions, and the resources needed to maintain a technology. Business plans need to include value chains. They must devise a strategy for localizing service provision and licensing. Wherever feasible, they should find ways to localize production and assembly. Addressing the matter of how new products will jack into existing structures and institutions cannot be an afterthought; it will determine whether the innovation is feasible. These topics must be integrated into and addressed by future research and considered when devising policies if gridless innovation systems are to gain traction in the places where they are needed to expand access and improve human health and well-being.

References

Agbokey, F., Dwommoh, R., Tawiah, T., Ae-Ngibise, K., Mujtaba, M., Carrion, D., Ali Abdulai, M., Afari-Asiedu, S., Owusu-Agyei, S., Asante, K., & Jack, D. (2019). Determining the Enablers and Barriers for the Adoption of Clean Cookstoves in the Middle Belt of Ghana—A Qualitative Study. *International Journal of Environmental Research and Public Health*, *16*(7), 1207. https://doi.org/10.3390/ijerph16071207

Andersson, K., Otoo, M., & Nolasco, M. (2018). Innovative sanitation approaches could address multiple development challenges. *Water Science and Technology*, *77*(4), 855–858. https://doi.org/10.2166/wst.2017.600

Barquet, K., Segnestam L., & Dicking S. (2021). MapStakes: a tool for mapping, involving, and monitoring stakeholders in co-creation processes. Manuscript in preparation.

Bergek, A., Jacobsson, S., Carlsson, B., Lindmark, S., & Rickne, A. (2008). Analyzing the Functional Dynamics of Technological Innovation Systems: A Scheme of Analysis. *Research Policy*, *37*(3), 207–229. https://doi.org/10.1016/j.respol.2007.12.003.

Girardeau, H., Oberholzer, A., & Pattanayak, S. K. (2021). The enabling environment for household solar adoption: A systematic review. *World Development Perspectives*, *21*, 100290. https://doi.org/10.1016/j.wdp.2021.100290

Jürisoo, M., Lambe, F., & Osborne, M. (2018). Beyond buying: The application of service design methodology to understand adoption of clean cookstoves in Kenya and Zambia. *Energy Research & Social Science*, *2018*(39), 164–176. https://doi.org/10.1016/j.erss.2017.11.023

Lambe, F., Ran, Y., Kwamboka, E., Holmlid, S., Lycke, K., Ringström, S., Annebäck, J., Ghosh, E., O'Conner, M., & Bailis, R. (2020). Opening the black pot: A service design-driven approach to understanding the use of cleaner cookstoves in peri-urban Kenya. *Energy Research & Social Science*, *70*, 101754. https://doi.org/10.1016/j.erss.2020.101754

Murphy, J. T. (2001). Making the energy transition in rural east Africa: Is leapfrogging an alternative? *Technological Forecasting and Social Change*, *68*(2), 173–193. https://doi.org/10.1016/S0040-1625(99)00091-8

Olsson, O., & Barquet, K. (2020). *SEI Initiative on Gridless Solutions*. [SEI Fact Sheet]. Stockholm Environment Institute (SEI). https://cdn.sei.org/wp-content/uploads/2020/12/sei-initiative-on-gridless-solutions-fact-sheet.pdf

Peters, J., Sievert, M., & Toman, M. A. (2019). Rural electrification through mini-grids: Challenges ahead. *Energy Policy*, *132*, 27–31. https://doi.org/10.1016/j.enpol.2019.05.016

Tigabu, A. D., Berkhout, F., & van Beukering, P. (2015). Technology innovation systems and technology diffusion: Adoption of bio-digestion in an emerging innovation system in Rwanda. *Technological Forecasting and Social Change*, *90*, 318–330. https://doi.org/10.1016/j.techfore.2013.10.011

Vigolo, V., Sallaku, R., & Testa, F. (2018). Drivers and Barriers to Clean Cooking: A Systematic Literature Review from a Consumer Behavior Perspective. *Sustainability*, *10*(11), 4322. https://doi.org/10.3390/su10114322

Village house with solar panel, Uganda © PHILIPPE LISSAC / GODONG / GETTY

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