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Regulators and Utility Managers Agree About Barriers and Opportunities for Innovation in the Municipal Wastewater Sector

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Alida Cantor^{1,2} , Luke Sherman^{2,3} , Anita Milman⁴ and Michael Kiparsky² ¹ Department of Geography, Portland State University, Portland, OR, United States of America² Center for Law, Energy and the Environment, School of Law, University of California at Berkeley, Berkeley, CA, United States of America³ Energy and Resources Group, University of California at Berkeley, Berkeley, CA, United States of America⁴ Department of Environmental Conservation, University of Massachusetts, Amherst, MA, United States of AmericaE-mail: acantor@pdx.edu**Keywords:** innovation, regulation, regulators, public utilities, wastewater treatment, Clean Water ActSupplementary material for this article is available [online](#)**Abstract**

Despite pressures to improve performance and reduce costs, innovation in the municipal wastewater sector in the United States has been notoriously slow. Previous research has suggested that wastewater utility managers may see regulation as a barrier to developing and deploying new technologies. To better understand how environmental regulation may fuel or hinder innovation in this sector, we conducted a nationwide survey of wastewater utility managers and wastewater regulators in the United States, asking both populations about their perceptions of specific aspects of regulation and innovation. Survey results revealed broad agreement between the two groups that funding and capacity, regulatory relationships, and complexities and inconsistencies within the regulatory environment present key barriers to and opportunities for enabling increased innovation in the municipal wastewater sector. While utility managers perceived almost all aspects of regulation as stronger barriers and opportunities than regulators did, both groups ranked them similarly. These results are promising evidence of common ground between wastewater regulators and municipal wastewater utility managers, and suggest shared views of key leverage points for encouraging innovation. Notably, neither regulators nor utility managers viewed reducing regulatory stringency as a productive way to encourage the deployment of new technologies. Rather, our survey results suggest that improving relationships and communication between utility managers and regulators, along with additional funding support for increased capacity of both utilities and regulators, would be more fruitful ways to encourage innovation in the municipal wastewater sector.

1. Introduction

Municipal wastewater treatment has played an essential role in the health and safety of humans and the environment. However, wastewater treatment systems in the United States must evolve to keep up with changes such as urban growth, climate change, and aging infrastructure (Kiparsky *et al* 2013, Sedlak 2014). The United States water sector—including both drinking water and wastewater treatment—has been characterized as slow to innovate despite numerous technical advances and a clear and pressing need for change (Thomas and Ford 2005, Kiparsky *et al* 2013, Sedlak 2014, Kiparsky *et al* 2016). Given this ‘innovation deficit’ (Kiparsky *et al* 2013), it is important to better understand barriers to innovation by municipal wastewater utilities. Utility managers may see regulation as a barrier to innovation (Ajami *et al* 2014, Kiparsky *et al* 2016), even though water quality regulations are generally intended to be ‘technology-forcing’ (Gerard and Lave 2005, Eisner 2007, Glicksman *et al* 2010, Sherman *et al* 2020). Better understanding the intersection between regulation and innovation may inform actions that support the sector as a whole in protecting environmental health while encouraging advances in wastewater treatment technology.

In this paper, we examine two sets of key decision makers involved in innovation in the wastewater sector. Municipal wastewater utilities, also known as Publicly Owned Treatment Works (POTWs), are the entities that implement new ideas, technologies, and practices. State and federal regulators and regulatory agencies regulate POTW discharges under the federal Clean Water Act (CWA). Individual regulators and regulatory agencies play an important role in innovation since they are in effect responsible for overseeing and approving the implementation of new technologies. While processes leading to innovation include a variety of other actors, including consultants and other organizations, we focus on utility managers and regulators as primary decisionmakers.

The municipal wastewater sector is a complex institutional and infrastructure system which resists transformational change (Markard 2011, Kiparsky *et al* 2013). Public sector utilities may be interested in new technologies that improve environmental performance or lower costs, but may be unsure of the financial or regulatory implications of implementing them. Regulators may understand the need for innovation and simultaneously feel constrained by convention or bureaucratic silos (Sørensen and Torfing 2011, Wagner and Fain 2018). In addition, regulators' sensitivity to environmental risks can make them justifiably wary of unproven technologies (Baldwin *et al* 2012). These two sets of entities—utility managers and regulators—have different roles in the innovation process, and may understand differently how regulation affects innovation. Moreover, their distinct roles can lead to a baseline assumption of oppositionality between utility managers and regulators. This assumption can hinder appropriate collaboration, consistent with the respective responsibilities of the two communities, and stymie creativity. Identifying where utility managers and regulators have overlapping or diverging perspectives could help identify ways to overcome institutional inertia.

To compare perceptions of regulation and innovation in the U.S. municipal wastewater sector, we conducted a national survey of wastewater utility managers and wastewater regulators across the United States. The survey asked respondents about regulatory barriers to innovation and opportunities for regulation to encourage innovation. In this paper we examine how the perspectives of the two groups of respondents overlap and diverge. We find that utility and regulator perspectives are broadly aligned with regard to regulatory barriers and opportunities to encourage innovation. Neither utility managers nor regulators emphasized reducing regulatory stringency as a key opportunity for encouraging innovation; instead, both groups pointed to the importance of capacity (including funding, time, knowledge, and staff), relationships and communication. In this paper we analyze the perceptions of each group and how they compare with one another, and discuss policy-relevant insights about the relationship between regulation and innovation.

2. Innovation and regulation in the municipal wastewater sector

Innovation in the municipal wastewater sector is the adoption of new technologies and management practices. This innovation is motivated by the need to address challenges and dynamic changes that utilities face, including urban population growth, changing climate conditions, aging infrastructure, budget reductions, and increasing environmental performance expectations (Kiparsky *et al* 2013, Sedlak 2014). For this study, we focus on innovation as it relates to the adoption and diffusion of new technologies (Sunding and Zilberman 2001, Kiparsky *et al* 2016). Examples of innovation include the use of membrane technologies for wastewater treatment, resource recovery processes, nature-based treatment solutions, and intelligent monitoring and information technologies.

While innovation and regulation need not be at odds with one another (e.g., Driesen 2003, Wagner and Fain 2018), the two processes necessarily intersect. Environmental regulation involves the processes of developing and implementing statutes, rules, permits, and programs intended to protect natural resources and public health (Fiorino 2006). In this paper, we define regulation broadly to also include the wider regulatory environment and the relationships between regulators and the regulated community (Black 2002, Sherman *et al* 2020). In practical terms, utilities often need approvals from regulators in order to implement new wastewater treatment technologies. Regulators, on the other hand, must be confident that treatment technologies will achieve discharge standards in order to grant discharge permits. Both parties could face legal consequences if water quality standards are violated (May 2003).

An important locus of regulation for U.S. wastewater utilities is the writing and enforcement of permits to discharge treated wastewater under the CWA's National Pollutant Discharge Elimination System (NPDES) program (33 U.S.C. §§ 1251–1388). Wastewater utilities must comply with limitations on specific pollutants in discharged effluent. Some effluent limitations are defined based on the expected performance of secondary treatment processes, although the regulations do not require use of specific control technologies (EPA 2010). In addition, many utilities must meet more stringent water quality-based effluent limitations. Interactions between wastewater utilities and CWA regulators typically occur during the NPDES permitting process every five years, and, if violations occur, during enforcement actions. Wastewater utilities may be subject to other regulations

under federal, state, and local laws as well (for example, requirements related to air quality, land use, solid waste disposal, etc).

Previous research has examined whether environmental regulation encourages or acts as a barrier to innovation (Porter and Van der Linde 1995, Ambec *et al* 2013). Results have been mixed, and reveal many relevant variables, including regulatory stringency, types of regulatory mechanisms used, and uncertainty about future regulation (Stewart 1981, Bernauer *et al* 2007, del Río González 2009, Hemmelskamp *et al* 2000, Sherman *et al* 2020). Most studies have examined the impact of regulation on private-sector businesses, but the vast majority of U.S. municipal wastewater utilities are publicly owned, and exhibit different innovation-regulation dynamics than private firms (Wolf 1979, Brubaker 2002, National Research Council 2002, Markard and Truffer 2006, Sherman *et al* 2020). Further, existing research mostly compares effects of specific regulatory instruments such as bans, commands, subsidies, or pollution trading (e.g. Hemmelskamp 1997, Kemp and Pontoglio 2011, Coglianesi and Nash 2017). To date, there is little research that looks at regulator perspectives on innovation. On the wastewater utility side, most research has only coarsely examined regulatory barriers to innovation (Ajami *et al* 2014, Kiparsky *et al* 2016). To our knowledge, none has combined both perspectives in a detailed comparison. This paper seeks to identify specific aspects of the regulatory process that serve to bar or promote innovation in the municipal wastewater sector, and where and how the perspectives of these two stakeholder communities overlap and contrast.

3. Methods

We conducted an online survey of regulator and utility manager perceptions of the relationship between regulation and innovation in the wastewater sector. We briefly summarize the survey and analysis methods here (see Sherman *et al* 2020; see also Supplemental Information A for more detail).

Our survey included a series of Likert-type questions about aspects of regulation that act as barriers to innovation, and aspects of regulation that could encourage innovation. The survey also invited open-ended responses. Separate versions of the survey were developed for regulators and utility managers, with minor wording adjustments to account for respondent context. We received 225 complete responses from utility managers, representing an estimated 5% of the total population of POTW managers, collectively providing wastewater treatment to approximately 35% of the US population served by sewer systems. Responses from 79 NPDES permit writers, their managers, and related staff represent approximately 7%–15% of wastewater regulators.

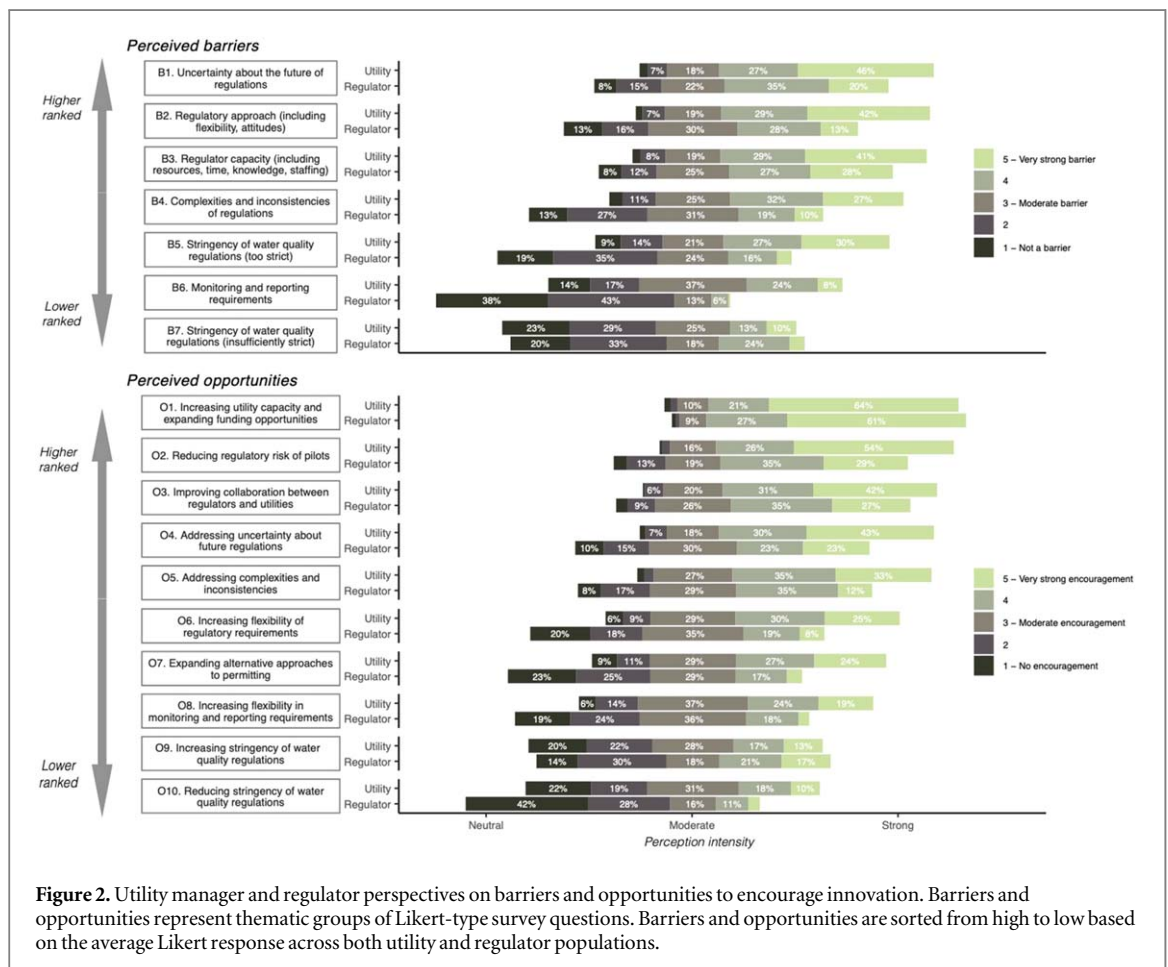
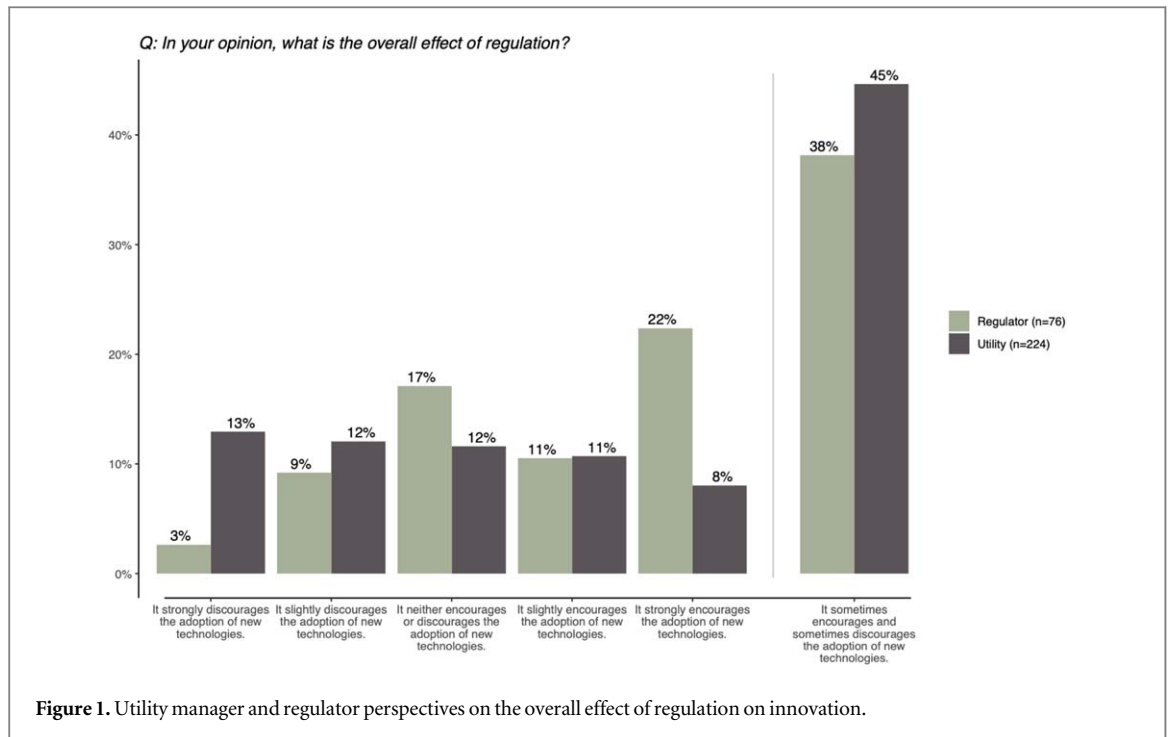
Analysis focused on comparing results from utility managers and regulators. Because our survey included a long list of questions (see Supplemental Information B for full list of survey questions and results), we used exploratory factor analysis to group survey questions into themes. We identified seven themes related to barriers to innovation and ten themes related to opportunities to encourage innovation. Additionally, open-ended comments were coded and analyzed using qualitative data analysis software (Atlas.TI).

Results are analyzed in several ways in the following sections. First, we examine *perception intensity*, which reflects how strongly a group perceived any particular aspect of regulation with respect to its effect on innovation, as reflected by the Likert-type score on any question. In the figures below, perception intensity ranges from ‘neutral’ (not perceived as a barrier/opportunity) to ‘strong’ (perceived as a strong barrier/opportunity). Second, we examine *agreement or alignment* between each group’s perceptions of a particular aspect of regulation by ordering aspects of regulation based on Likert scores and comparing perceptions of relative importance between the groups of respondents. Third, we analyze and discuss results *thematically* by aggregating barriers and opportunities on related topics into five main categories.

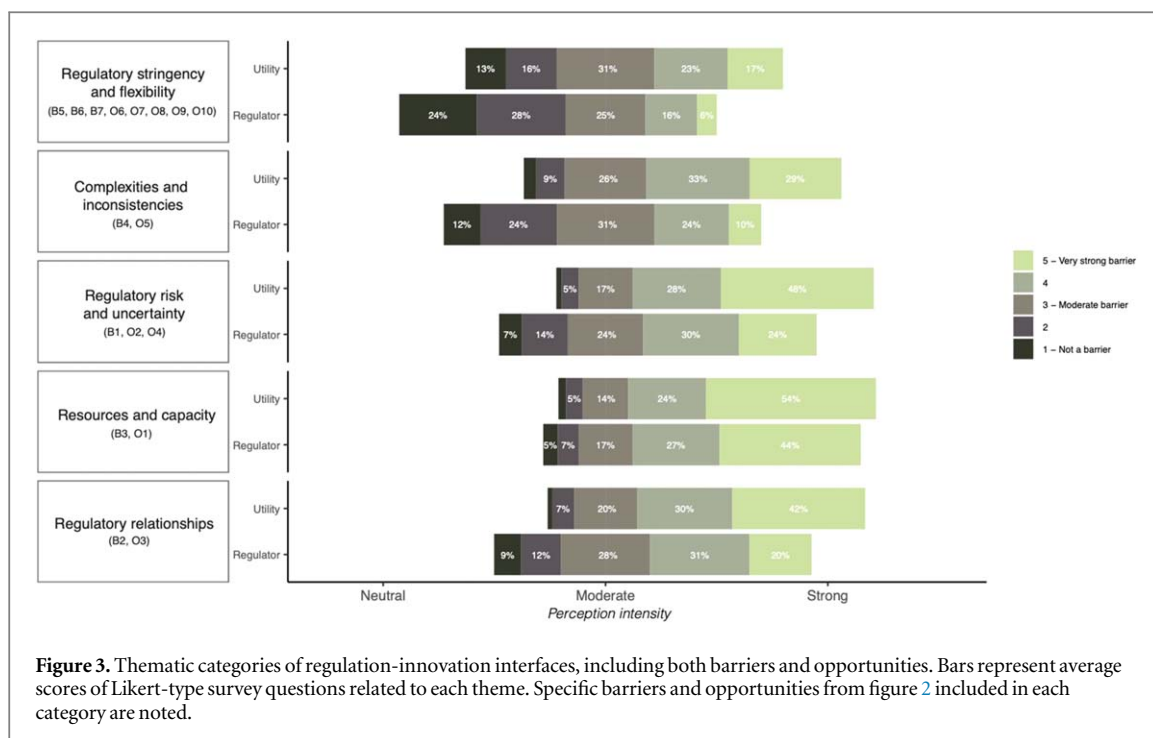
4. Results

Survey results indicate that, on the whole, utility manager and regulator perceptions of the relationship between regulation and innovation were well-aligned. When asked about the general relationship between innovation and regulation, a plurality of regulators and utility managers agreed that regulation ‘sometimes encourages and sometimes discourages’ innovation (figure 1), emphasizing the importance of examining specific aspects of regulation more closely, as this study does.

Both groups also had similar perceptions of specific regulatory barriers and opportunities to encourage innovation. Each group ordered barriers and opportunities similarly, (figure 2), suggesting overall alignment on the perceived impact of different aspects of regulation. Barriers and opportunities identified as most impactful also had the highest agreement between regulator and utility manager opinions. This suggests general alignment between the two communities on the most fruitful ways to encourage innovation in this sector.



Even so, there were gaps in perception intensity between utility managers and regulators. Utility managers perceived nearly every barrier and opportunity as stronger than regulators, as depicted by the consistent skewing of bars in each pairwise comparison in figure 2 (see also supplemental information B, Figures S1–S7 (available online at stacks.iop.org/ERC/3/031001/mmedia)). These data may imply that regulators do not have a full



understanding about the intricacies and operational challenges that utility managers face when attempting to implement new technologies. Or, regulators may be less aware of the ways in which various small and moderate barriers to innovation faced by POTWs interact or come together to limit innovation. Alternatively, it may suggest that utilities use the prospect of various regulatory hurdles to excuse their own risk aversion and avoid the consideration of new technologies (e.g., Rayner *et al* 2005, Ambec *et al* 2013).

Combining the barriers and opportunities listed in figure 2 into five interrelated themes provides a more concise picture of the overarching themes and perceptions discussed above (figure 3). Viewing the results in this way makes clear that regulators and utility managers are more aligned around themes of resources and capacity (e.g., funding, time, staff, knowledge), regulatory relationships, and regulatory risk. The groups have more divergent perspectives on themes of stringency and flexibility as well as complexities and uncertainties.

We discuss each of these five themes in further detail in the remainder of the results section.

4.1. Regulatory stringency and flexibility

The relationship between stringency of regulatory requirements and innovation in the municipal wastewater context is unclear. On one hand, regulatory requirements can drive implementation of new technologies: the need to comply with stringent water quality regulations may push utilities to innovate, despite institutional inertia (e.g., Markard 2011). At the same time, a set of rigid performance and monitoring requirements—especially those based on an incumbent technology—may not provide utilities sufficient flexibility or incentives to consider new approaches (e.g., Stewart 1981, del Río González 2009).

Utility managers and regulators did *not* identify either relaxation or tightening of regulatory stringency as an important way to stimulate innovation in the sector (figure 2: B5, B6, B7, O9, O10; figure S1 in supplemental information). Although the theme was not ranked highly as a barrier or opportunity by either group, there was a marked difference in perception intensity: utility managers perceived regulatory stringency and monitoring and reporting requirements as much stronger barriers than regulators (figure 2: B5; figure S1). Related questions about potentially increasing flexibility of regulatory requirements or exploring alternative approaches to permitting also revealed a perception gap, and were perceived as moderate opportunities by utility managers but lower opportunities by regulators (figure 2: O6, O7, O8, figure S1). Both regulators and utility managers identified other opportunities to encourage innovation as higher priorities than increasing regulatory flexibility.

4.2. Complexities and inconsistencies

In practice, wastewater utilities are bound not only by the CWA and the specific terms of NPDES permits, but also by other laws. Utilities frequently interact with other local, state, and federal agencies and must comply with regulations related to, e.g., air quality, land use, and solid waste disposal. Current trends in wastewater innovation may increase regulatory interactions, as new approaches in this sector often cross jurisdictional

boundaries to achieve multiple benefits (Harris-Lovett *et al* 2018, Luthy *et al* 2020). Thus, other areas of regulation, and the interactions between them, may also impact innovation in the wastewater sector.

Utility managers and regulators both considered complexities and inconsistencies across multiple sectors and areas of regulation to be a moderate barrier to and opportunity to encourage innovation (figure 2: B4, O5, figure S2). Overall utility managers perceived regulatory complexities and inconsistencies as a stronger barrier and opportunity to encourage regulation than regulators did (figure 3). In particular, utility managers saw conflicting monitoring and reporting requirements between different agencies as a stronger barrier than regulators did (figure S2). This difference may be because regulators are less aware of the broader regulatory context outside their focus area, while utility managers encounter multiple types of regulations in their day-to-day work.

4.3. Regulatory risk and uncertainty

Both regulators and utility decision makers are often and understandably characterized as risk averse (Baldwin *et al* 2012, Kiparsky *et al* 2016, Wagner and Fain 2018). New technologies often entail expensive, capital-intensive projects, and costs of failure are high. Utilities risk stranded assets, negative public perceptions, lawsuits, and penalties for violation of NPDES effluent limits should new technologies fail. Regulators are also at risk for lawsuits if they approve a technology that results in a water quality violation.

Regulators and utility managers both perceived regulatory uncertainty as a strong barrier to innovation (figure 2: B1). If utility managers are uncertain about what future regulations might hold, then investments in durable infrastructure become risky. Utility managers may be unwilling to invest resources in new technology with long design life and high financial breakeven points, if they are uncertain about long-term regulatory acceptability. Both utility managers and their regulatory counterparts agreed that addressing uncertainty about future regulations would be a high priority for encouraging innovation (figure 2: O4).

Regulators and utility managers also agreed that reducing regulatory risk of pilot projects would strongly encourage innovation (figure 2: O2), but did not completely agree about how exactly to do so. For example, a slightly larger proportion of utility managers than regulators thought the use of 'safe harbor' provisions to reduce liability when piloting new technologies would strongly encourage innovation (figure S3). Pilots of unconventional technology carry higher risk of failure than tried-and-true technologies. From a regulator's perspective, reducing risks of pilots is not always possible, and violations of NPDES permit terms are violations of the law even if they occur during a pilot of new technology.

4.4. Resources and capacity

Lack of funding is widely recognized as a barrier to innovation in the wastewater treatment sector (Environmental Law Institute 1998, ASCE 2016). Researching, piloting, constructing, and monitoring new technologies can be costly for utilities. Early in the history of the CWA, Congress introduced specific financial incentives to encourage the use of new technologies, including federal funding for modification or replacement if a technology failed to perform to design standards. However, federal funding for wastewater infrastructure and innovation decreased significantly after changes to the CWA in 1987 (Parker 1988, EPA 1989), shifting more of the financial burden of innovation onto utilities. State and local governments have since struggled to meet capital investment needs of POTWs. In our survey, we defined capacity more broadly to include not only funding resources, but also the time, staffing, and knowledge required to handle unconventional technologies.

Unsurprisingly, increasing capacity was viewed as the most fruitful avenues for encouraging innovation by utility managers and regulators alike (figure 2: O1), and also generated the highest level of agreement between the two groups (figure 3; figure S4). Sufficient resources are needed for utility managers to research, understand, and monitor unconventional and less familiar technologies. Yet only a few large wastewater utilities have substantive research capacity, and most utilities do not have even a single staff member specifically dedicated to research and innovation. In addition to supporting innovation-specific funding for utilities, both regulators and utility managers noted concern about regulators' capacity to handle innovative technologies (figure 2: B3). Utility managers and regulators both recognize capacity constraints of their counterparties, and suggest more resources on both sides could enable greater innovation.

4.5. Regulatory relationships

In addition to rules and parameters, regulation also involves communication and relationships between regulators and the regulated community (Black 2002, Willman *et al* 2003, Sherman *et al* 2020). When a utility is considering implementing new technologies, communication and relationships with regulators are particularly important. Improving communication between regulators and the regulated community may even be as important as designing better policy mechanisms for facilitating innovation (Janicke *et al* 2000, Black 2002).

On the whole, barriers and opportunities related to regulatory relationships were considered important by both regulators and utility managers (figure 2: B2, O3). The two groups were very well-aligned on the value of opportunities to encourage innovation through improved communication. However, they were slightly less well-aligned on the barriers related to relationships and communication, with a larger proportion of utility managers than regulators perceiving 'regulator approach toward rule enforcement' as a very strong barrier (figure S5).

5. Discussion

Existing literature on environmental regulation of private firms often emphasizes adversarial relationships between regulators and regulated communities (e.g., Eisner 2007). As a practical matter, an assumption of oppositionality is common in regulatory relationships in the U.S. municipal wastewater sector, stemming in part from the fact that utility managers answer to a range of interests such as elected board members and ratepayers, whereas regulators have a more singular job of upholding specific laws. To the extent that it dampens the potential for cooperative efforts, such seeming lack of alignment can slow progress on innovation.

However, in contrast to these assumptions, the results of this study indicate general agreement between regulators and the regulated community in how they perceive the relationship between innovation and regulation. The results also reveal potential joint support for actions to encourage innovation. The data highlight public utility managers' understanding of the value of regulation. For example, utility managers did not emphasize weakening regulatory stringency as an opportunity for encouraging innovation. Instead, they favor an increase in regulatory capacity, along with expanded communication and collaboration. Our results suggest that utility managers recognize the value of regulation, and share regulators' goal of effectively protecting the environment and public health, even if specific decisions can at times become contentious.

Based on the survey findings, we suggest specific actions likely to encourage innovation and generate buy-in from both utility managers and regulators. Table 1 synthesizes the survey findings and outlines actions that might encourage innovation.

The results from this study have key actionable implications for a range of decision makers including leaders within the wastewater sector and outside actors such as legislators (table 1). Decision makers seeking to foster innovation in wastewater treatment would ideally start by (a) developing opportunities for regulators to communicate with one another about strategic ways to increase flexibility and reduce risk while maintaining integrity of water quality; (b) improving relationships between utility managers and regulators to navigate complexities and evaluate benefits and risks of new technologies; (c) advocating for additional funding support for innovation, including research funding and funding to increase capacity of both utilities and regulators; and (d) investing in a collaborative, sector-wide process for discovering and highlighting areas of intersectionality and conflict between different classes and types of regulation to help utilities navigate multiple regulatory processes when implementing new technologies.

Improved communication is likely especially important due to differences between regulators and utilities given their respective roles within the regulatory process. For example, while utilities may seek regulatory flexibility, regulators may favor a precautionary approach, grounded in bright-line rules (Baldwin *et al* 2012, Brown and Osborne 2013). Indeed, regulator caution is important for making sure attempts at innovation are appropriate and likely to succeed. Communication can help with making sure decisions are transparent, navigating complexity, and helping both regulators and utilities better evaluate risk through improved understandings of the full context of proposed innovative technologies.

6. Conclusions

In this paper, we report on similarities and differences in perspectives on the relationship between innovation and regulation among utility managers and regulators in the U.S. wastewater sector. Understanding where these perspectives overlap and diverge can help guide improvements in regulatory processes that encourage innovation while ensuring environmental protection.

Crucially, our results support the notion that, in spite of potential for oppositionality in individual negotiations between utility managers and regulators, both groups share many views of the relationship between innovation and regulation. Both regulators and utilities are interested in innovations that protect public and environmental health while offering benefits over conventional technologies. Many attempts to innovate are necessary for meeting future challenges, rather than veiled attempts to circumvent water quality regulations.

Table 1. Synthesis of survey findings and recommendations, linking regulatory barriers and opportunities, perceptions of these barriers and opportunities as revealed by survey results, and actionable implications for decision makers.

Category	Level of agreement	Relative importance	Takeaways	Implications: what can be done to encourage innovation?
Regulatory stringency and flexibility	Low-medium	Low	Regulatory stringency was perceived as a stronger barrier by utility managers, but was not a major barrier or opportunity for either group. Utility managers saw some potential to encourage innovation by increasing flexibility.	<ul style="list-style-type: none"> • Increase communication within regulatory community to identify where opportunities for flexibility in NPDES permitting may exist. • Increase communication between regulators and utility managers to determine where such flexibility would be most helpful in encouraging adoption of innovative technologies.
Complexities and inconsistencies	Low	Medium	Utility managers perceived regulatory complexities and inconsistencies as a much stronger barrier than regulators did.	<ul style="list-style-type: none"> • Support utilities in navigating the various regulatory processes associated with wastewater innovation. • Make sure regulators understand how and why regulatory complexities and inconsistencies act as a barrier for utilities. • Align regulatory requirements when possible.
Regulatory risk and uncertainty	Medium	Medium	Both groups expressed risk-aversion and saw regulatory uncertainty as a barrier to innovation.	<ul style="list-style-type: none"> • Increase communication within the regulatory community to determine when it may be possible to mitigate regulatory risk during pilot projects. • Address uncertainty through improved communication.
Resources and capacity	High	High	Both groups perceived limited capacity as a barrier to innovation, both for themselves and for the other group.	<ul style="list-style-type: none"> • Increase funding and resources dedicated to innovation for both groups. • Build capacity of regulators to handle regulation of unconventional technologies. • Build internal research capacity and culture within a broader range of utilities. • Support academic- and industry-led research collaboratives working to research new technologies and build innovation capacity.
Regulatory relationships	Medium-high	High	Both groups saw potential to encourage innovation by improving communication and relationships.	<ul style="list-style-type: none"> • Support more frequent and substantive communications through the innovation process. • Support utilities in navigating complexities, understanding potential flexibilities, and evaluating potential risks.

Jointly focusing on this orientation, while keeping sight of necessary safeguards, can serve as an important starting point in conversations about innovative wastewater technologies.

This study shows general alignment between wastewater regulators and the regulated community of wastewater utility managers on the factors that stand in the way of innovation, as well as the types of regulation-related opportunities that would encourage innovation. This alignment points towards actionable steps. In particular, regulators and utility managers converged around solutions involving funding and capacity building in order to support the unique and potentially time-consuming regulatory needs of innovative technologies. Additionally, both regulators and utility managers identified improvements to regulatory relationships and communication as more likely to encourage innovation than reducing the stringency of particular regulatory requirements. Expanded emphasis on collaboration and communication between utilities and regulators—when supplemented with funding and other resources—may help to overcome many of the regulatory barriers to innovation identified in this study. Internal communication within and among regulatory communities may also help to identify specific ways that regulators can alleviate risk and uncertainty, address complexities and inconsistencies across different areas of regulation, and identify opportunities for permitting flexibility while maintaining regulators' main responsibility of protecting public and environmental health.

Future refinement of the ideas and conclusions presented here could improve understanding of regulation-innovation dynamics. Further research examining utility manager and regulator attitudes toward risk could add more nuance. Additionally, while private ownership of municipal wastewater treatment utilities is currently rare in the United States, some utilities have explored privatized management, and future analysis could examine whether there are differences between innovation-regulation dynamics in public versus private utilities. Future research could also examine the role of citizen groups and other stakeholders in innovation and regulation.

Ultimately, evidence of common ground between wastewater regulators and municipal wastewater utility managers suggests shared views about how to encourage innovation. Understanding, acknowledging and addressing regulatory barriers and opportunities can foster innovation in the wastewater sector.

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Data availability statement

The data that support the findings of this study are openly available at the following URL:<https://purl.stanford.edu/np896ft3086>.

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