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Models of demand response and an application for wastewater treatment plants[1]

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Background and Motivation

Demand response can be defined as any change of the usual electricity demand pattern in response to a price signal from the electricity supplier. It is widely seen as a promising tool to increase energy system flexibility: electricity demand can increase when there is a surplus of electricity available, such as when wind levels are high, and can reduce when there is a shortage of electricity. In the industrial sector in particular, the potential for demand response can be significant. This is because electricity costs can be a big share of total costs and therefore there is a strong incentive to reduce electricity expenditures in order to be competitive. However, to date, the demand response from industrial electricity users has only been examined in a generic way, without taking account of their specific characteristics. Any results arising from these examinations are therefore of limited use for policy makers and industry participants.

This study is a review of the existing literature on demand response modelling. We investigate how industrial demand response is traditionally modelled and whether the existing approaches capture industry-specific characteristics properly. Furthermore, we present the wastewater treatment process as a case study for an industrial process with potential for flexible operation. We analyse whether a lack of suitable modelling tools causes an underutilisation of potential demand response in this particular industry.

Wastewater treatment is an electricity-intensive process. The biological treatment of wastewater involves the growth of microorganisms that break down hazardous matter in the wastewater. In order to support the growth of these microorganisms, oxygen is introduced to the wastewater with blowers, which require a considerable amount of electricity. Wastewater pumping consumes a significant amount of electricity as well. However, these processes have potential for flexible operation, as confirmed by several case studies. Those studies suggest that turning off the blowers and pumps for a certain amount of time is feasible without having any negative implications for the wastewater standards. Additionally, wastewater treatment plants have large wastewater tanks, which usually have surplus capacity. This means that the tanks can be used to withhold wastewater before releasing it for treatment, which also affords the wastewater treatment plant some flexibility in switching off equipment. There is also a potential to use biogas for on-site electricity generation, which can help to bring electricity costs down.

[1] This Bulletin summaries the findings from: Kirchem, D.*, Lynch, M., Bertsch, V., Casey, E. (2020) "Modelling demand response with process models and energy systems models: Potential applications for wastewater treatment within the energy-water nexus", *Applied Energy*, Available online: https://doi.org/10.1016/j.apenergy.2019.114321

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Despite these technical options for flexibility in wastewater treatment operation, wastewater treatment plants rarely participate in demand response programs. The question remains as to whether the economic gains are large enough to justify a shift in operating schedules from business as usual. Furthermore, the costs and benefits for the electricity system as a whole, and for electricity consumers, have yet to be quantified.

Results and Implications

So far, energy systems models for demand response do not include a detailed representation of industrial processes. Many of them assume a generic resource for aggregated demand response provision. However, understanding the demand response potential of a specific industrial process requires a model that considers the industry process itself in detail. On the other hand, industrial process models, which analyse the potential for demand response of a specific end user, do not model the effects of demand response on the electricity system. They assume electricity prices to be uninfluenced by demand response. In reality, large-scale demand response programs can affect system operation and prices in the short term, as well as electricity generation investment decisions in the long term. We conclude from the literature review that the existing modelling approaches cannot capture the full picture of industrial demand response and a new approach is needed.

Therefore, we propose an integrated energy systems model for demand response, which includes details about both the electricity system operation and the industrial process operation. This would facilitate a comprehensive assessment of the flexibility potential of many industries. In the case of wastewater treatment, such a model would enable the comparison of the demand response potential from pumps, blowers and overcapacity in tanks, and the identification of the best demand response strategy.

This study's findings suggest that an integrated model, which considers both the characteristics of the industrial process and the operation of the electricity system, would be of great benefit for policy makers and industry participants alike. For this reason, future work at the ESRI will focus on developing such an integrated model.

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