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Pizzi, Enrico; Fratini, C.F.; Mishra, A. D.; Ingildsen, P.; Mikkelsen, P. S.; Valverde Pérez, B.; Vezzaro, L.

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Building a Synergistic Vision for Multi-Objective control of WRRFs through Stakeholder Engagement

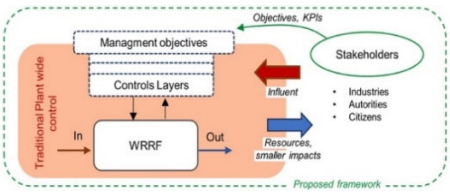
Enrico Pizzi*,**,C.F. Fratini**, A. D. Mishra*, P. Ingildsen*, P. S. Mikkelsen**, B. Valverde Pérez**, L. Vezzaro**.*

Introduction: The pursuit of improved eco-efficiency in operation of Water Resources Recovery Facilities (WRRFs) is an absolute priority in modern environmental management. The opportunities created by advanced data collection systems, combining online sensors and cloud storage solutions, integrated with Digital Twins (Therrien et al., 2020), pave the way for plant-wide controls. These represent a precious tool to improve plant performance with limited infrastructure investments, promoting environmental sustainability and economic benefits in dynamic ecosystems (Regmi et al., 2019). In the development of plant wide control, the first layer in the control hierarchy (Larsson and Skogestad, 2000) implies the definition of the (multiple) control objective(s). This step is often overlooked, potentially leading to neglecting processes that can play a significant role in improving the WRRF eco-efficiency and thus creating an unbalanced model. This study introduces a comprehensive framework that encompasses stakeholders such as industries, public authorities, and environmental regulators outside the Hillerød WRRF (Danmark) is presented. The framework involves identifying influential factors conducting stakeholder interviews, co-creation of Key Performance Indicators, assessing environmental challenges and regulatory pathways, and anticipating future challenges (e.g. increasing inlet loads, demand for lower emissions), while considering economic and energy implications. These external stakeholders contribute to the definition of multiple objectives (quantified through Key Performance Indicators). **Methods and data**: This study presents a comprehensive framework for identifying influential factors for establishing an effective control strategy in WRRFs. The framework is illustrated through a practical case study of the Hillerød Forsyning WRRF in Denmark. The proposed method employs structured interviews with key stakeholders directly engaged with the plant, including internal staff, major industries discharging into the facility, the local municipality, and the community. The questions were tailored and selected based on the stakeholders' specific roles to ensure better alignment with the contextual requirements. The analysis subsequently considers the bottleneck involved in the implementation of the control strategies, focusing on the economic and energy implications of the different scenarios. Additionally, an examination of the environmental status and relevant regulations was explored, incorporating valuable perspectives from internal biologists directly engaged in the management of outflow basins. The discussions with industrial representatives primarily focused on key performance indicators (KPIs) related to their discharges and sustainability practices, the possibility of adjusting their processes to meet treatment requirements, potential benefits achievable through a cooperative relationship with the plant (e.g., clean water, heat, energy), strategies for managing and potentially sharing output data with utility providers and local communities, as well as projections for future growth and anticipated requirements. Lastly, data was gathered from the municipality of Hillerød and the local community, with a focus on citizen well-being, upcoming legislative changes, the community's perception of the WRRF, and potential actions and initiatives to enhance the integration of the plant within the community. **Results**: Results are shown in the Tab 1:

Table 1. Overview of the involved stakeholders, their primary interests, potential for data sharing, potential benefits from interacting with WRRF.

Stakeholder	**Primary Interest**	**Benefit**	**Activities**	**Data**	**KPI**
Major Industries	Taxes, ESG policy, Energy.	Public opinion, Clean water	Neutralization strategy, control system for their discharge, Storage during rainfall, Integrated sewers.	Confidentiality	Ph, P, $N_{tot,}$ E, Chemicals
Citizen	Environmental status	Taxes reduction	Awareness activities with data sharing	x	COD, P, N_{tot}
Authorities and Municipality of Hillerød	Limits	Anticipate obligations	Detection of environmental priority.	Possibility of an integrated data system to share	Q, COD, P, N_{tot}, E,

Figure 1. Schematic representation of the proposed framework



**HFORS enpi@hfors.dk, epiz@dtu.dk **DTU 2800 Lyngby luve@dtu.dk*