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Regulatory interventions to sustain circular economy in the water sector. insights from the Italian Regulatory Authority (ARERA)

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Abstract

In the circular economy system, the water sector is increasingly becoming a field of concrete experimentation and application on an industrial scale of techniques intended to save and produce energy and to produce materials from water treatment cycles. The water cycle itself represents a 'circular economy system' connected to the use of water resources and to the processes of recovery of 'secondary' resources, such as energy and raw materials. This paper aims to identify the measures that can be taken by the institutions responsible for regulating the sector to encourage operators to invest in the circular economy and to develop corporate policies based on environmental sustainability and efficiency. It describes: the main actions for the recovery of energy and matter in the management of the water cycle; the current configuration of the regulatory measures adopted in Italy by the Italian Regulatory Authority of Energy, Networks and the Environment (ARERA); and some future developments in regulation policies. The views expressed in this paper are those of the authors and do not necessarily represent those of ARERA.

Key words: circular economy, energy efficiency, environmental sustainability, incentives, quality, water service regulation

Highlights

- Briefly describing the most recent technological developments concerning the circular economy in the water sector, with reference to energy and material recovery and water re-use, and how these technologies could potentially be used to set up an innovative circular economy system related to water cycle.
- Highlighting a framework of potential policies and regulatory interventions to promote the circular economy, defined also through an analysis of measures carried out at international level.
- Illustrating the current structure of the regulatory and normative measures adopted in Italy to encourage circular economy-based activities (referring especially to the Italian Regulatory Authority of Energy, Networks and the Environment (ARERA)), and some measures (mostly non-regulatory ones) which could have indirect effects on potential circular economy emerging.
- Based on the above-mentioned experiences, providing some insight on the design of new economic incentives to promoting circular economy development in the water sector and on the role of regulatory authorities on governing the transition to sustainability and energy efficiency system.

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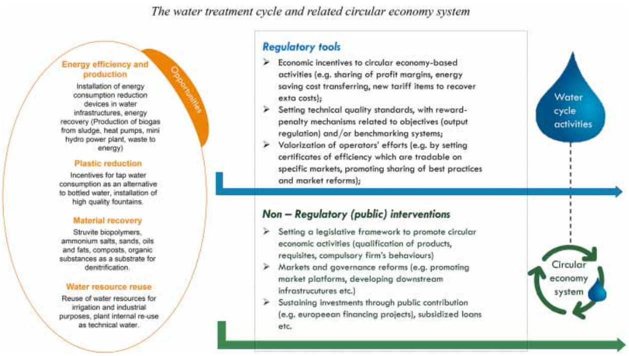
Graphical Abstract



THE WATER TREATMENT CYCLE AND RELATED 'CIRCULAR ECONOMY SYSTEM'

In the circular economy, the water sector is increasingly becoming a field of concrete experimentation and application on an industrial scale of techniques intended to save and produce energy and materials. The sector, consisting of the segments of the drinking water supply chain, the collection of wastewater and its treatment and discharge into the final receiving water bodies in compliance with legal requirements, is in itself an example of a circular economy, in which the water resource, collected from supply sources (surface water, aquifers and springs) is released back into the environment after being used for human and industrial needs and subsequently purified of contamination deriving from these uses.

Figure 1 shows the cycle of water use, from collection to return to the final receiving bodies; almost every step of the water cycle is then connected with further 'circular models' of energy and raw material recovery, as follows:

- energy efficiency choices in the distribution, collection and treatment of waste water;
- energy production by hydroelectric plants capable of exploiting potential energy;

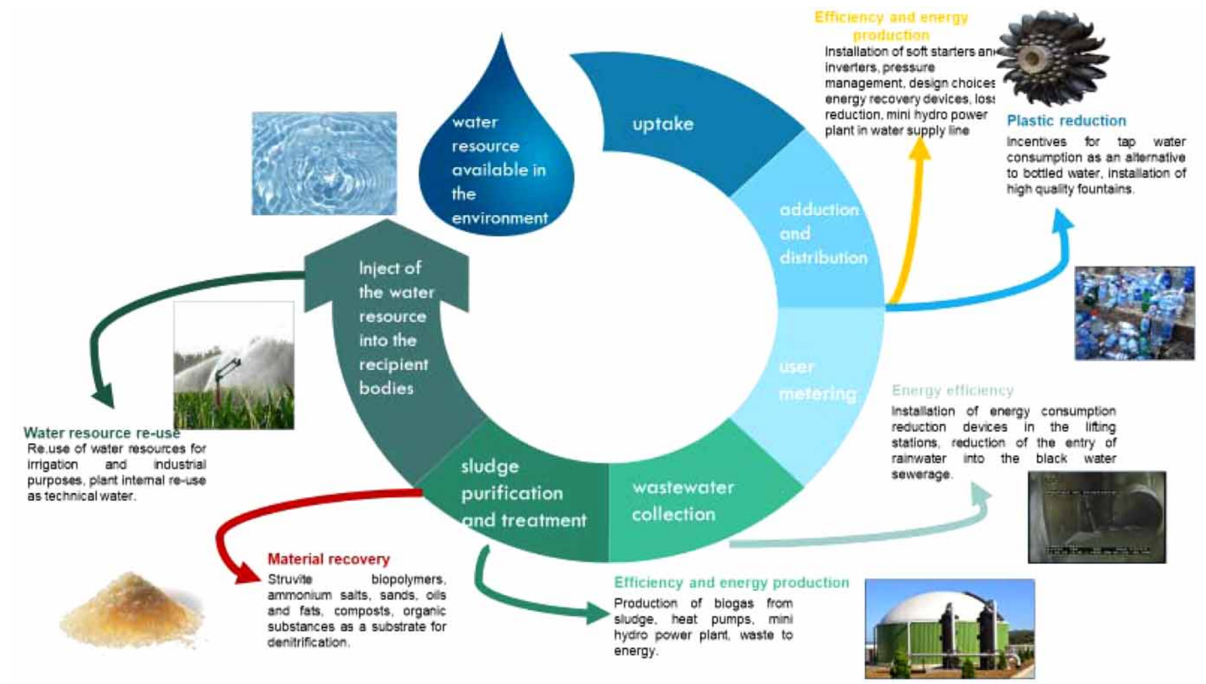


Figure 1 | The water treatment cycle and related circular economy system.

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- energy production by plants that can exploit thermal energy (heat pumps) and chemical energy (pyrolyzers and biodigesters);
- reduction of plastic by promoting the consumption of tap water; recovery of raw materials, such as biopolymers and chemicals, from sewage sludge;
- re-use of treated water in agriculture and industry.

To summarize, the water treatment cycle is itself a 'circular economy system' involving the use of water and the processes of recovering 'secondary' resources, such as energy and raw materials, as you can see in Figure 1.

This paper aims to identify the measures that can be taken by the institutions in charge of sector regulation to encourage operators to invest in the circular economy system, promoting business policies based on environmental sustainability and efficiency.

The current section shows the main actions for the recovery of energy and matter in water cycle management, the related technical solutions and how widespread the practice is among businesses in the sector. The next section describes the current structure of the regulatory measures adopted in Europe to encourage investment in the circular economy, referring especially to the Italian Regulatory Authority of Energy, Networks and the Environment (ARERA), which has been responsible for water services since 2011. The final section will then outline some recommended future developments for regulatory action in order to offer more effective incentives to operators, in light of the risks to which investments in the new circular economy business are exposed, and of the positive effects that such investments can have in terms of reduced environmental impact (e.g. CO_2), reduced business costs and/or new revenue opportunities.

The management of water networks and systems includes numerous actions to optimize the use of water resources, by reducing losses, reducing energy consumption and producing energy and raw materials.

Energy saving (Collivignarelli & Sorlini 2014) actions peculiar to the water system include water leakage control. This is intended to safeguard water and aquifers and guarantee continuity of service; it also has the secondary purpose of reducing business costs. Environmental and economic regulation does not always set goals for companies in terms of limiting losses; this is why, in Europe, the average rate has been to date rather high, Italy being somewhere in the middle, though improving, in part thanks to recent actions by ARERA. The Authority's latest survey, conducted in 2016, on 110 operators that serve around 70.6% of the Italian resident population showed average leakage rates of 42.4% (including what are known as 'apparent losses'), whereas around one-third of the sample population showed rates of less than 35% (ARERA 2019a). With the entry into force of the Technical Quality provision in 2018, ARERA set environmental performance targets, including the reduction of network leakages, as described below in this paper.

The water service operator can also choose to produce electricity by exploiting the potential energy of the 'jumps' along the sewer lines. The mini-turbine systems installed inside the sewer lines produce energy thanks to connection with electric generators installed externally, reducing loss of load by means of vertical axis turbines, for example. These systems are ideal for installation in gravity pipes, or for replacing pressure reducing valves, insofar as they harness the force of the water in an optimal manner, avoiding dispersion via inefficient 'braking' systems. The costs incurred by the operator are mainly due to investment in mini hydro power plants, periodic maintenance and the operational costs of electrical and control systems. The energy produced can be self-consumed, used to operate systems adjacent to the power plant or reintroduced to the grid becoming a source of revenue.

In terms of social and environmental sustainability, many water service operators are installing high-quality fountains in high traffic areas of towns and cities; these deliver water from the water supply network treated with filtration systems, reverse osmosis and UV rays to make it more pleasant

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to drink. The water from the fountains can be supplied free of charge, as is the case in many central Italian administrations, or by paying a few cents per litre. The installations are built by the SII (integrated water service) operator using public funds (Municipal Authority resources) or its own funds, in the form of public contributions and donations.

The local effects of this type of action are twofold:

- people are provided with water of a quality equal to that of store-bought bottled mineral water, but free of charge, creating a kind of compensation for the annual water bill;
- the consumption of bottled mineral water and the consequent production of plastic waste is drastically reduced, which generates positive impacts in terms of CO_2.

As a proof of these effects, the water service operator Acque stated that, in 2018, the free distribution of over 30 million litres of high-quality water through its 54 public water fountains could have had a 'potential economic savings for citizens – had they bought bottled mineral water – of almost €6.5 million (based on the cost of bottled water provided by Mineralacque: €0.21 per litre)', and significant environmental savings 'for every 819 tonnes of plastic bottles saved, equivalent to 1,883 tonnes of carbon dioxide and 1,638 of oil otherwise used in the production and transport of bottled mineral water'. Acque has finally estimated that, 'since the project started, the public water fountains have saved households in the Basso Valdarno over €57 million, against investments of around €3 million' (Acque S.p.a. 2019).

In the wastewater treatment segment, treatment plants can be operated like a factory of renewable resources (see Box 1); in addition to producing technical water for use within the plant, the process can also recover: sand and oil from the primary treatment; nutrients from the secondary treatment, such as phosphorus and nitrogen, to be used in the chemical industry and as agricultural fertilizers;

Box 1 | Water treatment plants: a factory of renewable resources

Water treatment plants are increasingly being used as factories to extract resources, such as fertilizers, biopolymers, biogas for energy production and transport, composts and improvers for agriculture and technical water for plant processes and for re-use.

The production of nutrients involves the conversion of orthophosphate into struvite, by adding calcium and magnesium salts to the supernatant of the sludge line, managed with controlled pH. Struvite can be marketed as a fertilizer for agricultural purposes. Likewise, nitrogen can be obtained by stripping the ammonia and then mixing it with a sulphuric acid solution. Nitrogen extraction saves on the costs of energy for the oxidation of ammoniacal nitrogen in secondary treatment tanks. Other techniques involve the use of materials such as activated zeolites, to be used directly in agriculture once they have been used in water treatment (You Valderrama & Cortina 2019).

Poly-hydroxy-alkanoates (PHAs) are biopolymers that originate from a three-step process involving sludge fermentation to produce volatile fatty acids, followed by enrichment with microorganisms that accumulate PHA and then separation of the biopolymers through nutrient reduction. This process can also be linked to the production of struvite in the third step. Currently, only a few companies are trialling these processes in pilot projects, especially in northern Europe (Fra-Vàzquez *et al.*).

Biogas is an alternative energy source to fossil fuels, obtained from the fermentation of organic material in an oxygen-free environment. The anaerobic digestion produces biogas, from which the carbon dioxide and sulphur are removed and it is transformed into biomethane and digestate. Some companies use biomethane as fuel for their vehicles; the digestate is used on a pilot scale for the extraction of struvite and nitrogen (Szymańska *et al.* 2019).

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biopolymers and biogas can also be obtained from the sewage sludge, which, when refined, produces biomethane that can be used as fuel for company vehicles or CHP plants, replacing fossil fuels; the anaerobic digesters can also yield a compost to be used as an agricultural fertilizer (Figure 2).

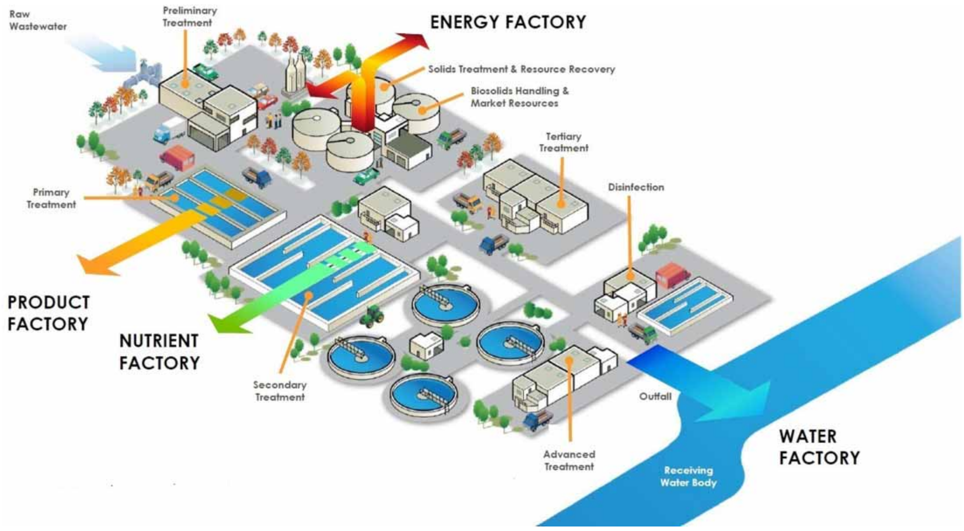

Figure 2 | The treatment plant as a renewable resource factory (adapted from Umble 2018).

In water treatment, re-use in industry and agricultural irrigation is becoming increasingly widespread internationally. Certain operators in Italy have adopted such systems. Re-use operations require the revamping of the water treatment plants and the addition of a tertiary treatment line with sand filtration and final disinfection; this improves the quality of the water normally discharged into the final receiving bodies, reducing or eliminating the possibility of 'exceeding' the parameters listed in the tables of Legislative Decree 152/2006 and, at the same time, complying with the parameters set by Ministerial Decree 185/2003 on direct re-use for agricultural purposes. In some cases, such as Nosedo in Milan, the re-use is indirect, i.e. the water is introduced into a surface water body from which the irrigation distribution network branches out, usually managed by special consortia. This solution, also adopted in Val di Cornia (Livorno) on ASA plants and in Mancasale (Reggio Emilia) on IREN plants (Bianco 2018), enables derogation from the stringent limits set by Ministerial Decree 185/2003, especially as pertains to nutrients, applying the normal environmental discharge parameters provided for by Legislative Decree 152/2006.

Water re-use has an immediate environmental impact, safeguarding aquifer and its quality, thanks to greater withdrawals limiting salt wedge formation; it also helps industry and agriculture by supplying water at times when this resource is not available naturally.

Many operations were financed through public contributions, especially regional ones. However, in some cases, the costs of revamping the treatment plant and installing the tertiary treatment line were covered by increased tariffs since these investments improve the quality of the treatment service. To prevent these forms of cross-subsidization, where all the costs for the treatment of drinking water and wastewater users and supplying water are charged to farmers at a controlled cost, the legislator and ARERA should intervene to regulate more effectively this practice, which is increasingly widespread among water companies.

Regulatory actions

As is well-known, the water service is managed as a natural local monopoly because of the essential and non-replicable nature of the network infrastructure that ensures its operation (it is a capital-

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intensive service). Moreover, the underlying infrastructures are vertically integrated along the entire water cycle chain, which means that the monopolist (who is entrusted with operating the service) generally operates right from the water abstraction phase to the wastewater treatment phase and the return of the resource to the environment. To prevent this condition from leading to prices being set that fail to reflect the actual service provided in the absence of proper controls, Italy's national legislator – as in other European countries – intervened, in 2011, assigning the SII regulation to ARERA, an independent regulatory authority already operating in the electricity and gas sector.

The regulatory tools (including incentives) adopted by the Italian Authority to date have been oriented towards defining tariff rules that ensure that the costs incurred by operators are properly covered and that, at the same time, encourage operational efficiency and the development of investments to close the infrastructural gap that has widened over the years with respect to the highest European standards. In recent years, these measures have been accompanied by quality regulation and incentive models, by means of setting common national standards, in part to prevent the need to minimize costs by compromising the level of service offered by operators.

However, the actions taken to promote the circular economy of the water cycle have not yet benefited from incentives by the national regulator, except indirectly. In addition to regulatory measures, there are also provisions adopted by the national legislator, implementing EU directives requiring Member States to meet standards of energy efficiency and to promote the use of renewable sources in each sector in the medium–long term.

In order to illustrate the regulatory measures adopted in Italy to encourage investment in the circular economy, the following sections describe: a framework of potential policies and regulatory interventions to promote the circular economy defined also through an analysis of measures carried out at international level; the incentives offered by the existing regulation and any positive direct and indirect effects on the promotion of energy efficiency and environmental sustainability; the incentives offered by legislation (e.g. to integrate national electricity production with renewable energy sources), which have an impact on regulation, in addition to those cases in which potential circular economies emerge that are not yet supported (or only partially supported) by incentives under the regulatory and legislative measures in force (e.g. the issue of water re-use for irrigation in Italy).

A framework of potential interventions to promote the circular economy

The public interventions to boost investments promoting environmental sustainability and the circular economy include: market and governance reforms; economic incentives; strict legal provisions requiring corporate conduct more oriented towards the green economy paradigm (Figure 3).

Type of Interventions		Actors	Strength	Drawbacks
Compulsory behaviour		Law makers (Parliaments and Governments)	Timeline	Risk of economic losses caused by the behaviour required
Economic incentives	*Regulatory tool*	Independent authorities, ministerial agencies	Timeline; Reduced risk for companies thanks to cost recovery rules	Risk of reducing market engagement in a circular economy and increasing the tariff burden for customers
	Non-regulatory intervention	Public bodies and bank	Lending policies could have a higher economic efficiency than grants	Long-term horizon; Market risk borne by companies in case of borrowing
Market and governance		Law makers, regulators, utilities	High economic efficiency	Long-term horizon; Market risk borne by companies

Figure 3 | Interventions to promote a circular economy.

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Market and governance reforms may include several interventions on different segments of the supply chain introducing new market platform and players. These reforms involve state-owned entities that aim to create value for the material recovered by utilities performing circular based-economy practices: this choice was made in the Netherlands with the institution of an entity controlled by 14 Dutch water utilities for the disposal of residuals and for their optimum valorisation in the resources market. By contrast, in the UK, the national water regulator Ofwat instituted a new market platform called the 'bioresources market', which matches the supply and demand of residuals. This choice counterbalances the strict boundaries adopted by Ofwat to prevent possible subsidization of the circular economy through increased water tariffs since the regulator aims towards the market development of residuals instead of promoting circular economy through public subsidies. Indeed, the bioresources market website (Ofwat 2020) provides public information from water utilities on the capacity of facilities they want to make available to third parties under commercial agreements.

The market reforms also include the cap and trade mechanism, similar to that developed at EU level for greenhouse gas emissions (EC 2020) by energy-intensive factories or the white certificates mechanism for promoting the achievement of energy efficiency targets, which only partially concerns the water sector.

Economic incentives include several measures for allowing utilities to recover resources and costs from investments in circular economy-based activities and to maintain a margin. These measures are both regulatory and non-regulatory:

- public subsidies and grants to develop research projects, such as those issued by the European Commission with LIFE + and Horizon 2020;
- subsidized loans granted by public banks, such as the EIB, for financing 'green investments';
- new tariff items introduced by regulators to recover extra costs incurred by utilities to develop circular economy-based activities;
- extra premiums allocated by public authorities for the achievement of environmental goals, as occurs though output regulation.

Finally, the introduction by law of compulsory behaviour with greater focus on environmental sustainability is also a tool widely adopted for the water sector: for example, the environmental limits set for effluent discharge and sludge disposal (in Switzerland, e.g. the recovery of phosphorus from the treatment of sewage sludge is required by law, as shown in the European Sustainable Phosphorus Platform (ESPP 2019)) and those set for green procurement. At EU level, the Directive 2004/18/CE gives each Member State the power to introduce environmental criteria in the evaluation of offers in public procurement procedures; this approach has been adopted by several States, including Italy.

The three clusters of interventions mentioned above differ in terms of economic sustainability and timeline in the promotion of green actions. Market and governance reforms are based on a long-term horizon, and they have a concrete impact on corporate strategy only when the activities promoted are capable of generating economic value in terms of the circular economy: the slowdown in growth of bioresource market initiatives bears witness to the complexity of creating a new market, counterbalanced by a low public expenditure and greater economic efficiency, once the market is effectively working. By contrast, the legal imposition of green behaviour acts in the short-term without considering the real economic value for companies of adopting such behaviour. Interventions based on the subtype of economic incentives provided by regulators could balance the timeline of 'by-law' actions and ensure at least the coverage of extra costs incurred by utilities, sometimes recognizing tariff increases, although with lower economic efficiency than that which flows from a market engagement approach.

The following sections describe the tools adopted by ARERA for promoting the circular economy and the increasing focus on the second type of interventions, mainly based on cost recovery rules (input regulations) and key performance indicators (output measures).

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The tariff methods

In 2014, the Authority's regulatory model for the integrated water service was organized into schemes (ARERA 2013), shown in Figure 4, intended in particular to promote infrastructure development and modernization (for investments) and operator efficiency (in terms of operating costs), as well as the rationalization of sector structures. These schemes were subsequently updated in the second regulatory period 2016–2019 (ARERA 2015, 2017b). According to this model, each local authority, called *Ente di Governo d'Ambito* or EGA (administration legally charged with organizing the water service in its area by choosing the most suitable form of operator assignment) selects the scheme that best matches the initial conditions of each operator (based on the size of the investments planned compared with the value of existing infrastructure, per-capita operating costs and any changes in the scope of the operator's activities). The selected scheme involves specific tariff rules for recovering investment costs and additional operating costs, as well as the maximum tariff variation for the same operator, expressed by the tariff multiplier θ. The tariff multiplier in a given year a is the result of the ratio between the operator's allowed amount of cost recovery expected (VRG) – i.e. the sum of the operator costs eligible for tariff recognition – and the estimated revenue of the SII operator, which includes revenue from the tariff structure and revenue from other water service activities (as shown in the financial statements for the year a-2).

		Per capita operating costs below the national average	Per capita operating costs over the national average	Aggregations, changes in operator objectives or activities
Investments	Limited investment needs compared to the value of existing infrastructures	Scheme I Price limit: 6.0%	Scheme II Price limit: 5.5%	Scheme III Price limit: 6.5%
	High investment need compared to the value of existing infrastructures	Scheme IV Price limit: 8.5%	Scheme V Price limit: 8.0%	Scheme VI Price limit: 9.0%

Figure 4 | Matrix of the 2016–2019 regulatory schemes (Decision 664/2015/R/idr).

In terms of the rules underlying tariff calculation, ARERA's regulatory model requires the application of a series of mechanisms (some of which serve as incentives), as follows:

- a **revenue cap** on the total costs that can be recovered by tariff increases;
- a **price cap** on the annual change in tariffs; this depends on a sharing factor (X), whose weight varies depending on the operator's position in the matrix of regulatory schemes;
- a **rolling cap** mechanism on so-called endogenous costs (i.e. costs that can be directly influenced by operator activities) that guarantees that the operator will retain the efficiencies achieved in the event of cost reduction;
- *ex-post* recognition of realized investments and standardized (financial and fiscal) parameters to cover capital procurement costs (**cost of service**).

The incentive effect of the ARERA regulatory model is twofold: the reduction in operating costs (all other conditions being equal) guarantees the possibility of obtaining higher tariff increase limits, as well as retaining a margin with respect to the level of costs recognized by the regulatory mechanism, which can be re-invested to improve further the level and quality of its services.

The costs of purchasing electricity are included in 'updateable' operating expenses, which, unlike endogenous costs, are not considered by the regulator to be fully influenced by the operator's

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decisions and are thus updated every year based on the inflation rate. Thus, the tariff method does not currently provide for measures to encourage energy savings, but only an energy efficiency improvement mechanism for the purchase price (which allows the reimbursement of the minimum value between the cost of supply 2 years before the establishment of the tariff and the average sector cost increased by 10%), which implies the full transfer of any energy cost reduction to the user by means of tariff changes.

Regulating technical quality

The incentive mechanism for technical quality – established under Decision 917/2017/R/IDR (ARERA 2017a, 2017b) – is divided into different stages of assessment (described in Figure 5), with the dual purpose of, on the one hand, encouraging the *maintenance* of quality levels for operators who have already achieved the goals set by the regulator and, on the other hand, promoting performance improvements for less advanced operators. Performance is valued according to a series of indicators (macro-indicators), which refer to the main technical quality outputs achievable in the water supply network, sewerage and treatment activities that make up the integrated water service (see Box 2).

Objectives	Assessment levels: *Basic*	*Advanced*	*Excellence*
Maintaining objectives (*Class A*)	**Stage I** Reward (penalty) determined ex post, on the basis of a predetermined aggregate incentive, divided by the number of those who have (not) reached the goal (Minority Game Theory)	**Stage III** Reward (penalty) for each macro-indicator, assigned to the top three (to the bottom three), established in relation to the VRG, with ranking determined according to the TOPSIS	**Stage V** Reward given to the top three operators, established in relation to the VRG, with ranking determined according to the TOPSIS considering all macro-indicators simultaneously
Improvement objectives (classes other than A)	**Stage II** Reward (penalty) determined ex post, on the basis of a predetermined aggregate incentive, divided by the number of those who have (not) reached the goal (Minority Game Theory)	**Stage IV** Reward (penalty) for each macro-indicator, assigned to the top three (to the bottom three), established in relation to the VRG, with ranking determined according to the TOPSIS	

Figure 5 | SII technical quality incentives: rewards and penalties (Annex A to Decision 917/2017/R/IDR).

In particular, for operators who already offer high levels of quality, there are three levels of assessment: *basic*, which consists of verifying whether or not the maintenance objective is reached, for each macro-indicator; *advanced*, which rewards (penalizes) the top three (bottom three) operators in terms of absolute performance recorded for each macro-indicator and *excellence*, applied to the best operators in relation to a level of technical quality that includes all macro-indicators. The objective of performance improvement instead only has basic and advanced levels, which are assessed by looking at the differences highlighted by each operator with respect to their starting situation. The 'advanced' and 'excellence' levels are assessed through multi-criteria analysis performed using the *Technique for Order of Preference by Similarity to Ideal Solution* (TOPSIS), which summarizes the multidimensional character of technical quality in a single value that reflects the deviation of each operator from the ideal situation (given by the highest quality levels for each macro-indicator).

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Box 2 | Technical quality of the Integrated Water Service (RQTI) – model structure

The regulation of technical quality for the integrated water service, implemented by ARERA with Decision 917/2017/R/IDR, has been in force since 1 January 2018 and is based on a system of indicators divided into the following categories:

(a) specific standards identifying the performance parameters to be guaranteed in the services provided to each individual user, and whose non-compliance, as a rule, involves the awarding of compensation; these standards relate in particular to the continuity of water supply (interruption of water supply, activation of consequential supply services and notice to users);

(b) prerequisites, representing the necessary conditions for admission to the incentive scheme associated with the general standards;

(c) general standards, broken down into macro-indicators and simple indicators, which describe the technical conditions for providing the service and to which is associated an incentive scheme involving rewards and penalties.

The model set by the Italian regulator is therefore an output-based model aimed towards the achievement of annual objectives by the operator, defined by the positioning of the same operator in a given class based on the level of performance highlighted in a specific reference year*. For each of the macro-indicators, the annual objectives are divided into two categories: maintenance (of the performance level under conditions of excellence) and improvement (divided into classes, with differentiated values based on the starting conditions).

The performance levels are described in detail by six macro-indicators covering the entire integrated water service supply chain through the following targets: limitation of losses, through an effective control of the water supply network infrastructure (macro-indicator M1 – Water losses); maintaining service continuity, including through a suitable configuration of supply sources (macro-indicator M2 – Service interruptions); adequate quality of the water intended for human consumption (macro-indicator M3 – Water quality); minimization of the environmental impact of collecting wastewater (macro-indicator M4 – Sewerage system adequacy); minimization of the environmental impact of wastewater treatment (macro-indicator M5 – Sludge disposal and macro-indicator M6 – Quality of the treated water).

*For its first application, 2016 was identified as the base year for the 2018 objective.

The incentive effect of technical quality regulation is demonstrated through:

- *rewarding or penalizing the operator* (which will be quantified from 2020 on the basis of performance recorded in the two previous years) – according to a stick and carrot mechanism – the rewards (quantified economically) are foreseen for all the assessment stages and consist of a set 'jackpot' in Stages I and II (to be shared among those who have achieved their objective), while for Stages III, IV and V, the value of the incentive – for the top three – is established in relation to the costs attributed to the operator by the tariff regulation (given by operator's allowed amount of cost recovery expected, VRG), weighted to reflect the importance of the target to be reached and the ranking position; the penalties (foreseen for all levels except Excellence) consist of a reduction in attributed costs (starting from 2020 performance evaluation, while in the previous evaluation period 2018–2019, penalties will be allocated to a fund), in the event of worsening quality state (Stages I and III), and through the obligation of a fund in the case of negative quality variations (Stages II and IV), and are also established in relation to the operator's VRG level and certain corrective factors;
- *the reputational effect of publishing the performance* under assessment, according to the sunshine regulation principles (according to Article 2.6 of Annex A to Decision 917/2017/R/IDR).

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The possible effects of the incentive mechanisms implemented by the Authority as part of the technical quality regulation model in stimulating the energy efficiency of operators may only be visible indirectly. In fact, although it is an output-based model, characterized by the technological neutrality of the regulator, many of the measures and management activities planned by operators to ensure the achievement of certain identified targets (e.g. reducing water losses and sewer flooding), already described in the previous paragraph, can also help to reduce the energy consumption of the underlying networks and plants, thus improving their energy efficiency. Similarly, in terms of environmental sustainability, the objectives set for water treatment, in particular the minimization of landfill sludge disposal, require that operators make efforts to pursue alternative strategies for recycling or re-using the total quantity of sludge produced, for example in agriculture – through direct spreading or through composting and producing soil improvers – or recovering energy through waste-to-energy plants. Data acquired by ARERA reveal that, in 2016, on a national level, more than 80% of the sludge produced was destined for re-use or recovery, with agricultural use being by far the most common (both direct spreading on land and indirectly through the production of compost), while energy recovery in plants such as incinerators or cement works has remained residual, confined almost exclusively to the northern regions. On the other hand, the production of compost is widespread in the central-southern regions, while in the north, there is a prevalence of direct spreading, probably due to a greater availability of suitable agricultural land (ARERA 2019a). Recently, in Italy, Art. 41 of Legislative Decree 109/2018 (Urgent provisions on the management of sewage sludge) acted in favour of direct spreading practices, closing a regulatory gap resulting from the lack of limits established for certain parameters (C10–C40 hydrocarbons) for the purpose of using sewage sludge in agriculture, which had led to inconsistent approaches at regional level. In particular, restrictive legal measures had led in some regions to a halt in agricultural spreading, using temporary storage at the plants to stock surplus sludge (where landfill disposal and incineration were not sufficient), with the risk of compromising plant operation and consequently the treatment process.

Biomethane and energy production incentives

With reference to the production of biomethane, the national legislator adopted in 2013 a series of regulatory acts (most recently the Inter-Ministerial Decree of 2 March 2018) promoting the use of this type of fuel in Italy (together with other advanced biofuels), especially in the transport sector, and the use of biogas conversion plants, with the general aim of promoting the use of renewable sources in this sector, including through the development of circular economy initiatives and virtuous waste management practices. Producers (defined by the above mentioned Inter-Ministerial Decree as the entity in charge that is licensed to build and operate a biomethane plant) who inject biomethane into consumption grids are given the following incentives:

- the issue by the GSE (the Energy Services Manager), through a specific contract with the producer, of 'certificates of release for consumption' (CIC), whose value is determined by market trading with the entities under feed-in obligation, plus premiums linked to the raw materials used (up to 30% of the weight); each CIC certifies the injection into the natural gas network (destined for the transport sector) of:
  - 10 Gigacalories of non-advanced biofuel, including biomethane;
  - 5 Gigacalories of advanced biofuel, including advanced biomethane, or non-advanced biofuel produced from the raw materials listed in part B of Annex 1, part 2-bis of Legislative Decree no. 28 of 3 March 2011;
- in case of 'advanced' biomethane production (if obtained from the materials listed in part A of Annex 3 of Ministerial Decree 10 October 2014 and subsequent amendments and additions):

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(i) the issue of a CIC with a value of €375 per certificate, plus premiums linked to the plant used (20% increase in the value of the CICs); (ii) dedicated withdrawal, by the GSE, of the advanced biomethane – even for a partial quantity – at a price equal to 95% of the average monthly price recorded on the spot market for natural gas; (iii) alternatively, independent selling.

Entities that inject petrol and/or diesel for consumption (defined as 'Entity under Obligation' by law) are required to achieve certain objectives of biofuel injection, including by purchasing CICs from entities that have obtained them. The production plants that can access the provisions and incentive schemes must first be approved by the GSE and the biomethane release must be certified by a supply contract between producer and distributor and through the invoices recording biomethane sold.

In a national context, industrially more advanced integrated water service operators (Recycling Industry 2017; Gruppo CAP 2019) are experimenting with technologies for producing biomethane from biogas obtained from the anaerobic digestion of sewage sludge, which, as already described, is mainly used to fuel the operator's vehicle fleet (thus useful to the performance of the activities falling within the scope of the SII). The direct benefits for the users of the SII deriving from these applications can be quantified in terms of reduced electricity costs (which would be self-produced by the plant itself) consequently reflected in lower tariff charges, while the operator pays a lower cost for the purchase of fuel (with the margin retained entirely by operator, since it is qualified as an endogenous operating cost); in addition, there are the possible revenues obtained from CICs and from selling to third parties the surplus biomethane after fuelling its own vehicle fleet. This revenue, from a tariff point of view, would be valued under the category of 'Non-water activities that also use integrated water service infrastructures', defined as residual by the regulator, as compared with the activities that make up the perimeter of integrated water service. This configuration implies that the costs and revenues of these activities have no effect on the tariff multiplier as described in the paragraph *The tariff methods* (the former being not attributed to the numerator in the VRG, while revenues are not included in the denominator), providing an indirect incentive to the operator to conduct this type of activity if it guarantees the achievement of operating margins.

The legislator has also implemented measures to promote renewable energy sources, providing economic support to those who produce electricity from wind, hydro, geothermal, biomass, biogas, sewage and landfill gas, bioliquid and solar thermodynamic plants, regardless of their size.

The first subsidy schemes consisted of issuing certificates for electricity production from renewable sources (Renewable Energy Certificates, RECs) and granting an all-inclusive tariff to those who produced and supplied clean energy to the electricity grid. Gradually, these tools have been replaced by other incentives, introduced with Ministerial Decree 6/07/2012 and subsequently updated with Ministerial Decree 23/06/2016. There are two types of incentive granted by the GSE according to the net electricity a plant can feed into the grid, depending on its power:

- an all-inclusive feed-in tariff, consisting of a single tariff that also reimburses the electricity withdrawn by the GSE, including any premiums to which the plant is eligible;
- an incentive, calculated as the difference between the basic incentive tariff and the hourly zonal price of the energy since the energy produced remains available to the operator. Again, any premiums to which the plant is entitled are added to this incentive.

The incentives granted (quantified in euro/MWh) vary according to the renewable source used, the power of the plant and its useful life.

Ministerial Decree of 23/06/2016 established three ways of accessing the incentives: (i) direct (upon request to the GSE) for small plants, (ii) by registering with special registers for the allocation of the available power quota and subsequent application made to the GSE, for medium-sized plants

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and (iii) by participating in reverse auctions for the allocation of the available power quota, for large plants.

The latest regulatory measure in policies to support renewables is the Renewable Energy Sources Decree 'FER 1' established by the Ministry of Economic Development (MISE), containing the general terms and conditions for access to incentive mechanisms. This measure, in line with the Europe 2020 and 2030 strategies and with national targets, defines incentives to reward the self-consumption of energy from renewable source plants integrated on building installations up to 100 kW and the removal of asbestos, as well as the production of sustainable and renewable energy. Access to the incentives will be regulated by two methods – registers and auctions – depending on the power of the plants:

- plants with an output of less than 1 MW must participate in public project selection procedures;
- photovoltaic plants with a power equal to or greater than 1 MW, on the other hand, access state incentives via auction.

The groups in which calls for registration and auction are organized include hydroelectric plants and plants for residual gas from treatment processes, with the former being required to produce energy without additional abstraction from water bodies in order to join the group (as established in art. 4, paragraph 3 of the Ministerial Decree of 23 June 2016). In order to be eligible, all plants must possess the necessary permits for construction and operation, including licences, where applicable, and a final accepted estimate for connection to the electricity grid. The decree also provides for the creation of a market platform for the long-term trading of energy from renewable sources.

As regards the impact of these tools on the integrated water service, the sale of electricity, although carried out using water service infrastructures, is included by the Italian regulator under 'non-water activities', as is the case for revenue from the sale of biomethane, with the same tariff implications for the operator. In specific cases, where high levels of integration between the RES production plant and SII infrastructure are observed, some forms of cost recovery within the regulatory perimeter could be taken into consideration, due to the direct benefits for the user deriving from self-consumption of the energy produced, which would be used to power the water service plants, thus reducing the amount of energy withdrawn from the grid and the relative cost of supply, and consequently the corresponding tariffs for users.

Energy efficiency incentives

The White Certificates (or Energy Efficiency certificates, TEE) scheme came into force in Italy in January 2005 and has gradually become the main tool for promoting energy efficiency in the industrial, network infrastructure, services and transport sectors, as well as being used in the civil sectors and in the area of behavioural measures, to the extent that Legislative Decree 102/14, implementing Directive 2012/27/EU into Italian law, established that this tool must contribute to the achievement of at least 60% of the cumulative energy savings target for 2020. The energy efficiency certificates mechanism is a quantity-based economic tool that relies on setting primary energy savings requirements – quantified in tons of oil equivalent (TOE) – for larger electricity and natural gas distributors, and on the existence of a market for trading in certificates for the energy savings actually achieved. The annual energy efficiency target is cumulated at national level but has to be achieved individually by the electricity distributors that are subject to the requirement. This tool is, therefore, characterized by the existence of demand, supply and trading of negotiable securities (TEEs) related to 'additional' savings, corresponding only to measures that result in higher efficiencies than those deriving from mandatory legal standards or from those already widespread in the market (ARERA 2016). The existence of a securities exchange market means that the value of the economic incentive is not predetermined, but depends on the matching of supply and demand of securities, in which:

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- the size of demand – represented by electricity and gas distributors who, as at 31 December of the previous year, had at least 50,000 end customers connected to their networks – is defined by the Ministry of Economic Development by means of its own decrees, according to the national savings targets for 2020;
- the TEEs offer, on the other hand, derives from the energy savings achieved through projects undertaken by both distributors under obligation and volunteering entities. These volunteers include both electricity and gas distributors not subject to obligations and the companies they control and also – due to regulatory developments – entities that have appointed an energy manager or have in place an energy management system certified in accordance with the ISO 50001 standard, thus extending the scope of this scheme to sectors beyond energy and gas; the ISO 50001 standard defines the requirements for creating, implementing, maintaining and improving an energy management system (SGE), with the objective of allowing organizations to pursue, with a systematic approach, the continuous improvement of its energy performance and the actual SGE.

The regulation of the scheme – until 2013 under the responsibility of ARERA – was transferred by inter-ministerial decree to the GSE, while the competent ministries are responsible for adapting the guidelines, i.e. the operating rules for project execution and evaluation.

The TEEs are issued by the GME (the national Energy Markets Operator), upon authorization by the GSE, which assesses and certifies the energy savings achieved by projects promoting high energy efficiency technologies among end users, and the TEEs deriving from them. The GSE awards a certificate for each TOE saving achieved thanks to the implementation of the energy efficiency measure. TEEs are traded either on a specific market organized by the GME (TEE exchange) or under bilateral contracts for the remaining quota.

In 2018, the Ministry of Economic Development, with the Ministerial Decree of 8 May, updated the operating rules of the White Certificates scheme, first of all adopting measures to stabilize the performance of exchange prices in the market, which in the last year were marked by volatility and disproportionate increases not justified by the initial investment choices or by the trend in costs of the technologies used. In this regard, the MISE deemed it appropriate to set a maximum recognition value of €250 for each individual White Certificate, in line with the size of the investments made in measures for which an incentive application has been received in recent years under the above scheme.

Secondly, the most recent GSE Operating Guide (approved by Managerial Decree of 30 April 2019) included the integrated water service among the production sectors in which energy efficiency measures can be implemented and for which methodologies have been defined for calculating primary energy savings. Concerning the SII, Table 1 of the Ministerial Decree of 11 January 2017, as amended by the Ministerial Decree of 10 May 2018, indicates the following actions:

1. 'improving the energy efficiency of electricity, gas and water networks';
2. installation or replacement of 'fine bubble diffusers for wastewater treatment plants';
3. installation or replacement of 'compressed air production systems for treatment plants';
4. automation and control systems, within the behavioural measures, including the 'adoption of efficient warning and management systems'.

There are many types of project detailed in the guide, broken down according to the service (water supply network, sewerage and treatment) and the plant section of the service itself. These may include, for example: the construction and energy efficiency improvement of water purification plants, the re-layout of networks, pressure and leaks management and control, interventions on biological oxidation treatment and on the sludge line of treatment plants (construction of new tanks, replacement of compressed air production, distribution and diffusion systems, sludge dewatering systems). Almost all projects fall under the first type of intervention. Therefore, an integrated water

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service operator that presents an energy efficiency improvement project for its plants (the cost of which could be included as CAPEX in the limit of expected cost recovery because of the potential impact on technical quality objectives) eligible for the White Certificates scheme, would generate revenues (quantified by the sale of the TEEs) that would be fully recognized for the operator as an activity other than those related to the integrated water service, despite the reduction in electricity costs (resulting from the energy savings achieved), which would instead be entirely transferred to the user, these costs being classified as upgradable OPEX and subjected to the aforementioned cost minimization scheme foreseen by the tariff method. However, it should be noted that the diffusion of White Certificates in the integrated water service is still marginal (Industry Chemistry 2019), despite it being a sector with high potential for energy savings, estimated at over 2 TWh for the Italian water sector (Energy & Strategy Group 2018); thus, the economic and tariff impact of this tool can at present only be valued in theory.

Sustainability: the development of 'water kiosks' or 'high-quality fountains' and possible incentives for re-use in agriculture

With regard to the definitions of integrated water service perimeters provided by ARERA for the purposes of applying the tariff method – and according to the provisions of national law, the activities of installing and managing 'water kiosks' and wastewater re-using were included among the other water-related activities, i.e. 'all activities relating to water services other than those included in the SII' (paragraph 1.1 of Annex A to Decision 664/2015/R/IDR). The Italian tariff method allows the recognition of the investment underlying these works as fixed assets regulated by the SII (paragraph 13.2), ensuring for related operating management costs the reimbursement of 50% of any margin achieved by the operator (paragraph 29.1), thereby constituting a profit sharing of the activity between operator and users.

With reference to the so-called 'water kiosks' or 'high-quality fountains', their financing can therefore come from tariffs or a public contribution (generally municipal or regional funds). Usually, to encourage users to take advantage of these facilities (and indirectly to promote the use of tap water, given that water supplied comes from the same networks), prices are set lower (in some cases, the running water is supplied for free) as compared with the annual management and maintenance costs of the infrastructure, which can be estimated at 2.3 euro cents per litre supplied (Torretta 2013). The latest 'Manuale operativo sui chioschi dell'acqua' (Operating Manual on Water Kiosks) (Utilitalia ANIMA & Aqua Italia 2017) estimates that, with reference to water operators, about 36% of the water kiosks managed demand a fee for the supply of water (in particular water with added CO_2) ranging from a minimum of 3 to a maximum of 8 euro cents per litre, with an average value of 5 euro cents.

Therefore, the qualification of the installation and management of water kiosks as 'other water-related activity' envisages the following methods of cost recognition under the current tariff method:

- the investment for the construction of the water kiosk, where not covered by fees that the municipal authority pays for the work, is included among the fixed assets of the SII, whose capital cost is recognized under the CAPEX included as part of the allowed amount of cost recovery expected granted to the operator (VRG) and therefore affecting the tariff multiplier;
- the revenues from water supplied through fountains are included in the denominator of the tariff multiplier under the revenues from other water-related activities;
- the operating costs for managing the infrastructure are covered by any revenues generated by fees charged to the municipal authorities and/or by the tariff directly charged to service users. For tariff purposes, if the operator achieves a margin from these activities, 50% of this margin is recovered in the VRG; if instead the revenues from these activities are sufficient to cover the costs (no margin) or the operator even incurs losses, no (negative) margin is recognized in the VRG.

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Consequently, the operator credits the investment to the water tariff, by maintaining only 50% of the possible gross operating margin deriving from the management of the water kiosks. Increases in revenues have the effect of reducing the tariff multiplier (with a relative weight considering the overall activities performed by the SII operator).

As regards the re-use of treated water, international studies have included re-use in agriculture among the most widely experimented practices, followed by other uses for non-drinking purposes, such as re-use in industrial processes (e.g. plant cooling), re-use for recreational purposes (irrigation of golf courses), urban purposes (e.g. street washing or park irrigation) and finally groundwater recharge or environmental wetland restoration. Other poorly tested practices (especially due to problems of social acceptability) concern direct re-use as drinking water, which consists of returning adequately treated waste to the distribution networks, and indirect re-use as drinking water, in which properly treated wastewater is released into water bodies and groundwater that are used as drinking water sources. So far, European legislation has defined general principles and provisions concerning this practice: the Wastewater Directive states that treated wastewater should be reused where appropriate (Annex IV, part B), while the Water Framework Directive indicates re-use among the possible measures that could be included in the programme of measures for each river basin (art. 12). Most recently, a proposal by the European Commission, currently being discussed within the European Community, although aimed at encouraging the dissemination of re-use practices at national and international level, appears strictly technical in nature, pursuing the following objectives: defining the European standards that the reused waters must meet in order to be used for irrigation in agriculture; establishing permits for the supply of treated waste water and drafting risk management plans by treatment plant operators for the mitigation of health and environmental risks. The goal is to boost re-use in agriculture (the Commission estimates an increase in recovered volumes of between 1.7 billion and 6.6 billion per year, with positive effects in terms of reducing water stress). The use of such practices should be encouraged, given the potential for re-use emerging at European level and in individual Member States. In Italy, a survey conducted by the Authority on a sample of water operators that supply around 61.5% of the population (approximately 37 million people) revealed that, in 2016, 'Despite there being already today a potential 20% of the total volume of treated water (in cubic metres) adequate for re-use, only 4% is reused (mainly for irrigation) and almost exclusively in the northern regions' (ARERA 2019a).

The issue of the tools and measures to be adopted in the pursuit of economic incentives for the re-use of wastewater has not yet been fully addressed in terms of regulation. In particular (in addition to social acceptability barriers against re-use as drinking water), in various European countries, there are still large price differentials between reused water and running water, due in part to the failure to apply (or only partial application) in some countries of the full cost recovery principle sanctioned by art. 9 of the WFD and the related existence of numerous public subsidies for supplying 'standard' water, which leads to the risk of an inadequate price system that does not reflect the actual cost of these resources, and can discourage the operators from implementing still-expensive re-use technologies. With regard to the Italian tariff method, in the absence of specific incentive tools, the tariff rules for the reimbursement of costs and revenues for the re-use of treated water are the same as those described with reference to water kiosks.

Regulatory action in promotion of circular economies: future developments

The ARERA regulation of the SII has developed gradually, starting with the precise identification of the cost items to be taken into account in the calculation of tariffs (transparency), followed by the objective of ensuring greater coherence of the decisions taken at local level (in terms of objectives to be achieved in the territory, planned interventions and tariff reflectivity) and with the adoption

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of measures to promote growth in investments and operating cost efficiency (effectiveness and efficiency) and finally with rules to promote quality of services and affordability, pursuing a convergence between different areas of the country. The adoption of measures to support the development of circular economies (that could help 'close' the water cycle), by means of establishing sustainability and energy saving objectives, can constitute a new phase of the regulatory process, which must include the following assessments:

- the possibility of extending the regulatory tools aimed up to now towards the development of investments, cost efficiency and quality of water services, to include energy efficiency and environmental sustainability goals, as a prerequisite for circular economy measures;
- the applicability of incentive measures introduced by the legislation and already adopted in other regulated sectors (such as electricity and gas) to the integrated water service (in particular in terms of energy efficiency);
- the effectiveness of supporting regulatory and normative interventions to encourage and guarantee the development of new activities downstream of the integrated water service or related to it in a circular economy perspective (e.g. re-use of waste water in agriculture and sale of high-quality drinking water through water kiosks).

The development of a circular economy within the integrated water service must also ensure the correct application of the Community full cost recovery principle: on the one hand, avoiding making users of the water service pay for the costs of the measures that are not reflected in as many benefits for these users (e.g. improving operator efficiency and the quality of the service provided) and, on the other hand, triggering the double counting of costs or incentives for the operator. In fact, the impact of the mechanisms described above in support of measures to increase energy efficiency and environmental sustainability is linked to the possibility of recognizing (fully or partially) these activities within the regulatory boundaries defined by the Authority. This also depends heavily on the degree of integration between water infrastructure and other infrastructures, and on whether a single infrastructure (be it a plant or a water network) can simultaneously perform both functions.

One element to be taken into consideration in the creation of an effective incentive policy is the possible synergic effect of measures to upgrade and integrate existing infrastructures, aimed for example at the recovery of materials and energy, on water services performance, whose impact could be adequately measured by means of technical standards. In this regard, the technical quality regulation model implemented in Italy – and the related rewards and penalties mechanism – described in the previous paragraph, is well suited to broadening its scope of application to include additional standards of energy efficiency output, given that it is a dynamic and updatable model (in the two consultation documents that preceded Decision 917/2017/R/IDR, the Authority also proposed a series of energy efficiency indicators that could be adopted in a further phase of technical quality regulation). Another tool that could be used by the regulator is the establishment of national benchmarking systems that promote sustainability and efficiency objectives by comparing and publishing operators' performances. The advantages of these initiatives are twofold: firstly, they let the regulator monitor how similar utilities are acting to reach the same objective; secondly, through benchmarking, each operator could improve its individual production processes and increase its efficiency, by identifying the best practices derived from performances analysis and comparison (learning by others). This system could be more useful if issued at international level, involving water operators from different States. The efficiency of benchmarking depends on the structure of the sector and on the context in which the water service is provided: in sectors with similar structured operators and with a low influence of exogenous factors (e.g. geography, urban pattern), it could be easy to implement; while in fragmented sectors characterized by different-sized utilities that operate in different geographical and technical conditions, it could be difficult to identify a proper set of indicators to compare and

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to collect a complete set of data and information, hence benchmarking could work if it is adopted for specific clusters of operators.

As well as for technical regulation models, we can also adapt certain economic principles adopted by the regulator in its tariff method to encourage and reward energy savings by the operator, accompanying the efficiency mechanisms for the purchase price of electricity (which protects users from excessive hikes) with consumption efficiency mechanisms on, aimed at paying the operator (in a logic of profit sharing) a share of the cost savings achieved through energy efficiency actions. Transferring energy cost savings achieved by operators to the water utility is the further step towards which the Italian Regulator is directing its action: in its last tariff method for the third regulatory period 2020–2023 (ARERA 2019b) the Authority has integrated the minimization mechanism concerning energy prices (previously described in this paper) by letting the operator keep part of the energy cost savings (25%), if the energy consumption measured in 1 year is less than the average energy consumption of the previous four years, the savings being linked to energy efficiency initiatives. This (positive) incentive is structured to provide the operators with remuneration for their energy efficiency investments, maintaining the benefit for users of a tariff reduction. The efficacy of this tool (whose implementation will be monitored in the coming years) will depend both on its contribution to the technological progress of the sector and by the degree of regulatory compliance by the operators and their priorities of action (certain areas of the country require energy-intensive interventions to reach the minimum level of service, e.g. providing wastewater treatment services where they are absent or inadequate).

With reference to the national policies encouraging energy efficiency and sustainability (savings, integration of electricity from renewable sources, development and promotion of biofuels), an analysis of the tools in force has revealed that legislative developments are also offering water service operators the possibility of benefiting from these incentives. Thus, for example, to obtain white certificates, an operator can be classified as a 'voluntary entity' (if compliant with the certification requirements described in paragraph 3) and present a project for one of the measures eligible for energy efficiency certificates (such as improving the efficiency of its water networks). Possession of the necessary requisites would also enable access to the incentive measures described towards the production of electricity from RES and biomethane; in this second case, the 'profitability' of the measure depends on: firstly, the operator's ability to develop efficiency projects within the activities and the infrastructures serving the integrated water service (taking advantage of the 'synergy' that would ensure greater economic sustainability of the investment), for which the regulator is required to apply adequate separation of asset control and accounting, in order to avoid undue in-tariff cost reimbursements and revenues; secondly, the degree of development of the infrastructures that, downstream, should receive the operator's surplus production (which must adopt national policies on, e.g. dedicated financing, loans at favourable conditions and priority of access to the network for certain types of sources).

The same tools can also be replicated with reference to the diffusion of water kiosks and re-use of wastewater for irrigation, specifying that the supply of water through high-quality fountains and re-use involve a greater level of integration with SII infrastructures (water purification networks and plants in the first case, treatment plants in the second). Attention should be focused on the economic effects of these activities and on the correct allocation of costs and revenues among those who benefit from the respective services: therefore, the regulator must focus its efforts on clearly defining who pays for the innovations in the treatment of wastewater for re-use and in the treatment for the production of increasingly high-quality water, as well as how to set the tariffs to be paid by agricultural and industrial users, as well as by those who buy from water kiosks (who are not necessarily the same as the users of integrated water service). This implies a clear definition of the positioning of these activities with respect to the water service supply chain and its regulatory perimeter. Another consideration concerns the degree of maturity and the potential of downstream markets, which can add value to

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treatment processes products – such as nutrients – and transform them into raw materials to be used in other sectors. Recent studies have highlighted the potentiality of the latest advanced technologies for resource recovery from sewage sludge, such as the recovery of phosphorous (in terms of facing the possible future shortage of a limited primary resource and in terms of reducing dependence on foreign supply, mainly extra-UE, where reserves are principally localized), illustrating however the main barriers to implementing these practices, summarised as follows: uncertainty of legislation on the qualification and commercialization of these resources, with different standards and requisites at national level and the lack of a common European framework; difficulty of evaluating the technical and economic feasibility of recovery projects, due to the lack of a resource valuation system, and consequently of a market (Canziani & Di Cosmo 2018). In the last ten years, several advanced recovery projects have been developed on a European scale (among others, SMART-Plant, P-REX and Reco-Phos), promoting networks of operators and experts. The dissemination of material recovery practices also relies both on establishing incentives to foster operator investment and on establishing a European legal framework to promote the adoption of circular economies. From a regulatory point of view, e.g. the Italian Authority recently identified in the 'other water-related activities' category (previously described in this paper) a list of innovative activities related to energy and environmental sustainability (ARERA 2019b), including, among others, raw material recovery from water and wastewater treatments, providing for the in-tariff reimbursement of a higher margin achieved by the operator (75%), increasing the profit sharing of these activities. These regulatory drivers could be more effective if accompanied by legislative actions towards developing or creating new markets, as described above within the discussion on public interventions to promote circular economies.

DATA AVAILABILITY STATEMENT

All relevant data are included in the paper or its Supplementary Information.

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