Household drinking water meters

Results of an exploratory study in Odisha

Samir Lal
Liby T Johnson
Siddharth Patil

Mohuda, Ganjam District, Odisha 760002

October 2024

Table of Contents

Introduction

Gram Vikas has been supporting rural communities in Odisha in establishing and operating drinking water supply systems that provide water on tap to every household in the village. The Village Development Committee, a representative democratic institution in the village, manages the operations and maintenance of the drinking water supply. The Jal Jeevan Mission envisages every rural household in India accessing drinking water through functional household tap connections, with Gram Panchayats and Village Water and Sanitation Committees managing the water supply systems. The experiences of Gram Vikas and the villages where it has supported such systems have been part of the process of strengthening the Jal Jeevan Mission for the past several years.

In the early days of Gram Vikas' interventions that started in the mid-1990s, the demand and supply of water was an uncomplicated matter in the villages of Odisha. There were few contestations, as users had limited needs and groundwater resources were abundant. The village-level committees could easily manage the system with fewer challenges. The households considered a flat user fee for water just and fair. Environmental, social and economic changes have since led to a very different situation.

There has been a significant shift in water consumption patterns at the household level. Water supplied through the piped water systems is now used for various purposes beyond drinking and domestic use, including livestock rearing, maintaining backyard vegetable gardens, and cleaning household vehicles. These changes have led to a wider disparity in water consumption across households, making flat fees for water use increasingly seem unfair and needing re-evaluation.

As water availability decreases and groundwater levels drop in many areas, effective water management becomes increasingly urgent. It is crucial to ensure that drinking water is available for households during critical periods of the day. A survey conducted by Gram Vikas in 2020 covering 26,893 households with functional household taps showed that 28% of the households had a 24/7 supply on all days of the year, while 46% had a supply on all days but at fixed times every day. Twenty per cent of the households had a 24/7 supply, but not all months of the year. All these households had a 24/7 water supply on all days of the year when their village-level piped water supply systems were commissioned.

Government agencies in the rural drinking water sector tend to view household water meters as unreliable equipment. The general belief is that users tamper with the meters, and there is little scope for the supply utility to adopt volumetric billing based on actual water usage. As such, user fee collection in rural water supply projects tends to be low, and it is believed that installing household-level meters is an exercise in vain.

Gram Vikas had installed household-level water meters in some of its early projects. However, these devices were of insufficient quality, which lack of sufficient quality of the devices led to operational issues and, ultimately, village communities abandoning them. In discussions, village-level committees operating the water supply systems have begun articulating the need for better information about water use to manage the systems better. The need for information about water supplied and used can be used to decide on more equitable water fee collection, allowing those who use less to pay less. Many committees also stated that knowing how much water is being used will help manage supply decisions better. In a few cases, the villages also mentioned the need for more regulation of water use, given the dwindling water resources.

In 2019, Gram Vikas reintroduced household water meters after obtaining better quality devices which were found to withstand local conditions. During 2019 to 2023, water meters have been included as a standard element of the piped water supply projects in 144 villages. The meters have been installed in 7,898 households with 39,074 water users.

The exploratory study

There are widespread apprehensions about the utility of water meters in influencing water use behaviours and enabling effective management of water supply systems. Gram Vikas has taken up household water meters as an integral part of the community-owned and managed piped water supply systems. This provides an opportunity to assess the effectiveness of water meters in enabling sustainability of piped water supply systems. As a first step, an exploratory study was taken up in villages where such meters were installed.

The study was carried out from May 2023 to February 2024 by Samir Lal, a development economist who was consulting with Gram Vikas at the time.

To meter or not? The answer looks emphatic enough

Acceptance

In villages where water scarcity has traditionally been an issue, the response from the community has been largely positive. Nearly every household interviewed as part of the study reported becoming more conscious of their water consumption as a result of the meters, and not a single one has proposed any changes to this system of meter-based water management and billing, which they find to be *bangsa* (meaning “good” in the local Saura language).

A majority of the respondents from these villages understand the purpose of the meters, and a sizable proportion of them support seeing this purpose fulfilled through the implementation of a system that utilizes the meters for billing. Far from unaccustomed, people are demanding such a system. The perception among those in villages where this system currently is in place will be further instrumental in determining a course of action; however, based on what most people seem to be saying, it seems straightforward - use the meters.

Economic sense

Analysis of data shows that volumetric tariffs are likely to generate higher revenues for the water supply system. Compared to a fixed-rate system, the revenue from volumetric billing was found to be 2% to 2.4% higher. It was also more equitable, with households using less water paying less than half of what they pay under a fixed-rate system. Conversely, for households with high usage, the cost was likely to be up to double what they pay under the fixed rate; that being said, a concurrent wealth analysis of these households shows that those using more water, and thus liable to pay higher costs, are the wealthier ones.

The response to volumetric billing has been overwhelmingly positive, with several respondents reinforcing their sentiments by emphasizing how impressed they are with everything. This level of enthusiasm indicates that the system isn’t just “passable” - it’s legitimately popular.

Results in detail

The study was planned in four parts.

Part-1: Household-level quantitative analysis of the factors influencing water consumption

- This was taken up in four villages in Gajapati district to assess the factors influencing water consumption at the household level

Part-2: Comparative analysis of water meter systems at the village level

- This part covered 11 villages in Gajapati and Ganjam districts to evaluate the impact of the meters on water consumption at the village level

Part-3: Perception and reception of water meters

- Taken up in 10 villages in Gajapati, Ganjam, and Mayurbhanj districts for exploring the qualitative impact of these water meter systems at the village and household level

Part-4: Water meter systems, cost equity, and sustainability

- A case study of Kamapalli village in Ganjam district with a comparative analysis of meter-based and non-meter-based billing systems to understand cost equity and sustainability related matters

The following sections provide a basic summary of findings from the four parts of the Study. Those interested in a more detailed report can access the full report prepared by Samir Lal **here**.

The study results need to be seen in the context of two serious limitations it suffers from. One, the sample size is very small, and two, all villages originally intended to be covered could not be included, for logistical reasons. Limited training was provided to the enumerators who conducted the household level interactions, and this has resulted in the process remaining incomplete in some cases.

In addition to sharing the results of the exploratory study, this document also identifies points for follow-up. The findings of this Study provide many points for how further, more rigorous and detailed analysis can be taken up. The final section discusses these recommendations.

Part-1: Household-level quantitative analysis of the factors influencing water consumption

This part examined the factors influencing household water consumption by analysing six months of data from village level ledgers for the period January to June 2022, in four villages - Saratal, TIA Colony, Kumundia, and Jhagadi - in Gajapati district of Odisha. These villages were selected because they were the only ones with household meters that used actual water consumption as the basis for billing. The villages had consistent records of usage and charges.

A total of 135 households were included in the analysis. The primary hypothesis tested was that household size, defined as the number of people living in the household for at least nine months of the year, was the most significant factor affecting water consumption. The analysis considered other independent variables, including:

- Wealth
- Proportion of children in the household
- Education level, measured by the highest number of years of schooling completed by a household member
- Village involvement, measured by the number of VDC meetings attended in the past year
- Primary water use, a dummy variable indicating whether bathing was the main use of water

The analysis reveals that household size is the only independent variable with a statistically significant impact on water consumption. As expected, larger households use more water. This insight, while intuitive, can still guide future water conservation efforts or inform pricing strategies, such as charging larger households at higher rates. Other variables showed mostly predictable trends:

- Wealth had a positive effect, as wealthier households tend to own assets that require more water
- Proportion of children had a negative effect since adults typically engage in more water-intensive activities
- Education had a negative effect, with more educated individuals likely to understand the need to conserve water
- Bathing as the primary use of water had a positive effect, as households that use water primarily for bathing were among the highest consumers

The only surprising result was the positive effect of village involvement (number of VDC meetings attended), which could be due to reverse causality—households that consume more water might attend more meetings to address their water issues. However, since none of these variables (except household size) were statistically significant, interpreting their effects is ultimately not meaningful.

Further investigation on a larger scale, with a more diverse sample, is needed. However, it is important to recognise that certain village-level factors - such as water availability and per-unit pricing - would be

excluded from any household-level analysis of factors influencing water consumption. These factors likely have some impact on usage. To address this, Part 2 focuses on the effect of metering on village water consumption, aiming to empirically determine whether metering is an effective method of reducing usage.

Given that household size was found to exert the most significant influence on household water consumption, efforts can be taken to ensure that larger households are getting the most out of the water meters. Villages with particularly large average household sizes should receive special attention when meters are being implemented, and water conservation methods should be promoted with a focus on minimizing consumption among each household member - reducing overall household consumption.

Part-2: Comparative analysis of water meter systems at the village level

This part of the Study assessed the impact of various systems of water meter implementation on water consumption at the village level. The analysis used village water consumption data for two months, collected with bulk meters that had been installed for the purpose of this study.

Data from eleven villages was available for analysis. These villages belonged to four categories.

Category-1: Villages following a volumetric tariff, in which each household is charged a per unit rate according to their meter reading	Saratal, TI Abas Colony, and Kumundia in Gajapati district
Category-2: Villages where water meter readings are taken, but households are charged the same fixed rate, regardless of what the meter reads	Kamapalli, Mitrapur, and Narayanpalli in Ganjam district
Category-3: Villages where water meter readings are not taken, and households are charged the same fixed rate	A Totapalli, DNT Colony, and Sarakat in Ganjam district
Category-4: Control villages with no household water meters	Upper Tendi and Hitchagandi in Gajapati district

Four villages were planned for each category, but some had to be excluded because they either failed to record the bulk meter reading on time, did not have a bulk meter installed, or had it removed (as in Ghodagagudi, where residents feared the bulk meter would reduce water pressure).

In these 11 villages data was collected during November 2023 to January 2024. The hypothesis was that water consumption would be lowest in villages with a volumetric tariff (Category 1), where costs are linked to usage. The average household consumption was derived by dividing the total water usage from the bulk meter by the number of households in the village.

The other independent variables were:

- Category (as listed above)
- Average household size
- % of ST households
- % of adults in the population
- Average education level
- Wealth (the 90th percentile for the village of the composite score used in Part 1)
- Inequality (the difference between the village's highest wealth score and the 90th percentile)
- Number of functional hand pumps
- Average number of VDC meetings attended in the last year (again, a proxy for village involvement)

Category was found to have a positive effect on village water consumption, which seems intuitive - the lowest category is the volumetric tariff, with each successive category incorporating the meters less and less (the final category, of course, being those without meters at all). However, this was only the case when all variables were included; when just Category was included, it had a negative effect (insignificant) and when both Category and Average Household Size (the previous study's lone significant variable) were

included, the effect of both were found to negative, and insignificant - both of which are reversed when all variables are included. The only commonality, in fact, is the lack of statistical significance across the board and low R-squared (which indicates the explanatory power of the model). This suggests that there is no way around it - the study is inherently flawed.

Eleven villages is much too small a sample for meaningful analysis. In fact, even the initially planned 16 villages would not have been enough. There is also too little a difference between Categories 1 and 2 for them to have been separated. The original purpose of this study was to assess the impact of meters on village water consumption, but it got convoluted because so many of the villages with meters are not using them at all.

Also, in retrospect, it was a mistake including Narayanpalli in Category 2, as it is more of a hybrid system - households are charged a flat rate of ₹ 30, in addition to which a volumetric tariff of ₹ 5.50 is applied to every kilolitre beyond 30 KL. This system is unique in this regard and, thus, defies category; furthermore, as will be elucidated by the following study, this system is quite popular.

Part-3: Perception and reception of water meters

This part of the Study sought to examine user perception of water metering in villages where household meters have been installed. This was done through semi-structured qualitative interviews with 340 households in 10 villages. The analysis presents results from 6 villages: A. Totapalli, DNT Colony, Kamapalli, Narayanpalli, and Mitrapur in Ganjam district and Ghodagagudi village in Mayurbhanj district.

Not every household in these villages was interviewed, as the enumerators faced challenges, especially in Ganjam district, in getting full participation. Some households were hesitant to engage, stating they “didn’t know what to say,” though many others responded with "I don’t know" to each question. It is possible that some households felt uncomfortable discussing topics they believed were outside their knowledge or authority, especially when speaking to perceived authority figures. This hesitation may stem from a fear of giving the wrong answer, which merits further exploration in future studies, as it is important that everyone in the community feels empowered to share their views.

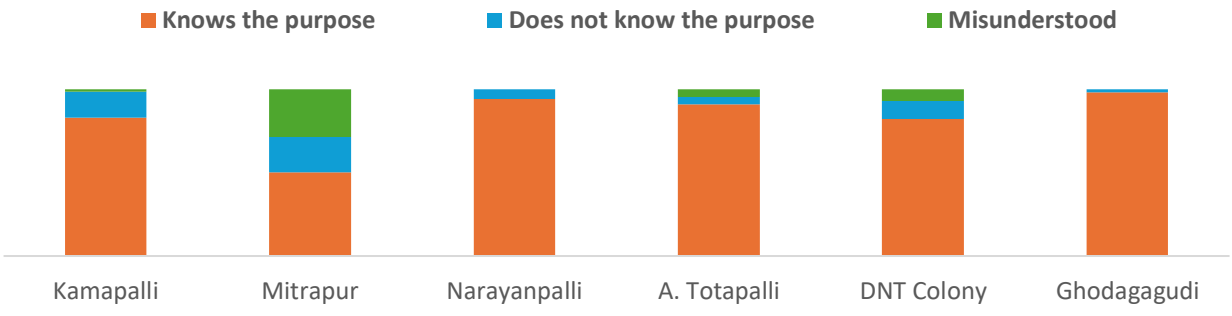
Three questions were asked to the households:

1. What is the purpose of a household water meter?
2. What has changed in your household since the installation of the household water meter?
3. What suggestions do you have for improving your village’s current meter system?

What is the purpose of a household water meter?

Responses to the question came in three forms:

- Correctly identified the purpose of a household water meter as a means of tracking/monitoring household water usage
- Unable to identify the purpose of a household water meter
- Misunderstood the question as “what is the purpose of piped water supply?”

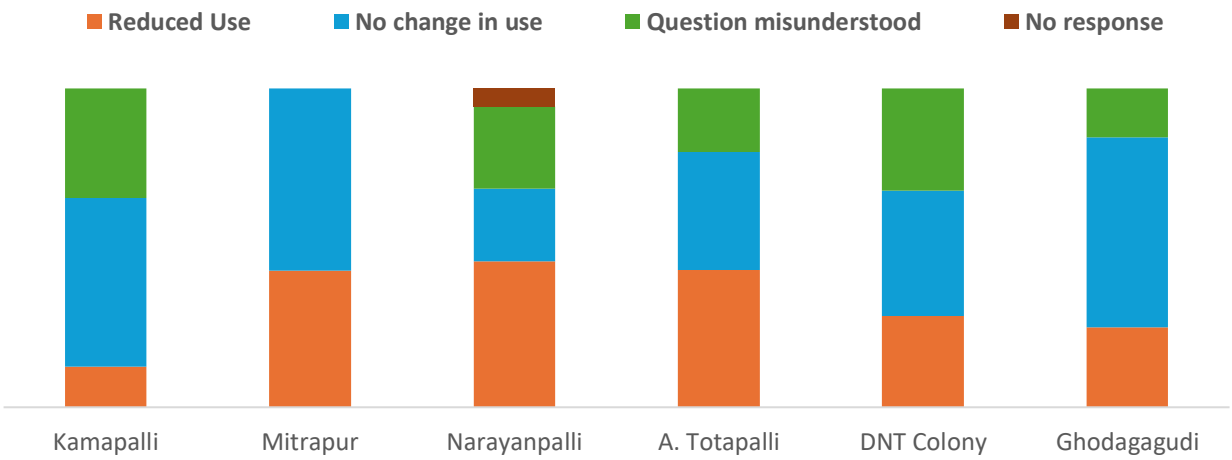


What has changed in your household since the installation of the household water meter?

The responses came in four categories:

- Reported curbing water usage as a result of the household meter
- Reported no change in water usage as a result of the household meter
- Misunderstood the question as "what changes have you noticed since the installation of piped water supply?"
- Did not provide a response (only in Narayanpalli village)

Among those who reported no change in water use as a result of the meters, one-third of the respondents in DNT Colony village indicated that they had always been conscious of the amount of water used and the meters did not add anything to it.



What suggestions do you have for improving your village's current meter system?

The households interviewed provided a wide range of responses. These could be categorised as follows:

- Provided no suggestions for improving the meter system, as everything is fine the way it is
- Suggested switching to a system in which households are charged per unit of water used, rather than the current fixed rate system
- Wanted the village committee to address maintenance-related issues
- Unable to provide any suggestions for improving the meter system, as it is not fully understood how the system works
- Stated that personal feelings about the meters did not matter, as ultimately whatever the village decides to do must be abided by regardless
- Falsely believe that the current system is based on usage
- Merely described the system and were not probed further by the enumerator to provide any feedback

In most villages, most respondents were aware of the purpose for installing meters. The one exception is Mitrapur, in which just half of all respondents identified the correct purpose, while over a fifth of the village was not able to do so. This can potentially be explained by the fact that Mitrapur is also reported to have the lowest average level of education per household, at around four years of completed schooling; however, this analysis is complicated by the fact that almost 30% of respondents misunderstood the question and were not further probed with the correct question by the enumerator.

The enumerators were not fully effective in conducting the interviews, likely due to their background in quantitative surveys and lack of training in probing and rephrasing for qualitative research. This led to many unusable responses, including irrelevant answers related to the piped water supply system. While results can be interpreted to some extent—especially in villages like DNT Colony, where most residents advocate for reform—many irrelevant responses in other villages hinder meaningful analysis.

It can be argued that the mere act of taking readings, thereby shedding at least some light on a household's consumption patterns, can influence that household's future consumption. Based on the results of the previous study, though, it appears that those in villages not taking meter readings exhibited higher average household consumption.

Given that non-meter-based systems were shown to be associated with higher water consumption, the importance of utilizing the meters properly should be emphasized across all villages in which they are installed.

Part-4: Water meter systems, cost equity, and sustainability

This part explored the cost equity implications of both meter and non-meter-based billing structures, focusing on one village in which both have been used at different points: Kamapalli. At the time of the study Kamapalli was charging a fixed rate of ₹ 60 per month per household, regardless of water use. Previously, there was a volumetric tariff of ₹ 5.50 per kilolitre, but that was abandoned due to concerns by the VDC that this was not earning sufficient revenue to meet the costs of operations and maintenance.

Another reason given by the Committee for not continuing with readings was that the meters became foggy and difficult to read. This seems an implausible reason, particularly because meters come equipped with a wiper specifically for cleaning the fog. Either the function of the meters was not properly explained, or this was simply used as an excuse.

Data of household meter readings maintained from June 2022 was used to analyse alternate scenarios of revenue generation potential. Two alternatives for volumetric billing were considered.

- A higher volumetric tariff of ₹ 8 per kilolitre, in place of the ₹ 5.50 that the village had used
- A tiered system based on use:
  - between 0-10 kilolitres a month at ₹ 7 per kilolitre
  - between 10-20 kilolitres a month at ₹ 8.50 per kilolitre
  - between 20-30 kilolitres a month at ₹ 10 per kilolitre

These figures were arrived at by experimenting with different rates to see which would yield at least as much revenue as the ₹ 60 fixed rate; for the tiered system, figures were chosen which were equidistant from one another, and these figures were further tested to ensure that households falling into the lower tier of usage would be paying less than ₹ 60 a month while also maintaining the minimum revenue requirement set by the ₹ 60 fixed rate.

Both alternatives generated more revenue than the current fixed rate, with the tariff of ₹ 8 per kilolitre giving an increase of 2.5% in revenue and the tiered system resulting in an increase of 2.4%.

Both alternatives also resulted in lower costs for a significant portion of the village.

- Raised volumetric tariff (₹ 8 per kilolitre)
  - Over half of the village would pay less than the current ₹ 60 fixed rate
  - More than 20% would pay less than ₹ 30
  - About 9% of households would pay at least double (≥ ₹ 120)

- Tiered system
  - Nearly 60% of households would pay less than ₹ 60
  - Close to 30% would pay less than ₹ 30
  - The same 9% of top-tier users would pay more than double the current rate

It is quite likely that those falling in the top tier of usage (20-30 kilolitres per month) would reduce their usage to avoid paying the highest rate of ₹ 10 per kilolitre. This would substantially reduce total revenue, putting the VDC in the same predicament that led them to revert to the fixed rate in the first place. Thus, if

raising revenue is the primary concern, then perhaps the superior alternative would be the higher volumetric tariff of ₹ 8/kilolitre, which would result in 14.3% more revenue collected from the nearly 70% of the households in the village that use less than 10 kilolitres per month, taming the impact of reduced usage among those at the top.

As Part-3 of the study indicates, people are more than willing to pay for water if it is done in an equitable way - specifically, if they are charged according to how much they are using. Of course, any form of technology which has been implemented in a village cannot be sustained without generating the revenue to cover the costs of operations and maintenance. The case of Kamapalli demonstrates that the best system for satisfying both the need for equity and sustainability is in fact a meter-based system.

Recommendations for more detailed understanding

A major limitation of the exploratory study was the small sample size. The next step therefore would be to expand the study and conduct it a lot more intensively at the village and household level. Ideally, in any robust comparison study, demonstrating parallel trends is essential - without this, any observed differences following treatment cannot be linked to treatment itself. In the future, with better planning and implementation, a more rigorous study can be undertaken - with a qualitative component as well, to inform how the intervention is carried out.

Following are some recommendations for future work in this direction, based on the experience of the four parts of the exploratory study.

Household level analysis on factors influencing water consumption

This has great value for contextual purposes. The idea of charging larger households a higher volumetric tariff is actually pointless. These households, as the evidence demonstrates, are already going to consume more water - thus, under a regular volumetric tariff, they will naturally be paying more per month. However, there would be both contextual and potentially policy value in expanding the study to cover a larger and - most importantly - more heterogeneous sample of households, which would then mean that more villages would need to be included by extension.

Heterogeneity, in this context, would mean more variation across the previously homogeneous inputs, including (but not limited to): religion, caste, climate, head of household (i.e. male or female), and perception of piped water (i.e. necessary or unnecessary). By surveying households across a larger sample of villages, heterogeneity is likely to emerge organically. As long as the metered villages are relatively evenly dispersed across multiple districts, each with their own unique demographic characteristics, then randomization is already somewhat built-in; however, if metering has been concentrated mostly in one or two districts, with the others only having a few metered villages, efforts will need to be taken in order to create a purposive sample - that is, a sample which selects specific villages for inclusion that represent different potential combinations of inputs, in order to ensure that all of these combinations are equally represented across the sample.

Also, it may be beneficial to conduct this as a longitudinal study, over a period of time longer than six months to observe seasonal and other time variant trends. These can inform billing structures which incorporate time-of-season pricing, in which the volumetric tariff increases during periods of heavy water demand and decreases/stabilizes during periods of low/moderate water demand.

Village level analysis on consumption

This can empirically link water metering to decreased water consumption. Much needs to be done to see it reach this potential. A sample with significantly more villages, at least 100, is required to assess the impact of metering, with village level bulk meters installed. An impact assessment study with a much more varied and robust sample of metered villages can be undertaken, which can then be matched with an equally large and varied control group of unmetered villages. Such a study is likely to obtain far more reliable results.

This would, of course, require a bigger team. A large deployment of enumerators, all thoroughly trained, is crucial for this scale of survey administration to be possible.

There should also be a survey of the billing systems used by the villages, and this information should be stored in a database for reference. Future research would greatly benefit from this, as it would be much easier to determine what needs to be done and where when it can be confirmed, instantly, what is currently being done and where. Information on groundwater potential and water sources across the metered villages will also be needed, which will require activities such as aquifer mapping and the identification and measurement of village water sources (most likely using GIS), as well as assessment of water source sustainability.

The potential of bulk meters is also quite vast. With bulk meters, village water consumption trends can be tracked across several seasons to identify those in which demand is relatively higher and those in which demand is relatively lower. These can then be designated “peak” and “off-peak” periods, each which would have different corresponding volumetric tariffs. These “macro” trends across villages can complement “micro” trends across households within a given village (using Study 1’s household level observations over time). At an even more macro level, if similarities in consumption are observed across villages within a given Gram Panchayat (GP), or even across an entire Block, then time-of-season pricing can be scaled up and standardized across the GP, or Block, if trends are consistent at that level. Of course, it would be necessary to first verify through longitudinal observation (i.e. no less than two years) whether consumption patterns maintain consistency across each village at the macro (GP or Block) level.

A detailed analysis where water consumption has reduced

Based on the results of the village level analysis, if it is determined that water metering has a statistically significant downward impact on water consumption, then a study which looks at which particular village-level inputs in metered villages are most effective in producing this impact would be justified and, in fact, quite useful.

Inputs assessed should include:

- Per unit rate charged
- Strength of VDC
- Water availability/groundwater potential/water source sustainability (whichever is deemed most relevant)
- Average education level
- % of adults in the village
- Caste/tribe/religion composition

Qualitative impact assessment of water meters

This has immense potential, if it is conducted properly with enumerators sufficiently trained in qualitative research methods. These would include the ability to probe or rephrase a question when an irrelevant response is given, which would as a prerequisite require the enumerators to fully understand the purpose of the question itself.

There can, in fact, be even more qualitative variables included - perhaps “level of trust in water meters” (which can be a number 1-10 that respondents are asked to provide in response to the question “On a scale of 1-10, how much do you trust the water meters to accurately report your consumption?”) or “number of cultural/spiritual ceremonies which involve the significant use of water” (which can again be a number that comes from respondents listing all of the various ceremonies they partake in that use a significant amount of water, with what constitutes “significance” being predetermined ahead of time).

It will be interesting to pair wealth analysis with specifics for the individuals and their perceptions of metering (i.e. “this household with a wealth index score of ___ reported dissatisfaction with the current system”) to conduct some insightful in-depth analysis of the intersection between wealth and perception

of meters (i.e. __% of those in the top 10% of wealth index scores said ____, while ___% of those in the bottom 40% of wealth index scores said ___).

A comprehensive ethnography of the various cultural groups which comprise the villages may be worthwhile, as it is possible that there are differences in practices and norms surrounding water use. This would get captured by variables controlling for caste/tribe/religion, but with the caveat that numbers have limits and should not be relied upon as the sole source of analysis. This is why a measured approach, which is informed by both quantitative and qualitative components, should be taken.

Understanding equity and sustainability

- Expand to a larger sample of villages, some of which are using a volumetric tariff and an equal amount of which are using a fixed rate; ensure that both groups are heterogeneous - either through randomization or purposive sampling.
- Determine the O&M costs for each of these villages to calculate a working ratio and identify the minimum revenue amount needed for the system to be sustainable.

Then, directly compare which is more effective in collecting the identified minimum revenue amount; alternatively, if a large and varied sample is not feasible, this can be scaled down to just one village as long as at least the second step is followed. If it is indeed possible to do a multi-village comparison, with randomization, then the analysis can further be strengthened by comparing the revenue generation potential of the volumetric and fixed approaches to billing with that of a tiered system in which different rates correspond to different levels of use - and if not many villages have currently implemented such a system, then a group of villages can be randomly or purposively selected to do so for the purposes of this comparison.

Finally, regarding cost equity, in addition to evaluating whether those at lower levels of *consumption* would be paying less under a meter-based system, what would be even more insightful would be evaluating whether those on the lower end of the *wealth spectrum* would be paying less under such a system. This can be done by simply applying the proposed volumetric tariff/tiered rate to the meter reading data on household consumption and then matching those households to their previously calculated wealth index score.