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Supplementary Material

Table S1. Parameter distribution and justification.

Parameter	Parameter Values				Justification
	Base Case	Low	High	Distribution for Probabilistic Sensitivity Analysis	
Effect of CLTS on longitudinal prevalence of child diarrhea (Reduced days of child diarrhea per year)	1.6	0.2	2.6	normal	Base case: 1.6 days, 95% Confidence Interval from the trial
Life-span (years)	10	5	15	N/A	base case: reference, mean value: 10.0, standard deviation: 1.7
Value of Statistical Life (VSL, Int'l$)	45,194	27,094	66,141	lognormal	base case, low and high values: Radin M et al. [1], Robinson LA et al. [2,3]
Discount rate (%)	3	0	8	N/A	base case, low and high values: Drummond MF et al. [4]
Income growth (%)	2	0	4	uniform distribution	base case: reference, low and high values represent +/-100% of base case estimate.
Hourly income (Int'l$)	0.67	0.39	0.5	normal	point estimate and 95% CI from the trial
Value of time (5–14 years, %)	25	0	50	N/A	base case: reference, mean value: 25.0, standard deviation: 8.3
Value of time (>14 years, %)	50	25	75	N/A	base case: reference, mean value: 50.0, standard deviation: 8.3
Case Fatality Rate (CFR, <5 years, %)	0.07	0.05	0.09	normal	point estimate and 95% CI from the Global Burden of Disease study
CFR(5–14 years, %)	0.02	0.01	0.03	normal	point estimate and 95% CI from the Global Burden of Disease study
CFR(>14 years, %)	0.03	0.02	0.05	normal	point estimate and 95% CI from the Global Burden of Disease study
Operation & Maintenance (O&M, %)	10	5	15	N/A	base case: reference, low and high values represent +/- 50% of base case estimate.
Education (%)	10	5	15	N/A	base case: reference, low and high values represent +/- 50% of base case estimate.

CLTS–community-led total sanitation; N/A-Fixed value; CFR–case fatality rate of diarrhoea.

Table S2. Parameter values (base case).

Age Group	Parameters	Unit	Value	Data source
Overall	Number of villages	village	24	Trial data
	Improved latrine uptake (intervention group)	%	35.0	Trial data
	Households in the intervention group	households	1,737	Trial data
	Number of children (<5)	person	1,301	Trial data
	Number of children (5–14)	person	3,804	Trial data
	Number of adults (≥15)	person	4,608	Trial data
	Discount rate	%	3	Reference [1]
	Annual income growth	%	2	Reference [5]
	VSL(Value of Statistical Life)	Int'l $	45,194	Reference [1,2,3,5]
	Useful life of an improved latrine	years	10	Reference [6–12]
	Operation & Maintenance cost (proportion of annualized cost of initial investment)	%	10	Reference [13]
	Time constructing a latrine (per household)	hours	120	Trial data
	Diarrhea case fatality rate (<5)	%	0.07	Reference [14]
	Diarrhea case fatality rate (5-14)	%	0.02	Reference [14]
	Diarrhea case fatality rate (≥15)	%	0.03	Reference [14]
Children (<5)	Proportion of children with diarrhea whose caregivers sought care	%	62.8	Trial data
	Proportion of children with diarrhea taken to health facilities	%	56.1	Trial data
	Proportion seeking treatment from drug store	%	2.0%	Trial data
	Proportion seeking treatment from a traditional healer	%	1.0%	Trial data
	Proportion of health facility careseekers becoming outpatients	%	50.9	Trial data
	Proportion of health facility careseekers becoming inpatients	%	5.2	Trial data
	Average days of hospitalization (per case)	days	5.0	Trial data
	Caregiver lost days due to home care for a child with diarrhea	days	1	Trial data
	Number of diarrhea cases avoided per year (under-5 children)	cases	1.51	Trial data
	Treatment cost (health facilities)	Int'l$	0.70	Trial data
	Treatment cost (drug stores)	Int'l$	0.55	Trial data
	Treatment cost (traditional healers)	Int'l$	0.25	Trial data
	Meal cost	Int'l$	0.20	Trial data
	Transportation cost (round trip)	Int'l$	0.75	Trial data
	Accommodation cost (inpatient)	Int'l$	3.66	Trial data
Other groups (5–14 or ≥15)	Proportion of diarrhea patients whose caregivers sought care (or who sought care themselves)	%	45.40	Trial data
	Proportion of diarrhea patients taken to health facilities	%	34.69	Trial data
	Proportion seeking treatment from drug store	%	5.61	Trial data
	Proportion seeking treatment from a traditional healer	%	6.12	Trial data
	Proportion of health facility careseekers becoming outpatients	%	32.40	Trial data
	Proportion of health facility careseekers becoming inpatients	%	2.29	Trial data
	Average days of hospitalization (per case)	Days	3.50	Trial data

Other groups (5-14 or ≥15)	Caregiver lost days due to home care for a child with diarrhea	Days	1	Trial data
	Treatment cost (health facilities)	Int'l$	0.70	Trial data
	Treatment cost (drug stores)	Int'l$	0.55	Trial data
	Treatment cost (traditional healers)	Int'l$	0.25	Trial data
	Meal	Int'l$	0.30	Trial data
	Transportation cost (round trip)	Int'l$	1.49	Trial data
	Accommodation cost	Int'l$	7.32	Trial data
	Hourly income (before application of valuation percentages)	Int'l$	0.67	Trial data
	Switched from open defecation to a household latrine (5-14)	%	2.85	Trial data
	Switched from open defecation to a household latrine (≥15)	%	4.18	Trial data
	Switched from a communal latrine to a household latrine (5-14)	%	3.65	Trial data
	Switched from a communal latrine to a household latrine (≥15)	%	2.95	Trial data
	Switched from a neighbor's latrine to a household latrine (5-14)	%	48.99	Trial data
	Switched from a neighbor's latrine to a household latrine (≥15)	%	20.35	Trial data
	Saved time from the switch (open defecation, round trip)	minutes	9.13	Trial data
	Saved time from the switch (a communal latrines, round trip)	minutes	10.00	Trial data
	Saved time from the switch (a neighbor's latrine, round trip)	minutes	4.50	Trial data
	Number of diarrhea cases avoided per year (5-14)	cases	0.41	Trial data
	Number of diarrhea cases avoided per year (≥15)	cases	0.32	Trial data

Table S3. Benefits and costs reflecting slippage (average annual reduction: 3.5%) (present value in 2016, Int'l$).

	Item		Age Group				
			<5	**5–14**	**≥15**	**Sum**	**%**
Benefits	Avoided diarrhea cases	Treatment costs saved	2746	1088	1025	4859	13%
		Transportation costs saved	2822	1927	1,816	6565	
		Meal costs saved	753	388	366	1,506	
		Accommodation costs saved	281	81	108	470	
		Time saved for intensive care	42,903	16,935	31,911	91748	
		Time saved from health professionals	52,213	10,340	9742	72,295	
		Sum	101,718	30,759	44,968	177,443	
	Averted premature deaths	Value of statistical life	506,440	114,232	161,438	782,109	58%
	Time saved from increased accessibility	Switch from open defecation		27,737	98,558	126,296	29%
		Switch from using communal latrines		38,908	76,185	115,093	
		Switch from using neighbors' latrines		78,333	78,832	157,165	
		Sum		144,978	253,575	398,554	
	Grand total		608,158 (45%)	289,969 (21%)	459,981 (34%)	1,358,106 (100%)	100%
Costs	Initial costs						
	Project implementation & management	Recurrent				223,845	54%
		Capital				14,580	
		Sum				238,425	
	Investment of community members and local stakeholders	Recurrent				102,353	42%
		Capital				84,337	
		Sum				186,690	
	Sum of initial costs					425,115	
	Operation & management Education for the lifespan of a latrine	Operation & management				8,245	4%
		Education				8,245	
		Sum				16490	
	Grand total					441,605	100%
	Benefit-Cost Ratio				3.1		
	Net Present Value		916,500 (38,188 per community; 528 per household)				

Table S4. Benefits and costs reflecting the population growth of 2.7% (present value in 2016, Int'l$).

Item			Age Group				
			<5	**5–14**	**≥15**	**Sum**	**%**
Benefits	Avoided diarrhea cases	Treatment costs saved	3800	1506	1419	6725	13%
		Transportation costs saved	3906	2667	2513	9086	
		Meal costs saved	1042	537	506	2085	
		Accommodation costs saved	389	111	150	650	
		Time saved for intensive care	59,986	23,678	44,617	128,281	
		Time saved from health professionals	73,003	14,457	13,621	101,082	
		Sum	142,126	42,956	62,826	247,909	
	Averted premature deaths	Value of statistical life	708,096	159,717	225,720	1,093,533	58%
	Time saved from increased accessibility	Switch from open defecation		38,782	137,803	176,584	29%
		Switch from using communal latrines		54,400	106,521	160,921	
		Switch from using neighbors' latrines		109,524	110,222	219,745	
		Sum		202,706	354,546	557,250	
	Grand total		850,222 (45%)	405,379 (21%)	643,092 (34%)	1,898,692 (100%)	100%
Costs	Initial costs						
	Project implementation & management	Recurrent				223,845	54%
		capital				14,580	
		sum				238,425	
	Investment of community members and local stakeholders	Recurrent				102,353	42%
		capital				84,337	
		sum				186,690	
	Sum of initial costs					425,115	
	Operation & management	Operation & management				9,892	4%
	Education for the lifespan of a latrine	Education				9,892	
		Sum				19,784	
	Grand total					444,899	100%
	Benefit-Cost Ratio				4.3		
	Net Present Value		1,453,794 (60,575 per community; 837 per household)				

Table S5. Benefits and costs reflecting the treatment and transportation costs reported by caregivers (present value in 2016, Int'l$).

	Item		Age Group				
			<5	**5–14**	**≥15**	**Sum**	%
Benefits	Avoided diarrhea cases	Treatment costs saved	30,307	10,584	9972	50,863	15%
		Transportation costs saved	3,566	2312	2718	8056	
		Meal costs saved	1042	537	506	2,085	
		Accommodation costs saved	389	111	150	650	
		Time saved for intensive care	59,986	23,678	44,617	128,281	
		Time saved from health professionals	73,00,3	14,457	13,621	101,082	
		Sum	168,293	51,679	71,584	291,017	
	Averted premature deaths	Value of statistical life	708,096	159,717	225,720	1,093,533	56%
	Time saved from increased accessibility	Switch from open defecation		38,782	137,803	176,584	29%
		Switch from using communal latrines		54,400	106,521	160,921	
		Switch from using neighbors' latrines		109,524	110,222	219,745	
		Sum		202,706	354,546	557,250	
	Grand total		876,389 (45%)	414,102 (21%)	651,850 (34%)	1,941,800 (100%)	100%
Costs	Initial costs						
	Project implementation & management	Recurrent				223,845	54%
		capital				14,580	
		sum				238,425	
	Investment of community members and local stakeholders	Recurrent				102,353	42%
		capital				84,337	
		sum				186,690	
	Sum of initial costs					425,115	
	Operation & management	Operation & management				9,892	4%
	Education for the lifespan of a latrine	Education				9,892	
		Sum				19,784	
	Grand total					444,899	100%
	Benefit-Cost Ratio				3.8		
	Net Present Value				1,239,001 (51,625 per community; 713 per household)		

Text S1. Comparisons of the Interventions Between the Intervention and the Control Groups

Although the Ethiopian government adopted nationwide sanitation improvement policy (Community Led Total Sanitation and Hygiene) in 2008, the programme has not been carried out in many districts due to a lack of resources [15,16,17].

In response to this, the Ethiopian government launched a large-scale Community-Led Total Sanitation and Hygiene (CLTSH) programme in 2012–2015 in the Southern Nations, Nationalities, and Peoples' Region (SNNPR), Amhara, Tigray, and Oromia states of the country in collaboration with UNICEF and the Global Sanitation Fund [17]. Eighty-six districts in these states benefited from the CLTSH programme for the first time. The SNNPR state comprises of 15 zones (an administrative unit below State) and 77 districts. The Gurage zone where the Cheha and Enemor Ena Ener districts belong to was not included in the intervention area [41]. These districts were classified as a control area in the evaluation to investigate the effect of the CLTSH programme [17].

The Ethiopian government submitted the proposal of the water, sanitation and hygiene project of the Korea International Cooperation Agency (KOICA) in 2013 and the target areas of the project were selected among the districts that had no previous intervention of the CLTSH [40]. The SNNPR state has been implementing the Community-Led Total Sanitation (CLTS) program in eight districts since 2009 but the Cheha and Enemore Ena Ener districts were not included in the target dirstricts [17].

According to the two project managers of the KOICA CLTS intervention, one of them is a former deputy director of the District Health Office, CLTS interventions had never been implemented in the two target districts, and no Health Extension Workers (HEWs) had been trained on CLTS prior to the intervention (individual communication between 5–18 January 2019). The local project manager and former deputy director stated that there was no budget allocated for sanitation improvements in the two districts.

However, we estimated how much budget is being indirectly allocated to sanitation improvement at the district and the village level on the basis of published reports. In a decentralized system, the director of the district health office is the key figure responsible for spearheading sanitation and hygiene promotion throughout the district [15,17]. The Health Extension Workers (HEWs) have the main responsibility of sanitation improvements in their catchment area as a front-line government official, and they were charged with 16 key tasks. Most health posts in rural areas of Ethiopia are staffed by two HEWs, and they serve an average population of 5,000 individuals. There were some studies examining HEWs' time allocation on their billable activities (i.e., the user of the activities, an individual or a community, was identifiable) [18–20]. The time spent on different activities by HEWs in Ethiopia was estimated in 2014 in the Health Extension Workers Time Motion Study across 22 districts in Ethiopia. The study suggested that HEWs spent 1600 minutes on billable activities per month, and roughly 25% of total encounters, referring to each discrete time an activity was performed, were spent on hygiene and environmental sanitation education or services for rural HEWs [19]. They spent 51% of their time at the health post, 15% in community outreach and 13% visiting households [20]. Based on the results of the studies, we calculated how many minutes and costs are being spent on hygiene and environmental sanitation education or services.

Given that an average monthly cost of rural HEWs for hygiene and environmental sanitation education/services including supplies, supervisor salary, and other overhead cost was US$88.4 for rural HEWs and there were two HEWs per health post covering a sub-district, and 48 health posts exist in the two districts, we estimated that US$50,918 was being spent on sanitation improvements in the two districts. Finally, we estimated that US$5,764 was spent on sanitation improvements both in intervention and control arms in terms of HEWs activities.

According to recent reports [21.22], the Ethiopian government spent 0.006% of the GDP on sanitation in 2014. The gross domestic product (GDP) was 43,311 million US$, which means the Ethiopian government spent US$2,598,660 on sanitation across the country [5,21,22]. Dividing this by 770 districts of Ethiopia, we estimate that one district expended US$3,374 on sanitation improvements, and US$764 was spent on sanitation in 24 Gotts by the government.

Although these are indirect and preliminary estimates on government expenditures, and need to be verified with the local government, the incremental cost of the CLTS intervention in the 24 Gotts would remain the same because CLTS activities were carried out only in the intervention group.

Text S3. Lifetime of an Improved Latrine in This Study

The lifetime of a latrine has been suggested by many organizations to range from 2 years for simple pit latrine to 20 years for an improved pit latrine [6–12,23–28]. While World Bank reports do not describe the rationale for the estimated lifespan of a latrine, the WHO and UNICEF reports estimate it based on the pit volume or depth. The World Bank reports estimated lifespans of 2–4 years for a simple pit latrine and 10–20 years for an improved latrine. The WHO estimates a 20-year lifespan for a ventilated improved pit latrine. The lifespan of a pit latrine is often calculated based on the accumulation rate of faecal waste or sludge (n = v/rP: n, lifespan; v, pit volume; P, the number of users; r, accumulation rate) [7]. The accumulation rate ranges from 0.02 to 0.09 (m^3/person/year) [8]. Estimating the lifespan solely based on the pit space or pit depth is not sufficient because other factors affect latrine durability, such as geological and climatic factors, as well as the materials of the latrine structure. Several other factors also affect pit latrine filling such as throwing rubbish into latrines [9], water inflows [10], flooding [11], cleaning time [11], and degradation/decomposition [12]. The definition of an improved latrine in this study (i.e., a latrine equipped with a pit deeper than 2 meters, slab, pit-hole, wall, door, roof, and handwashing facility) is stricter than that of the report of Joint Monitoring Programme for Water Supply and Sanitation (JMP) [29]. Correspondingly, considering the widely accepted parameter values for the lifespan of latrines by type, 10 years for an improved latrine in this study is not an overestimated value, even when taking the possible abandonment rate into account.

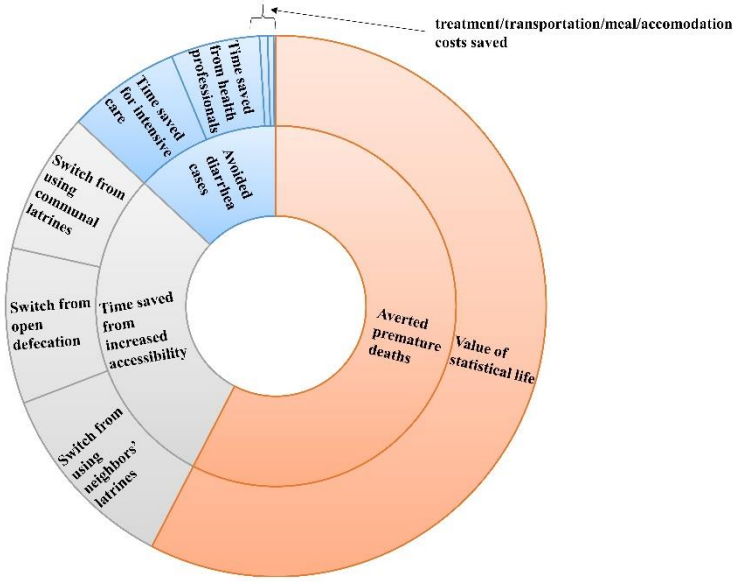


Figure S1. Distribution of benefits by item.

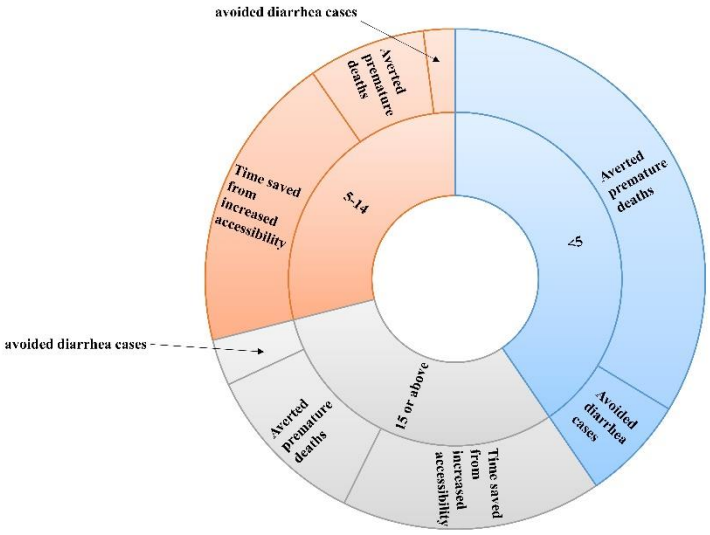


Figure S2. Distribution of benefits by age group.

References

1. Radin, M.; Jeuland, M.; Wang, H.; Whittington, D. Benefit-cost analysis of community-led total sanitation: Incorporating results from recent evaluations. *J. Benefit Cost Anal.* **2020**, 1–38, doi:10.1017/bca.2020.6.
2. Robinson, L.A.; Hammitt, J.K.; Cecchini, M., Chalkidou, K.; Claxton, K.; Cropper, M.; Eozenou, P.H.-V.; de Ferranti, D.; Deolalikar, A.B.; Guanais, F. *Reference Case Guidelines for Benefit-Cost Analysis in Global Health and Development*; Harvard University: Boston, MA, USA, 2019. Available online: https://cdn1.sph.harvard.edu/wp-content/uploads/sites/2447/2019/05/BCA-Guidelines-May-2019.pdf (accessed on 27 June 2020).
3. Robinson, L.A.; Hammitt, J.K.; O'Keeffe, L. Valuing Mortality Risk Reductions in Global Benefit-Cost Analysis. *J. Benefit Cost Anal.* **2019**, *10*, 15–50.
4. Drummond, M.F.; Sculpher, M.J.; Claxton, K.; Stoddart, G.L.; Torrance, G.W. *Methods for the Economic Evaluation of Health Care Programmes*, 4th ed.; Oxford University Press: Oxford, UK, 2015.
5. The World Bank. *GNI Per Capita, Atlas Methods (US$ and International $)*; World Bank: Washington, USA, 2020. Available online: https://data.worldbank.org/indicator/NY.GNP.PCAP.CD?locations =ET (accessed on 27 June 2020).
6. Hutton, G. *Financial and Economic Impacts of the Swachh Bharat Mission in India*; United Nations Children's Fund India: New Delhi, India; 2017. Available online: https://www.unicef.org/india/reports/financial-and-economic-impacts-swachh-bharat-mission-india (accessed on 27 June 2020).
7. WRC. Design and operating requirements to optimize the life span of VIP toilets: WRC report 1630/1/07. Water Research Commission: Pretoria, Republic of South Africa, 2007.
8. Nakagiri, A.; Niwagaba, C.B.; Nyenje, P.M.; Kulabako, R.N.; Tumuhairwe, J.B.; Kansiime, F. Are pit latrines in urban areas of Sub-Saharan Africa performing? A review of usage, filling, insects and odour nuisances. BMC Public Health, **2016**, *16*. doi:10.1186/s12889-016-2772-z.
9. Still D & Foxon K. Tackling the challenges of full pit latrines. How fast do pit toilets fill up? A scientific understanding of sludge build up and accumulation in pit latrines. WRC Report 1745/2/12. Water Research Commission: Pretoria, Republic of South Africa, 2012.
10. Todman, L.C.; van Eekert, M.H.A.; Templeton M.R.; Hardy (née Kelly), M.; Gibson, W.T.; Torondel, B.; Abdelahi, F.; Ensink, J.H.J. Modeling the fill rate of pit latrines in Ifakara, Tanzania. *J. Water Sanit. Hyg. De*. **2014**,*5*,100–106.
11. Nakagiri, A.; Kulabako, R.N.; Nynje, P.M.; Tumuhairwe, J.B.; Niwagaba, C.B.; Kansiime, F., Performance of pit latrines in urban poor areas: a case of Kampala, Uganada. *Habitat Int*. **2015**, *49*, 529–537.
12. Foxon, K. Scientific support for the design and operation of ventilated improved pit latrines (VIPS). School of Chemical Engineering University of KwaZulu-Natal, Durban, Republic of South Africa,2008.
13. Hutton, G.; Bartram, J. Global costs of attaining the Millennium Development Goal for water supply and sanitation. *Bull. World Health Organ.* **2008**, *86*, 13–19.

14. GBD 2016 Causes of Death Collaborators. Global, regional, and national age-sex specific mortality for 264 causes of death, 1980–2016: A systematic analysis for the Global Burden of Disease Study 2016. *Lancet* **2017**, *390*, 1151–1210.
15. FMOH. *Implementing Guideline for CLTSH Programming*; Federal Ministry of Health: Addis Ababa, Ethiopia, 2012.
16. KOICA. *Basic Design Study: Water, Sanitation and Hygiene Project in SNNPR State, Ethiopia*; Korea International Cooperation Agency: Seongnam, Korea, 2014.
17. SNNPR. *Community-Led Accelerated Wash Project Annual Performance Report*; Southern Nations, Nationalities, and Peoples' Regional Office (Water and Irrigation Development Bureau): Hawassa, Ethiopia, 2018.
18. Tilahun, H.; Fekadu, B.; Abdisa, H.; Canavan, M.; Linnander, E.; Bradley, E.H.; Berman, P. Ethiopia's health extension workers use of work time on duty: Time and motion study. *Health Policy Plan.* **2017**, *32*, 320–328.
19. Canavan, M.E.; Linnander, E.; Ahmed, S. Mohammed, H.; Bradley,E.H. Unit Costing of Health Extension Worker Activities in Ethiopia: A Model for Managers at the District and Health Facility Level. Int. J. Health Policy Manag. **2017**,7, 394–401.
20. Mangham-Jefferies, L.; Mathewos, B.; Russell J.; Bekele, A. How do health extension workers in Ethiopia allocate their time? Hum. Resour. Health, 2014, 12. doi:10.1186/1478-4491-12-61.
21. WHO/UN-Water. GLAAS 2014 Special Report for Africa. World Health Organization: Geneva, Switzerland, 2014.
22. WHO/UN-Water. TrackFin Initiative: Tracking financing to sanitation, hygiene and drinking-water at the national level. World Health Organization: Geneva, Switzerland, 2017.
23. Hutton, G.; Chase, C. The Knowledge Base for Achieving the Sustainable Development Goal Targets on Water Supply, Sanitation and Hygiene. *Int. J. Environ. Res. Public Health* **2016**, *13*, 536.
24. Hutton, G. Global costs and benefits of reaching universal coverage of sanitation and drinking-water supply. *J. Water Health* **2013**, *11*, 1–11.
25. Hutton, G. *Benefits and Costs of the Water, Sanitation and Hygiene Targets for the Post-2015 Development Agenda: Post-2015 Consensus*; Copenhagen Consensus Center: Copenhagen, Denmark, 2015. Available online: https://www.copenhagenconsensus.com/sites/default/files/water_sanitation_assessment_-_hutton.pdf (accessed on 27 June 2020).
26. Hutton, G. Global costs and benefits of reaching universal coverage of sanitation and drinking-water supply. *J. Water Health* **2013**, *11*, 1–11.
27. Hutton, G. *Benefits and Costs of the Water, Sanitation and Hygiene Targets for the Post-2015 Development Agenda: Post-2015 Consensus*; Copenhagen Consensus Center: Copenhagen, Denmark, 2015. Available online: https://www.copenhagenconsensus.com/sites/default/files/water_sanitation_assessment_-_hutton.pdf (accessed on 27 June 2020).
28. Nyarko, K.B.; Buamah, R.; Nunoo, F.K.N.; Appiah-Effah, E.; Afful, K.M.; Samwini, N.A.; Owusu-Boakye, A. *Latrine Technology Manual*; United Nations Children's Fund Ghana: Accra, Ghana, 2016. Available online: https://www.susana.org/en/knowledge-hub/resources-and-publications/library/details/3313 (accessed on 27 June 2020).
29. WHO/UNICEF. *Progress on Household Drinking Water, Sanitation and Hygiene 2000–2017: Special Focus on Inequalities*; World Health Organization: Geneva, Switzerland, 2019.



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