Higher than you think: the Invisible Costs of Water and Sanitation Services Embedded in Housing

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1. Introduction

How much does it really cost for households to use water from piped water networks in their homes and to remove and treat wastewater from their homes? The answer to this question is important because the United Nation's Sustainable Development Goal (SDG) 6 for water says that water services should be both "affordable" and available "on the premises." In other words, the international community no longer deems it sufficient for households to have a potable water source near their residence if they have to walk from their home to the source to collect water (United Nations, 2020). This paper shows that the services households want from piped water and sanitation networks are much more expensive than is commonly appreciated because approximately half of these costs are invisible and embedded in the cost of the housing stock, i.e., in the in-house plumping, fixtures, and appliances, the added indoor space required for these appliances, and the costs of connecting the piped water and sewer networks to the house.

Water and sanitation professionals typically think of the costs of the piped water network to get potable water to the home and the cost of collecting and treating a household's wastewater as the main financial barriers to providing poor households with modern water and sanitation services. This paper demonstrates that there are large financial costs embedded in housing that are also required for households to take full advantage of these piped water and sanitation networks. The affordability challenge in the Global South is thus much greater than is commonly appreciated because many households lack not only piped water and sanitation network infrastructure, but also modern housing with indoor plumbing.

This paper explores the relationship between the affordability of water and sanitation services (SDG 6) and the affordability of housing (SDG 11) by looking at five illustrative cases on a housing-water development path. Each housing-water case has a different combination of 1) public water and sanitation infrastructure outside the house; 2) private infrastructure outside the house; and 3) private infrastructure inside the house. The literature on the costs of water and sanitation services has focused on the first and second cost components (Whittington et al. 2009). The third cost component has been largely invisible to water sector planners and policy analysts, but has important implications for their assessment of the affordability of water and sanitation services and the feasibility of meeting SDG 6.

The paper is organized as follows. The next, second section of the paper provides more background on the SDGs for water and housing and the affordability benchmarks in these two sectors. The third section describes how households undertake five main water-using activities and their relation to housing type. The fourth section introduces the concept of a housing-water development path presents five illustrative housing-water cases. The fifth section presents our analytical approach for estimating the financial costs associated with different combinations of 1) public water and sanitation infrastructure outside the house; 2) private infrastructure outside the house; and 3) private infrastructure inside the house. The sixth section presents the results of these calculations, and the seventh section concludes with some observations about the costs of water and sanitation

services embedded in housing and why they have been largely ignored by water, sanitation, and hygiene (WASH) professionals.

2. Background: Sustainable Development Goals for Water and Housing

Most of the United Nation's Sustainable Development Goals (SDGs) emphasize that the goods and services to be provided should be "affordable" to everyone. Both the water and sanitation and the housing sectors have rules of thumb that suggest what percent of a household's budget is an affordable expenditure for that service. Water professionals have a guideline or social norm that 3-5% of household income is an "affordable" expenditure for water and sanitation services (World Bank Water Demand Research Team 1993, MacPhail 1993). This 3-5% rule of thumb does not specify the level of water and sanitation service to be provided. Most water and sanitation network services in the Global South are heavily subsidized; many households do not even pay the full operation and maintenance costs of the network services they receive, much less the capital costs (Danilenko et al. 2014). Thus, this 3-5% threshold is rarely exceeded if network services are available. Most households with piped water and sanitation services spend less than 2 percent of their income on their water bill.

The United Nations' Sustainable Development Goal (SDG) 6 is to "ensure access to water and sanitation for all." Within SDG6, there are two targets that relate to water and sanitation: 1) "By 2030, to achieve universal and equitable access to safe and affordable drinking water for all" (Target 6.1); and 2) "By 2030, achieve access to adequate and equitable sanitation and hygiene for all and end open defecation, paying special attention to the needs of women and girls and those in vulnerable situations" (Target 6.2). These targets are measured with three indicators: 1) "Proportion of the population using safely managed drinking water services" (Indicator 6.1.1); 2) "Proportion of population using safely managed sanitation services" (Indicator 6.2.1a); and 3) "Proportion of population with handwashing facilities with soap and water at home" (Indicator 6.2.1b). The definition of "safely managed" in Indicator 6.1.1 is that "… people must use an improved source that meets three criteria: 1) it should be accessible on premises; 2) water should be available when needed, and 3) water supplied should be free from contamination."[2]

The requirement that water be available "on premises" to meet SDG 6 brings water to a homeowner (or renter's) property, but not necessarily inside the house. For example, a yard tap or handpump on the homeowner's property would meet this criterion. However, from the household's perspective this level of service hopefully would be only a temporary stage on the housing-water development path. Households want piped water and wastewater services so that they can use water inside the house, which entails private investments in plumbing, fixtures, and appliances, as well as increased floor space.

[2] See the definition of "safely managed": https://washdata.org/monitoring/drinking-water

SDG 11 is to “Make cities and human settlements inclusive, safe, resilient and sustainable”; one of the targets is to “ensure access for all to adequate, safe and affordable housing and basic services and upgrade slums.” But there is no indication in SDG 11 as to what basic services such as water supply and sanitation should occur inside the house and which may occur outside. Like the WASH sector, the housing sector has defined affordability guidelines in terms of the percentage of income that a household can afford to spend on housing. The widely accepted benchmark is that a household should not have to spend more than 30% of its income for housing (Herbert et al. 2018, United States Department of Housing and Urban Development, 2019). This 30% of income is assumed to include utilities, such as water and sanitation services, electricity, fuel for heating and cooling, and telecommunications (e.g. phone, internet). So, if a household spent 5% of its income on its water and sewer bill (the maximum amount that would be affordable under the common-cited water affordability benchmark), it would need to spend less than 25% of its income on housing and other utilities, in order not to exceed the housing affordability benchmark.

3. Five Household Water Use Activities

Households use water in or near their home for five main activities. First, households need small amounts of water for drinking and cooking (approximately 5-10 liters per capita per day). Second, households use water for washing themselves and their possessions (e.g., dishes, clothes, their houses, tools, bicycles, and automobiles). Third, many households use water for feces and urine disposal. Fourth, households provide water to both indoor and outdoor plants, both for growing food and for aesthetic purposes (e.g. growing vegetables and watering lawns). Fifth, households provide water to their animals (e.g., pets and livestock) for drinking, washing, and food preparation.

Most of these water-using activities can be undertaken either indoors or outdoors, and with more or less technology and associated capital investment. For example, clothes washing can be carried out at a river with no capital equipment; outside the house but on the premises; inside the home in a bathroom using a bucket and soap; or inside the home using a washing machine. Similarly, dishwashing can occur outside the home at a surface water source such as a pond or river; outside the house but in the yard using water from, for example, a private handpump; or inside the home at a sink washing by hand or using a dishwasher. Urine and feces removal can occur away from home (e.g. open defecation or an offsite public latrine), on the premises but outside the home (e.g., a pit latrine), or inside the home (e.g., a water-sealed toilet connected to septic tank or a sewer line).

Using water inside the home requires that housing units themselves change to accommodate more water-using activities. These changes in the housing units are costly and take time and money for households to implement. There are three main reasons that carrying out these five water-using activities inside the home is more expensive than using water outside. First, the house needs plumbing to convey water to different rooms and to remove the wastewater from the dwelling. The more water-using activities carried out inside the house, the more extensive and costly plumbing required.

Second, in addition to plumbing costs, households must purchase (or rent) the appliances and fixtures needed to carry out the water-using and wastewater disposal activities. Kitchens require sinks, faucets, and perhaps a dishwasher. Clothes washing may involve the purchase of a washing machine. Feces and urine removal requires water-sealed toilets. Bathing requires a bath tub or shower fixtures. Washing dishes, clothes, and bodies is more effective and pleasurable with hot water, which requires the installation of a hot water heater and more plumbing (hot and cold water lines to different rooms).

Third, houses need to be larger to accommodate these water-using activities--and thus are more costly. A washing machine requires floor space. A dishwasher requires a larger kitchen. A toilet and a shower require floorspace in a bathroom. Two toilets and two showers entail more plumbing and more floor space.

Some housing units in developing countries are too small for members of the household to do any water-using activities inside. There is simply no room for a sink, toilet, or shower. For example, median floor space in a one-room slum dwelling in cities in India is about 11 m^3 (Gupta and Gupta 2017, Naik 2015, Bag et al. 2016). All available floor space is allocated for beds for sleeping and perhaps one chair for sitting. But even in high-income countries, it is common for some housing units to be too small to accommodate all of the possible indoor water-using activities. For example, at the beginning of the 20th century many flats in multifamily buildings in high-income countries were designed without plumbing for a shower or hot water heaters.[3] Even after the Second World War it was common in many countries to design multifamily buildings with a dedicated room for communal clothes washing (and drying) and a centralized hot water system that served all flats.

Although in developing countries public sector water supply and sanitation network services are heavily subsidized to make them more affordable to households, the private costs of water and sanitation services that are embedded in housing costs are typically not subsidized.[4] Yet for households to make full use of the public water and sanitation network infrastructure, they need a housing unit with in-door plumbing, fixtures, and appliances. If a poor household receives heavily subsidized piped water services delivered to a yard tap outside on their premises, it cannot necessarily afford a house with sufficient floor space for indoor plumbing, fixtures, and appliances. The value of the subsidized public infrastructure to such a household will be less than for a household that can afford these private costs embedded in their housing.[5]

[3] Personally, when I was a student in London in 1970, I lived in a 2-room flat (approximately 50 square meters) in a multi-family building with a roommate (a 7-story walk-up; not a dormitory). The only plumbing inside the flat was a cold-water line to the kitchen and a toilet; there was no hot water, shower or bath, much less a washing machine or dishwasher. We bathed in public facilities or at a neighbor's flat who had a bathtub and hot water.

[4] Of course, there are subsidized housing programs in both low and high-income countries. See, for example, Phang et al. 2014 for a discussion of Singapore's public housing program.

[5] Of course, having a yard tap outside the home may eliminate the need for the household to carry water from a public tap and thus save the household time. Such time savings can be valuable (Whittington and Cook 2019), but the housing stock may still preclude the

As governments in developing countries and donors struggle to finance and expand public water supply and sanitation infrastructure, households struggle to finance the private costs of water and sanitation services both inside and outside their housing units. The timing and sequencing of the public and private investments necessary to enable households to use water in their house need to be coordinated. Land and housing markets provide this coordination function to some extent (Bertaud 2018). There is little point in a real estate developer building a multifamily apartment building with water-sealed toilets in each flat if there is not piped water network available and no way for the developer to self-supply water to the building. Real estate developers will thus assess the likelihood that the public sector with succeed in bringing network services to different land parcels and bid for the land accordingly. Similarly, there is little point in the public sector building infrastructure such as sewerage systems and wastewater treatment plants if households cannot afford water-sealed toilets in their homes or a connection to a sewer line. But such planning requires that the public sector be able to forecast demand for sewer connections, a skill that it often lacks, in part because there are no financial penalties to a city planner from poor forecasts.

4. Housing-Water Development Path: Five Illustrative Cases

As shown in Figure 1, as their incomes grow, households typically move along a housing-water development path on which more and more of these water-using activities occur inside the home (with the obvious exceptions of outdoor gardening and lawn-watering and watering livestock). To illustrate the full financial costs of household water use, we use five illustrative cases of housing units of different sizes and with different combinations of water and wastewater facilities inside and outside the dwelling. The five cases were selected to show different situations on a housing-water development path, for a very poor household with most water use activities outside a small house to a relatively rich household with most water use activities occurring inside a large house.

Figure 2 and Table 1 summarize the five housing-water cases. The first housing-water case is a small, one-room house or flat without any indoor plumbing in a low-income country. Water and sanitation services are only available of the premises (e.g., public tap and public latrine), and, except for drinking, water is not used inside the house. The second housing-water case is a two-room house with limited indoor plumbing (kitchen sink, shower, but no toilet, clothes washer, or hot water heater) in a low-income country. The house is connected to a piped water distribution system, but is not connected to a wastewater collection system. A pit latrine on the premises is used for feces and urine disposal. Greywater is discharged to natural water runoff systems, open neighborhood drains, or soak pits.

The third housing-water case is a small modern apartment in a multifamily building in a middle-income country. The flat is connected to a piped water distribution system, and a wastewater collection system, but the wastewater is not treated. The flat has indoor plumbing except for clothes washing (which is assumed to be done

household from taking further advantage of the public infrastructure.

in the building in a communal facility or outside the building in a laundromat or through an individual offering the service).

The fourth housing-water case is a larger flat in a multi-family building in a high-income country, again without clothes washing but the sewer collection system is connected to wastewater treatment facilities. Finally, the fifth housing-water case is a modern, single-family house with complete indoor plumbing and appliances in a high-income country. This house is connected to a piped water network and a sewage collection treatment with associated wastewater treatment facilities.[6] For each of these five housing-water cases, the full financial costs required for the household to engage in water activities are estimated, and the costs of the publicly-provided infrastructure services are compared with the private costs incurred by the household inside and outside their house.[7] In the next section, we describe how we estimate these costs.

5. Analytical Strategy

This section of the paper describes the analytical strategy and assumptions used to approximate the financial costs of a) the public infrastructure required to deliver water to a house, and remove and treat a household's wastewater; b) private costs outside the home; and c) private costs of using water inside the house (pumping and appliances, including operating and maintenance costs and connection to the public infrastructure networks). Calculations are made for monthly household water and sanitation costs for each of these three components for the five housing-water cases.

The distribution of the total financial costs between households and the public sector is important for the assessment of household affordability. Because water tariffs in the Global South are heavily subsidized, taxpayers (and perhaps donors) bear the majority of the financial costs of the public infrastructure. However, in most cases households themselves pay directly the private costs outside the home; and private costs of using water inside the house. Many households without water and sanitation facilities on their premises may also incur additional "coping costs" in using off-site facilities and in treating and storing poor quality water supplied by the public network infrastructure (Pattanayak et al. 2005; Cook et al. 2016). For example, households using to public taps and latrines will spend time to and from such facilities. Some households will incur additional health expenditures from drinking poor quality water. Whether such coping costs should be included in affordability metrics for monitoring progress toward the SDGs is a question of active discussion (WHO-UNICEF Joint Monitoring Programme, 2018). The analytical strategy used here is to present estimates of both 1) the financial costs of a household using different levels of public water and sanitation services and the

[6] There are, of course, houses in the fourth and fifth cases in low-income countries, and houses in the first, second, and third cases in high-income countries. The five housing-water cases selected for analysis in this paper are simply illustrative; they do not exhaust the possibilities.

[7] In this paper we assume that the water and sewer networks are publicly owned and operated. We acknowledge that some networks are privately owned and operated, but this distinction is not important for the purposes of this paper. Note also that the household may bear part of the financial costs of the publicly-owned and operated infrastructure through the water bills it pays.

financial costs embedded in their housing unit; and 2) the costs incurred by households themselves, including coping costs.[8]

These calculations show more clearly both the financial costs of the public water and sanitation sector infrastructure compared to the private financial costs embedded in the housing stock, as well as the financial costs of a household's use of water and sanitation services at different stages on the housing-water development path. The cost estimates from the household perspective that include coping costs show more clearly the affordability challenges for each of the five housing-water cases.

The unit of analysis is the household; the time period is one month. Costs are expressed in current US dollars. The cost estimates are only intended to indicate approximate relative and absolute magnitudes; actual costs will vary by location due to supply and demand factors in the housing market, the governance and organization of the water and sanitation sector, and the local water resources situation. In some cases, costs will be much different than the illustrations presented here. However, we believe these calculations are sufficiently accurate to gain several important insights about the affordability of water and wastewater services when the private costs of water and sanitation embedded in housing are considered.

Financial costs of the public infrastructure required to deliver water to a house, and remove and treat a household's wastewater

To estimate the household-level costs of delivering water to the perimeter of the dwelling, assumptions are made about the costs per cubic meter for water supply, for wastewater collection, and for wastewater treatment in a low-, middle- and a high-income country and the monthly water use of a household living in housing-water case i (i = 1-5). Table 2 presents the costs estimates for three different components of the public piped water and sanitation infrastructure, as well as monthly costs of public taps and public latrines not located on-site, i.e., not on the premises of the household's dwelling unit, and private latrines located on-site.

For several reasons, household monthly water use from the public piped network is assumed to vary across these five housing types. First, households living in more expensive types of housing have more water-using appliances indoors and will thus have higher water use than households living in poor houses, controlling for household size. Second, for a given housing-water case and household size, richer households will choose to use somewhat more water and can afford to pay the higher water bills.[9] If a household on the lower end of the housing-water

[8] The financial costs of a household using different levels of public water and sanitation services and the financial costs embedded in their housing unit include the public subsidies that households do not pay in their water bill, but not the private coping costs such as time spent collecting water. The costs incurred by households themselves, including coping costs, do not include the public subsidies.

[9] There is strong empirical evidence that the elasticity of residential water use with respect to income is positive in both industrialized and developing countries (see Dalhuisen et al. 2003, and Nauges and Whittington, 2009).

development path does not have a toilet, we assume it is not connected to a sewage collection system and its water use does not impose wastewater collection or wastewater treatment costs on the public infrastructure systems (although negative externalities could certainly be imposed on the household's neighborhood by the use of a public latrine or a pit latrine outside the house).

Based on a household with 5 members, the following monthly household water use quantities from a piped connection are assumed for housing-water cases 2-5: 8 m^3 for housing type 2; 10 m^3 for housing type 3; 12 m^3 for housing type 4; and 20 m^3 for housing type 5 (Table 3). Multiplying the cubic meters households use in each housing-water case by the assumed costs per cubic meter (Table 2) yields an estimate of the monthly water and wastewater costs associated with the public infrastructure. Households in in housing-water case 1 do not have piped water on the premises; they are assumed to use about 4-5 m^3 per month from public taps.

Public and/or Private costs outside the home

Households with housing-water case 1 are assumed to use public taps provided by a public sector water utility, which are also assumed to cost US$3 per household per month. Housing types 1 and 2 do not have indoor toilets. Household members are assumed to rely on public latrines or pit latrines or water-sealed toilets (not connected to a sewer line) on their premises. These sanitation facilities are also assumed to cost a household US$3 per month.

Private costs of using water inside the house

In addition to the assumptions about monthly household water use, Table 3 presents a set of basic assumptions about household income and the value of the housing unit (and imputed monthly rent) in each of the five housing-water cases. A household living in housing-water case 1 (a simple one-room dwelling of 25 square meters in a low-income country) is assumed to have an annual income of US$2000 (US$167 per month). The market value of the house (US$8000) is assumed to be four times annual household income. Imputed monthly rent (US$42) is assumed to be 25% of monthly income.

A household living in housing-water case 2 (a simple two-room dwelling of 50 square meters in a low-income country) is assumed to have an annual income of US$5000 (US$417 per month). The market value of the house (US$20,000) is again assumed to be four times annual household income. Monthly rent (US$104) is assumed to be 25% of monthly household income.

A household living in housing-water case 3 (a modern flat of 60 square meters in a multi-family building in a middle-income country) is assumed to have an annual income of US$10,000 (US$833 per month). The market value of the house (US$40,000) is assumed to be four times annual household income and monthly rent (US$250) is assumed to be 30% of monthly household income.

A household living in housing-water case 4 (a modern flat of 100 square meters in a multi-family building in a high-income country) is assumed to have an annual

income of US$30,000 (US$2500 per month). The market value of the flat (US$120,000) is assumed to be four times annual household income. Monthly rent (US$750) is again assumed to be 30% of monthly household income.

A household living in housing-water case 5 (a modern single-family house of 250 square meters on a 0.15 hectare lot in a high-income country) is assumed to have an annual income of US$80,000 (US$6667 per month). The market value of the house (US$320,000) is assumed to be four times annual household income. Monthly rent (US$2000) is assumed to be 30% of monthly household income.

In order to make full use of the water delivered by the public sector to the house, a household must incur private capital costs and operating and maintenance (O&M) costs. Housing units that use network services provided by the public sector also incur costs to connect the house to the public piped network(s). The market value of the housing unit should reflect the capital costs of both the in-door plumbing, fixtures, and (to some extent) the appliances, as well as the private costs to connect the housing unit to the public piped water and wastewater collection networks. Thus, for each of the five housing-water cases, we estimate these private water and sanitation costs embedded in the housing unit as a proportion of the assumed market value of the house. The capital cost of the in-house plumbing, fixtures, and appliances – and connection costs- are assumed to be 12% of the value of the house, not including the value of the land. We assume that 20% of the market value of the house is the cost of land and 80% is the cost of the structure. So, the capital cost of the in-house plumbing, fixtures, appliances and connection to the public networks is …

Capital cost of in-house plumbing, fixtures, appliances, connection = 0.12 [0.8(Value of house)]

In effect, an increase in the market value of the structure is assumed to entail a proportionate increase in the costs of in-house plumbing, fixtures, appliances, and connection embedded in the housing unit.

The total capital cost of in-house plumbing, fixtures, appliances, and connection is multiplied by a capital recovery factor of 0.058 to obtain the annual capital cost. The capital recovery factor (CRF) assumes a real interest rate of 4% (i.e., net of inflation) and a 30-year average life of the capital stock. To calculate the monthly capital cost, the annual capital cost is divided by 12 …

Monthly capital cost of in-house plumbing, fixtures, and appliances = 0.058 [total capital cost]/12.

In addition to the capital costs of in-house plumbing, fixtures, and appliances, the household incurs operation and maintenance (O&M) expenses to use this capital. There are two types of O&M costs: 1) electricity costs of using electric appliances such as a hot water heater, washing machine, and dishwasher, and 2) periodic repair costs for toilets and appliances, and the plumbing system itself. These monthly O&M costs are assumed to be 20% of the monthly capital costs …

Monthly O&M Costs of in-house plumbing, fixtures, and appliances = 0.20 [Monthly capital cost]

The total monthly costs of in-house plumbing, fixtures, and appliances for each housing type is the sum of the monthly capital cost and the monthly O&M cost. Table 4 summarizes these assumptions and the key parameter values used in the cost estimates.

Household's Perspective

To better illustrate what the costs of using water and sanitation services look like from the household's perspective, we make two adjustments to the financial cost estimates described above. First, we assume that households in Cases 1, 2, and 3 only pay one third of the costs of the public infrastructure that they use. This means that these households pay approximately the operation and maintenance costs of the public infrastructure, but very little if any of the capital costs. Households in cases 4 and 5 are assumed to pay the full costs of the public infrastructure services they use.

Second, we assume that households in Cases 1, 2, and 3 incur additional "coping costs" to collect store, and treat water and to manage fecal waste (e.g. emptying private pit latrines). These coping costs are highly site-specific and the composition and magnitude of coping costs varies for different housing-water cases. For purposes of illustration, we assume that households in Cases 1-3 all incur coping costs of US$10 per month, which is indicative of coping costs in Kathmandu, Nepal (Gurung et al. 2017) and Ho Chi Minh City, Vietnam (Thuy et al., 2020).

6. Results

Financial Costs of Infrastructure required to deliver water to a house, and remove and treat a household's wastewater

Table 5 shows the results of the calculations for the costs required to deliver water to a house, and remove and treat a household's wastewater for each of the five housing types. For household-water cases 1, 3, 4, and 5 all of these costs are for public infrastructure. For household-water case 2, the costs for water are for public infrastructure and the costs for sanitation are for a private pit latrine on the premises built by the homeowner.

The total financial costs for these water and sanitation services vary widely, from US$6/mo for a household using a public tap and public latrine in the neighborhood in a low-income country using 4-5 cubic meters per month to US$100 per month for a household in a single family home in the high-income country using 20 cubic meters per month.

The largest absolute increase in monthly financial costs shown in Table 5 occurs on the housing-water development path from housing-water case 4 (US$60 per

month) to case 5 (US$100 per month). This is because this step from a multifamily dwelling to a single-family home entails a large increase in the volume of water used by the household, with a corresponding increase in the volume of wastewater that must be collected and treated.

The largest proportional increase in monthly financial costs occurs on the housing-water development path from housing-water case 2 (US$13 per month) to case 3 (US$32 per month). This is because this step entails the addition of the costs of wastewater collection, as well as an increase in both the volume of water use and the per cubic meter cost of proving water services.

Private WASH Costs Embedded in Housing

Table 6 presents the results of the calculations for the private monthly water and sanitation costs of in-house plumbing and appliances for each of the five housing types. As shown, the results vary widely, from US$11 per month for housing type 2 to US$178 for housing type 5. It is important to emphasize that these monthly costs do not include the costs of the public infrastructure to deliver water to the house, the cost of the sewerage collection network to remove wastewater from the house and treat it, for for housing-water case 2, the costs of a private pit latrine on the premises but outside the home. These are the private costs embedded in housing. The largest relative increase in monthly private costs embedded in housing occurs from housing-water case 3 (US$22 per month) to case 4 (US$67 per month) because this is the step on the housing-water development path with the largest increase in household income and thus housing value. The largest absolute increase in monthly private costs occurs on the housing-water development path from housing-water case 4 (US$67 per month) to case 5 (US$178 per month).

Total Monthly Cost Estimates for Housing Types

Table 7 presents the total monthly costs of water and sanitation services, i.e., the sum of the financial costs for public infrastructure, the costs of the private pit latrine on premises for housing-water case 2, and the private costs embedded in housing. Table 7 also presentthe ratio of private costs to total costs and the ratio of the total WASH cost to household income.

For housing-water case 1, all of the WASH costs are based on the public infrastructure because the household does not use water indoors. For housing-water cases 2, 3,4, and 5 the private WASH costs embedded in housing increase rapidly from US$11 per month to US$178 per month as household income and the value of the house increases. The total private and public WASH costs increase from US$24 per month (housing-water case 2) to US$278 (housing-water case 5).

For housing-water cases 2 and 3, 46% and 41% of the total WASH costs are private costs embedded in housing. This percentage increases to 53% for housing-water case 4 and to 64% for housing-water case 5. Given the approximate nature of these

calculations, these results suggest that about half of the monthly costs of using water and sanitation services are embedded in housing costs.

As a percentage of household income, the total WASH costs range from 4% of monthly income for housing-water case 1 and case 5, to 6% of monthly income for housing-water cases 2 and 3. Thus, viewed from the perspective of total monthly WASH costs, the affordability challenge as a percentage of income actually increases as households transition from low-income to middle-income status and try to bring water and sanitation services indoors, with ensuing high housing costs.

Household's Perspective

Table 8 presents cost estimates for households in housing-water cases 1-5, adjusting housing-water cases 1, 2, and 3 for the actual water bills they pay for subsidized public network services and the additional coping costs they bear dealing with unreliable, poor quality water from the public distribution system. For housing-water cases 2 and 3, the two adjustments leave the total WASH costs per month very similar to the total WASH costs in Table 7. The two adjustments -- removing the public sector subsidies from the public WASH costs and adding the coping costs-- effectively cancel each other out. However, for housing-water case 1, the coping costs are almost double the value of the public subsidies assumed for a public tap and public latrine. Total WASH costs for housing-water cases 4 and 5 remain unchanged because we have assumed these two adjustments were unnecessary for these two housing types.

As shown in Table 8, the WASH costs for public infrastructure that are paid by the household as a percentage of household income are low for all five housing-water cases, ranging from 0 percent for housing-water-case 1 to 2% for housing-water cases 4 and 5. Seen from the public sector perspective, water and sanitation services seem very affordable to households.

Table 8 also shows the total WASH costs paid by the household, including both coping costs (for housing-water cases 1, 2, and 3) and the private costs embedded in housing (for all five housing-water cases as a percentage of household income. These percentages are much higher, ranging from 6% for housing-water case 1, to 4% for housing-water type 5. The differences from the public WASH costs paid by the household as a percentage of household income are especially large for housing-water cases 1, 2, and 3. (5-6 times larger for housing-water cases 2 and 3). Moreover, in contrast to WASH costs for public infrastructure paid by the household as a percentage of household income, the percentage of total WASH costs paid by the household decline as income increases.

7. Conclusions

Households are largely unaware of the magnitude of the subsidies that they receive from the water utility. Water utility officials are largely unaware of the magnitude of the coping costs households incur dealing with unreliable, poor quality water supplies. Policymakers, WASH professionals, and utility managers

are unaware of the magnitude of the private costs embedded in housing that households incur to use piped network services provided by water utilities.

The calculations in this paper show that the costs to households of carrying out water and sanitation activities inside their houses is much larger than many people realize. As economic growth proceeds, and economies transition from low to middle-income status, the combined public and private financial costs of bringing water and sanitation activities inside housing units presents the state and households with an affordability challenge that has not been widely appreciated. The results show that—ignoring coping costs—that the ratio of total public and private WASH financial costs as a percent of income likely peaks in middle-income countries at around 7% of the income. In low-income and high-income housing-water cases, the ratio of total WASH cost to income is about 4%.

Economists have investigated whether household use is responsive to the average or marginal prices they face for infrastructure services such as electricity and water (Ito, 2014). For the water bills that households pay water utilities, it seems likely that many households respond to average water prices, not the marginal price signals embedded in complex tariff structures. However, in the case of the costs of water infrastructure embedded in housing, we believe that the vast majority of households treat these as sunk costs and not relevant for decisions about how much water to use. Indeed, households in high-income countries, who are paying the most to use water indoors, are largely unaware of these invisible costs. Using water indoors for cooking, washing, and waste removal is simply taken for granted as a normal, expected part of life. Households in high-income countries never envisage returning to housing units without indoor plumbing, and thus do not respond to the total average cost of using water in the five activities described in this paper. They may respond to marginal or average prices charged by water utilities for access and use of water from the public piped network, but these average price signals do not reflect the full private costs of water and sanitation embedded in housing units.

Poor households in developing countries at the bottom of the housing-water development path face different choices. For them the tradeoffs between using water outdoors at lower costs and bringing water-using activities indoors and incurring higher private costs are very real. Water policy analysts who look at affordability of water and sanitation services only through the lens of the costs of public infrastructure fail to see the tradeoffs facing poor households as they struggle to improve both housing and water conditions.

Policymakers working in the water and sanitation sector typically try to make services affordable by heavily subsidizing the public piped water and wastewater networks, and thus charging households far less than the costs of service. This strategy for making WASH services affordable does not reduce the invisible costs of WASH services embedded in housing. Moreover, it is likely to distort the housing-water choices that poor households make as they seek to advance along the housing-water development path. This is because households may expect low prices for network services to continue in the future when they make decisions today about the cost of bringing water-using activities indoors, when in fact such

subsidies are increasing hard for higher level government to sustain in an area of climate change and growing water scarcity.

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Table 1 – Attributes of Five Illustrative Housing-Water Cases

	Housing-water case 1 – one-room, thatched roof	Housing-water Case 2 – 2 rooms, concrete floor, metal roof	Housing-water Case 3 -Modern Flat in multi-family building	Housing-water Case 4 - Modern Flat in multi-family building	Housing-water Case 5 – Modern, single-family house
Location	Low-income country	Low-income country	Middle-income country	High-income country	High-income country
Size of housing unit (floorspace)	25 square meters	50 square meters	60 square meters	100 square meters	250 square meters on 0.15 hectare lot
Indoor water activities	None	Cooking, dishwashing, bathing, no hot water	Cooking, dishwashing, bathing, hot water	Cooking, dishwashing, bathing, hot water, but no clothes washing	Cooking, dishwasher, bathing, hot water (multiple sinks, showers), clothes washing
Indoor sanitation activities	None	None	One water-sealed toilet	One water-sealed toilet	Two water-sealed toilets
Public water facilities	None on premises (Public tap)	Piped water to premises	Piped water to premises	Piped water to premises	Piped water to premises
Public sanitation facilities	None on premises (Public latrine)	None on premises (Private pit latrine on premises)	Wastewater collection (but no wastewater treatment)	Wastewater collection & wastewater treatment	Wastewater collection & wastewater treatment

Table 2 – Assumed Costs for network and nonnetwork water and sanitation services, on and off premises (including costs per cubic meter for piped water supply, wastewater collection, and wastewater treatment in a low-income and high-income country)

Costs per cubic meter for … (US$ per m3)	Low-income Country	Middle-Income Country	High-income Country
Public tap/handpump (off premises)	US$3 per mo.	NA	NA
Public latrine (off premises)	US$3 per mo.	NA	NA
Pit latrine (on premises)	US$3 per mo.		
Piped Water supply	US$1.20 per m^3	US$1.60 per m^3	US$2.00 per m^3
Wastewater collection	US$1.20 per m^3	US$1.60 per m^3	US$2.00 per m^3
Wastewater treatment	US$0.60 per m^3	US$0.80 per m^3	US$1.00 per m^3
Total	US$3.00 per m^3	US$4.00 per m^3	US$5.00 per m^3

Based on estimates in Whittington, D., W.M, Hanemann, C. Sadoff, and M. Jeuland. (2009).

Table 3 – Cost Assumptions for five housing-water cases

	Housing-water case 1 – one-room, thatched roof	Housing-water Case 2 – 2 rooms, concrete floor, metal roof	Housing-water Case 3 -Modern Flat in multi-family building	Housing-water Case 4 - Modern Flat in multi-family building	Housing-water Case 5 – Modern, single-family house
Size	25 square meters	50 square meters	60 square meters	100 square meters	250 square meters
Monthly household water use from public piped water network	5 m^3 (from public tap)	8 m^3	10 m^3	12 m^3	20 m^3
Annual household income	US$2,000	US$5,000	US$10,000	US$30,000	US$80,000
Monthly income	US$167	US$417	US$833	US$2,500	US$6667

Value of house (4x annual income)	US$8,000	US$20,000	US$40,000	US$120,000	US$320,000
Monthly rent	US$42	US$104	US$250	US$750	US$2000

Note: For housing-water cases 1 & 2, the monthly rent/monthly income ratio = 0.25; and the house value/annual rent ratio = 16. For housing-water cases 3, 4, & 5, the monthly rent/monthly income ratio = 0.30; and the house value/annual rent ratio = 13.

Table 4: Key parameters and assumptions in the calculations

Parameter	**Value**
Household Income – Housing-water case 1	US$2000
Household Income – Housing-water case 2	US$5000
Household Income – Housing-water case 3	US$10,000
Household Income – Housing-water case 4	US$30,000
Household Income – Housing-water case 5	US$80,000
Housing value	4 x [household income]
Land Value/housing value	0.2
Cost of Structure/housing value	0.8
Capital Cost of in-house plumbing, fixtures, appliances & connection to public piped networks	0.12 [0.8(Housing value)]
Monthly rent/Monthly household income – Housing-water cases 1 & 2	0.25
Monthly rent/Monthly household income – Housing-water cases 3, 4 & 5	0.30
Capital recovery factor	0.058
Housing value/annual rent - Housing-water cases 1 & 2	16
Housing value/annual rent - Housing-water cases 3, 4, & 5	13
Monthly O&M Costs of in-house plumbing, fixtures, and appliances/ Monthly Capital Costs of in-house plumbing, fixtures, and appliances	0.20

Table 5 – Financial Costs of the Infrastructure for Five Housing-water Cases (including the private costs of private pit latrine on premises for Housing-water Case 2)

Level of Public water and sanitation service	Housing-water case 1 – one-room, thatched roof	Housing-water Case 2 – 2 rooms, concrete floor, metal roof	Housing-water Case 3 -Modern Flat in multi-family building	Housing-water Case 4 - Modern Flat in multi-family building	Housing-water Case 5 – Modern, single-family house
Pubic tap in neighborhood	US$3 per mo.	NA	NA	NA	NA
Public latrine in neighborhood	US$3 per mo.	NA	NA	NA	NA
Private pit latrine on premises	NA	US$3 per mo.	NA	NA	NA
Piped water service	NA	US$9.60/mo (US$1.20 per m^3 x 8 m^3)	US$16/mo (US$1.60 per m^3 x 10 m^3)	US$24/mo (US$2.00 per m^3 x 12 m^3)	US$40/mo (US$2.00 per m^3 x 20 m^3)
Wastewater collection	NA	NA	US$16/mo (US$1.60 per m^3 x 10 m^3)	US$24/mo (US$2.00 per m^3 x 12 m^3)	US$40/mo (US$2.00 per m^3 x 20 m^3)
Wastewater treatment	NA	NA	NA	US$12/mo (US$1.00 per m^3 x 12 m^3)	US$20/mo (US$1.00 per m^3 x 20 m^3)
Total Financial Cost (US$/mo)	US$6/mo	US$13/mo	US$32/mo	US$60/mo	US$100/mo

Table 6 – Private WASH Costs Inside the Dwelling (Embedded in Housing)

	Housing-water case 1 – one-room, thatched roof	Housing-water Case 2 – 2 rooms, concrete floor, metal roof	Housing-water Case 3 -Modern Flat in multi-family building	Housing-water Case 4 - Modern Flat in multi-family building	Housing-water Case 5 – Modern, single-family house
Value of house[1]	US$8,000	US$20,000	US$40,000	US$120,000	US$320,000
Capital cost of in-house plumbing & appliances[2]	None	US$1920	US$3840	US$11,520.	US$30,720.
Monthly capital cost of in-house plumbing and appliances[3]	None	US$9.28/mo	US$18.56/mo	US$55.68/mo	US$148.48/mo
Monthly O&M for indoor plumbing & appliances[4]	None	US$ 1.86/mo	US$3.71/mo	US$11.14/mo.	US$29.70/mo.
Total monthly cost for indoor plumbing & appliances[5]	None	US$11.10/mo ≈ US$11/mo.	US$22.27/mo ≈ US$22/mo.	US$66.82/mo ≈ US$67/mo.	US$178.18/mo. ≈ US$178/mo.

1 – Value of house = 4 x annual household income
2- Capital cost of in-house plumbing = 0.12[(Housing Value – land value)] where land value = 0.2 [housing value]
3 – Monthly capital cost of indoor plumbing = CRF [Capital cost of in-house plumbing]/12 where CRF = capital recovery factor = 0.058 (assuming a 30-year life of the capital and an interest rate of 4%).
4 - Monthly O&M for indoor plumbing & appliances = 0.20 [Monthly capital cost of indoor plumbing & appliances]

5 - Total monthly cost for indoor plumbing & appliances = Monthly capital cost of indoor plumbing & appliances + monthly O&M costs

Table 7 – Total Monthly Costs – Public Infrastructure Costs and Private Costs Embedded in Housing (US$ per month)

	Housing-water case 1 – one-room, thatched roof	Housing-water Case 2 – 2 rooms, concrete floor, metal roof	Housing-water Case 3 -Modern Flat in multi-family building	Housing-water Case 4 - Modern Flat in multi-family building	Housing-water Case 5 – Modern, single-family house
Size	25 square meters	50 square meters	60 square meters	100 square meters	250 square meters
Public water and sanitation outside	Drinking, cooking, washing (e.g. public handpump)	Piped water supplied to house,	Piped water & wastewater (sewage) collection; no wastewater treatment	Piped water & wastewater collection & treatment	Piped water & wastewater collection & treatment
Private water & sanitation outside	Bathing, clothes washing, feces disposal (e.g., private pit latrine)	Clothes washing, feces disposal (e.g. private pit latrine)	Clothes washing outside flat (inside multi-family building)	Clothes washing outside flat (inside multi-family building)	None
Private water & sanitation inside	Drinking	Drinking, cooking, bathing	Drinking, cooking, bathing, feces removal	Drinking, cooking, bathing, feces removal	Drinking, cooking, bathing, feces removal, clothes washing, gardening, lawn watering
Public WASH costs	US$6/mo	US$10/mo	US$32/mo	US$60/mo	US$100/mo
Private WASH Costs on premises outside house	NA	US$3/mo.	NA	NA	NA
Private WASH costs embedded in housing	US$0	US$11/mo.	US$22/mo.	US$67/mo	US$178/mo.
Total	US$6/mo.	US$24/mo.	US$54/mo.	US$127/	US$278/mo.

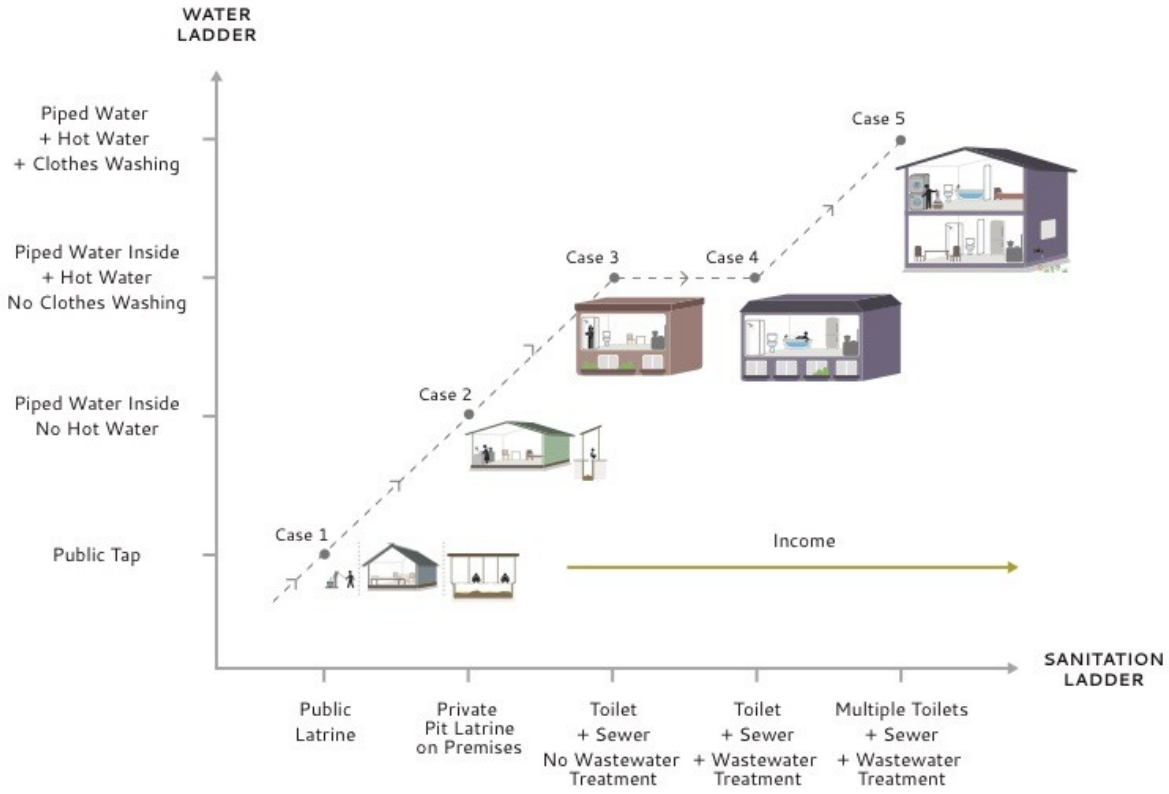
WASH Costs/mo.				mo.	
Private cost inside/ total WASH cost	NA	0.46	0.41	0.53	0.64
Total Wash costs/income	0.04	0.06	0.06	0.05	0.04

Table 8 – Total Monthly Costs from the Household's Perspective (US$ per month) – Adjusting for Subsidized Water Bills and Coping Costs

	Housing-water case 1 – one-room, thatched roof	Housing-water Case 2 – 2 rooms, concrete floor, metal roof	Housing-water Case 3 -Modern Flat in multi-family building	Housing-water Case 4 - Modern Flat in multi-family building	Housing-water Case 5 – Modern, single-family house
Public WASH costs paid by household	US$0/ mo[10]	US$3/mo	US$11/mo	US$60/ mo	US$100/mo
Coping costs incurred by household	US$10/ mo.	US$10/mo.	US$10/mo.	US$0	US$0
Private WASH costs embedded in housing	US$0	US$11/mo.	US$21/mo.	US$67/ mo	US$178/ mo.
Private WASH Costs on premises outside house	NA	US$3/mo.	NA	NA	NA
Total WASH Costs	US$10	US$27	US$42	US$127	US$278
Private cost embedded in housing/total cost	0	0.41	0.50	0.53	0.64
Total Private cost /total cost	NA	0.89	0.74	0.53	0.64
Public WASH costs paid by household/income	0.00	0.01	0.01	0.02	0.02
Total WASH costs paid by household/income	0.06	0.06	0.05	0.05	0.04

[10] Assumes water from public taps is free to the household.

Figure 1: Housing–Water & Sanitation Development Path



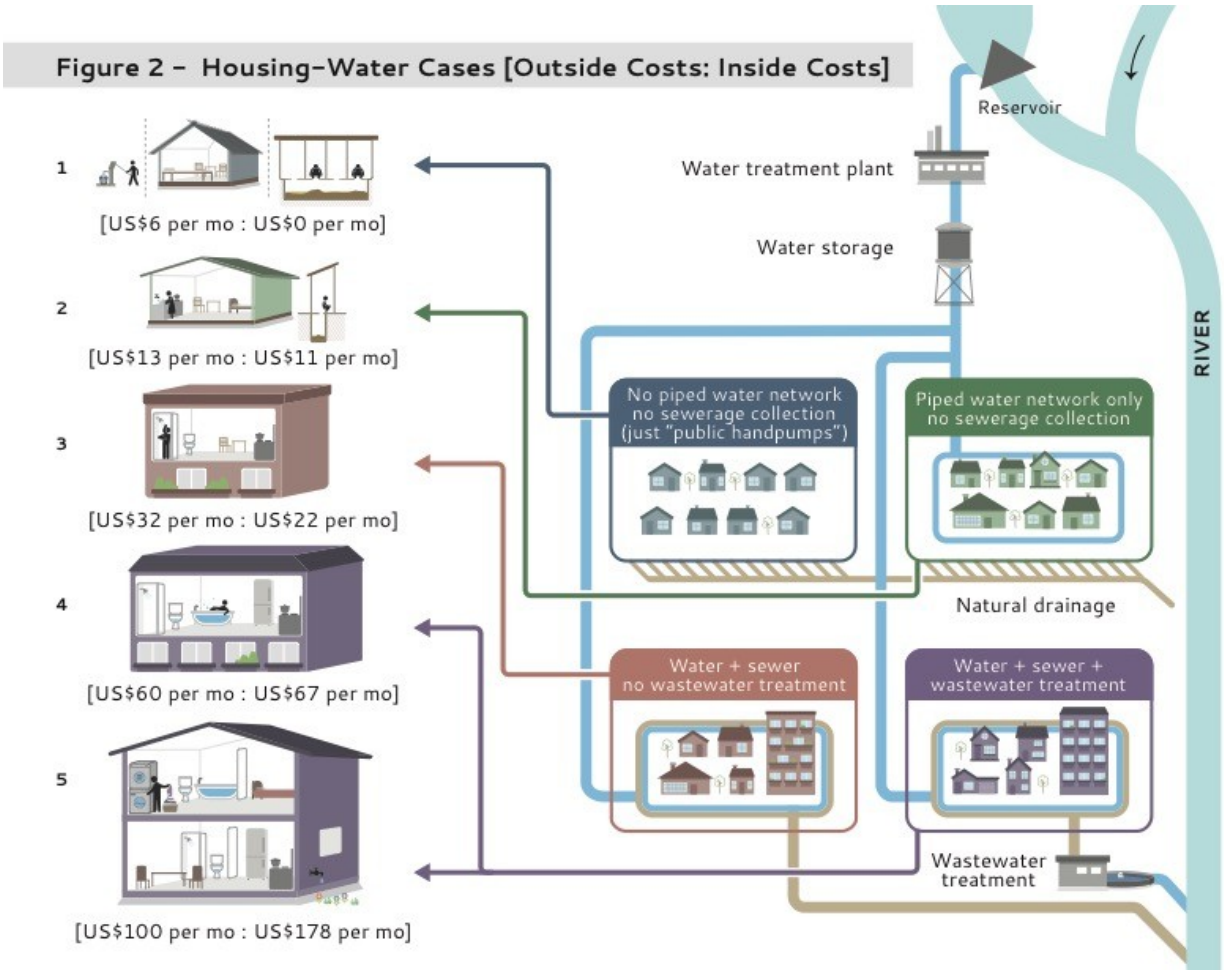


Figure 2 – Housing–Water Cases [Outside Costs: Inside Costs]
1
[US$6 per mo : US$0 per mo]
2
[US$13 per mo : US$11 per mo]
3
[US$32 per mo : US$22 per mo]
4
[US$60 per mo : US$67 per mo]
5
[US$100 per mo : US$178 per mo]
Reservoir
Water treatment plant
Water storage
RIVER
No piped water network
no sewerage collection
(just "public handpumps")
Piped water network only
no sewerage collection
Natural drainage
Water + sewer
no wastewater treatment
Water + sewer +
wastewater treatment
Wastewater
treatment