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Water utility regulatory models for energy procurement in Europe: An empirical investigation

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HIGHLIGHTS

- An overview of regulatory models for energy costs of water utilities is provided.
- A detailed examination of the diverse approaches adopted in Europe is given.
- Regulatory authorities have limited awareness of the value of incentive schemes.
- A framework to identify options for regulating energy purchasing prices is defined.
- Regulatory authorities should revise methods for cost recovery of water utilities.

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ABSTRACT

Since the latter half of 2021, energy prices have risen owing to gas and fuel shortages following the rapid economic recovery after the restrictive measures due to the COVID-19 pandemic, with the 2022 Russian invasion of Ukraine exacerbating this stress. As energy prices rose, procurement became a strategic process even in regulated natural monopolies. To give the right impetus to water utilities, entrusting public bodies in several countries with setting rules for cost recovery, tariff methodology, and ensuring quality standards is essential. These bodies must also recognise that incentive-based regulation will influence energy procurement, especially through tariff methodologies applied by water regulators to recover the costs incurred. Therefore, this study provides an overview of the regulatory models adopted in Europe by National Regulatory Authorities (NRAs) to determine allowed energy costs, along with a detailed examination of the diverse national approaches adopted before the energy crisis. It further highlights instances where certain NRAs demonstrated limited awareness of the importance of incentive schemes associated with energy procurement. Building upon existing models, this study developed a framework to identify alternatives and incentives for regulating energy purchasing prices in the water sector. This framework benefits NRAs seeking to update their methodology for cost recovery of water utilities.

1. Introduction

Since the second half of 2021, Europe has experienced an unprecedented increase in energy costs (see Fig. 1) due to the combined effect of several factors occurring simultaneously as a 'perfect storm' in energy markets [1,2]. These factors include low natural gas storage levels in Europe, the post-COVID-19 economic recovery, and, significantly, Russia's attempt to gain political leverage over European countries by curtailing natural gas supplies [3] and exposing consumers to higher energy bills. Compared to the period before 2021, electricity market prices increased by a factor of 4–5 by the summer of 2022, peaking at EUR 500/MWh in some markets in August 2022.

This extraordinary energy crisis affected the entire European economy, including regulated public service providers, such as water utilities [4]. With the increase in energy prices, procurement has become a strategic process, even in regulated natural monopolies. The

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International Energy Agency reports that electricity consumption in the water sector accounts for 4 % of total electricity consumption. In 2014, the energy needs of the water sector in Europe amounted to approximately 80 TWh [5], equivalent to Belgium's gross electricity generation. This accounted for around 2.6 % of the European Union's (EU) total electricity consumption [6].

From a utility perspective, global energy costs constitute a significant portion (approximately 30 %–40 %) of the overall operational costs for drinking water and wastewater services [7]. The water sector's primary energy requirements encompass various activities. These include drinking water supply, comprising groundwater and surface water treatment, desalination, distribution to end-users, and wastewater treatment. Although certain costs are inevitable, inefficiencies in water utilities can be gradually mitigated [8]. Loureiro et al. [9] suggest that energy consumption in the water sector could be reduced by 15 % by 2040 by implementing suitable energy efficiency measures such as reducing water leakages. Cardoso et al. [8] highlight that the lack of human resources, the need to focus on daily issues, and the lack of funding are barriers to improving energy efficiency in the water sector.

Fluctuations in energy prices have significant implications for the financial stability of water utilities grappling with escalating electricity and gas costs. The rising expenses associated with powering water networks, pumps, and wastewater treatment plants pose considerable challenges for operators [10], even those operating within a stable regulatory framework. In numerous countries, water utility tariffs are determined based on the methodologies established by National Regulatory Authorities (NRAs). These NRAs, entrusted with the economic regulation of vital facilities and natural monopolistic infrastructure services, such as the water industry, have the power to set cost recovery rules, monitor key performance indicators (KPIs), safeguard quality assurance, and conduct inspections [11]. However, water utilities operating under NRAs have struggled to fully cover mounting energy purchasing expenses due to the extreme market volatility of the last few years. Consequently, tariff mechanisms should be adapted to reflect new macroeconomic constraints and be more flexible in accommodating extraordinary requests for tariff adjustments [8]. Simultaneously, these mechanisms should provide the right incentives to improve efficiency during the procurement process.

Furthermore, an effective tariff method can catalyse energy-efficiency projects and resource utilisation, such as solar or wind power installations, and the conversion of sewage sludge into sustainable energy, all at a reasonable cost. The continued high energy prices may reduce the risk of inadequate investment returns for such undertakings. Although many renewable energy projects demonstrate an economic rationale, they often require significant capital expenditure. Current regulatory incentives may not always be sufficient for companies to proceed with capital-intensive investments that yield operational cost savings. Cardoso et al. [8] highlight the importance of using performance and efficiency indicators, as well as accurately defining energy and environmental targets, to facilitate benchmarking, yardstick competition, and long-term policy formulation.

Moreover, investment decisions in the water sector require a long-term perspective that considers evolving technologies, a supportive socio-cultural regime, and a stable regulatory framework [12]. Companies must carefully assess their specific circumstances to select the most suitable technological options, such as utilising biogas for electricity generation or injecting it into the grid. Therefore, the regulatory framework's stability is a critical prerequisite, providing the confidence for companies to pursue investments in self-production.

This study offers a comprehensive overview of the regulatory models adopted by NRAs in European countries to define the allowed energy costs. It also examines how these models provide appropriate price signals to companies, encouraging them to achieve higher efficiency in their procurement processes. Thus, this analysis primarily focuses on the regulatory method for incentivising an efficient purchasing strategy. In contrast, consumption and self-production are only partially addressed and require special focus on a dedicated contribution.

This study presents a detailed overview of the diverse approaches taken at the national level before the energy crisis. It reveals that some NRAs exhibited limited awareness of the importance of incentive schemes associated with energy procurement. Building on existing models implemented at the country level, this study developed a framework to identify various alternatives for regulating energy purchasing prices within the water sector. This framework outlines the advantages and disadvantages of each approach, considering their respective incentive mechanisms. This framework can serve as a valuable resource for NRAs seeking to update their methodologies for recovering the energy costs incurred by water utilities, thereby incorporating lessons learned from the previous crisis.

To the best of our knowledge, this study represents the first attempt to recognise the whole set of methodologies adopted by NRAs and structure a decision support system that could sustain water regulators during the design step of the rules to recover energy costs.

The remainder of this article is structured as follows. Section 2 provides an overview of the water sector, highlighting the key characteristics of water infrastructure and its energy requirements. It also discusses the role played by NRAs in the water sector, emphasising the status of water regulation at the European level. Section 3 elaborates on the methodologies applied during the research process and how the information and data utilised in this study were gathered through a series of interviews and focus groups involving members of NRAs belonging to the European Water Regulators (WAREG). Section 4

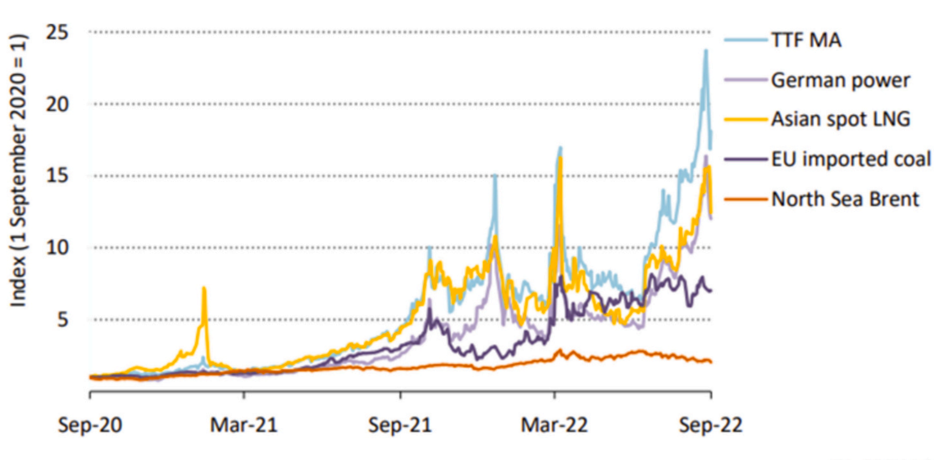

Fig. 1. Evolution of price indicators since September 2020 [1].

presents the results, providing specific details on how energy costs are regulated in each selected country. The section also introduces a framework that presents a menu of regulatory tools to cover energy costs and different price signals and incentives designed to enhance procurement processes. Finally, Section 5 concludes the article with final remarks encompassing the policy implications and applicability of the findings.

2. Background on the water sector

2.1. Energy for water: An overview of the water industry in Europe

The water sector provides three essential services to households and non-domestic consumers: drinking water distribution, wastewater collection, and wastewater treatment. In the EU, approximately 50 billion m^3 of freshwater was extracted annually for public supply in 2017, serving approximately 500 million people; this translates to an average daily usage rate of about 245 l per person [13] As of 2020, 95 % of the population was connected to a secondary wastewater treatment plant. The volume of sewage collected and treated is influenced not only by the consumption of drinking water but also by the inflow of stormwater into sewers, which are often designed to accommodate such water.

In recent years, as countries have placed more emphasis on environmental goals, the role of water utilities has expanded to include additional services provided directly to consumers and the environment. These services include recharging groundwater aquifers, producing treated wastewater for irrigation and industrial purposes, generating energy through water networks using hydropower plants, and producing biogas and biomethane through proper sludge valorisation. Furthermore, water utilities face significant challenges due to climate change and rapid population growth. To address these challenges, utilities are adopting innovative solutions, such as desalination and water reuse, to overcome water scarcity issues affecting conventional water sources [14].

According to the OECD [15], the current water and wastewater services expenditure across the 28 EU member states is estimated at EUR 100 billion. Per capita expenditure varies among member states, with some spending over EUR 250 per capita annually while others spend less than EUR 100 per capita. EurEau [16] estimates that investments in infrastructure amount to approximately €45 billion, equating to EUR 82 per inhabitant per year. To address the upcoming challenges in the water sector, an OECD report suggests a total cumulative additional expenditure of EUR 289 billion by 2030, thus implying an increase of over 20 % in current annual investments. The tariff system serves as the primary source of financing for current expenditures, accounting for approximately 70 %, whereas public funds cover the remaining funding.

In terms of physical assets, the length of the drinking water network per connected inhabitant ranges from 4.35 m per inhabitant in Romania to 19.57 in Finland. The total length of the drinking water network spans 4.3 million kilometres of pipes, while the wastewater network amounts to 3.2 million kilometres. Additionally, 23.6 % of the collected wastewater underwent treatment for organic matter removal, 63.7 % for nutrient removal, and 11.3 % for more stringent requirements than those specified by the Urban Waste Water Treatment Directive (UWWTD) [16].

These data highlight the complexity of the water process and underscore the expected challenges in the future. The evolution of the water sector is accompanied by increased energy requirements and the potential for higher greenhouse gas (GHG) emissions, resulting in significant cost increases. As Table 1 presents, drinking water accounts for the largest share of energy consumption within the sector, representing 43.5 % of total energy consumption. This segment alone contributes to 1.13 % of the overall electricity consumption in the EU. Moreover, when considering desalination as an alternative water source, its share of energy consumption increased to approximately 69 %, with a corresponding impact of 1.8 % on the EU's total energy consumption [6]. Wastewater operations represent one-third of the sector's energy use and, when combined with other segments, account for 2.60 % of overall EU energy consumption (see Table 1).

Table 1
Breakdown of volume treated and energy requirements for the water sector in 2017.

Segment	Volume (billion m^3)	Energy (GWh)	Share of energy	Share of EU electricity consumption
Drinking water supply	49.5	35.000	43.5 %	1.13 %
Desalination	2.1	20.695	25.7 %	0.67 %
Wastewater treatment	47.9	24.747	30.8 %	0.80%
Total	99.5	80.442	100 %	2.60 %

Source: [6], p. 23.

The factors under 'drinking water' included the type of water sources used (groundwater, surface water, or seawater), the number of pumps employed, and population density. Conversely, the energy consumption of wastewater treatment depends on the pollution level in the collected wastewater, the inflow of stormwater, and required quality standards for the receiving water bodies, particularly in environmentally sensitive areas. These factors exhibit diverse characteristics among utilities, resulting in varying energy-cost burdens. For instance, population density can affect the performance of network services [17], whereas economies of scale play a role in wastewater treatment plants [18,19]. Thus, energy costs related to different consumptions could—at least partially—vary according to certain uncontrollable variables beyond the responsibility of the water operator.

Energy costs constitute a significant proportion of overall expenses incurred by water utilities. According to Zschille [20], German drinking water service providers allocate approximately 16.6% of their costs to energy expenditure on average. As highlighted by Limaye and Welsien [21], the World Bank indicates that electricity costs within the drinking water sector can account for up to 80% of non-labour operational expenses. Furthermore, WAREG [4] emphasises that the proportion of energy costs to the total annual costs among the regulated utilities of the surveyed NRAs varies considerably, ranging up to 30% in certain individual cases, while country averages typically fall within the range of 10–20%.

According to the Water–Energy Nexus Special Report [22], electricity consumption in the water sector is projected to increase globally, surpassing 4% of the total global electricity demand by 2040. Fig. 2 illustrates the changes in energy consumption across different water segments. The largest increase is expected in desalination, which serves as an alternative water source to address the challenges of water scarcity, affecting an increasing number of countries. Furthermore, the wastewater treatment sector is expected to experience increasing energy consumption by 2040, driven by the expanding coverage of wastewater treatment services and the need to meet stricter environmental regulations for treated effluent discharge. However, the increase in energy consumption is partially offset by the effective utilisation of sludge to harness its energy potential, a practice implemented by utilities.

In terms of energy procurement practices, water utilities are pursuing different patterns [23]. Variable price contracts are agreements in which the price of energy can fluctuate based on market conditions. These contracts tie the energy cost to prevailing market prices, meaning they can significantly vary over time depending on supply and demand dynamics. This type of contract offers the potential for cost savings when market prices are low but also exposes the buyer to the risk of price increases. Utilities and companies opting for variable price contracts must closely monitor market trends and may employ risk management strategies to mitigate potential cost spikes.

Fixed-price contracts involve setting a predetermined price for

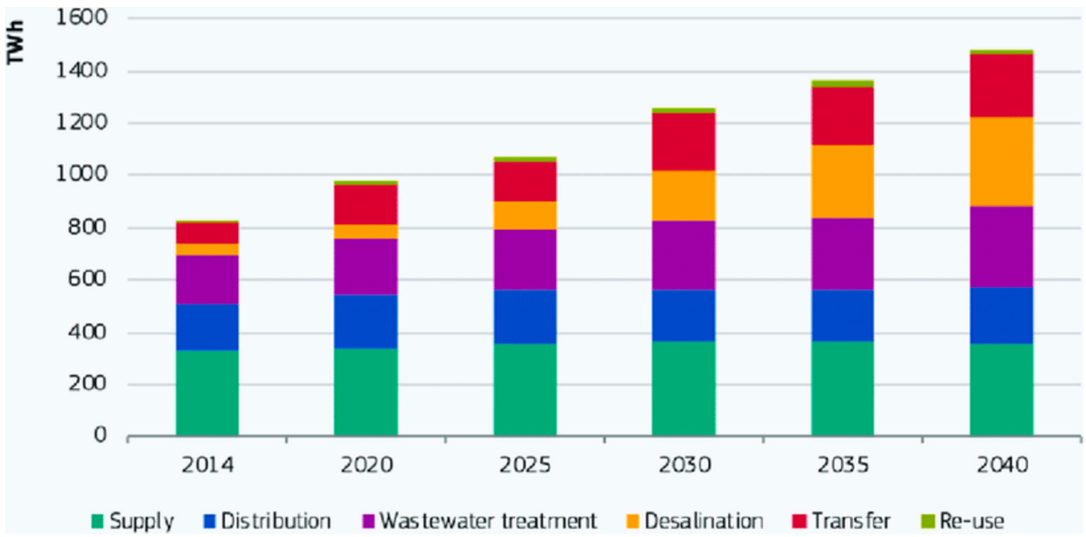

Fig. 2. Electricity consumption in the water sector by process, 2014–2040. Source: [5].

energy over the duration of the contract. This type of contract provides stability and predictability in energy costs, shielding the buyer from market volatility. Fixed-price contracts are advantageous for budgeting and financial planning as they allow for accurate forecasting of energy expenses. However, buyers locked into a fixed-price contract may pay more than the current market rate if market prices decline. These contracts are often favoured by organisations that prioritise cost certainty over potential savings.

Mixed contracts, also known as hybrid contracts, combine elements of both variable and fixed-price agreements. These contracts may specify that a portion of the energy is purchased at a fixed price while the remainder is subject to variable pricing. The mix can be adjusted based on the buyer's risk tolerance and market conditions. Mixed contracts offer a balanced approach, providing some level of cost certainty while allowing for potential savings if market prices are favourable. This flexibility makes mixed contracts an attractive option for organisations seeking to manage risk while optimising costs.

Portfolio management involves a strategic approach to energy procurement, where a diverse mix of contracts and purchasing strategies is employed to achieve optimal results. This approach may include a combination of variable price, fixed price, mixed contracts, and other mechanisms like futures contracts and energy derivatives. The goal of portfolio management is to balance risk and reward by diversifying the procurement strategy. Utilities and companies using portfolio management can tailor their energy procurement to their specific needs and market conditions, leveraging market intelligence and financial instruments to effectively manage costs.

Each of these contract types offers advantages and challenges. The choice of contract will depend on the specific needs, risk tolerance, and market outlook of the procuring entity. By understanding and strategically deploying these different types of energy procurement contracts, utilities and companies can better navigate the complexities of the energy market and achieve cost-effective, reliable energy supply.

2.2. The role played by NRAs

The Water Framework Directive (WFD) 2000/60/EC was established to ensure the efficient use of water resources and the protection of water consumers. One of its key principles is full cost recovery, which aims to cover all relevant costs associated with water services. EU Communication COM (2000) 477 further clarifies the specific costs that should be covered through tariffs, including operation and maintenance, capital, and environmental and resource costs. The directive requires the regulation of water prices charged to consumers to ensure cost recovery while discouraging the allocation of additional funds to operators for their inefficiencies [24,25].

Although the WFD does not provide detailed rules for tariff-setting methodologies, it has prompted many EU member states to assign responsibility to public entities for developing such methodologies. Consequently, independent authorities, water agencies, and ministerial offices across Europe act as economic regulators with varying powers. According to WAREG [26], most members possess tariff powers that enable them to define cost components, establish or update tariff methodologies, and approve tariffs. These powers aim to protect consumers and prevent utilities operating under the conditions of a natural monopoly from earning excessive profits. Some water regulators also monitor the technical and contractual quality of service and assign rewards and penalties based on operators' ability to achieve specific targets. Additionally, regulators are involved in setting unbundling rules, monitoring and approving investment plans, granting and revoking licences, implementing measures to ensure affordability, protecting water consumers, enforcing regulations, and addressing operator non-compliance.

The organisational structure of water regulators is influenced by the diverse range of tasks they undertake, leading to variations in their independence from national governments, size, and level of specialisation. Some countries, such as Ireland, Italy, and Portugal, have established authorities independent from other public entities. These authorities have the autonomy to determine their organisational structure, make hiring decisions, and are financed through fees paid by regulated entities without state subsidies. In these cases, the appointment of board members follows a strict procedure to ensure their independence [27]. Meanwhile, other countries, such as Hungary, have created agencies that are partially dependent on governmental decisions regarding their organisation and the economic rules they adopt. Finally, in some instances, economic regulation is directly conducted by ministerial offices, maintaining a direct link with the government; examples include Greece, Flanders (in Belgium), and Spain. The number of sectors regulated by these entities also varies across countries, with some opting for a multisectoral authority that regulates multiple infrastructural services such as electricity and gas transmission and distribution, district heating, and waste collection and treatment. Others chose specialised entities that primarily focus on water services.

The tariff methodology serves as the primary regulatory tool employed by water NRAs. It is also relevant to the current study, as it defines the rules for cost recovery, including energy costs. The application of the cost recovery principle varies depending on the approach taken by each Member State within the framework provided by the

WFD. WAREG [28] offers a detailed analysis of the tariff methodologies adopted by NRAs, highlighting the wide variety of rules in place. The tariff frameworks range from 'cost-plus' (7 out of 23 cases) to rate of return (4 out of 23), price cap and revenue cap (8 out of 23), and other approaches (4 out of 23). This implies that different incentive schemes are provided to water utilities, with some prioritising investment maximisation in the case of the rate of return, while others provide efficiency targets with price and revenue caps.

The rate of return and cost-plus methods are used to determine the allowed revenues for water utilities based on the costs incurred during a specified period, which is usually the most recent financial period for which data are available. Although the regulatory period can be relatively short, sometimes just a year, these methods are designed to ensure that water utilities fully recover their incurred costs. This includes obtaining a rate of return on investments when using the rate of return method. These methodologies do not provide direct incentives for cost optimisation but encourage operators to make investments to maintain the set level of remuneration.

Conversely, the revenue/price cap method covers a longer regulatory period, typically ranging from three to six years, and establishes allowed revenues/prices based on planned costs and business plan analysis. In addition to cost control, regulators often set service quality targets. Under this methodology, the maximum revenue/price is set for the regulatory period, and these variables are adjusted over time to account for inflation (RPI) and promote efficiency growth (X). The inclusion of an efficiency factor (RPI-X) acts as an incentive to reduce costs. The revenue cap approach includes volume risk, meaning that water utilities bear economic losses from demand shortages unless volume adjustments are implemented.

In addition to the general regulatory framework, the tariff methodologies adopted at the country level may include various incentive schemes, some of which may be specifically linked to individual cost items such as energy costs. These schemes aim to promote efficiency in the purchase and consumption processes of water utilities.

3. Methodology

This study aims to identify and analyse the frameworks of the various regulatory models adopted by NRAs prior to the energy crisis, determine the allowed energy costs, and then identify general rules for an effective design of models.

This study relied on a combination of qualitative and quantitative data gathered from 18 NRAs in Europe. Data were obtained at the end of 2022 using a customised questionnaire comprising 32 multiple-choice and open-ended questions. The questionnaire covered various aspects, including the impact of electricity prices on the cost of water service and the tariffs paid by consumers; different methodologies used to set water tariffs; the recovery of electricity costs through water tariffs; the frequency and procedures to update/adjust electricity costs; the possibility of triggering an extraordinary review of tariffs; incentives for energy conservation/efficiency under a 'business-as-usual' setting; the use of KPIs to monitor energy costs; measures that regulatory entities have undertaken in response to the energy crisis; and the extent to which the current regulatory governance and tariff frameworks are suitable to address the impacts of the energy crisis.

The questionnaire was designed for a study titled 'Impacts of the energy crisis on the price of water services.' A comparative assessment of regulatory responses across Europe was conducted by WAREG [4]. Of the 31 WAREG members, 18 NRAs actively participated in the questionnaire and subsequent follow-up interviews. During the interviews, the NRA representatives discussed their questionnaire responses and provided additional information not covered in the questionnaire. The interviews were semi-structured to allow for flexibility in the discussion. The preliminary results obtained from the questionnaire and interviews were further discussed during two hybrid workshops organised by WAREG. These workshops provided opportunities for the participants, including NRA members and other stakeholders, to share additional insights and information and validate those collected during the first step of the data collection process.

The data collected from the questionnaire, interviews, and workshops were analysed within the context of each country and its local energy markets. Country-specific information was then compared with data from other countries to identify any specificities and design the regulatory models that are included in this study's framework.

For further details regarding the specific questions asked and responses received, the WAREG [4] report can be consulted. This study specifically focuses on data collected regarding the tariff methods used to account for energy costs and purchase prices, as well as the electricity procurement practices pursued by water companies.

The article illustrates the main methods adopted for assuring the recovery of energy costs incurred by utilities, describing the details of their mechanisms, their strengths and weaknesses, assuming the need to provide the right incentives to operators for optimising the electricity procurement process and having in mind the necessity to hedge them under these mechanisms from energy peak deriving from the extraordinary event. The energy cost recovered includes "raw material" energy, transmission and distribution services, taxes and subsidies for renewables, and other type of subsidies required by the system. This is an exploratory study on a relevant issue for the water sector, considering the high amount of energy purchased for internal consumption. It is also a first attempt to sensibilise NRAs on the topic and carefully design the related regulatory mechanisms.

4. Field evidence

4.1. Electricity purchase practices of water companies

This section provides an overview of the electricity purchase practice of water utilities and how these practices were impacted by the energy crisis (Table 2). Most water utilities buy electricity from the competitive market, either directly (spot market or futures market) or through an energy trading company (long-term fixed contracts). However, in some Southeast European countries, utilities buy energy at a regulated fixed price. This is the case in Albania, Kosovo, Moldova, and the smaller water companies in North Macedonia (utilities with annual revenue below 2 million euros and a maximum of 50 employees). Malta is in a similar situation due to derogations under the EU Electricity Directive.

Table 2
Electricity purchase practices of water service providers.

Country	Regulated price	Long-term contracts at a fixed price	Spot market (variable price)	Futures market
Albania	✓			
Belgium (Brussels)				✓
Belgium (Flanders)				
Bulgaria			✓	
England & Wales		✓	✓	✓
Estonia		✓	✓	
Hungary		✓	✓	✓
Ireland		✓	✓	
Italy		✓	✓	
Kosovo	✓			
Latvia		✓	✓	✓
Lithuania		✓	✓	
Malta	✓			
Moldova	✓			
Montenegro		✓		
North Macedonia	✓		✓	
Portugal	✓	✓	✓	
Romania		✓	✓	

During the energy crisis, the regulated fixed electricity prices in these countries remained unchanged or increased much less than the market price; therefore, the water companies have not yet faced the majority of the burden from higher energy costs. Consequently, a response by the water utility regulatory authority was not required either.

Long-term fixed contracts are used in many countries. The contracted energy traders secure long-term positions in the futures energy market, ensuring predictable energy purchase costs for their clients. Some of these contracts are still valid in late 2022 (e.g., Belgium-Brussels, Ireland, and selectively in other countries), having successfully protected the contracting water companies from rising energy prices. However, many of the contracts have expired, and in 2022, it became increasingly difficult to renew them, especially on favourable terms. Therefore, many water utilities had to start buying electricity directly from the spot market, being exposed to much higher prices than previously. Water companies that have traditionally procured energy from the spot or futures markets (even before the energy crisis) also experienced a steep rise in their energy costs, multiplying their expenditures on electricity.

Governments in some countries intervened to mitigate high energy costs for specific groups of energy users, sometimes including the water sector or selected water sector participants (e.g., smaller service providers).

In Bulgaria, the government fully subsidises energy costs above 127 EUR/MWh. In Latvia, there is a partial subsidy above 160 EUR/MWh, and other concessions are detailed in Section 6.5, the Latvian case study. In North Macedonia, any additional cost above the regulated price is subsidised for those water utility companies that need to make their purchases in the spot market. In summary, the full impact of the energy crisis on water companies is observable only in some countries, most notably Estonia, Hungary, Italy, Latvia, Lithuania, Portugal, Romania, and the UK (England and Wales). Even in these countries, long-term contracts provide temporary protection to some water companies. Companies that are fully exposed to energy price increases face electricity costs of 100–300 EUR/MWh as opposed to past multi-year average values of 40–80 EUR/MWh. The total costs of water utility companies in the least favourable situations (high baseline share of energy costs and full exposure to the energy market price changes) may even double.

4.2. Case examples from the survey of NRAs

This section examines how NRAs regulate energy costs in selected EU member states based on the survey described in Section 3. The chosen method varies depending on the regulatory framework, energy purchase practices, and energy markets in each country.

Outside the EU, water utilities in many countries are supplied by regulated energy suppliers. However, Malta is the only country with this practice within the EU, as it is exempt from the common EU energy market rules owing to its island status. In Malta, water utilities are not subject to spot prices and do not procure electricity themselves. Instead, the water utility regulator sets the electricity cost at a regulated price.

Several EU member state regulators, including those in Belgium, Bulgaria, Italy, Estonia, and Moldova, use historically realised energy prices or historical spot prices to determine the energy cost for future tariffs. In Belgium and Bulgaria, no ex-post adjustment exists for energy prices deviating from the allowed or historical prices, except for inflation adjustments. However, significant deviations may warrant extraordinary adjustments upon utility requests. Estonia employs an open-ended regulatory period. No regular tariff adjustments exist, but companies can request tariff reviews when costs deviate significantly from past costs. However, this review did not include ex-post adjustments to past costs.

In Italy, a cap is applied to the energy cost components, limited to the average energy cost in the sector, and an additional 10 %. This cap applies to all regulated utilities and only affects the price and not the quantity of energy used. Initially, small- and medium-sized operators expressed concerns about fitting under the cap due to their size. However, they have successfully responded to this requirement by forming auction pools to organise a common auction for energy and obtain lower prices. If a company's actual costs are lower than the cap, the regulator uses a lower cost level for tariff setting. A recent update to the tariff methodology incentivises improved energy efficiency because energy savings can be used towards additional tariff allowances. According to this rule for the recovery of energy costs, which do not provide price signals in advance, a large part of the Italian water utilities follow a portfolio management approach [23] to avoid high-risk exposure by choosing one of the extremes of the range (fixed or variable price contracts).

In Estonia, justified energy costs are determined by estimating the energy consumption and prices set in contracts with energy suppliers. Fixed-price contracts require the water utility to demonstrate that it secured the most favourable price, which is then used for the cost calculation. For market price contracts, the Estonian Competition Authority considers the average Nord Pool power exchange price over the 12 months prior to the tariff review, adding a sales margin according to the contract. During the energy crisis, this price period was reduced to account for increased market volatility.

Romania, Hungary, Latvia, and Lithuania analyse the justified energy prices on a case-by-case basis. Utilities with long-term fixed contracts use the contract prices as the justified energy prices. In Romania, utilities are notified of expected price increases by incorporating the elements of future price projections. For utilities without long-term contracts, Latvian and Lithuanian regulators rely on forecasts based on Nord Pool power exchange data, as most utilities purchase energy through this exchange. Lithuania uses the three-month average of futures prices for the next year from Nord Pool, whereas Latvia uses the weighted average monthly price of electricity during the forecasting period. Similar to Estonia, Latvia also utilises an open-ended regulatory period, allowing companies to request reviews for significant cost deviations without ex-post adjustments to past costs. In Ireland, Portugal, England, and Wales, energy costs are not treated separately. Instead, the regulators group operating expenditure elements and analyse them as a whole.

4.3. A framework of models for regulating energy purchasing prices

This section presents a comprehensive analysis of various models at the country level for regulating energy purchase prices in the water sector. Table 3 provides a menu of alternatives along with their respective advantages and disadvantages while highlighting their potential incentive power[1]. The framework serves as a valuable resource for NRAs seeking to update their existing methodologies for energy cost recovery in water utilities by incorporating lessons learned from recent crises. The models were meticulously designed, considering the following options:

1. Inclusion of the energy cost among the allowed costs (yes/no).
2. The energy price is estimated before the beginning of the regulatory period to provide an effective price signal for water utilities (EX-ANTE yes/no).
3. If Option (2) is activated, adjustments could be made to the costs incurred by the water utility based on the actual expenses during the regulatory period (EX-POST yes/no); if the option is not implemented, a post-regulatory intervention becomes necessary to establish the allowed energy cost, considering the actual results achieved.

[1] Belgium adopts the 'tunnel methodologies' on overall opex, even if (different to England and Wales) the forecast is obtained from aggregating all cost items, including energy cost.

Table 3
Comparison of European Water Regulators' tariff models from the energy procurement cost allowance perspective.

Type of model	The cost of energy is specifically treated by the tariff method	EX-ANTE Estimation of planned cost of energy	EX-POST Tariff adjustments according to the difference between forecast and actual costs	EFFECTS	PROS	CONS	Countries where the model is adopted
Price cap with estimation of overall opex	No	**Forward-looking approach**, based on a statistical methodology, with the inclusion of energy within other operating expenditures	Cost adjustments could be possible, but mainly on overall OPEX	Aim to improve overall efficiency.	Incentive for increasing efficiency (not only in purchasing energy (EUR/kWh)). Incentive for reducing consumption (kWh/m^3).	Risk that the estimated energy cost may not accurately reflect the prevailing market conditions during the regulatory period.	England and Wales. Belgium and Ireland. Possibility of tariff reopening when a materiality threshold is overpassed.
Forward market	Yes	According to the **forward price of energy** for the regulatory period.	No	Aim to buy energy at a price aligned to the forward price used by the regulators. Alignment of the price of energy within the sector (forward price).	Possible room for efficiency in the purchasing process (EUR/kWh) since any variance with forecast price (forward) is accounted to the operators.	Risk of poor liquidity in the market, especially with a long regulatory period (more than 1 year). Risk of high variance in operators' gross margin in case of forward market shortages. An unexpected over-consumption of energy could imply extra costs due to the access to the spot market.	This model is similar to what the Italian regulator has adopted in the regulated gas retail market since the 3rd quarter of 2022. Latvia adopts a forward-marked model for water utilities without a long-term contract (three-month average of forward prices in North Pool). Latvia applies an open-ended period.
Spot market (day ahead-intraday)	Yes	Yes/No Estimations from the regulator could be based on several alternative methods, including (a) historical Spot Market prices; (b) forward market prices; and c) a mixed approach.	Cost recovered according to an **average of actual price** recorded in the spot market.	Aim to buy energy at a price aligned with the spot market price.	Possible room for efficiency in the purchasing process (EUR/kWh) since any variance with spot price is accounted for by the operators. Using daily prices to calculate the actual average spot market price could incentivise a more efficient usage profile, moving consumptions to lower-priced hours. The spot/day-ahead market is usually very liquid and considered an efficient method to procure electricity (no risk of wrong procurement practices).	Risk of economic losses for operators entering long-term contracts with non-indexed prices. Users are exposed to the risk of uncontrollable energy costs due to fluctuations in the market.	Estonia uses a spot market model for recovery energy costs, but only for those water utilities with a short-term procurement.
Average price of sector	Yes	According to the lower between past costs (a-2) incurred by operators and the average cost of the sector.	Cost adjustments are made if the allowed cost differs from the actual cost, **with a threshold given by the purchasing price incurred, on average, by the sector**.	Aim to reduce energy prices since the average sector price is not known in advance, and prices exceeding this threshold	Possible room for efficiency in the purchasing process (EUR/kWh) since any variance with the cost of the sector could be left to operators. The cost of the	Ex-ante, no clarity exists on the target price; thus, utilities could purchase energy with several degrees of freedom. Consequently, a high variance risk could appear in the operators' gross	Italy adopts a method based on the price of the sector, which sets a threshold for allowed costs. Any extra cost incurred is left to the operators. Any savings are passed

(*continued on next page*)

Table 3 (*continued*)

Type of model	The cost of energy is specifically treated by the tariff method	EX-ANTE Estimation of planned cost of energy	EX-POST Tariff adjustments according to the difference between forecast and actual costs	EFFECTS	PROS	CONS	Countries where the model is adopted
			The average price of the sector is made by the actual price of each operator included in a panel, weighted by consumptions.	cannot be recovered through tariffs.	sector could better represent the real way operators are purchasing energy than market prices.	margin. Risk of coordination and collusions among larger operators "to make" the sector price (mitigated if there are many operators and if they have different governance typologies). The risk cost of the sector is less reliable than a market price since the regulator estimates it according to its own methodology.	to consumers. A price cap mechanism of total costs further limits ex-post cost adjustments. The Italian model also sets incentives for reducing consumption (kWh/m^3).
Forward market model with cost adjustments	Yes	**According to the forward price of energy** for the regulatory period.	**Cost adjustments with actual costs incurred by the company** allow the identification of (in) efficiency that is then shared between utilities and consumers according to a given rate.	Aim to buy energy at a price aligned to the forward price used by the regulators. Alignment of the price of energy within the sector (forward price).	Possible room for efficiency in the purchasing process (EUR/kWh) since a part of the variance with forecast price could be left to operators.	Risk of poor liquidity in the market, especially with a long regulatory period (more than 1 year). Risk of high variance in operators' gross margin in case of forward market shortages.	
Pass thorough	Yes	Energy costs could be planned according to different methods (e.g., past spot price or forward).	Actual costs are fully covered with a case-by-case approach (pure pass-through method)		The benefits from any decrease in the energy market are fully passed to consumers.	The costs from any increase in the energy market are fully borne by consumers (risk of uncontrollable energy cost for users). No incentives for reducing energy costs.	Bulgaria, Lithuania, Romania.

Six models were designed, with the majority aligning, at least to some extent, with specific solutions adopted at the country level, drawing inspiration from the WAREG network. The effects in terms of operators' reactions to the incentive base mechanism are explained, beside the strengths and weaknesses of each model.

One model is characterised by including energy costs within operating expenditure in a price cap method or total expenditure in a Total Expenditure method without any specific mechanism for estimating purchasing prices, consumption, or the efficiency target. The total cost can be estimated using different approaches. In some countries, such as the UK, a firm's cost target is estimated through a statistical cost function for the water sector, considering specific environmental and organisational variables. This forward-looking approach has a high potential incentive for efficiency improvements because, at the end of the regulatory period, cost savings could be, at least partially, maintained by the water utility as a margin. Although energy costs are not specifically mentioned by the tariff methods, the model is based on total costs (opex or capex+opex), and the linked incentive scheme could induce water utilities to reduce purchasing prices and energy consumption. The choice of this highly potential incentive scheme fits with sectors where privately owned utilities operate, which must take responsibility for their energy procurement strategy. However, as with other models, regulators must address certain drawbacks. As energy costs are influenced by uncontrollable factors such as the geographical characteristics of the serviced area, plant size, and water sources, these effects should be considered in the cost function. However, obtaining accurate data for these variables can be challenging. For example, it may be difficult to determine an index that accurately measures the geographical complexity of a region by considering factors such as mountains without water or sparsely populated areas. Furthermore, the actual energy cost can significantly deviate from that included in the total costs, especially due to unforeseen events in the energy market, such as the price spikes experienced during the 2022 crisis. These fluctuations may necessitate tariff adjustments to ensure operators achieve full cost recovery or prevent windfall profits in the case of unexpected price decreases. Generally, this model relies primarily on past sector performance and does not provide advanced price signals that should be considered when formulating an energy purchasing strategy.

To address the limitations of the first model, the second model introduces a forward-looking approach by setting the purchasing price for the next regulatory period based on the forward market. When working without an ex-post adjustment, this method gives water utilities a strong incentive to secure their positions in advance by purchasing energy at a price aligned with the forward market. Although this offers a significant advantage, a potential drawback exists when dealing with regulatory periods longer than one year, as poor liquidity may arise in energy market contracts with longer time horizons. In such cases, if unexpected consumption occurs, firms may need to purchase energy from the spot market, potentially leading to economic losses if there is a negative variance between the spot and forward prices. This drawback does not necessarily represent a limitation because the negative variance due to a suboptimalenergy procurement can be attributed to the managerial responsibility. However, adopting a forward market model with cost adjustments based on actual costs (as described in the fifth model in Table 3) can mitigate the impact of unexpected cost variances.

The third model also relies on market prices. However, it operates after the conclusion of the regulatory period and calculates the average energy price using different frequency alternatives such as hourly, daily, or weekly prices. Utilising lower frequencies allows water utilities greater flexibility in adjusting consumption towards periods with more favourable prices (e.g., specific hours if the allowed cost is based on a daily price average). Unlike in the forward market model, liquidity issues should not arise with this approach. However, this model does not provide price signals in advance, granting a higher degree of freedom to the utility's purchasing strategies. Consequently, a risk of loss exists if purchases are made at prices that are not indexed to the spot market.

The 'average price of the sector' model (fourth model in Table 3), which calculates allowed costs based on the average purchasing prices incurred by a sample of water utilities, deviates from a strict link with the energy market. Although this model aims to establish a sectoral benchmark, it has certain drawbacks. Since no price signals are provided in advance, water utilities do not receive any guidance from the regulator regarding their purchasing strategy. Consequently, sector prices may significantly vary during periods of market turbulence, such as the events of 2022. Contracts indexed to the spot market could align with or even fall below the average, whereas contracts with fixed prices might exceed the average. Conversely, fixed-price contracts may prove more favourable during backwardation than the spot market. Additionally, when the sector price is estimated based on a selected panel of utilities, the model faces the risk of subjectivity and potential reliability issues. Measures were taken to mitigate these limitations in the country where this model was implemented; for instance, robust samples of firms have been carefully selected.

Unlike the previous five models, the sixth model does not offer any specific incentives to firms as it completely removes energy prices from managerial responsibility. Under this approach, all cost variances are passed on to consumers. While this solution simplifies the regulatory burden associated with market-based models, it places the entire price variance risk on the consumers.

Considering the strengths and weaknesses of the observed models, this final section presents the key considerations for designing a regulatory framework for energy in the water sector.

While water utilities have some degree of control over prices (EUR/kWh) and consumption (kWh), exogenous market factors and uncontrollable environmental variables can affect the overall energy cost. In certain cases, regulators may not account for the utilities' ability to influence energy costs and instead adopt a pure pass-through approach. A potential drawback of this approach is that energy procurement and consumption inefficiencies are fully transferred to consumers without incentivising operators to adopt more efficient strategies. This approach has been mainly implemented in countries such as Bulgaria, Lithuania, and Romania, where only wholly public-owned utilities operate. The choice of a pass-through approach could depend on the scarce interest of these types of companies to profit from the difference between the actual versus the allowed price of energy. Additionally, the main aim of NRAs is to tie the price of purchased energy to the prevailing market prices and fully recover the cost incurred by utilities.

An alternative, more incentive-based than a pure pass-through approach, could allow the regulator to hold utilities accountable for the entire variance in energy costs. However, a potential drawback of this approach is that operators may be burdened with uncontrollable variances beyond their responsibility.

A more balanced solution involves a combination of the aforementioned alternative approaches; that is, utilities would be responsible for the variances resulting from their own actions and decisions, whereas the portion attributed to the uncontrollable energy market and environmental conditions would be passed on to consumers. Implementing such a solution requires adherence to certain principles.

To allocate at least a portion of the responsibility for energy costs to water utilities, regulators must establish and clearly communicate a target price for energy. This would provide utilities with a definitive guideline on procuring energy, enabling them to mitigate the impacts of uncontrollable market variables by implementing effective hedging strategies.

The chosen target price should be objective, verifiable, and consistently reflective of prevailing market conditions. As an alternative approach, an ex-post methodology could be employed in which the target energy price is calculated after the regulatory period. This could involve determining the actual average of energy spot prices with the methodology disclosed in advance before the regulatory period begins.

By setting a target price through a forward-looking or ex-post approach, the regulator establishes a transparent framework that enables utilities to make informed decisions regarding energy procurement, including self-production. This approach helps align the responsibilities of utilities with market conditions and encourages effective cost management strategies. It reduces the need for extraordinary interventions set by the NRA to ensure a full cost recovery in case of energy price spikes. During the recent energy crisis, for instance, 5 out of 18 regulators underwent unscheduled tariff reviews. These reviews introduced cost items linked to unexpected price variances and, in some cases, anticipated the coverage of cost items compared to the planned timeline.

5. Conclusion and policy implications

Over the past two years, the rising energy price has unexpectedly emerged as a critical issue in European economies, affecting the water sector because of its substantial energy consumption. In response, the European Commission proposed an electricity market design to enhance EU protection against manipulation in the wholesale energy market and reduce dependence on short-term electricity prices by emphasising dependence on long-term contracts (Directive EU/2024/1711; Regulation EU/2024/1747). Additionally, for the water sector, the Commission set the goal of energy neutrality in the new UWWTD, assigning energy efficiency and self-production targets to water utilities, along with environmental objectives related to wastewater treatment before discharge.

Given the increasing importance of energy in water policy, regulators should begin comparing their approaches to energy cost recovery and identify best practices and standard solutions. This article provides an overview of the different regulatory models adopted by NRAs at the EU level to determine the allowed energy costs, highlighting the significant variations in terms of price signals provided to utilities and the potential incentives for efficiency improvements. This wide range of approaches is primarily due to the lack of clear provisions at the European level regarding energy efficiency in the water sector. Currently, no specific references to energy costs in the water packages of directives exist, aside from the recent UWWT proposal, and no internationally recognised guidelines on how to handle energy costs from a regulatory perspective have been formulated.

The menu of regulatory tools presented in this analysis can assist NRAs in updating their methodology for energy cost recovery, considering the lessons learned from the recent crisis, and simultaneously be valuable for water stakeholders who wish to contribute to reviewing the tariff methods. The market turmoil has underscored the importance of utilities addressing energy procurement and consumption, prompting regulators to share a portion of their responsibility for energy costs with water utilities. This shift aims to raise awareness among utilities while mitigating the potential tariff shocks that European citizens may experience. However, regulators should provide clear reference target prices in advance to minimise the risk of incorrect purchasing strategies leading to financial difficulties for utilities.

In summary, among the various models described, this study emphasises those that at least partially allocate the burden (or benefit) of price variances to utilities and concurrently provide price signals to operators before the start of the regulatory period. A principle of economic regulation states, "*Incentive regulation is the use of rewards and penalties to induce the utility to achieve desired goals where the utility is afforded some discretion in achieving goals*" [29]. Comparing incentive-based regulation with command-and-control approaches, the former provides higher degrees of freedom to the utility, which can identify its own strategies to achieve the target [30].

Applying this rule to energy costs incurred in the water sector, combining a price/revenue cap with an energy price update mechanism based on forward prices can provide relevant incentives and support water utilities' hedging strategies. Without such a mechanism, only having a price/revenue cap might necessitate reopening due to significant energy price fluctuations beyond inflation. However, a tariff reopening implies no clear attribution of responsibility for a high energy price, with the risk of assigning the cost of energy market shortages to the utility or passing the cost of utility inefficiencies to the consumer. Amid the AMP 8 debate in the UK, some water utilities urged OFWAT to implement a Real Price Effects mechanism for Energy, Chemicals, Supply chain, and Labour, specifically requesting updates to energy prices according to current forecasts [31].

Following this rule, the Italian NRA has recently launched the rules for the regulatory period 2024–2029, introducing a portfolio of energy contracts to estimate the allowed price, combining 70 % of variable prices contracts and 30 % of fixes prices contracts recorded in the sector at the end of the interim period 2024–2026. This approach attempts to adjust the drawbacks of the previous method, providing opportunities for hedging strategies and efficiency improvement [32].

However, as with other regulatory tools, these principles for recovering energy costs must follow a design process based on the analysis of sector problems and objectives, as outlined by Ehrhardt et al. [33]. This involves examining the role the NRA can play in moving the sector towards these objectives by identifying appropriate regulatory actions, in line with a contingent approach, as suggested by Romano et al. [34].

Finally, highlighting the main limitation of this study is important. As it is a preliminary effort to identify NRA's methodologies for recovering energy cost items, it lacks an extensive literature review. The empirical survey on NRAs gathers details about their methodologies; future research could evaluate the regulatory impact of each approach, monitoring its effects on the value of energy prices and consumption recorded by water utilities.

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CRediT authorship contribution statement

Balázs Felsmann: Writing – review & editing, Writing – original draft, Validation, Project administration, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Andrea Guerrini:** Writing – review & editing, Writing – original draft, Validation, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Gent Hajdari:** Writing – review & editing, Writing – original draft, Validation, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **András Kis:** Writing – review & editing, Writing – original draft, Validation, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Giulia Romano:** Writing – review & editing, Writing – original draft, Funding acquisition, Conceptualization.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

Data will be made available on request.

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