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Sustainability and the Social Construction of Technology: The Case of RWH as Source of Water Supply in Greater Accra

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Abstract
The paper discusses the sustainability of roof rainwater harvesting (RWH) in Greater Accra, Ghana. We take a holistic approach, but focus especially on the social dimension. The discussion is grounded in a research and development project including a holistic sustainability assessment of selected RWH designs based on LCA, cost-benefit analysis and a KAP survey, as well as training of local artisans, stakeholder dialogue and pilot implementation of 21 RWH systems. The performance of the systems largely met the expectation. The households could expect long-term savings, and there were benefits in terms of convenience, hygiene and water sharing. On the other hand, high initial costs, limited awareness, and lack of capacity to implement supportive policies were impediments to wide-scale adoption. The sustainability of the solutions is discussed in further detail. A social construction of technology (SCOT) perspective is applied to throw light on how the stakeholders constructed drivers, barriers, and indeed the technical solutions themselves. We find that the technology was at a stage of low stabilization, meaning-wise, and this clearly affected its sustainability in the local context. The findings suggest that more attention should be paid to social construction in sustainability research and transition efforts.

Keywords: Sustainability, holistic approach, social construction, rainwater harvesting

1. Introduction

RWH has been identified as an effective adaption option and source of water supply for countries facing water shortages (Che-Ani et al. 2009, Sharma et al 2015, Sojka et al 2016). However, there is debate about the overall sustainability of the technology (Campisano 2017). Installation costs are high and the knowledge about maintenance, use requirements and risks is limited. Skepticism prevails, and policy frameworks to facilitate wide-scale adoption are still lacking in many countries (Sharma et al 2015).

A range of studies have explored social experiences among end-users and discussed various governance issues (cf. White 2011, Domènech and Sauri 2011, Ward et al 2016). However, the influence of meaning creation and stakeholder negotiations on the sustainability of RWH has not been much in focus. This paper discusses RWH as source of water supply in Greater Accra, Ghana. We take a holistic approach, concerned not only with yield, water quality and environmental footprint, but also with economic and

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social aspects, and in particular with how the social construction of the technology seemed to affect its sustainability in the local context.

2. The Project and Solutions in Question

The basis for our discussion is a research and development project carried out in 2013-2015.[1] Its aim was to promote RWH and generate local business by identifying and assessing the sustainability of a limited number of RWH designs, and subsequently training 25 local artisans in how to make business out of three model systems, retrofitted to existing homes:

1) ***"Advanced"***, with a robust collection, supply and storage system including self-cleaning screens in the downspouts, an automated first flush diverter, automated pump, cartridge filters, UV disinfection, and in most cases an overhead tank, to maintain indoor water supply during power outages.

2) ***"Intermediate"***, similar to the "advanced", but without disinfection and with a manual pump.

3) ***"Basic"***, with the same reliable collection, transfer and storage system, but without filters, pumps, disinfection and indoor distribution.

Twenty-one pilot systems were installed. They were monitored for 6-12 months, and there was extensive stakeholder dialogue throughout the project period.

The initiative was developed with a view to Ghana's National Rainwater Harvesting Strategy. Ghana will be a water stressed country by 2025, but there is only limited adoption of modern RWH. The strategy states that this is due mainly to lack of awareness, high cost of available components, fears about the water quality and lack of supportive policies (MWRWH 2011). Against this backdrop, we saw it as essential to address the social dimension, as much as the technical and economic performance of the RWH systems.

3. Perspectives on Social Sustainability

According to Vallance et al (2011), social sustainability is a concept in chaos. In current research, there are at least three strands of meaning. *"Development sustainability"* addressing basic needs, social capital, justice, etc.; *"bridge sustainability"* concerning changes in behaviour to achieve environmental goals, and; *"maintenance sustainability"* referring to preservation of cultural heritage, and how people actively embrace or resist change (ibid.). While these are in harmony in some respects, there is also difference and discord.

Likewise, there is no authoritative approach to social sustainability assessment, but various interpretations regarding what issues to address (Murphy 2012, Dixon & Colantonio 2008). There are also arguments that the selection of measures tends to be a function of power (Littig & Griessler 2005). Most studies focus on sustainability as a

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[1] "Rainwater harvesting for resilience to climate change impact on water availability in Ghana". Carried out by SINTEF in collaboration with CSIR, funded by the Nordic Climate Facility, and administered by the Nordic Environment Finance Corporation (NEFCO).

condition and measuring it with a series of indicators, and influential groups are more likely to have their concerns reflected than are others.
Thus, it is necessary to integrate criteria of different quality and pay due respect to the importance attributed to them by various stakeholders (Omann & Spangenberg 2002). To invite a more open and dynamic approach, the following definition has been proposed; *"Social sustainability is: a life-enhancing condition within communities, and a process within communities that can achieve that condition,"* (McKenzie 2004:12). The definition comes with a non-exclusive list of key indicators, considered as inherent to the process: equity, diversity, interconnectedness, quality of life, governance/participation, and social maturity/awareness.
Several studies indicate that it is necessary to develop a stronger linkage between the social and environmental pillars (Littig & Griessler 2005, Murphy 2012). Vallance et al (2011) suggest the need to rely less on 'objective data' and turn more towards exploration of how actors interpret, embrace and resist eco-strategies. When it comes to RWH, Capisano et al (2017) found that the focus on acceptability and financial returns has detracted attention from wider benefits, as well as from systemic factors influencing the hydrosocial contract and diffusion of the technology.
With a view to the above, we draw on social construction of technology (SCOT) analysis (Pinch 2010). SCOT focuses on why and how a certain technology design is emerging, by looking at the meanings in focus among the relevant social groups (Pinch and Bijker 1984). Its notions of interpretive flexibility, stabilization and closure of meaning may throw light on the stages of innovation uptake. While Madsen et al (2017) applied SCOT in a comparative discourse analysis of stormwater control, we use it to throw light on social construction as one among several aspects of sustainability. To our knowledge, this is a novel approach.

4. Methodological Approach

The population of Greater Accra has increased eight-fold the last 50 years, but infrastructural development has not kept pace with the population growth. Mean annual rainfall is 790.6 mm, and groundwater salinity limits the options for water supply (Owusu & Teye 2014). Greater Accra is also Ghana's main business and industrial hub, with the highest concentration of citizens with the resources to invest in private water solutions. Given the project objectives, we focused on four middle-class residential areas (Ashongman, Pokuasi, Kwabenya, Ashaley Botwe, and Adenta), where public water supply is inadequate and most households rely on commercial tanker water.
Random sampling was used to select 54 households for a knowledge, attitudes, practices (KAP) survey, on water use, social relations, health and hygiene, consumer choices and awareness of RWH and climate change. The survey was face-to-face, combined with observations on the physical structures and general conditions in the homesteads.
The KAP survey informed the key design criteria and served as baseline for the sustainability assessment. In addition to delivery performance, the assessment included subsets of indicators for environmental, economic and social sustainability. Life-cycle assessment (LCA) was used to assess the environmental dimension. The criteria for economic sustainability were; total expenditure for the first year, three years and ten

years; annual savings; payback period; and equivalent annuity. The social dimension was assessed via the following criteria and indicators:

- Health facilitation (amount, quality, safe handling of water)
- Resource independence (electricity, replaceable parts, skills/knowledge)
- Scope for entrepreneurship (local content, water beyond need, lifetime)
- Social capital (impact on social network, self-reliance, social standing)
- Usability (time, physical effort, maintenance)
- Social acceptability (satisfaction of needs, perception of origin and quality, alignment with existing knowledge attitudes and practices)

In line with McKenzie (2004), and Omann and Spangenberg (2002) both process and impact, quantitative and qualitative indicators were included. Qualitative indicators were evaluated along an ordinal scale, based on the KAP survey and stakeholder feedback. The three sub-assessments were integrated in a Principal Component Analysis (PCA).

The stakeholder dialogue and training were conducted with a Triple Helix approach, emphasizing participation and collaboration of public institutions, knowledge institutions, and businesses (Erosa 2012). The training included competency-based training in how to develop a business and production-based education linked with the construction of the pilot systems. The monitoring included user logs, laboratory tests and semi-structured user interviews. Water samples were collected monthly. Temperature, pH, conductivity, and turbidity were measured in situ. Physico-chemical and microbial laboratory analyses were done according to the APHA standard methods for examination of water.

SCOT analysis has been applied in connection with the final evaluation of the results. It draws on six stakeholder workshops as well as other formal and informal interactions during the project, and has partly been carried out in retrospect.

5. Results and Experiences

To communicate the different kinds of results and bring out the process of social construction, our findings are presented in three sections, relating to the design and development phase, the pilot implementation, and the final monitoring and stakeholder dialogue.

5.1 Design and development

Most of the surveyed households were middle class, with incomes above GHS 1000.00/month and 4-5 bedroom houses. Most (85%) had roofs suited for RWH, and most already had water storage tanks. The vast majority (87%) used sachet water for drinking. Most relied on tanker water for other domestic use, but some used wells, boreholes and rainwater in addition. Only three mentioned pipe-borne water as an option.

For the average household, water cost was around GHS 200.00/month. Still, their choices of water source depended on quality, reliability and convenience, as much as cost. All reported that they had enough water for their hygiene and daily needs, whereas 11% had suffered some kind of waterborne disease the last two weeks. Most respondents claimed that water provision was a shared responsibility in the household. They did not spend much time getting water, but water was still a regular conflict issue in the home.

While all were concerned about water availability, none related this to climate change. Most thought rainwater is mainly for washing, but some would also consider cooking and drinking it. Benefits associated with increased water availability were added income opportunities, sharing with others, and convenience.

Together with a set of key design criteria, this information was used to define 36 initial design alternatives. Stakeholder perspectives on these varied considerably. Some of the foreign researchers proposed including a broader variety of tank materials and components such as sand filters, ceramic purification and simple PET bottles for UV disinfection. Some NGOs and public stakeholders advocated ferro-cement, communal work, and simpler purification measures. One private actor favoured chlorination, while others argued for underground tanks. However, heeding the view of local researchers and suppliers, the final set of alternatives included mostly well-known, ready-made components.

The LCA indicated that all the RWH designs would reduce the impact to the environment, as compared to buying tanker water. Ferro-cement tanks showed the best results, while the worst was associated with oversized tanks. The "intermediate" and "advanced" systems tended to have higher environmental impacts than the "basic" ones.

In the social sustainability assessment, alternatives with more capacity relative to household size showed more positive results. Designs with ferro-cement tanks tended to score higher than designs with polyethylene tanks, mainly due to higher local content and longer lifetime. It was noted that in some cases "advanced" designs may not be utilized fully, due to infrastructural and social constraints, and "basic" may be preferable.

With the water price at the time (around GHS 20.00/m^{3}), using tanker service only was more expensive than supplementing with a RWH system, for all considered roof sizes (90-200 m^2). Economically, the "basic" designs performed better than the "intermediate" and "advanced", mainly because filter replacement increases monthly costs substantially. Bigger roof and bigger tank gave higher annual savings. However, the latter must be weighed against initial cost, so in economic terms, several tank sizes performed almost equally well. When the environmental, social, and economic dimensions were weighted equally, the overall sustainability of the designs came out as illustrated below (figure 1):

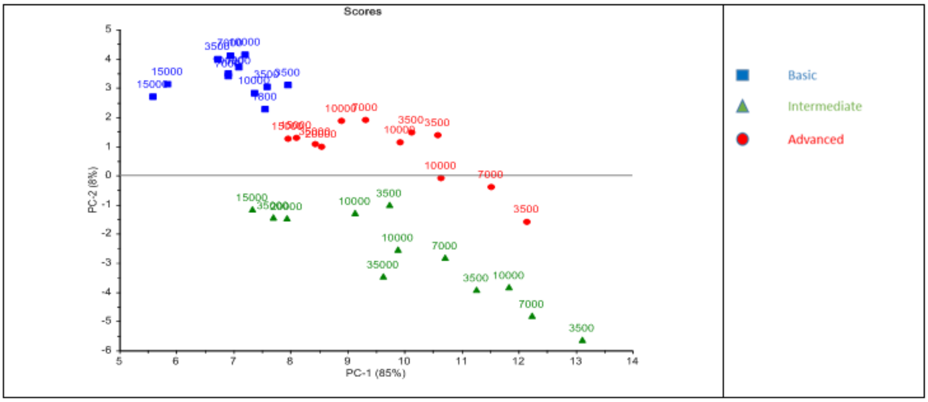

Figure 1: Overall sustainability (origo as optimal), equal weighting and integration of sub-assessments through PCA (numbers refer to tank size).

The "basic" designs appeared most sustainable. The variables with strongest loading and influence on overall sustainability were system efficiency, short-term economic indicators, and the criteria "scope for entrepreneurship", "social acceptability" and "usability". Still, with a view to different use and user preferences, plus the widespread scepticism about water quality, we went forward with the three model systems.

5.2 Pilot implementation and training

Local researchers and suppliers installed the pilot systems, together with the artisans participating in the one-year training programme. The artisans got compensation for their time, but with the required level of commitment, they were not easy to find.

In recruiting households and schools, we were torn between prioritizing marketing and business potential and providing opportunity to families in need. While the objective was clear, many stakeholders seemed to think of the activity as a traditional development project that should target disadvantaged groups.

To ensure a sense of ownership, the beneficiaries had to pay a 25% cost share. Many expressed interest, but Ghana is a network society where trust rests more on personal relations than formal contracts, and it was challenging to find house-owners and schools who actually committed and paid. Family funds are dispersed widely, and for many households it was difficult to mobilize the cost share. Public institutions, likewise, had to deal with a slow and extensive bureaucracy. In the end, those benefitting were quite well off. Many took a special interest in water solutions and wanted the "advanced" design for maximum benefit, even if they did not plan to drink rainwater.

Installing the systems took longer than expected. This was due to several factors, including level of coordination. However, it also had to do with stakeholder relations and interests in the project. Despite the Triple Helix approach, the artisans tended to take a subordinate role, as "students" and "workers". Some came when requested, but others were less accountable. The suppliers juggled between the project and other important customers, while the research team, perhaps, was more oriented to the scientific aspects than business development.

One artisan had experience from installing concrete, underground storage, and the foreign researchers wanted to include at least one ferro-cement tank, but the local team preferred sticking to polyethylene, as a known and safe alternative. Some team members also suggested measures such as overflow management and painting of the pipes, but others focused more strictly on water supply. While many of the artisans were used to simple tools and requirements, some customers and researchers had higher expectations as to technical and aesthetic detail. However, compromises were reached, and the standard increased considerably over the implementation period. The artisans were organised in multi-skilled groups tending to specific areas, as a first step towards a RWH cluster.

The actual costs of the implemented systems, presented in figure 2, were significantly lower than anticipated. The main reason for this was that the tank size in most cases was smaller, optimized in relation to local long-term rainfall data and available roof area.

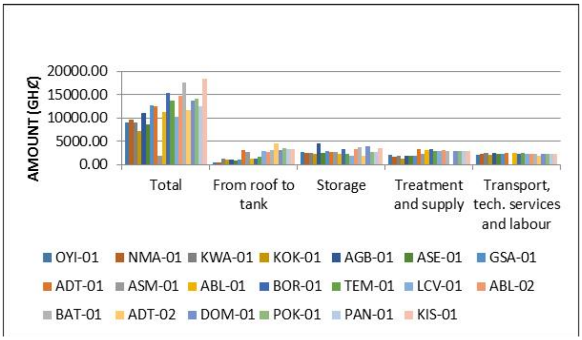

Figure 2: Total costs and major cost elements of the implemented household systems.

Total costs varied, mainly depending on system type, building structure and size of tank. As expected, storage was a major cost component. "Roof to tank" varied most, as some already had gutters, others not. Treatment and supply included the most advanced technology, mostly imported and with cost depending on system type. Transportation, technical services and labour also involved considerable costs, in all cases.

The breakdown illuminates potential cost reduction strategies. While new polyethylene tanks were included in all pilots, the initial survey, as well as Owusu & Teye (2014), indicate that a large proportion of households in Greater Accra already have existing water tanks that could be used for RWH, thereby reducing system costs substantially. Furthermore, ferro-cement tanks should be explored further, as they have longer lifetime and potential for cost reduction through own efforts. The costs of transportation, technical services and labour may be reduced through economies of scale, and many "roof to tank" components are technologically simple parts, where costs could be brought down through standardised local production.

5.3 Monitoring and stakeholder dialogue

The yield of the pilot systems is summarized in figure 3. As the log data did not allow easy comparison between reported and expected performance, a set of model calculations using daily rainfall data for the monitoring period and reported water usage was included.

Information about the installation					From log book		Model calc. based on daily rainfall Accra airport July 2014 - July 2015			
System ID	System type	Roof area, [m^2]	Storage tank volume, [m3]	No. of persons in house	Net water used, [l/day]	Net water harvested, [l/day]	Volume of harvested water per year, [m^3]	Average no. of days per year the system will supply daily water demand, [Days]	Demand met, [%]	Fraction of runoff from the roof that is collected, [%]
ADT-02	BASIC	220	4	6	133	37	41	309	85 %	61 %
KOK-01	INTERMEDIATE	150	7	4	62	53	23	365	100 %	15 %
KWA-01	INTERMEDIATE	150	7	4	64	55	23	365	100 %	16 %
AGB-01	INTERMEDIATE	250	14	3	76	103	28	365	100 %	11 %
NMA-01	INTERMEDIATE	150	7	5	132	101	48	365	100 %	33 %
GSA-01	INTERMEDIATE	150	10	12	187	200	68	365	100 %	47 %
ABL-01	ADVANCED	110	7	4	85	104	31	365	100 %	29 %
PAN-01	ADVANCED	140	12	5	151	81	55	365	100 %	40 %
BOR-01	ADVANCED	150	7	5	170	149	61	359	98 %	42 %
ADT-01	ADVANCED	150	7	5	204	326	70	342	94 %	48 %
KIS-01	ADVANCED	300	10	5	211	290	77	365	100 %	26 %
TEM-01	ADVANCED	250	7	6	227	171	80	353	97 %	33 %
POK-01	ADVANCED	200	7	6	228	222	80	348	95 %	41 %
OYI-01	ADVANCED	150	10	4	258	251	87	334	92 %	59 %

Figure 3: Recorded and modelled performance of installed systems.

According to the calculations, the pilot systems met more than 90% of the demand, with only one exception. The user interviews confirmed that in most cases, the system met the household's water needs. The percentage of demand met was considerably higher than the design phase estimate, of 72%. The latter was based on rainfall data over a 10-year period (yearly average 862 mm), whereas the monitoring period had a relatively high measured rainfall (1217 mm). While use patterns varied considerably, some households also saved water to secure their supply between rainfalls. This came at the expense of maximizing the amount of water harvested.

To assess water quality, samples were measured against the WHO guidelines and Ghana water quality standard (GS175-1(2013)). The results are compiled in figure 4.

System information		Physical - chemical			Microbiological		
System ID	System type	No of samples	No of non-compliat samples	Percent non-compliant, [%]	No of samples	No of non-compliat samples	Percent non-compliant, [%]
ADT-02	BASIC	0	-	-	4	4	100 %
KOK-01	INTERMEDIATE	6	0	0 %	5	5	100 %
KWA-01	INTERMEDIATE	9	0	0 %	13	13	100 %
AGB-01	INTERMEDIATE	8	1	13 %	10	10	100 %
NMA-01	INTERMEDIATE	10	0	0 %	11	11	100 %
GSA-01	INTERMEDIATE	7	0	0 %	11	11	100 %
ABL-01	ADVANCED	6	0	0 %	9	4	44 %
PAN-01	ADVANCED	0	-	-	2	2	100 %
BOR-01	ADVANCED	4	1	25 %	7	3	43 %
ADT-01	ADVANCED	4	0	0 %	8	1	13 %
KIS-01	ADVANCED	1	0	0 %	1	1	100 %
TEM-01	ADVANCED	3	0	0 %	9	4	44 %
OYI-01	ADVANCED	10	1	10 %	12	3	25 %

Figure 4: Level of compliance with water quality standards.

Except for pH, which is not important for our purposes, the pilot systems complied with the physical–chemical quality standards in nearly all cases. However, the raw water samples generally contained coliform bacteria and higher total bacteria counts (THB) than the guideline values, probably due to contaminated roof surfaces. Consequently, the "basic" and "intermediate" systems did not meet microbiological water quality standards.

The "advanced" systems were expected to produce drinking water quality, but 38% of the samples did not comply with one or more of the criteria for bacteria counts. This was probably due to repeated power outages and too long use of filter cartridges. The samples taken when UV disinfection was on and the system operated according to instruction show that the "advanced" design could produce drinking water quality.
14 out of the 20 households (70%) used more water than before, and all except one were very satisfied with the water quality. Several noted that the taste and smell is better than of tanker water, which tends to have a high salt content. 70% of the households experienced initial problems, but all were eventually satisfied with the operation and handling of their RWH systems. Other reported benefits were convenience, knowing one's water source, and the ability to share water with neighbors.
The stakeholder workshops highlighted the barriers to upscaling identified in the National RWH Strategy. Business actors saw limited awareness as the major hindrance. High initial costs were also stressed, most strongly by local researchers, who pointed out that the investment is too big for most Ghanaian families. In relation to this, lack of financing opportunities was presented as a major problem, considering local interest rates of 20-25%. Limited capacity to implement supportive policies and lack of public-private dialogue were also seen as key challenges.
In practice, it was difficult to rally any real support around the emerging RWH cluster. Financing institutions did not come on, and several of the larger, private actors saw little gain from collaboration with public institutions. Public actors stated their continued support, but their level of activity is dependent on available funding. A follow-up program with the RWH cluster, including installation of another 12 systems, has been organized through Ghana's Council for Technical and Vocational Education and Training (COTVET). Backed by the project documentation some artisans have secured individual RWH contracts, but the progress has been slow.

6. Discussion

The results with respect to water quantity and quality demonstrate the potential of RWH as adaptation measure for water supply in Greater Accra. However, the study also highlights vulnerabilities linked to use of electrical components and maintenance.
Where the use of "advanced" systems includes drinking, the necessity of back-up solutions such as chlorination or boiling in case of power outages must be emphasized. One should note, however, that most people in the study area use sachet water for drinking, even where water from the public network is available. While WHO standard should be target, the achieved water quality must also be considered in light of the available alternatives. In most cases, these were sachet and tanker water, of variable quality and likewise exposed to risks during handling and storage. At the same time, the active management required from users comes with its own risks and vulnerabilities. Even during the monitoring, too long intervals between filter changes affected the performance of some systems.
Given the variable rainfall and use patterns, it is difficult to be specific about long-term savings. Calculation based on the initial investments, current water price and volume of harvested water for the pilots indicated that benefits were in the range of GHS 460.00-

1740.00 for one year, with a payback time varying between 5 and 20 years. Maintenance and operation costs will reduce the benefits. On the other hand, the 90% demand met indicates that there is good potential for economizing less with the water. As households learn to exploit their potential, the overall benefits of the RWH systems are likely to increase considerably. The findings also indicate that other benefits, such as convenience and knowing the source are highly valued in the target population.

The dependence on user practices underscores the influence of the social dimension on the overall sustainability of RWH. Our findings further show that the RWH designs emerged in the interface between different stakeholder perspectives. At least three perspectives were at play:

a) **Development perspective;** RWH as water supply, increase access to safe water supply and meet basic needs, considering RWH promotion as a public responsibility, concern with policy and support schemes

b) **Business perspective;** RWH solutions as products, concern to demonstrate and develop a market, build awareness, create opportunities, establish incentives

c) **Scientific perspective;** potential and limitations of RWH in water resource management, testing and assessment of performance in terms of yield and water quality, long-term sustainability, documentation and knowledge/capacity-building

The respective sets of meanings were associated with different views on target groups, components and designs, as well as different emphases in the perspective on sustainability. Their interplay was most apparent in the selection of design alternatives, but influential also in later phases. The challenges in recruiting beneficiaries and scope for variation during pilot installation may be related to concurrence and discord in how stakeholders understood and presented the RWH solutions. The final functioning and appearance of the systems were also not given by technical specification, but resulting from stakeholder negotiations carrying the above-mentioned perspectives.

In line with Pinch and Bijker (1984), the solutions developed through a competition of designs in complex interaction between technology and people. Considering the range of meanings involved one may argue that RWH was associated with high interpretive flexibility: The stakeholders had not yet agreed on a stable expression and vision for the technology. On this background, it was difficult to "sell" in relation to users and decision-makers. Lack of stabilization also seemed to influence the pilot implementation, in that neither artisans, suppliers, nor researchers took full ownership of the total configuration, but related to it as an artisan's assignment, individual sale, or scientific test case. The monitoring was more oriented to collection of results than follow-up of customers and products. The cluster collaboration, despite the stated objectives and commitment, may have suffered from a lack of shared, underlying vision for the technology. The same could be said about the broader stakeholder dialogue, where there was a common understanding of barriers, but less closure in the construction of the technology itself.

The notions of interpretive flexibility, stabilization and closure are related to different stages in innovation uptake, and have also been associated with the shifting phases in sustainability transitions (de Haan et al 2014). A stage of predevelopment and low stabilization will reach a turning point, after which an innovative technology either breaks down or takes off, with increasing stabilization. Acceleration is followed by another phase of low stabilization, before the successful solution enters a more steady path towards transformation. In the studied case, modern RWH seemed to be at a quite early stage, and our findings suggest that this, in itself, affected the overall sustainability of the solutions.

In all, our results and experiences highlight the complexity of factors influencing the sustainability of RWH as source of water supply. Beside system efficiency, short-term economic impacts and acceptability, usability and scope for entrepreneurship came out as the most influential variables in the preliminary assessment. The latter criteria fall within the wider factors and benefits influencing the dissemination of RWH that Campisano et al (2017) advocate for further research on.

While much sustainability research relates to universal indicators, this study makes the point that overall sustainability will depend on contextual factors. Our findings highlight the influence of local infrastructural and socioeconomic constraints, while also pointing to important, long-term benefits, such as water-sharing and additional income opportunities, that may be more or less important in the local situation. Most importantly, local user practices varied greatly and will have considerable influence on the environmental, economic and social sustainability of the pilot systems.

The findings support the arguments for approaching social sustainability as a process as well as a condition (McKenzie 2004, Omann and Spangenberg 2002). We find that all the three strands of meaning identified by Vallance et al (2011) – that is development, bridge and maintenance sustainability – are important when discussing the sustainability of a specific technology. Coupling the criteria to system performance at indicator level maintains a linkage to the environmental dimension, as recommended by amongst other Littig and Griessler (2005) and Murphy (2012).

Our findings further suggest that not only the implemented technology, but the social construction from design and development, through to implementation, monitoring and stakeholder dialogue influences the potential, limitations and overall sustainability of RWH. This supports the arguments that it is important to look beyond 'objective data' and explore how stakeholders interpret and negotiate various aspects of the technology (Vallance et al 2011, Madsen et al 2017). It also indicates that the stage of innovation uptake and transition in the given water governance system will affect the sustainability of a given RWH solution.

7. Implications

The findings indicate that RWH may be a useful adaptation measure and supplementary source of water supply in Greater Accra. For systems including filtration and UV disinfection it is, however, important to address risks and vulnerabilities linked to irregular power supply and maintenance. Different solutions should be promoted for different uses, and "basic" systems will be most sustainable in many cases.

While the initial costs are high, there is a considerable potential for cost reduction. Financial benefits will vary, depending on building structure, system type and use patterns. Non-monetarized benefits, such as convenience and being in control of one's own water source, plus the potential for wider social benefits, should be given more attention.

The dependence on user practices highlights the social dimension of sustainability. The influence of social construction on the development, functioning and presentation of the technology further underscores the need for more research on how stakeholder relations and sociocultural processes affect the sustainability of RWH. In the studied case, high interpretive flexibility seems to limit the potential for wide-scale innovation uptake. There is thus the need for further dialogue on the use and potential of the technology. For this, public-private partnership will be essential.

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