SUPPORTING INFORMATION

Institutional barriers to on-site alternative water systems – A conceptual framework and systematic analysis of literature

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APPENDIX A: VISUAL REPRESENTATION OF KEY DIMENSIONS FOR UWM INNOVATION

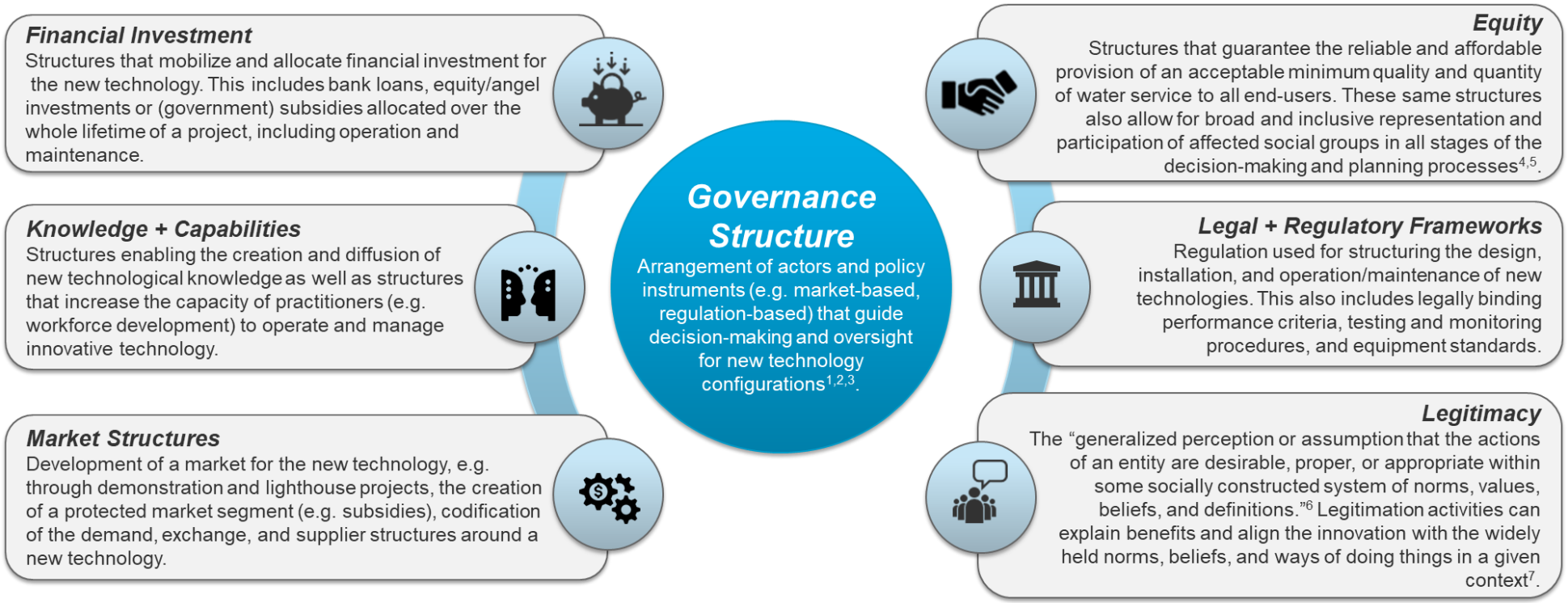

Figure S1. *Key dimensions for urban water management innovation.*

(1) Pakizer, K., & Lieberherr, E. (2018). Alternative governance arrangements for modular water infrastructure: An exploratory review. *Competition and Regulation in Network Industries*, *19*(1–2), 53–68. Scopus. https://doi.org/10.1177/1783591718814426

(2) Schramm, E.; Kerber, H.; Trapp, J. H.; Zimmermann, M.; Winker, M. Novel Urban Water Systems in Germany: Governance Structures to Encourage Transformation. *Urban Water J.* **2018**, *15* (6), 534–543. https://doi.org/10.1080/1573062X.2017.1293694.

(3) Hufty, M. *Investigating Policy Processes: The Governance Analytical Framework (GAF)*; SSRN Scholarly Paper ID 2019005; Social Science Research Network: Rochester, NY, 2011.

(4) US Water Alliance. AN EQUITABLE WATER FUTURE: A National Briefing Paper; 2017.

(5) Fauconnier, I. The Privatization of Residential Water Supply and Sanitation Services: Social Equity Issues in the California and International Contexts. Berkeley Plan. J. 1999, 13 (1). https://doi.org/10.5070/BP313113030.

(6) Suchman, M. C. Managing Legitimacy: Strategic and Institutional Approaches. Acad. Manage. Rev. 1995, 20 (3), 571–610. https://doi.org/10.2307/258788.

(7) Harris-Lovett, S. R.; Binz, C.; Sedlak, D. L.; Kiparsky, M.; Truffer, B. Beyond User Acceptance: A Legitimacy Framework for Potable Water Reuse in California. Environ. Sci. Technol. 2015, 49 (13), 7552–7561. https://doi.org/10.1021/acs.est.5b00504.

APPENDIX B: OVERVIEW OF KEY SEARCH TERMS USED IN LITERATURE RETRIEVAL PROCESS

	SPATIAL			WATER MANAGEMENT			TYPE OF TREATMENT
OR	Onsite		**OR**	Water		**OR**	treatment
OR	on-site		**OR**	Wastewater		**OR**	reuse
OR	"on site"		**OR**	"waste water"		**OR**	recycl*
OR	Decentralized		**OR**	sanitation		**OR**	harvesting
OR	Decentralised		**OR**	non-potable		**OR**	recovery
OR	Modular		**OR**	nonpotable		**OR**	"urban water management"
OR	Nongrid	**AND**	**OR**	blackwater	**AND**		
OR	Non-grid		**OR**	"Black water"			
OR	"Non grid"		**OR**	greywater			
			OR	"grey water"			
			OR	graywater			
			OR	"gray water"			
			OR	rainwater			
			OR	“rain water"			
			OR	stormwater			
			OR	"storm water"			
			OR	johkasou			

Figure S2. *Overview of key search terms used in literature retreival process.*

APPENDIX C: SUMMARY OF LITERATURE RETRIEVAL PROCESS

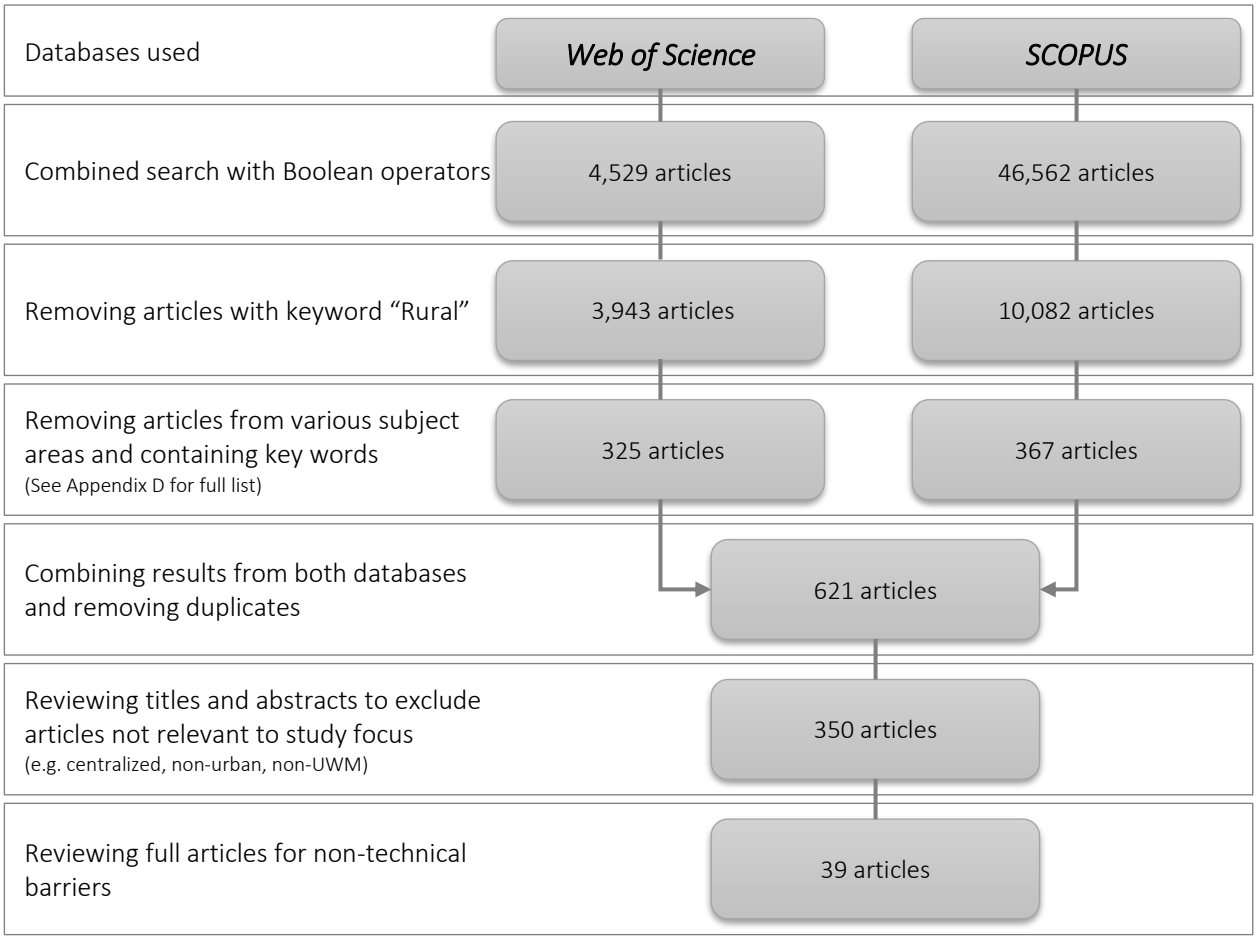

Figure S3. *Summary of literature retrieval process.*

APPENDIX D: DETAILED LITERATURE RETRIEVAL PROCESS

Table S1. *Detailed literature retrieval process.*

WEB OF SCIENCE		*SCOPUS*	
Combine three searches with AND connector	4,529 articles	46,562 articles	Combine three searches with AND connector
Excluding topical search: “Rural”	3,943 articles	42,356 articles	Excluding topical search: “Rural”
Excluding subject areas: “fisheries" OR "art" OR "mechanics" OR "plant sciences" OR "nuclear science technology" OR "chemistry analytical" OR "engineering electrical electronic" OR "geochemistry geophysics" OR "biotechnology applied microbiology" OR "computer science interdisciplinary applications" OR "archaeology" OR "computer science artificial intelligence" OR "biochemistry molecular biology" OR "infectious diseases" OR "pharmacology pharmacy" OR "limnology" OR "biophysics" OR "physics condensed matter" OR "zoology" OR "physics atomic molecular chemical" OR "physics fluids plasmas" OR "mining mineral processing" OR "tropical medicine" OR "soil science" OR "chemistry organic" OR "veterinary sciences" OR "forestry" OR "agriculture dairy animal science" OR "engineering biomedical" OR "entomology" OR "chemistry physical" OR "metallurgy metallurgical engineering" OR "medicine research experimental" OR "oceanography" OR "agronomy" OR "food science technology" OR "engineering petroleum" OR "surgery" OR "marine freshwater biology" OR "materials science paper wood" OR "microbiology" OR "mineralogy" OR "astronomy astrophysics" OR "nanoscience nanotechnology" OR "radiology nuclear medicine medical imaging" OR "engineering ocean" OR "immunology" OR "materials science biomaterials" OR "biochemical research methods" OR "chemistry inorganic nuclear" OR "optics" OR "sport sciences" OR "physiology" OR "polymer science”	2,771 articles	10,082 articles	Excluding subject areas: "bioc" OR "ener" OR "medi" OR "immu" OR "phar" OR "math" OR "neur" OR "heal" OR "nurs" OR "vete" OR ”dent" OR "chem"or "ceng" OR "agri" OR ”phys" OR "eart“ OR "comp" OR "mate"
Excluding subject areas: “anesthesiology” OR “audiology speech language pathology" OR "spectroscopy" OR "dentistry oral surgery medicine" OR "energy fuels" OR "transportation science technology" OR	2,574 articles	9,324 articles	Excluding topical search: “septic” OR “remote area”

"meteorology atmospheric sciences" OR "materials science coatings films" OR "gastroenterology hepatology" OR "hematology" OR "thermodynamics" OR "physics nuclear"			
Removed articles with: "septic", "remote area", "solid waste"	2,275 articles	4,781 articles	Excluding articles with: "agri*" OR "textile" OR "hospital" OR "lab*" OR "brew*" OR "wine*" OR "industr*" OR "remediation" OR "wastewater treatment plant" OR "WWTP" OR "desalinat*" OR "olive" OR "dye" OR "sewage treatment plant" OR "centralized" OR "solid waste" OR "swine OR "pig" OR "ash" OR "constructed wetland" OR "heat recovery" OR "energy" OR "groundwater" OR "refinery" OR "landfill" OR "estuary" OR "freshwater" OR "infiltration" OR "food" OR "manufact*" OR "ship" OR "heat*" OR "municip*" OR "plant" OR "permeable" OR "low impact" OR "wood" OR "mill" OR "fuel" OR "soil" OR "motion" OR "wetland" OR "road" OR "farm*" OR "porous" OR "detention" OR "cement" OR "river" OR "toxic*" OR "fish" OR "lake" OR "grass" OR "marine" OR "resin" OR "oil" OR "smelt" OR "cool*" OR "fed*" OR "coast*" OR "land" OR "mine" OR "electr*" OR "watershed" OR "steel" OR "waste management" OR "robot" OR "recreati*" OR "composite"
Removed articles with: "agri*", "wastewater treatment plant", "industr*", "desalinat*", "remediation", "textile", "hospital", "brew*", "wine*", "lab*", "sewage treatment plant", "groundwater"	374 articles	1,569 articles	Excluding articles with: water resources" OR "equilibrium" OR "zone" OR "kine*" OR "flue" OR "catalyst" OR "space" OR "concrete" OR "construction" OR "heavy metal" OR "adsorpt*" OR "exerg*" OR "organ*" OR "oxid*" OR "educat*" OR "biomass" OR "radio*" OR "bioretent*" OR "aquifer" OR "surface water" OR "min*" OR "landscap*" OR "asphalt" OR "activated sludge" OR "hazard*" OR "air*" OR "hydrog*" OR "ocean" OR "manure" OR "surface" OR "carbon" OR "indust*" OR "crop" OR "slag" OR "small communit*" OR "wire" OR "synthetic" OR "geograph*" OR "waste treatment" OR "biochar" OR "medic*" OR "sand filter" OR " runoff" OR "well*" OR "housing" OR "flood" OR "gravel" OR "metagen*" OR "polar" OR "color" OR "distill*" OR "leach*" OR "sorpt*" OR "veg*" OR "sea*" OR "poly*" OR "neur*" OR "pipe" OR "nano*" OR "arct*" OR "product*" OR "transp*" OR ""waste NOT water"" OR "gas" OR ""sludge NOT reuse"" OR "gam*" OR "chemic*" OR "spec*" OR "disas*" OR " post*" OR "acid*" OR "second*" OR

			"chlorin*" OR "agenc*" OR "finan*" OR "pollut*" OR "geo*" OR "bat*" OR "tid*" OR "utilit*" OR "bior*" OR "viru*" OR "turb*" OR "peri*" OR "mag*" OR "emis*" OR "lig*" OR "trace*" OR "iron*" OR "tour*" OR "sewer system" OR "win*" OR "fir*" OR "basin*" OR "disin*" OR "micro*" OR "mobi*" OR "biof*" OR "hydrau*" OR "hydrol*" OR "sum*" OR "opera*" OR "aqu*" OR "charg*" OR "combin*" OR "emerg*" OR "sand" OR "green infrastructure"
Reviewing titles for general applicability to UWM field	325 articles	367 articles	Reviewing titles for general applicability to UWM field
	621 articles		Combining both database results and removing duplicate articles
	406 articles		Removing articles that don't reference reuse in title OR abstract
	284 articles		Removing articles that are not related to onsite/decentralized UWM based on content in title OR abstract (e.g. rural, no reuse, centralized systems)
	34 articles		Removing articles that do not discuss non-technical barriers

APPENDIX E: GEOGRAPHIC DISTRIBUTION OF INTERMEDIATE AGGREGATION OF LITERATURE

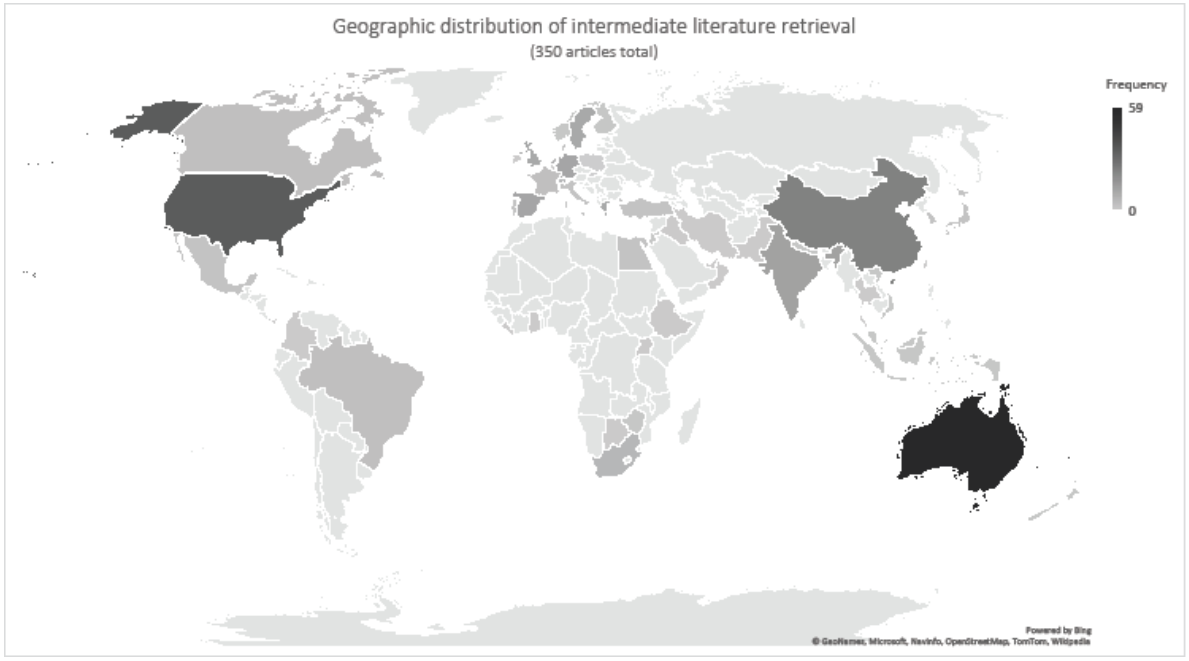

Figure S4. *Geographic distribution of intermediate aggregation of literature.*

APPENDIX F: FINAL LIST OF ARTICLES

Table S2. *Final list of articles. Abbreviations: BW-blackwater, GW-greywater, NPR-non-potable reuse, SW-stormwater, WW-wastewater*

Title	Country Focus	Technology System (Source; Reuse Purpose)
Bint, L., A. Garnett, A. Siggins, and R. Jaques. 2019. "Alternative Water Sources in New Zealand's Commercial Buildings." *Water Supply* 19 (2): 371–81. https://doi.org/10.2166/ws.2018.082.	New Zealand	SW, GW; NPR
De Boer, Marissa A., Anjelika G. Romeo-Hall, Tomas M. Rooimans, and J. Chris Slootweg. 2018. "An Assessment of the Drivers and Barriers for the Deployment of Urban Phosphorus Recovery Technologies: A Case Study of The Netherlands." *Sustainability* 10 (6): 1790. https://doi.org/10.3390/su10061790.	The Netherlands	WW; Agriculture
Czemiel Berndtsson, Justyna, and Ingrid Hyvönen. 2002. "Are There Sustainable Alternatives to Water-Based Sanitation System? Practical Illustrations and Policy Issues." *Water Policy* 4 (6): 515–30. https://doi.org/10.1016/S1366-7017(02)00042-9.	Sweden	WW; Agriculture
Hughes, Sara. 2013. "Authority Structures and Service Reform in Multilevel Urban Governance: The Case of Wastewater Recycling in California and Australia." *Urban Affairs Review* 49 (3): 381–407. https://doi.org/10.1177/1078087412458762.	Australia; USA	General; NPR
Anand, Chirjiv K., and Defne S. Apul. 2014. "Composting Toilets as a Sustainable Alternative to Urban Sanitation – A Review." *Waste Management* 34 (2): 329–43. https://doi.org/10.1016/j.wasman.2013.10.006.	Global	BW; Agriculture
Binz, Christian, Bernhard Truffer, Li Li, Yajuan Shi, and Yonglong Lu. 2012. "Conceptualizing Leapfrogging with Spatially Coupled Innovation Systems: The Case of On-site Wastewater Treatment in China." *Technological Forecasting and Social Change* 79 (1): 155–71. https://doi.org/10.1016/j.techfore.2011.08.016.	China	WW; NPR
Yu, Zita L. T., Anditya Rahardianto, J. R. DeShazo, Michael K. Stenstrom, and Yoram Cohen. 2013. "Critical Review: Regulatory Incentives and Impediments for On-site Graywater Reuse in the United States." *Water Environment Research* 85 (7): 650–62. https://doi.org/10.2175/106143013X13698672321580.	USA	GW; NPR
Parkinson, Jonathan, and Kevin Tayler. 2003. "Decentralized Wastewater Management in Peri-Urban Areas in Low-Income Countries." *Environment and Urbanization* 15 (1): 75–90. https://doi.org/10.1177/095624780301500119.	Global	WW; NPR, Agriculture

Lackey Katy, Sharkey Suzanne, Sharvelle Sybil, Kehoe Paula, and Chang Taylor. 2020. "Decentralized Water Reuse: Implementing and Regulating On-site Nonpotable Water Systems." Journal of Sustainable Water in the Built Environment 6 (1): 02519001. https://doi.org/10.1061/JSWBAY.0000891.	USA	WW; NPR
Brown, R. R., and M. A. Farrelly. 2009. "Delivering Sustainable Urban Water Management: A Review of the Hurdles We Face." *Water Science and Technology* 59 (5): 839–46. https://doi.org/10.2166/wst.2009.028.	Global	General; General
Gardiner, A. 2010. "Do Rainwater Tanks Herald a Cultural Change in Household Water Use?" *Australasian Journal of Environmental Management* 17 (2): 100–111. https://doi.org/10.1080/14486563.2010.9725255.	Australia	SW; NPR
Ormerod, Kerri Jean, and Christopher A. Scott. 2013. "Drinking Wastewater: Public Trust in Potable Reuse." *Science, Technology, & Human Values* 38 (3): 351–73. https://doi.org/10.1177/0162243912444736.	USA	WW; Potable
Starkl, Markus, Norbert Brunner, Magdalena Feil, and Andreas Hauser. 2015. "Ensuring Sustainability of Non-Networked Sanitation Technologies: An Approach to Standardization." *Environmental Science & Technology* 49 (11): 6411–18. https://doi.org/10.1021/acs.est.5b00887.	Global	BW; Agriculture
Ormerod, Kerri Jean. 2016. "Illuminating elimination: public perception and the production of potable water reuse." *Wiley Interdisciplinary Reviews: Water* 3 (4): 537–47. https://doi.org/10.1002/wat2.1149.	Global	BW; Agriculture
West, Camilla, Steven Kenway, Maureen Hassall, and Zhiguo Yuan. 2017. "Expert Opinion on Risks to the Long-Term Viability of Residential Recycled Water Schemes: An Australian Study." *Water Research* 120 (September): 133–45. https://doi.org/10.1016/j.watres.2017.04.077.	Australia	WW, SW; NPR
Neighbour, Danielle, and Ye Qi. 2018. "Identifying Implementation Gaps in Water Recycling Policy of Beijing Municipality." *Chinese Journal of Population Resources and Environment* 16 (4): 355–63. https://doi.org/10.1080/10042857.2018.1544750.	China	WW; NPR
Brands, Edwin. 2014. "Prospects and Challenges for Sustainable Sanitation in Developed Nations: A Critical Review." *Environmental Reviews* 22 (4): 346–63. https://doi.org/10.1139/er-2013-0082.	Global	BW; Agriculture
Crosson, Courtney. 2018. "Innovating the Urban Water System: Achieving a Net Zero Water Future Beyond Current Regulation."	USA	General; General

Technology|Architecture + Design 2 (1): 68–81. https://doi.org/10.1080/24751448.2018.1420966.		
Mcconville, Jennifer, Elisabeth Kvarnström, Håkan Jönsson, E. Kärrman, and Mats Johansson. 2017. "Is the Swedish wastewater sector ready for a transition to source separation?" 91. https://pub.epsilon.slu.se/15265/.	Sweden	BW; Agriculture
Medilanski, Edi, Liang Chuan, Hans-Joachim Mosler, Roland Schertenleib, and Tove A. Larsen. 2007. "Identifying the Institutional Decision Process to Introduce Decentralized Sanitation in the City of Kunming (China)." *Environmental Management* 39 (5): 648–62. https://doi.org/10.1007/s00267-005-0321-0.	China	BW; Agriculture
Domènech, Laia, Hug March, Maria Vallès, and David Saurí. 2015. "Learning Processes during Regime Shifts: Empirical Evidence from the Diffusion of Greywater Recycling in Spain." *Environmental Innovation and Societal Transitions* 15 (June): 26–41. https://doi.org/10.1016/j.eist.2014.01.001.	Spain	SW, GW; NPR
Ndeketeya, Annah, and Morgan Dundu. 2019. "Maximising the Benefits of Rainwater Harvesting Technology towards Sustainability in Urban Areas of South Africa: A Case Study." *Urban Water Journal* 16 (2): 163–69. https://doi.org/10.1080/1573062X.2019.1637907.	South Africa	SW; NPR
Welie, Mara J. van, and Henny A. Romijn. 2018. "NGOs Fostering Transitions towards Sustainable Urban Sanitation in Low-Income Countries: Insights from Transition Management and Development Studies." *Environmental Science and Policy* 84: 250–60. https://doi.org/10.1016/j.envsci.2017.08.011.	Kenya	BW; Agriculture
Schramm, Engelbert, Heide Kerber, Jan Hendrik Trapp, Martin Zimmermann, and Martina Winker. 2018. "Novel Urban Water Systems in Germany: Governance Structures to Encourage Transformation." *Urban Water Journal* 15 (6): 534–43. https://doi.org/10.1080/1573062X.2017.1293694.	Germany	General; General
Brown, Rebekah, Megan Farrelly, and Nina Keath. 2009. "Practitioner Perceptions of Social and Institutional Barriers to Advancing a Diverse Water Source Approach in Australia." *International Journal of Water Resources Development* 25 (1): 15–28. https://doi.org/10.1080/07900620802586090.	Australia	General; General
Simha, Prithvi, and Mahesh Ganesapillai. 2017. "Ecological Sanitation and Nutrient Recovery from Human Urine: How Far Have We Come? A Review." *Sustainable Environment Research* 27 (3): 107–16. https://doi.org/10.1016/j.serj.2016.12.001.	Global	BW; Agriculture

Papasozomenou, Ourania, Timothy Moss, and Natàlia García Soler. 2019. "Raindrops Keep Falling on My Roof: Imaginaries, Infrastructures and Institutions Shaping Rainwater Harvesting in Berlin." *Journal of Environmental Policy & Planning* 21 (4): 358–72. https://doi.org/10.1080/1523908X.2019.1623658.	Germany	SW; NPR
Cook, Christina. 2016. "Regulating the Risks of Domestic Greywater Reuse: A Comparison of England and California" 42 (2): 230–42. https://doi.org/10.2148/benv.42.2.230.	England; USA	GW; NPR
Särkilahti, Maarit, Viljami Kinnunen, Riitta Kettunen, Ari Jokinen, and Jukka Rintala. 2017. "Replacing Centralised Waste and Sanitation Infrastructure with Local Treatment and Nutrient Recycling: Expert Opinions in the Context of Urban Planning." *Technological Forecasting and Social Change* 118 (May): 195–204. https://doi.org/10.1016/j.techfore.2017.02.020.	Finland	GW, BW; Agriculture
Lee, Ju Young, Moo Young Han, and Hyoungjun Kim. 2010. "Review on Codes and Application of Urban Rainwater Harvesting Utilization: Focused on Case Study in South Korea." *International Journal of Urban Sciences* 14 (3): 307–19. https://doi.org/10.1080/12265934.2010.9693687.	South Korea	SW; NPR
Quezada, George, Andrea Walton, and Ashok Sharma. 2016. "Risks and Tensions in Water Industry Innovation: Understanding Adoption of Decentralised Water Systems from a Socio-Technical Transitions Perspective." *Journal of Cleaner Production* 113 (February): 263–73. https://doi.org/10.1016/j.jclepro.2015.11.018.	Australia	SW, GW, BW; NPR
McConville, J. R., E. Kvarnström, H. Jönsson, E. Kärrman, and M. Johansson. 2017. "Source Separation: Challenges & Opportunities for Transition in the Swedish Wastewater Sector." *Resources, Conservation and Recycling* 120 (May): 144–56. https://doi.org/10.1016/j.resconrec.2016.12.004.	Sweden	BW; Agriculture
Craig, Madeleine, and Richman, Russell. 2018. "Towards Development of a Standard Methodology for Testing Field Performance of Residential Greywater Reuse Systems: Case Study of a Greywater Reuse System Installed in 22 Homes in Southern Ontario (Canada)." *Journal of Water Reuse and Desalination* 8 (2): 135–52. https://doi.org/10.2166/wrd.2017.020.	Canada	GW; NPR
Wilcox, Jonathan, Fuzhan Nasiri, Sarah Bell, and Md. Saifur Rahaman. 2016. "Urban Water Reuse: A Triple Bottom Line Assessment Framework and Review." *Sustainable Cities and Society* 27 (November): 448–56. https://doi.org/10.1016/j.scs.2016.06.021.	Global; England	General; NPR
Schuetze, T. (2013). Rainwater harvesting and management—Policy and regulations in Germany. Water Science and	Germany	SW; NPR

Technology-Water Supply, 13(2), 376–385. https://doi.org/10.2166/ws.2013.035		
Campisano, A., Butler, D., Ward, S., Burns, M. J., Friedler, E., DeBusk, K., Fisher-Jeffes, L. N., Ghisi, E., Rahman, A., Furumai, H., & Han, M. (2017). Urban rainwater harvesting systems: Research, implementation and future perspectives. Water Research, 115, 195–209. https://doi.org/10.1016/j.watres.2017.02.056	Global	SW; NPR
Rupiper, A. M., & Loge, F. J. (2019). Identifying and overcoming barriers to onsite non-potable water reuse in California from local stakeholder perspectives. Resources, Conservation & Recycling: X, 4, 100018. https://doi.org/10.1016/j.rcrx.2019.100018	USA	GW; NPR
Jonasson, O. J., & Kandasamy, J. (2018). Decentralised water reuse in Sydney, Australia: Drivers for implementation and energy consumption. Journal of Environmental Engineering and Science, 13(1), 2–7. Scopus. https://doi.org/10.1680/jenes.17.00012	Australia	SW, WW; NPR
Poortvliet, P. M., Sanders, L., Weijma, J., & De Vries, J. R. (2018). Acceptance of new sanitation: The role of end-users' pro-environmental personal norms and risk and benefit perceptions. Water Research, 131, 90–99. https://doi.org/10.1016/j.watres.2017.12.032	The Netherlands	GW, WW: Agriculture