Coversheet

Who has rådighet? An agency-centred perspective on water conservation

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Who has rådighet? An agency-centred perspective on water conservation

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Abstract

Water conservation is usually catalogued by technology – efficient fixtures, leak control, reuse, metering, process integration. That framing hides a stubborn fact: realised savings consistently fall short of engineering potential and often fade with time. Rebound, poor maintenance and behavioural decay explain part of the gap, but not all. We argue that a large share is an agency mismatch: the actor who would benefit from a measure lacks the authority, capacity and incentive to deploy it, while the actor who holds them does not benefit. Using the Scandinavian concept of rådighet (agency), we map water-conservation measures to the actors holding primary and secondary agency. Clear patterns emerge: agency is concentrated for network measures and fragmented for building-scale ones; the largest potentials sit with the weakest-agency actors; and standards, pricing and digital infrastructure act as agency bridges. Two Swedish field trials show why misaligned agency undermines otherwise sound technology, and we set out what an agency-first approach means for policy.

The gap that will not close

Anyone who has worked with water demand management knows the pattern. A measure looks excellent on paper – the technology works, the payback is short, the savings are real in the lab – and yet, rolled out across a city or a sector, it delivers a fraction of what was promised, and the effect erodes within a few years.

Field evaluations of efficient fixtures typically come in 20–40 % below model estimates[1]; behavioural feedback shows strong early effects that attenuate within one to three years[2]; industrial audits routinely flag 10–30 % savings that are never fully captured[3]. The literature offers four overlapping explanations.

The first is the rebound effect: efficiency is partly eaten by behaviour, such as longer showers under an efficient head[4]. The second is maintenance drift: fixtures, analytics and membranes quietly lose performance without upkeep. The third is behavioural decay: norms and restrictions fade once the crisis or novelty passes. And the one this article foregrounds is agency mismatch: the measure exists and pays, but the actor who would benefit does not hold the decision, or the one who holds it does not benefit. The first three are well studied; the fourth is not, because it sits awkwardly across engineering, economics, governance and institutional sociology. It is also the most fixable by policy, because a mismatch can be diagnosed and an instrument chosen to repair it.

Rådighet: authority, capacity and incentive in one word

Swedish water and environmental law has a useful term that English lacks: rådighet, loosely “command over a thing”. It bundles three ideas that the English literature usually keeps apart: the legal authority to act, the practical capacity to act (skills, capital, information), and an incentive structure that makes acting rational. Throughout this article, an actor has agency over a measure when it holds all three. Where several actors are involved, the one who actually decides and implements has primary agency; the others – who must cooperate, finance, permit, supply or comply – hold secondary, enabling agency.

With that lens, a deliberately coarse set of nine actor categories is enough to map almost any urban or industrial measure: household/user, building owner/property manager, water utility, municipality, national regulator, EU/supranational regulator, industrial operator, industry association/standards body, and

finance/supply-chain buyer. Coarseness is the point – it keeps the map transferable across countries. Fig. 1 shows the resulting agency map for a representative set of measures, coding each actor as primary (P), secondary/enabling (S) or not meaningfully involved (blank).

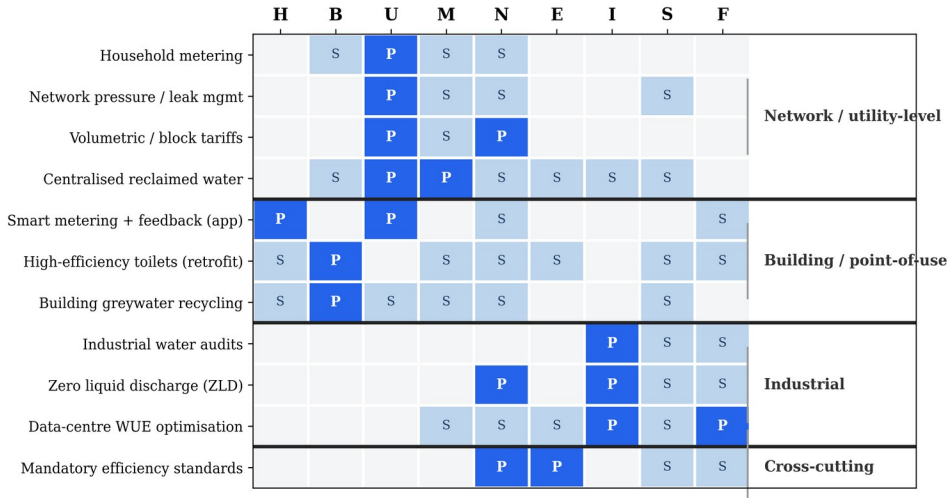

Fig. 1 | Agency map for eleven representative water-conservation measures, grouped by level. Each cell codes an actor as holding primary agency (P, dark blue), secondary/enabling agency (S, light blue) or none (blank). Actors: H, household/user; B, building owner/property manager; U, water utility; M, municipality; N, national regulator; E, EU/supranational regulator; I, industrial operator; S, industry association/standards body; F, finance/supply-chain buyer. Primary agency clusters in the utility column for network measures, in the building-owner and household columns for building measures, and in the industrial-operator column for industrial measures.

Where agency sits – and why it predicts what scales

Read down the columns of Fig. 1 and the pattern is immediate. For network measures – metering, leak and pressure management, network-level tariffs – primary agency is concentrated in one or two actors, almost always the utility, sometimes with the regulator. Volumetric metering alone cuts household use by 10–25 % versus an unmetered baseline[5], and the utility decides whether, when and how to meter; leakage, which globally averages around 30 % of water produced[6], is the cleanest case of all, with the utility owning the pipes, the pressure regime and the repair schedule. Because one identifiable actor can move the whole lever, these measures scale rapidly and uniformly across a service area once the regulatory and financial environment rewards them.

Building-scale measures behave in the opposite way. Fixtures, greywater recycling and rainwater harvesting have primary agency spread across millions of building owners and households, and they proceed slowly, household by household, unless something bridges the gap. The textbook obstacle is the split incentive: in rented housing the tenant pays the water bill but the landlord chooses the fixture[7], so technically attractive replacements stall in the rental segment unless a standard or subsidy intervenes. Reuse is different again – it needs a coalition. Centralised reclaimed water requires utility, municipality and regulator to act as co-primary actors at once; remove any one and the project fails, often for institutional rather than engineering reasons. Two general rules fall out: the largest technical potentials frequently sit with the weakest-agency actors (greywater in rental stock, data-centre water-use efficiency in capital-constrained siting), and a measure's agency structure predicts its real-world trajectory better than its headline effect size does.

Industrial water: concentrated control, diffuse accountability

Industry inverts the urban picture. Water use is concentrated in a handful of thirsty sectors – thermal power, primary metals, pulp and paper, chemicals, refining, textile dyeing, food and beverage, and now

data centres – and within each sector the gap between best-in-class and typical performance is often a factor of three to ten. Crucially, primary agency is almost always held by a single actor, the facility operator, who alone decides whether to reorganise a rinsing cascade, close a cooling loop or install a membrane bioreactor. Audits routinely surface 10–30 % avoidable losses, and process-integration methods such as pinch analysis can cut intake by 20–60 % in water-intensive plants[3]. On paper, this is the cleanest agency structure of all: one decision-maker, clear levers.

Yet the motive to act is diffuse. The operator decides, but regulators set discharge limits, investors condition capital on disclosure, supply-chain buyers impose water standards, insurers price business-continuity risk, and host communities contest withdrawal rights. None of these decides, but collectively they determine whether the operator has any incentive to move. Industrial water agency is therefore concentrated in form but diffuse in motive – the mirror image of the urban building stock, where motive is often clear (the resident wants a lower bill) but agency is fragmented. Two cases sharpen the point. Zero liquid discharge[8] has spread fastest precisely where primary agency shifted from operator to regulator through binding rules – as in Indian and Chinese textile clusters – rather than where it was left voluntary; the more costly the measure, the more often agency migrates from operator to regulator or to a powerful buyer. Data centres are the emerging cautionary tale: evaporative cooling can consume more than two litres per kWh of IT load[9], primary agency sits squarely with the hyperscale operator, yet the water burden falls on the host community whose only lever is municipal permitting. Technical agency and political accountability are sharply misaligned, which is why new instruments – mandatory water-use-efficiency disclosure in siting approval – are being proposed to rebalance them.

Two Swedish field trials, read through the agency lens

Two recent living-lab studies in Gothenburg make the argument concrete – and both, tellingly, land in cooperative/rental housing where water is included in the rent, so residents see no price signal and the building owner captures no saving. Fig. 2 summarises what they measured.

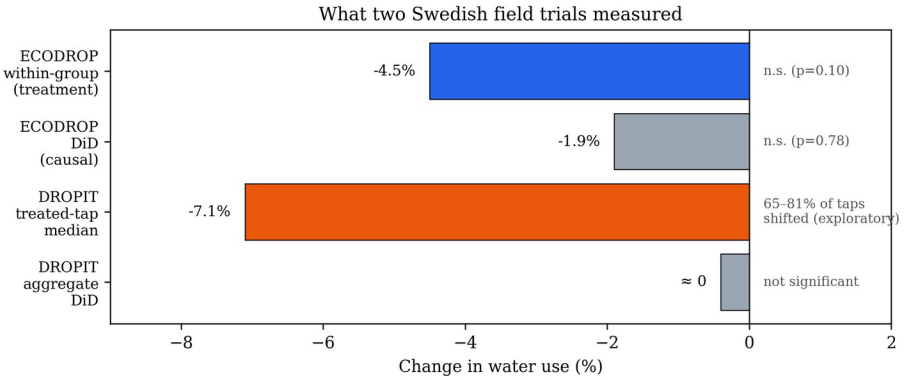

Fig. 2 | Headline results of two Swedish field trials. EcoDrop: real-time point-of-use feedback on kitchen taps in multi-family housing. DROPIT: tap-level monitoring of seven water-saving device categories at HSB Living Lab. n.s., not significant; the DROPIT treated-tap median is exploratory (events nested within taps). Aggregate difference-in-differences estimates were not significant in either study.

EcoDrop[10] placed a small LED device on kitchen taps that gave residents real-time feedback on their water use, in a controlled field experiment in Swedish multi-family housing (18 treatment, 47 control apartments). The treatment group reduced use by about 4.5 %, but the difference-in-differences estimate – the cleaner causal measure – was only about −1.9 % and statistically non-significant. The technology did roughly what the behavioural literature predicts[11,12]; the problem was structural. Residents have agency over their behaviour, but with water bundled into the rent they get no financial reinforcement, and feedback alone is a weak and decaying lever against that backdrop.

DROPIT[13] went further on measurement: over 32 months it logged 205 097 individual water-use events across 80 taps at HSB Living Lab and tested seven categories of off-the-shelf saving devices. Event-level analysis found significant distributional shifts in 65–81 % of treated taps (median reduction about 7.1 %), yet the aggregate difference-in-differences effect was not significant – and user satisfaction did not track measured savings, with the best-liked product showing no effect and the least-liked the largest. Here primary agency sits with the property owner who selects and installs the devices, while the residents who could change behaviour have neither the price signal nor, in many cases, awareness. The building was already efficient, which compresses the achievable margin further.

The shared lesson is not that the devices fail. It is that in this agency configuration – property owner holds the capital decision, resident holds the behaviour but no incentive, utility and municipality stand outside the building – even well-chosen technology underdelivers. The trials also expose a measurement asymmetry: aggregate difference-in-differences, the conservative estimator, returned non-significant effects in both, while finer event- and device-level analysis detected real distributional shifts. A utility or housing company relying on quarterly billing data would conclude, wrongly, that nothing happened. The capacity to measure at the right resolution is, in the rådighet sense, part of agency: an actor cannot manage what it cannot see.

Individual metering and billing: a partial agency repair

The trials point to an obvious instrument, and it is worth being honest that it is already arriving: individual metering and billing (IMD – individuell mätning och debitering) is being rolled out in more and more Swedish and European multi-family housing, partly driven by energy-efficiency rules for heating and hot water and increasingly extended to cold water. In agency terms it restores a price signal to the tenant for exactly the uses the tenant controls – shower length, tap habits, laundry frequency – re-closing the feedback loop the trials found open, and it hands the property owner per-apartment data, the practical capacity to see and target consumption. The expected effect is broadly comparable to introducing volumetric metering in the first place.

But IMD repairs only one link in the chain. It gives the tenant an incentive but neither authority nor capital: the tenant still cannot replace the toilet, choose an efficient washing machine, or decide whether a greywater system is installed – those remain the landlord's decisions. IMD therefore sharpens the behavioural lever while leaving the capital split-incentive intact, and for reuse it can even widen it: once tenants capture the water saving, a landlord who pays for a greywater system recovers even less, unless the saving is explicitly shared. IMD also carries distributional consequences that are not merely technical, which is why it is contested. In Sweden the Hyresgästföreningen (tenants' union) has resisted water and heat IMD, arguing that it shifts cost and risk onto households, can penalise larger or home-bound households and those whose consumption is shaped by building factors beyond their control, and that it erodes the collective rent model in which such costs were pooled. These are legitimate equity arguments, not obstruction. The balanced reading is that IMD is a genuine but partial repair – close to necessary if behavioural instruments are to work at all, insufficient on its own for the capital-intensive measures where the largest savings sit, and best paired both with instruments that move capital agency and with safeguards for vulnerable tenants.

Cross-cutting enablers are agency bridges

The agency lens also clarifies what pricing, standards, governance and digital infrastructure really do. None of them saves water directly; each moves decision rights between actors, or hands an existing actor new practical capacity. They are best understood as agency bridges. Mandatory efficiency standards (EU Ecodesign, WaterSense, WELS) dissolve the split incentive by removing inefficient products from the market – the landlord never has to choose the efficient fixture because the inefficient one is gone; much of Europe's 20–40 % per-capita reduction over four decades traces back to standards of this kind[15]. Pricing

distributes the response across millions of users[14], but only for measures over which the price-responsive actor already has agency: a higher tariff can shorten a tenant's shower but cannot make them replace the landlord's toilet. Governance frameworks set who may participate and on what terms. And digital infrastructure – the kind DROPIT demonstrates at tap level[16] – grants new practical capacity without changing any legal right, which is precisely half of what rådighet means.

Four patterns from the agency map

Read as a whole rather than measure by measure, the agency map yields four patterns that a technology-ordered catalogue tends to obscure.

1. Agency is concentrated for network measures and distributed for building-scale measures. Network measures place primary agency in one or two actors, so they roll out uniformly and quickly across a service area once the financing and regulatory environment rewards them. Point-of-use measures distribute primary agency across millions of building owners and households, so they advance slowly and unevenly unless an agency bridge intervenes.

2. The largest technical potentials often sit with the weakest-agency actors. Greywater recycling in rental housing, data-centre water-use efficiency in capital-constrained siting, and process integration in small and medium enterprises all carry large documented potential – and all have primary-agency holders whose incentive to act is weak relative to the savings on offer. This is where agency mismatch most clearly strands potential, and where the EcoDrop and DROPIT results locate themselves.

3. Cross-cutting enablers are bridges, not measures. Standards, pricing, governance and digital infrastructure move decision rights between actors or grant existing actors new practical capacity. Their footprint in the aggregate statistics often exceeds that of any single technology, yet they are under-counted in intervention inventories because they have no technology-style effect size.

4. Instruments work in proportion to how well they match the agency holder. Regulation bites where primary agency rests with a regulated actor; pricing works where the price-responsive actor already holds the decision; procurement and disclosure work where buyers and investors exert conditional pressure on operators; information and feedback work where households genuinely hold the behaviour. The recurring disappointments in the literature are mismatches in this precise sense.

Taken together, the ranking that matters most for practice is not technical effect size alone, but the joint distribution of effect size and well-matched primary agency. A modest measure with clean, well-matched agency will out-deliver a large measure whose agency is stranded.

Greywater and water reuse: the clearest test of the argument

If the agency framing is right anywhere, it is in water reuse, which concentrates the mismatches more sharply than any other measure family. Building-scale greywater recycling is technically mature and displaces 20–40 % of potable demand in multi-family housing[17], yet in aggregate it is almost absent from the rental stock and clusters instead in owner-occupied new builds, schools and hotels. The agency map explains why at a glance: primary agency rests with the property owner or developer; the utility and municipality are enablers through cross-connection rules and plumbing codes; and the tenant – the one actor who would see a lower bill – holds no agency over the system at all. Where water is bundled into the rent, even that benefit signal disappears, so greywater stacks the split-incentive problem on top of an absent price signal. Centralised reclaimed water shows the coalition variant: utility, municipality and regulator must all act as primary actors simultaneously, and reuse schemes far more often stall because one of them withdraws than because the treatment train fails.

A recent Swedish development shows that the mismatch can be designed out. At the Sörsjön development, the housing company Junehem built greywater recycling into the area from the outset,

treating shower water for reuse in toilet flushing. Two choices matter from an agency standpoint. First, by deciding at the construction stage, Junehem exercised primary agency at exactly the moment – the capital investment in a new build – when reuse is cheapest and least contested, side-stepping the retrofit problem that strands greywater in the existing rental stock. Second, and more unusually, tenants are billed for the recycled water as well, but at a significant discount relative to the potable cold-water tariff. That billing model is an elegant piece of agency engineering: it gives the tenant a genuine price signal – and therefore a reason to favour the cheaper recycled stream – while returning a revenue stream to the landlord that helps recover the capital cost, so the incentives of the two actors who must both be on board are aligned rather than split. Sörsjön thus repairs the capital split-incentive and the absent-price-signal problems at the same time.

Implications for policy and practice

For practitioners, the framework is a diagnostic. When a measure underperforms, before re-tuning the technology, trace the chain of agency: is primary agency held by the actor who benefits? Are the enabling actors given the information, permissions and finance to play their part? Is there an agency bridge – a standard, a certification, a mandate, a data platform – that could close the gap? This reframes intervention design as joint engineering-and-institutional design rather than a purely technical exercise.

For policy, instrument choice should start from an agency map, not a technology list. Once the primary-agency actor is identified, the effective menu narrows sharply: regulation for manufacturers and operators; procurement and disclosure for corporate buyers and investors; pricing for households and firms where they already hold agency; information and feedback for genuinely behavioural levers; and digital infrastructure as a near-universal enabler. Where primary agency is weak or contested, the priority is usually not to add another instrument but to repair the agency structure itself – ending split incentives through sub-metering and cost pass-through, requiring water-use-efficiency disclosure in data-centre permitting, or stabilising reuse agency through harmonised regulation. Reuse makes the clearest case. The highest-leverage move is rarely a better membrane; it is an instrument that relocates primary agency to the developer at the moment capital is committed, paired with a billing model that shares the saving. The Sörsjön development demonstrates both in practice.

The next decade’s most productive question is not only “how much can this technology save?” but also “who holds agency over its deployment, who enables or blocks it, and is the policy instrument matched to that structure?” Answering the second question is, on the evidence, what turns engineering potential into realised savings.

Data availability

No datasets were generated or analysed for this Perspective. The field-trial results discussed are reported in the cited primary studies.

Author contributions

J.K. conceived, researched and wrote the article.

Use of large language models

A large language model (Anthropic Claude) was used to assist with literature synthesis, drafting and editing of this manuscript. The author reviewed, edited and verified all content and takes full responsibility for it. The tool does not meet authorship criteria and is not listed as an author.

Competing interests

The author declares no competing interests.

References

1. Fidar, A., Memon, F. A. & Butler, D. Environmental implications of water efficient microcomponents in residential buildings. Sci. Total Environ. 408, 5828–5835 (2010).
2. Renwick, M. E. & Green, R. D. Do residential water demand side management policies measure up? J. Environ. Econ. Manage. 40, 37–55 (2000).
3. UNIDO. Industrial Water: Efficient and Sustainable Water Use in Manufacturing (UNIDO, Vienna, 2019).
4. Sorrell, S. Jevons' paradox revisited: the evidence for backfire from improved energy efficiency. Energy Policy 37, 1456–1469 (2009).
5. OECD. Water Governance in Cities (OECD Publishing, Paris, 2021).
6. International Water Association. Water Loss Management: The Manager's Non-Revenue Water Handbook (IWA Publishing, London, 2020).
7. Campbell, H. E., Johnson, R. M. & Larson, E. H. Prices, devices, people, or rules: the relative effectiveness of policy instruments in water conservation. Rev. Policy Res. 21, 637–662 (2004).
8. Tong, T. & Elimelech, M. The global rise of zero liquid discharge for wastewater management: drivers, technologies, and future directions. Environ. Sci. Technol. 50, 6846–6855 (2016).
9. Shehabi, A. et al. 2024 United States Data Center Energy Usage Report (Lawrence Berkeley National Laboratory, 2024).
10. Knutsson, J. & Nuur, A. Effectiveness of real-time point-of-use water feedback in multi-family housing: a controlled field experiment in Sweden (in review).
11. Ferraro, P. J. & Price, M. K. Using nonpecuniary strategies to influence behavior: evidence from a large-scale field experiment. Rev. Econ. Stat. 95, 64–73 (2013).
12. Brent, D. A., Cook, J. H. & Olsen, S. Social comparisons, household water use, and participation in utility conservation programs: evidence from three randomized trials. J. Assoc. Environ. Resour. Econ. 2, 597–627 (2015).
13. Knutsson, J. et al. Event-level monitoring of water-saving interventions in a living lab: combining high-resolution consumption data with user experience (in review).
14. Dalhuisen, J. M., Florax, R. J. G. M., de Groot, H. L. F. & Nijkamp, P. Price and income elasticities of residential water demand: a meta-analysis. Land Econ. 79, 292–308 (2003).
15. European Environment Agency. Water Resources Across Europe — Confronting Water Stress. EEA Report No. 12/2023 (EEA, 2023).
16. Cominola, A., Giuliani, M., Piga, D., Castelletti, A. & Rizzoli, A. E. Benefits and challenges of using smart meters for advancing residential water demand modeling and management: a review. Environ. Model. Softw. 72, 198–214 (2015).
17. Friedler, E. & Hadari, M. Economic feasibility of on-site greywater reuse in multi-storey buildings. Desalination 190, 221–234 (2006).