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Updated estimation of the costs of quaternary wastewater treatment in the EU

A comparison of cost models

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Contents

Abstract

The recast Urban Wastewater Treatment Directive (UWWTD), 3019/2024/EU, requires the removal of micropollutants from urban wastewater. To cover at least 80% of the costs, it mandates extended producer responsibility (EPR) schemes with two industrial sectors, pharmaceuticals and cosmetics, identified as main polluters. Using data available mostly from before 2021, the impact assessment (IA) of the UWWTD estimated a costs of treatment of ca. 1,2 billion Euro/year for the EU by 2040 when all treatment facilities would be in place (1,56 billion Euro/year in current prices due to the meanwhile relatively high inflation). On the other hand, the recast UWWTD requires less widespread treatment of micropollutants than assumed in the IA. The Commission, in the Water Resilience Strategy adopted in 2025, committed to conduct an updated study of costs and its potential impacts on concerned sectors.

As a contribution to such study, this technical report compares the costs in the IA with alternative estimates derived from recently published evidence. It shows that the alternative estimates support higher treatment costs per population equivalent (PE), generally within the margin of uncertainty of the IA. At the same time, the less widespread treatment required by the recast UWWTD mitigates the expected increase of total costs.

By 2045, when all the quaternary treatment would be in place, the costs that can be expected from the implementation of quaternary treatment in current prices can be estimated in the range 1,48-1,8 billion Euro/year i.e. between - 5% and +15% compared to the 1,56 billion Euro/year estimation of the IA corrected for inflation.

Such cost adaptation per se would not challenge the conclusions of the IA concerning the aggregated impact of costs on the industry and consumers, all the rest being equal.

Acknowledgements

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Authors

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1. Introduction

The recast Urban Wastewater Treatment Directive (UWWTD)[1] requires the removal of micropollutants from urban wastewater using advanced broad-spectrum treatment processes defined as “quaternary treatment”. This provision applies to all urban wastewater treatment plants (WWTPs) serving 150.000 population equivalent (PE) and above, as well as to those of 10.000 PE and above if justified by an appropriate risk assessment (Article 8). Quaternary treatment will have to be fully implemented by 2045, with intermediate deadlines. Article 9 of the UWWTD requires that at least 80% of the costs be paid by the industrial sectors responsible for the production and placement on the market of products leading to the release of micropollutants in urban wastewater (extended producer responsibility, EPR). Annex III of the UWWTD currently identifies as the main “producers” of micropollutants found in urban wastewater across the whole EU the pharmaceuticals and cosmetics industry, while more sectors could be added following a review foreseen, under Article 30, by 2033 at the latest. The producers, through mandatory Producer Responsibility Organisations, will have to determine their contributions based on pre-defined criteria (i.e. quantities and hazardousness of substances) (Article 9 (3)). If a substance put on the market proves to be rapidly biodegradable, it can be exempted from contributing (Article 9(2)). Producers putting less than 1 tonne of products containing micropollutants on the market are also exempted.

The impact assessment (IA) accompanying the UWWTD proposal (EC, 2022) estimated this provision to not cause unacceptable impacts in terms of affordability and accessibility of pharmaceutical products, based on the evidence available at the time of its preparation. In June 2025, as part of the EU Water Resilience Strategy (WRS: EC, 2025)[2], the European Commission committed to conduct a study to update the IA cost estimates of quaternary treatment and their potential impacts on the sectors concerned, in the context of the implementation of the EPR system.

The need to update the estimates of costs of quaternary treatment arises from three reasons:

- A hike in inflation since the preparation of the IA (that was using data from years up to 2020), due to various drivers in an increasingly complex geopolitical and economic scenario;
- The experience gained on quaternary treatment, particularly in Switzerland where provisions similar to the UWWTD are in place for about 10 years, hence the availability of more representative cost data;
- The differences between the initial legislative proposal by the Commission on which the IA calculations were based and the final adopted legal text of the UWWTD, which requires a smaller number of plants to implement quaternary treatment.

As a contribution towards the study required by the WRS, this report presents a comparison of the cost model used in the IA of the UWWTD (EC, 2022) with alternative cost models derived on the basis of more recent information, in order to check to what extent the initial cost estimates from the IA are still valid today. This check is necessary as a preliminary step before evaluating how the costs of quaternary treatment may affect the availability and affordability of medicines, in line with the EU Water Resilience Strategy.

[1] Directive - EU - 2024/3019 - EN - EUR-Lex

[2] Water resilience strategy - European Commission

2. Materials and methods

The analysis presented below consists of comparing costs estimated on the basis of different cost models, considering the inflation occurred during the period 2020-2025 in the EU, and under the provisions of the adopted legal text of the UWWTD compared with the initial legislative proposal by the European Commission.

In principle, costs could be estimated in detail for a given plant taking into consideration the design characteristics of quaternary treatment processes, the equipment, infrastructure and consumables entailed, the energy consumption etc. However, costs at the level of a single plant come with inherent variability due to their dependence on site specific conditions. Hence at a stage of strategic assessment it is more practical to plot the costs per treated PE ("unit costs") as "observed"[3] at an ensemble of plants as a function of the plant size (PE), and interpolate the data with a cost model (or "cost function"). The total cost of quaternary treatment for a plant is estimated by multiplying the plant size by the value returned by the cost model. Considering the recommendations in VSA, 2025, the approach is not expected to yield plant-specific estimates and should be considered only for aggregated estimations. While based on cost data, the assessment presented here is a comparison of estimates across a set of cost models available. In this section, we provide details on the cost models considered, the quantification of inflation, and of the expected outcome of implementing the legal provisions. The alternative cost models considered in this study are derived from evidence described with sufficient detail in publicly available reports or peer reviewed research papers, and were deemed adequate for a comparison with the model used in the IA.

2.1. Cost models

2.1.1. Cost function used in the IA

The cost estimates provided in the IA are based on the cost function proposed by a group of European experts (Pistocchi et al., 2022[4]), see **Figure 1**.

This relates the levelized yearly cost C per PE (Euro/PE/year) to the size of the plant, P (PE), as per **Equation 1**.

Equation 1. Cost function for quaternary treatment used in the IA

$$C = 1000\ P^{-0.45}$$

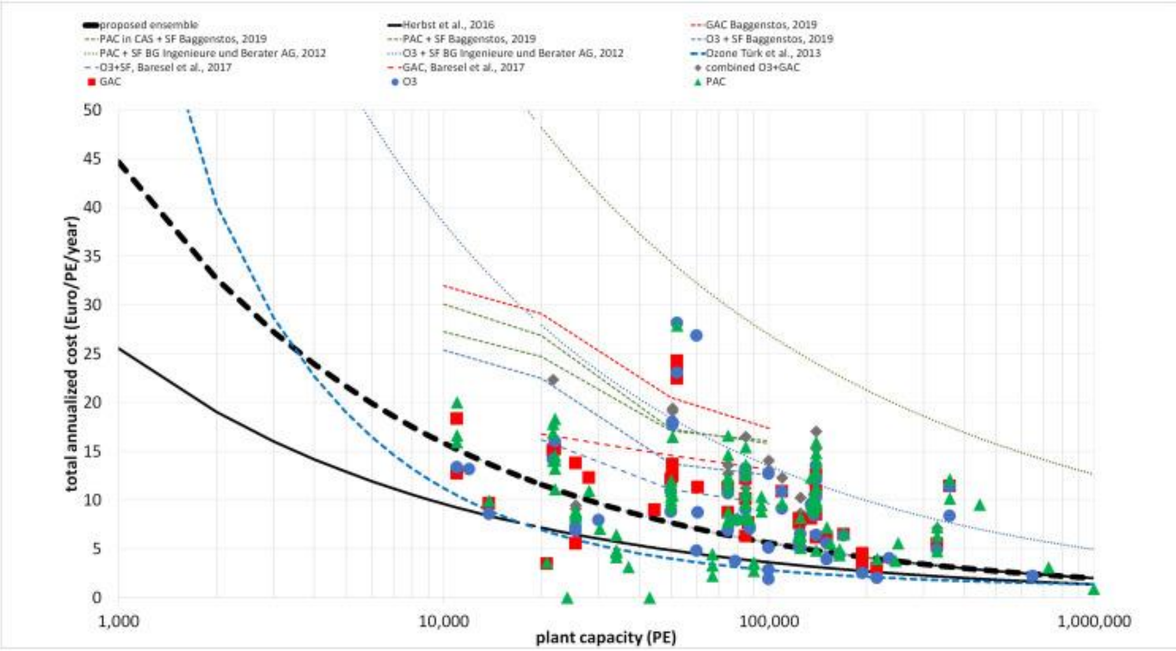
The levelized cost C is a combination of annual payments for the amortization of investments (capital expenditure or CAPEX) and operational expenditure (OPEX), and is proposed as a single indicative cost model irrespective of the treatment technology adopted, under the assumption that each plant would be equipped with the most convenient technology based on its specific design and operating conditions. The cost curve is plotted in **Figure 1**, where it is compared with other cost

[3] "Observed" costs are typically recorded or carefully estimated operational costs summed to the annual cost of the investment, based on the investment lifetime and an appropriate discount rate. They refer to a specific wastewater treatment plant.

[4] Pistocchi et al (2022) [Treatment of micropollutants in wastewater: Balancing effectiveness, costs and implications - ScienceDirect]

estimates available at the time of the IA, when the estimates had a declared uncertainty within a factor 2 (EC, 2022).

Figure 1. Plot of the cost function used in the IA, and comparison with other cost estimates. For details on the graph, see Source.



Source: Pistocchi et al., 2022

2.1.2. Correction for inflation

After the year 2020, there has been a significant increase in prices due to the interplay of various factors. This trend is detected by several statistical indicators. The Harmonized index of consumer prices (HICP) calculated by Eurostat[5] has risen from about 106 to about 130 (ca. +23%) in the EU. The index of total industrial producer prices[6] has also increased, exceeding +30% with peaks even above +40% over the same period (**Figure 2**), depending on how the various industrial sectors are considered. After 2023, prices have kept an approximately constant level. The increase has been higher for energy-related activities, and lower for other industrial sectors, and is slightly less pronounced for the non-domestic market. Quaternary treatment typically requires relatively energy-intensive inputs (oxygen, ozone, activated carbon) and can be expected to follow the same trends.

The cost figures in Pistocchi et al., 2022, are heterogeneous and mostly from before 2020 (a time when the changes in industrial price indexes were mostly unimportant, see **Figure 2**A). For these reasons, we assume a 30% increase in industrial prices to adjust the pre-2020 costs of the IA. Based on this assumption, we propose to correct the cost function of **Equation 1** as:

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[5] [prc_hicp_aind] HICP - annual data (average index and rate of change)

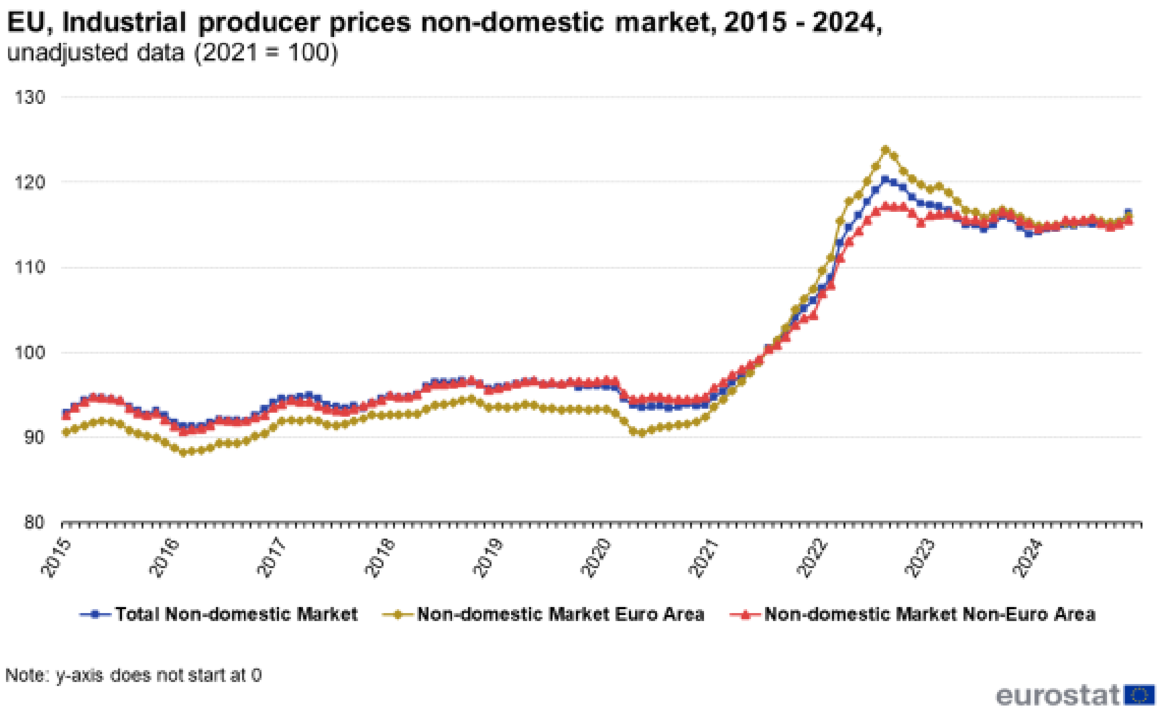
[6] Industrial producer price index overview - Statistics Explained - Eurostat

Equation 2. Cost function for quaternary treatment used in the IA, after correction for inflation

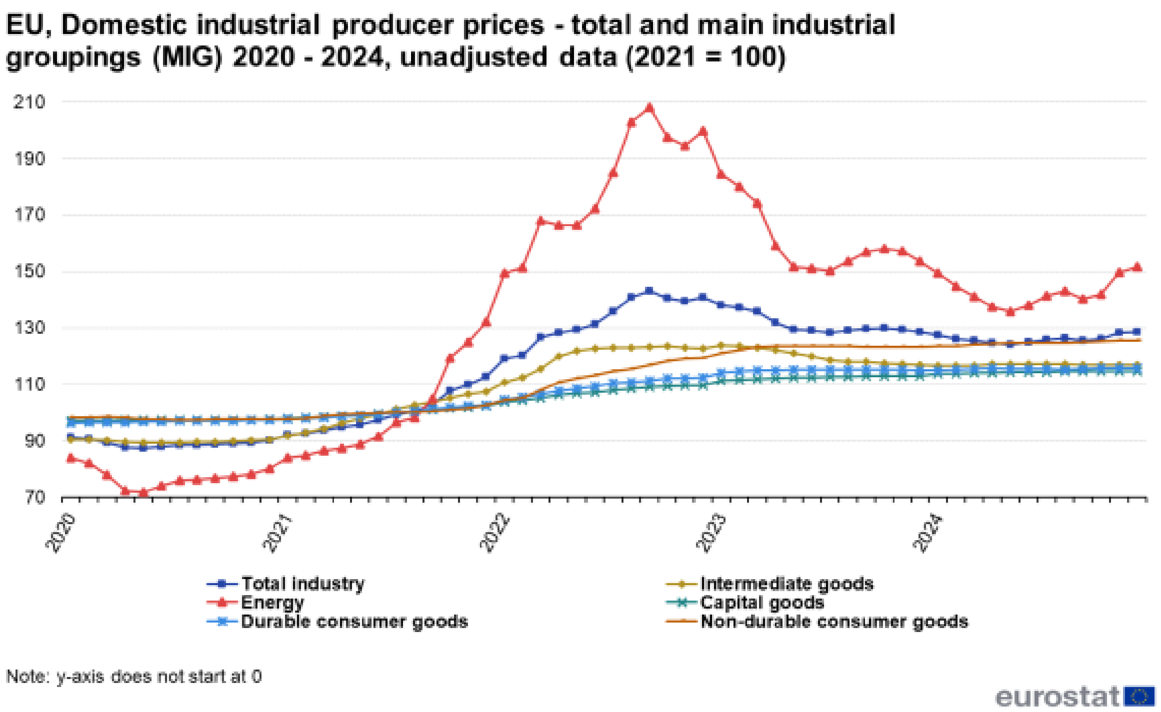
$$C = 1300\ P^{-0.45}$$

The above equation is the originally proposed cost function, expressed in price levels after 2023.

Figure 2. EU industrial production price indexes (A) for the EU, non-domestic and (B) domestic by sectors.



A



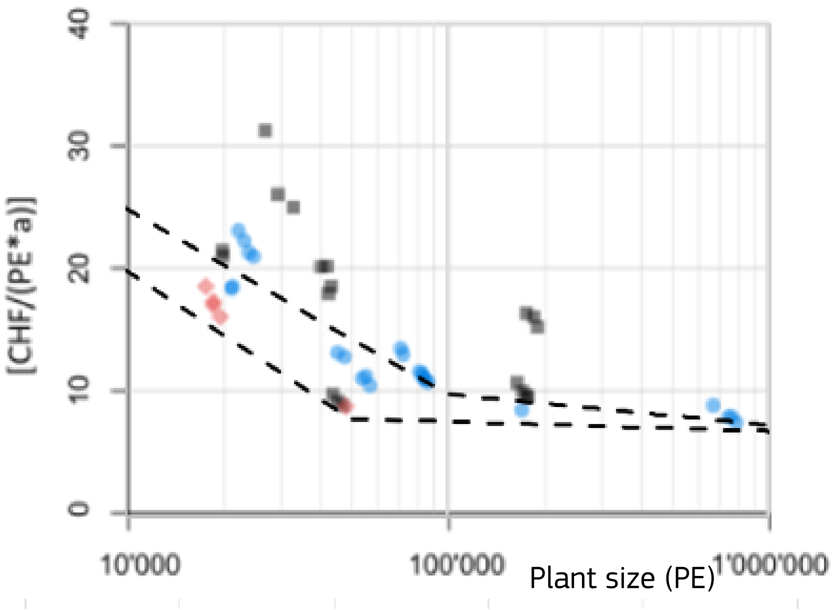
B

Source: Eurostat

2.1.3. Costs from VSA

The Verband Schweizer Abwasser- und Gewässerschutzfachleute (VSA) has published a report documenting the implementation of quaternary treatment over the past decade, containing data on the actual costs of a selection of representative urban wastewater treatment plants (VSA, 2025) providing quaternary treatment with powdered activated carbon (PAC), granular activated carbon (GAC) or ozonation, including levelized costs (CHF/PE/year) as shown in **Figure 3**.[7]

Figure 3. Cost functions based on the costs from VSA, 2025. The black dashed lines are the assumed cost functions, the upper representing "average" and the lower "optimized" costs. Grey, pink and blue dots represent plants with PAC, GAC and Ozone technologies respectively.



Source: modified from VSA, 2025

The reference time for the costs in the VSA report was December 2023. The exchange rate between CHF and Euro oscillated around parity during the period of operation of the plants considered in the VSA report (2014-2023)[8], and here we consider the two currencies as equivalent.

We interpolate the data using a bilinear relationship between unit costs (CHF/PE/year, assumed to be equal to Euro/PE/year) and plant size (PE). The relationship is parameterized through graphical comparison with the data and not through a statistical calibration procedure, hindered by the limited dataset.

[7] Evaluation of the energy and cost key figures of processes for the elimination of micropollutants in wastewater treatment plants - VSA Micropoll

[8] https://www.ecb.europa.eu/stats/policy_and_exchange_rates/euro_reference_exchange_rates/html/eurofxref-graph-chf.en.html

Equation 3. Cost function for quaternary treatment closely approximating the results of VSA, 2025

$$C = \max\left(C_0 - \frac{C_0 - C_1}{\log\left(\frac{P_1}{P_0}\right)} P, C_1 - \frac{C_1 - C_2}{\log\left(\frac{P_2}{P_1}\right)} P\right)$$

The Swiss data show how the lowest costs for a given plant size may be significantly lower than the average. This suggests the possibility of a "learning curve" whereby operators optimize the costs of treatment as they gain experience. A reduction of costs by optimization may not always be feasible due to practical constraints at plant level. However, for the purposes of this assessment, we consider an "average" cost curve, as well as an "optimized" cost curve reflecting the least cost achieved so far in the Swiss experience. The two are plotted in **Figure 3** and correspond to the parameters in **Table 1**. The "average" curve aims to follow data referred to plants with ozone treatment, while data for PAC and GAC treatment tend to depart significantly from the curve.

Table 1. Parameters adopted for **Equation 3**

Parameter	**Units**	**Average**	**Optimized**
C_0	CHF/PE/year[9]	25,00	20,00
C_1	CHF/PE/year	10,00	8,00
C_2	CHF/PE/year	7,50	7,00
P_0	PE	10.000	10.000
P_1	PE	100.000	50.000
P_2	PE	1.000.000	1.000.000

Source: JRC

2.1.4. Cost functions from PoliMi

A team from Politecnico di Milano (PoliMi), Italy, recently published a paper (Ianes et al., 2025[10]) including an assessment of costs of quaternary treatment on the basis of interviews with the industry and technology market data collection. Particularly, the paper quantifies unit costs (Euro/PE/year) as a function of plant size for ozonation, activated carbon in granular (GAC) and powdered (PAC) form, the latter being significantly more expensive. The cost functions are provided in graphical form and depend on the assumed operating parameters (ozone dose, GAC regeneration time, PAC dose and waste/extracted sludge), as shown in **Figure 4**. For the purposes of this analysis, we considered a bilinear approximation of the plotted curves (shown as a dashed black line in **Figure 4**):

Equation 4. Cost function for quaternary treatment closely approximating the results of Ianes et al., 2025

[9] The costs are considered equivalent to Euro/PE/year

[10] Micropollutants removal, residual risk, and costs for quaternary treatments in the framework of the Urban Wastewater Treatment Directive - ScienceDirect

$$C = \max\left(C_0 - \frac{C_0 - C_1}{P_1}P, C_1\right)$$

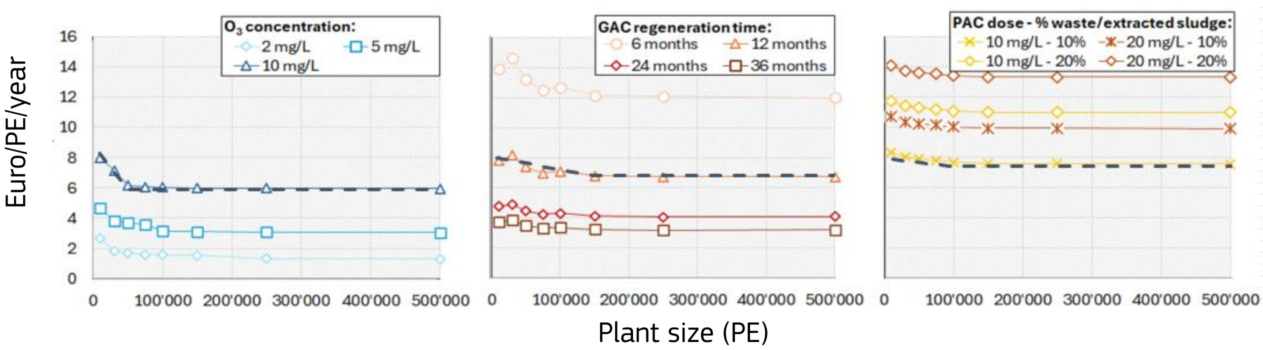
The parameters C_0, C_1 and P_1 used in this analysis, derived by graphical comparison with the data, are summarized in **Table 2**. The parameters correspond to the highest ozone dose, and to operation of GAC and PAC making their costs as close as possible to those of ozonation. This assumption corresponds to the fact that all facilities would prefer the cheapest option (ozonation) whenever possible, and would resort to GAC or PAC when needed, while trying to optimize the process in economic terms. In any case, the curve for GAC reflects the second-highest cost scenario in Ianes et al., 2025, while PAC appears to be generally more expensive than GAC and ozone.

Table 2. Parameters adopted for **Equation 4**

Parameter	**Units**	**Ozonation**	**GAC**	**PAC**
C_0	Euro/PE/year	9,00	8,00	8,00
C_1	Euro/PE/year	6,00	6,75	7,50
P_1	PE	50.000	150.000	100.000

Source: JRC

Figure 4. Cost functions proposed in Ianes et al., 2025. The black dashed line is the assumed cost function for comparison



Source: modified from Ianes et al., 2025

2.1.5. Cost functions from UBA

In 2023, experts from the German Environment Agency (UBA) argued that the IA estimates could be low, indicating that it would be more likely that costs would double rather than halve (UBA, 2023)[11]. For the sake of a first quantification, they suggested to replace the cost curve of **Equation 1** with two alternative formulations:

[11] https://www.umweltbundesamt.de/sites/default/files/medien/1410/publikationen/2023-06-28_sciopap_recast-urban-wastewater-treatment-directive_bf.pdf

Equation 5. Cost function for quaternary treatment proposed by UBA, variant 1

$$C = 1000\ P^{-0.40}$$

Equation 6. Cost function for quaternary treatment proposed by UBA, variant 2

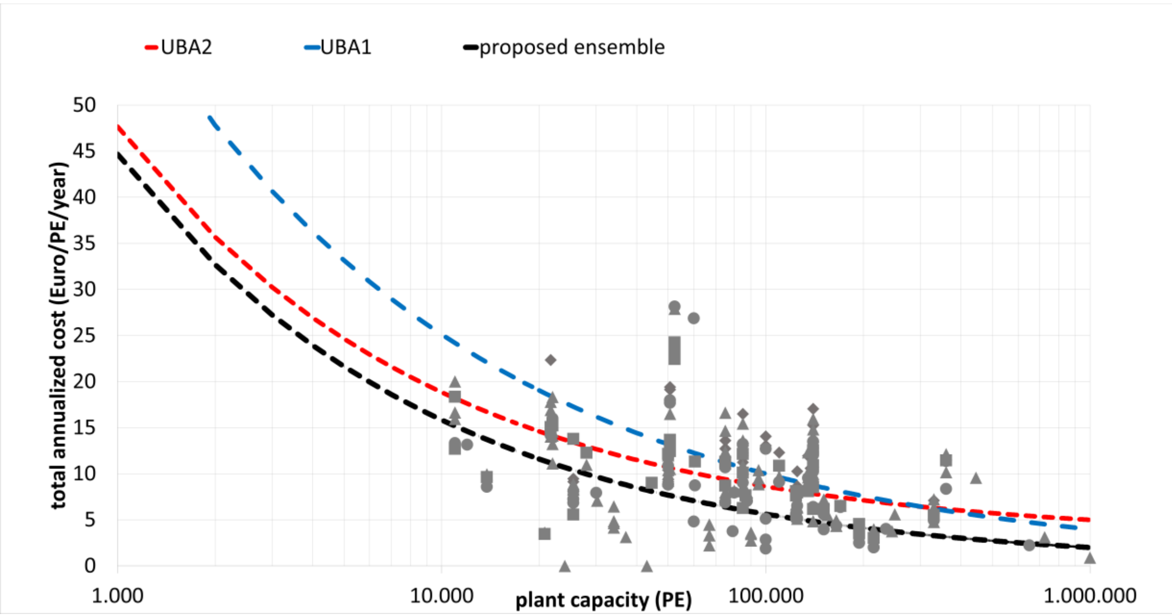
$$C = 1000\ P^{-0.45} + 3$$

They argued that both formulations would yield more realistic unit costs particularly for larger plants, as the data available for the IA included only a few plants larger than 500.000 PE

As shown in **Figure 5**, the above two cost curves are quite in line with the data, similar to the curve used in the IA. Compared to the IA, they match better plants between approximately 100.000 and 500.000 PE, but tend to overestimate cost data at smaller and larger capacities, while remaining in the declared range of uncertainty of the IA (a factor 2).

It should be noted that the data points in the graph of **Figure 5** aligned on a vertical line often represent relatively detailed cost estimates for alternative designs of processes at the same plant. In these cases, it is plausible that all alternatives with costs higher than the lowest would not be chosen for implementation, making the IA cost curve more consistent with the costs expected in practice at those plants. While the qualitative argument in UBA, 2023 is valid, the empirical evidence supporting these alternative cost functions remains limited. For the sake of completeness, we include them anyway in the comparison.

Figure 5. Comparison of cost functions from the IA with the variants proposed by UBA, 2023, and with the data available for the IA.



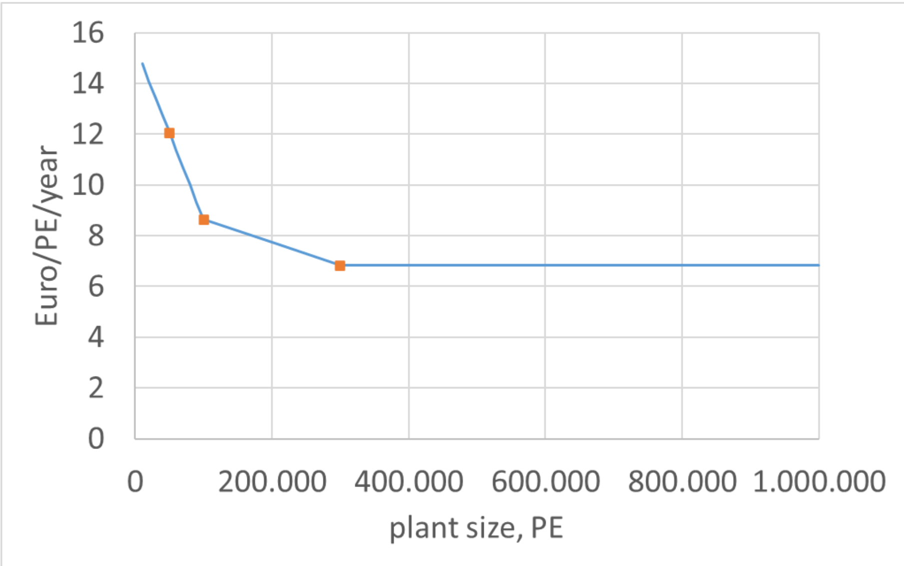
Source: JRC based on Pistocchi et al., 2022

2.1.6. Cost estimates in the Danish context (DK study)

Recent estimates conducted for Denmark by Envidan A/S, Teknologisk Institut (TI) and DANVA[12] quantify the levelized cost of treatment (net present value per m^3, combining CAPEX and OPEX) for the Danish context for various technologies and representative sizes of plants (**Table 3**). Eventually, they identify ozonation followed by sand filtration as the most cost-efficient.

For a comparison with the IA costs, we derive on this basis a cost function as shown in **Figure 6**. The cost curve interpolates linearly between the quantities in **Table 3**, and considers the costs to remain constant for plants above 300.000 PE Moreover, it assumes a volume of wastewater per PE of 204 liters per day in line with ENVIDAN, TI and DANVA, 2025, with 1 DKK = 0,13 Euro[13].

Figure 6. Cost curve for ozonation and sand filtration according to the Envidan, TI and DANVA estimates for Denmark, 2025.



Source: JRC based on ENVIDAN, TI and DANVA, 2025

The model is represented by the following equation with the parameter values of **Table 4**.

Equation 7. Cost function for quaternary treatment interpolating the results of ENVIDAN, TI and DANVA, 2025[12]

$$C = \max\left(C_0 - \frac{C_0 - C_1}{P_1 - P_0}(P - P_0), C_1 - \frac{C_1 - C_2}{P_2 - P_1}(P - P_1), C_2\right)$$

[12] https://www.envidan.com/da/nyheder/teknologivalg-4rensetrin/

[13] Danish krone (DKK)

Table 3. Costs of quaternary treatment for Denmark (DKK/m3)

Scenario	50.000 PE	100.000 PE	300.000 PE
Ozone and sand filtration	1,27	0,91	0,72
Ozone and GAC	1,42	1,17	0,95
GAC	1,17	1,01	0,9
PAC and sand filtration	1,32	1,14	1

Source: Envidan, TI and DANVA, 2025

Table 4. Parameters adopted for **Equation 7**

Parameter	Units	Value
C_0	Euro/PE/year	12,05
C_1	Euro/PE/year	8,64
C_2	Euro/PE/year	6,83
P_0	PE	50.000
P_1	PE	100.000
P_2	PE	300.000

Source: JRC

2.2. Quantification of legal requirements

The Commission proposal for a recast UWWTD required all urban wastewater treatment plants (WWTPs) serving 100.000 PE or more to install quaternary treatment. Additionally, plants serving agglomerations between 10.000 and 100.000 PE had to install quaternary treatment in several pre-defined areas (such as lakes, intakes for drinking water, streams with low dilution rates) "*unless the absence of risk for human health or the environment in those areas can be demonstrated based on a risk assessment*"[14]. In the IA, it was assumed that 70% of the load (i.e. treated PE) from plants serving agglomerations between 10.000 and 100.000 p.e and discharging in streams with a dilution ratio below 10, with the exclusion of coastal areas, would pose risks justifying quaternary treatment.

The adopted legal text introduced a reduction in the number of WWTPs unconditionally required to implement quaternary treatment, by raising the threshold from 100.000 to 150.000 PE

Moreover, in the legislative proposal all plants above 10.000 PE and below 100.000 PE would need to prove absence of risks to avoid the upgrade to quaternary treatment ("*treat unless*…"). In the adopted legal text, a facility will have to be upgraded if a risk assessment indicates so, thus reversing the criterion ("*treat only if*…"). Therefore, it can be expected that the number of facilities,

[14] Proposal for a revised Urban Wastewater Treatment Directive - European Commission

hence the percentage of load discharged from plants above 10.000 PE to be equipped with quaternary treatment may drop significantly. We reflect this expectation in the estimation of costs, by assuming that 35% of the load from plants treating between 10.000 and 150.000 PE and discharging in streams with a dilution ratio below 10, with the exclusion of coastal areas, will require quaternary treatment, compared to the 70% assumption used in the IA.

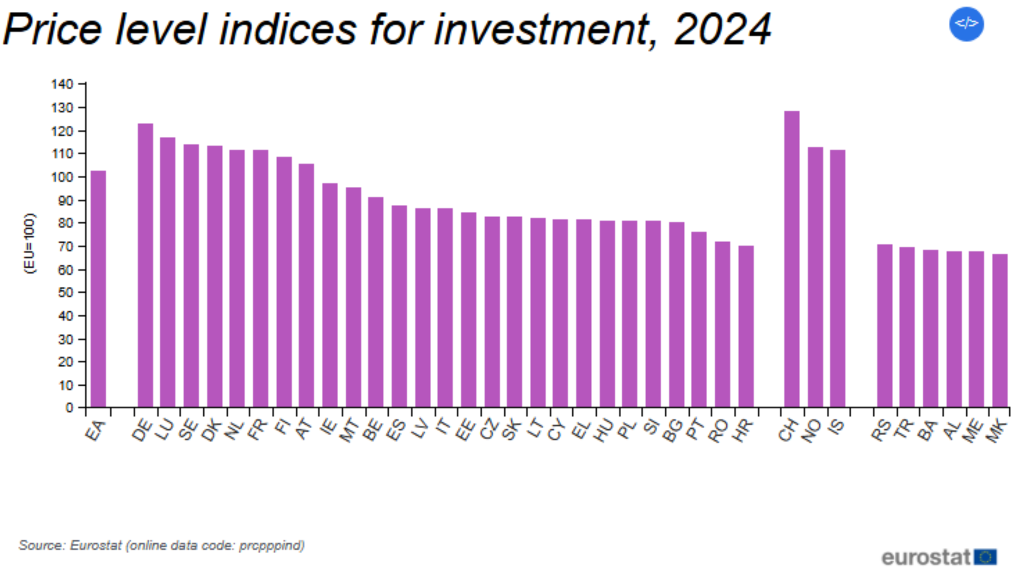
2.3. Variability of costs across Europe

While the cost function used in the IA aimed at EU-scale quantification, there is significant variability in the price levels across the continent, which may lead to a variability of treatment costs. In 2024, Eurostat[15] reports the price level index (a non-dimensional number) for investments in Switzerland to be 128 compared to 100 in the EU (while the range across the EU is 70-123); the same index for machinery and equipment in Switzerland is 120 when the EU average is 100 (range 91-112), see **Figure 7**. Also the cost of labour in Switzerland is higher than EU average[16] , see **Figure 8**. The construction costs included in **Equation 3** are about 45% of the total investment cost of quaternary treatment and embed a labour cost of 75 CHF/hour (VSA, 2025). Based on these considerations, we should account for a reduction of the Swiss costs when extrapolating to the EU context.

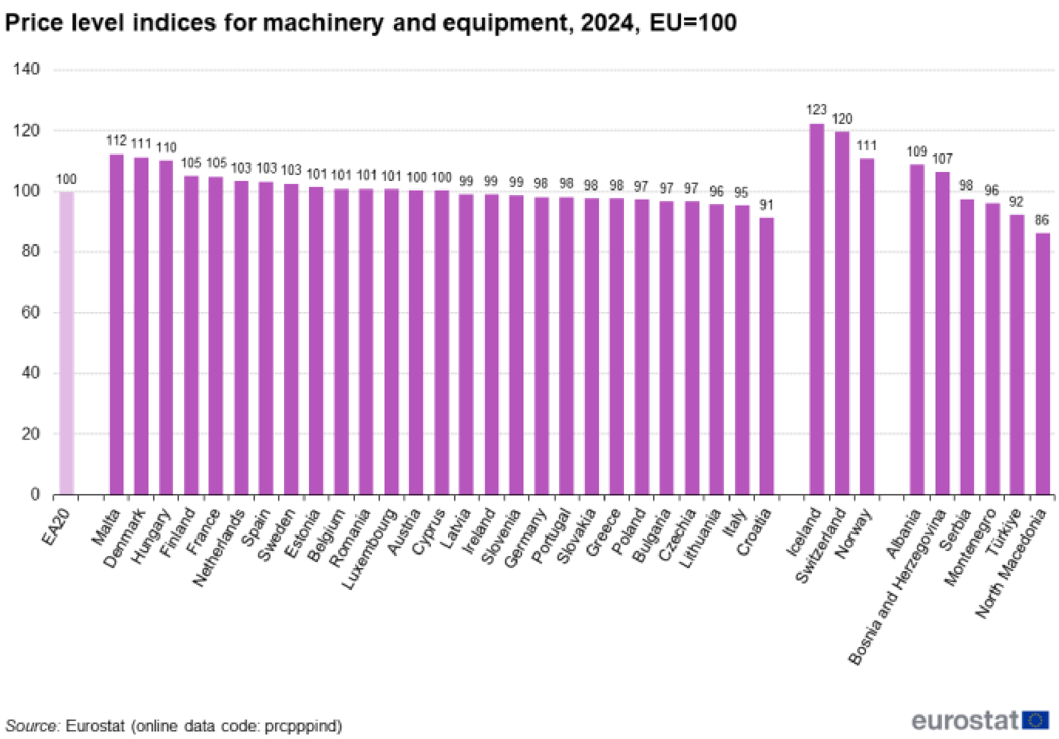
[15] Comparative price levels for investment - Statistics Explained - Eurostat

[16] Wages and labour costs - Statistics Explained - Eurostat

Figure 7. Price level indices for investments (A) and for machinery and equipment (B) in 2024



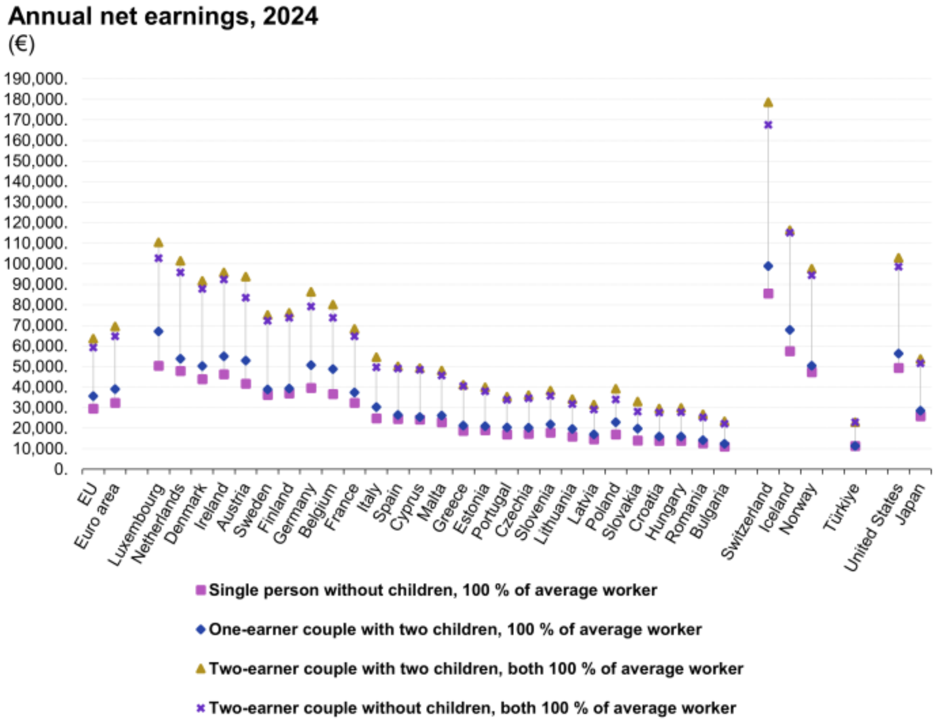
A



B

Source: Eurostat

Figure 8. Net earnings of labourers across Europe in 2024



Note: Data for Cyprus are not available on a regular basis.Therefore figures of the European aggregates do not include data for Cyprus to allow
a more precise comparison on European aggregates level across the last years.
Within the country groups, countries are sorted according to the indicator Two-earner married couple without children, both 100 % of average worker.
Source: Eurostat (online data code: earn_nt_net)

Figure 5: Annual net earnings, 2024
(€)
Source: Eurostat (earn_nt_net)

Source: Eurostat

3. Results

In order to ensure a consistent comparison with the costs of the IA, we apply the cost functions described above to all wastewater treatment plants resulting from the database used in Pistocchi et al., 2022 (available as supporting information with the open-access paper[17]) which was the basis for the quantification of costs in the IA.

Under the assumptions of the legislative proposal (IA), a plant in the set is assumed to require quaternary treatment unconditionally if it treats 100.000 PE or more, and if it treats between 10.000 and 100.000 and does not discharge in a stream with a dilution ratio of 10 or more, or in coastal areas. Consistent with the estimation of the IA, we multiply the sum of costs relative to plants below 100.000 PE by 0,7 to account for the fact that 70% of these plants would be found to need quaternary treatment.

Under the new legal requirements (adopted directive), in the same way a plant in the set is assumed to require quaternary treatment unconditionally if it treats 150.000 PE or more, and if it treats between 10.000 and 150.000 and does not discharge in a stream with a dilution ratio of 10 or more, or in coastal areas. We multiply the sum of costs of plants below 150.000 PE by 0,35 in line with the assumption that only 35% of the plants would be found to need quaternary treatment.

In **Table 5** we compare for each country the cost estimates under the assumptions made in the IA, as well as under the changed legal framework, using **Equation 1** for nominal costs. The less stringent requirements of the adopted directive are projected to reduce the costs compared to the adopted legislative proposal (IA) on average to 68% (in the range 51-86% for individual countries), all the rest being equal.

In line with the cost curves suggested by UBA (**Equation 5**, **Equation 6**), the VSA, PoliMi and DK study functions support the claim that the IA (**Equation 1**) underestimated the costs per PE (or "unit costs"). Therefore, while the changes from the legislative proposal to the adopted legal text lead to a decrease of costs, the alternative cost models all lead to an increase in the costs, all other conditions being equal. The net combined effect of less stringent legal requirements and higher unit costs is an overall increase of costs mitigated by the reduction in the number of plants required to implement quaternary treatment.

In **Table 6**, we compare how the costs aggregated at EU level change depending on the alternative cost model considered, under the assumptions of the IA and the adopted directive.

Under the IA assumptions, the alternative cost functions (**Equation 3** - **Equation 7**) yield costs that are between 1,55 and 2,39 times the costs, at nominal value, estimated in the IA (**Equation 1**). The discrepancies appear to be within the declared uncertainty of the IA model (a factor 2) even at nominal values (not accounting for inflation), except for the VSA costs (average) with a higher (2,39) factor. If we assume costs in Switzerland are 20% higher than the EU average (i.e. we divide the costs from **Equation 3** by 1,2 - see § 2.3), the upper end of the above ranges reduces from 2,39 times to 1,99. Factoring in inflation obviously reduces the discrepancies: the costs according to these alternative cost functions remain in the range of 1,19-1,84 times the cost estimated in the IA after

[17] https://ars.els-cdn.com/content/image/1-s2.0-S0048969722046915-mmc3.xlsx

adjustment (**Equation 2**). Also in this case, considering costs in Switzerland 20% higher than the EU average, the upper end of the above range reduces from 1,84 to 1,53.

Table 5. Comparison, at MS level, of costs from applying **Equation 1** under the requirements of the legislative proposal (IA)[18] and of the adopted directive.

MS	Cost (IA)	Cost (adopted directive)	reduction
AT	37.634.807	24.916.244	66,2%
BE	21.725.647	14.067.373	64,8%
BG	14.334.140	9.857.018	68,8%
CY	2.889.565	1.933.577	66,9%
CZ	14.178.119	8.627.440	60,9%
DE	237.800.055	166.652.726	70,1%
DK	35.665.167	19.152.318	53,7%
EE	4.553.421	2.753.367	60,5%
EL	17.426.127	11.885.572	68,2%
ES	165.086.613	116.415.088	70,5%
FI	12.565.555	9.806.950	78,0%
FR	129.053.695	94.553.887	73,3%
HR	5.070.514	2.620.796	51,7%
HU	33.482.887	23.469.767	70,1%
IE	8.304.274	4.856.266	58,5%
IT	174.940.939	115.937.683	66,3%
LT	6.709.591	5.437.916	81,0%
LU	1.683.707	1.244.615	73,9%
LV	2.271.436	1.952.374	86,0%
MT	2.101.382	1.477.121	70,3%
NL	65.501.893	44.770.529	68,3%
PL	101.982.908	68.128.515	66,8%
PT	32.290.777	19.493.384	60,4%
RO	32.197.743	24.670.127	76,6%
SE	29.297.083	19.184.492	65,5%
SI	1.874.222	1.117.437	59,6%
SK	7.686.018	3.796.896	49,4%
EU total	1.198.308.285	818.779.478	68,3%

Source: JRC

[18] The costs in this table show small differences compared to the ones presented in the IA, due to a minor coding mistake that was corrected in the application of the cost model. The annual expenditure predicted by the model does not change significantly, remaining about 1,2 billion Euro/year for the EU.

Table 6. EU-aggregated cost comparison under the assumptions of the legislative proposal and adopted directive. Costs in Euro per year.

Cost model	*EU Total cost (legislative proposal)*	Ratio of cost to nominal cost in the IA[19]	Ratio of cost to nominal cost in the IA (adjusted for inflation)	*EU Total cost (adopted directive)*	Ratio of cost to nominal cost in the IA [19]	Ratio of cost to nominal cost in the IA (adjusted for inflation)
Cost (IA) - Equation 1	1.198.308.285	1	0,77	818.779.478	0,68	0,53
Cost (IA) after inflation - Equation 2	1.557.800.771	1,3	1	1.064.413.322	0,89	0,68
VSA (average) - Equation 3	2.858.918.913	2,39	1,84	2.154.781.606	1,8	1,38
VSA (optimized) - Equation 3	2.353.552.642	1,96	1,51	1.835.774.786	1,53	1,18
PoliMi (O3) - Equation 4	1.854.051.195	1,55	1,19	1.484.315.667	1,24	0,95
PoliMi (GAC) - Equation 4	2.096.025.528	1,75	1,35	1.671.056.327	1,39	1,07
PoliMi (PAC) - Equation 4	2.284.043.039	1,91	1,47	1.836.343.916	1,53	1,18
UBA variant 1 - Equation 5	2.180.363.174	1,82	1,4	1.519.002.799	1,27	0,98
UBA variant 2 - Equation 6	2.110.162.482	1,76	1,35	1.553.351.611	1,3	1
DK study - Equation 7	2.467.022.359	2,06	1,58	1.880.351.942	1,57	1,21

Source: JRC

[19] These numbers show multiplication factors for the initial impact assessment cost (1,2 billion Euro/year) when the cost curves from different studies are applied without considering that they do not reflect the same price level.

Under the assumptions for the adopted legal text, the costs derived from the alternative cost models are between 1,48 billion Euro/year and 2,15 billion Euro/year, i.e. in the range of 1,24-1,8 times the 1,2 billion Euro/year estimated in the IA. Also in this case, if we assume costs in Switzerland 20% higher than the EU average, the upper end of the range reduces to 1,8 billion Euro/year, i.e. from 1,8 to 1,5 times.

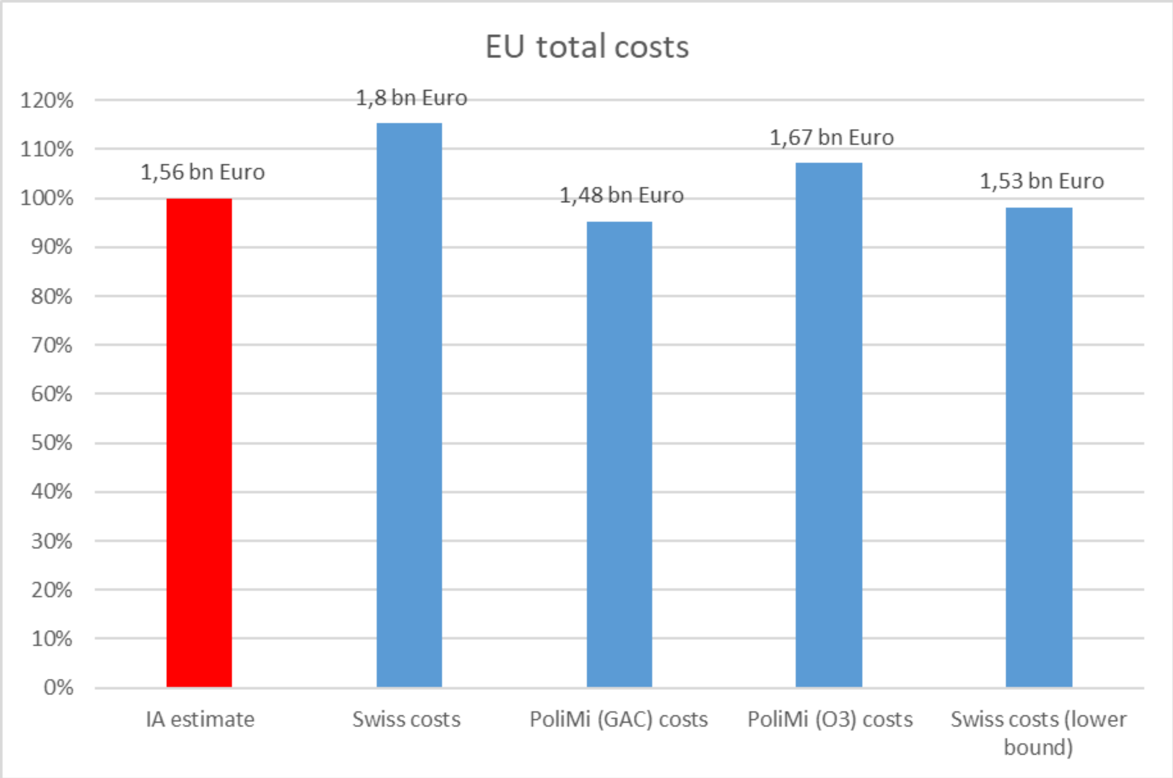
If we account for inflation (**Equation 2**), the costs estimated in the IA are adjusted to 1,56 billion Euro/year. The costs from the alternative models represent 0,95-1,38 times this number. Again, if the consider Swiss costs 20% higher than EU average the range is limited to 1,15 times.

The costs estimated with the Danish model (**Equation 7**) would become slightly higher than the costs with the Swiss model discounted by 20%. As costs in Denmark are also above EU average (**Figure 7**), we can still argue that the overall costs aggregated at EU level would not exceed the Swiss costs.

The key practical aim of the comparison is to understand how the total annual expenditure estimated in the IA should be corrected, due to the combined effect of less ambitious treatment objectives and increased costs per PE. In the IA the total EU cost was estimated at 1,2 billion Euro/year by 2040 when all the facilities will have to implement quaternary treatment. Accounting for a 30% inflation, this cost should be corrected to ca. 1,56 billion Euro/year. If we refer to the "average" Swiss costs after correcting for the higher prices, the costs would be 115% of this sum (1,8 billion Euro/year). If we refer to the PoliMi cost functions for ozone and GAC, the costs would be 95% and 107% of the adjusted IA estimate, respectively. The lower bound of the range in this case would be 1,48 billion Euro/year. The Swiss "average" cost function (**Figure 3**) reflects costs for a set of full-scale plants. The costs could also decrease towards an "optimized" cost function for a plant of a given size. Arguably, with the progress of experience, more facilities may converge to the most efficient solutions. When using the "optimized" cost curve, corresponding to the most efficient plants, the expected costs would be 1,53 billion Euro/year, or 98 % of the adjusted IA estimate, after correcting for 20% higher Swiss costs. The other alternative cost models yield results within this range.

In summary, the alternative cost functions suggest a range of 0,95-1,38 times those costs if we account for inflation, meaning expected costs between 1,48 billion Euro/year and about 2,15 billion Euro/year. If we also correct the Swiss costs to account for 20% higher prices compared to the EU, the range would become 0,95-1,15 (cost change between - 5% and + 15 %) for the whole of the EU compared to the IA, after accounting for inflation, meaning expected costs between 1,48 billion Euro/year and 1,8 billion Euro/year (**Figure 9**).

Figure 9. Comparison of the inflation-adjusted IA estimate to the Swiss costs, the cost estimate by Politecnico di Milano (PoliMi) using granular activated carbon (GAC) and ozonation (O3) as treatment and the Swiss costs when only focusing on the most efficient plants (Swiss costs -lower bound). All cost estimates include capital and operating costs.



Source: JRC

4. Discussion and conclusions

The results presented above indicate that the cost model used in the IA underestimates the costs of quaternary treatment, all the rest being equal. The underestimation remains within the limits of the stated uncertainty (a factor 2) of the model (EC, 2022; Pistocchi et al., 2022) except when looking at the average nominal costs from Switzerland, in which case the underestimation is slightly higher. If we consider that costs in the Swiss context may be higher than the EU average, the underestimation would remain in the limits of a factor 2 also in this case. The costs of the IA should be anyway corrected for the inflation meanwhile occurred. In this case, the discrepancies are further reduced and remain well within the stated uncertainty.

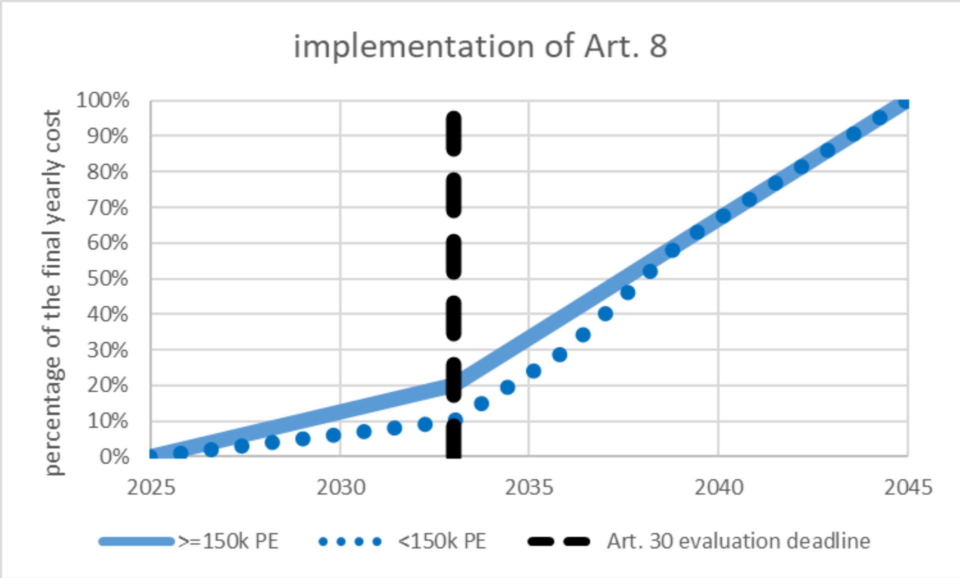
Considering the expected reduction in costs brought by the lower ambition of the adopted legal text compared to the legislative proposal of the recast UWWTD, the cost of quaternary treatment would vary between between ca. 1,48 and 2,15 billion Euro/year, i.e. between 95 % and 138 % of the inflation-adjusted IA estimate of 1,56 billion Euro/year. The upper end of the range does not consider that Swiss costs can be 20% higher than EU average, and could be regarded as a "worst case". If we correct for 20% higher Swiss costs, the range reduces to between 1,48 and 1,8 billion Euro/year, i.e. between 95 % and 115 % of the adjusted IA estimate.

It is worth stressing that energy costs represent an important share of the operational costs of quaternary treatment (Pistocchi et al., 2022). The energy neutrality requirements of the new UWWTD (Art. 11) may be expected to progressively reduce the costs of energy, hence of treatment.

Moreover, the fact that quaternary treatment will be progressively deployed at EU level could lead to economies of scales and other economic benefits due to the expanded size of the market for the relevant treatment technologies. For instance, it may open opportunities for the scaling up of innovative technologies already developed or under development in European and international research.

Finally, the total yearly cost at 2025 prices of 1,48-1,8 billion Euro/year for quaternary treatment in the EU refers to the case of 100% implementation of the Directive, which is due in 2045. During the next 20 years, implementation is supposed to progress gradually as per the deadlines set out in art. 8 of the Directive (**Figure 10**), thus further reducing the average cost over the period. For example, the average yearly cost between 2025 and 2045 would not exceed 40% of the final cost, at current prices.

Figure 10. Trajectory of implementation of article 8 of the new Directive from 2025 to 2045.



Source: JRC

In the IA (EC, 2022), the economic impacts of quaternary treatment in terms of accessibility and affordability of pharmaceutical products were quantified by comparing the expected cost (ca. 1,2 billion Euro/year) with the expenditure on pharmaceuticals and the profit margins of the industry. Based on the EPR feasibility study (Bio Innovation Services, 2021)[20], the IA considered an average annual spending per person on pharmaceutical products of EUR 338. The costs of quaternary treatment could be covered by the responsible producers by passing the costs entirely on to the consumers, by reducing the profit margins, or through a combination of these options. In the IA, depending on the choices of industry, the maximum average increase in cost of pharmaceuticals was estimated at EUR 1.9-2.4 per year/per person by 2040. If the whole cost is covered by the margin profits of the industry, the maximum reduction in profit margin was estimated at 0.6-0.9 percentage points.[20]

Assessing the economic impacts of quaternary treatment costs is beyond the scope of this report. However, a correction of the estimated costs even referring to the "worst case" increase of costs to 2,15 billion Euro/year (**Table 6**) would not change the order of magnitude of the indicators of impact presented in the IA. *A fortiori*, an increase of costs within the margins appraised above, i.e. in the range of 1,48-1,8 billion Euro/year (95 % to 115 % of the adjusted IA costs of 1,56 billion Euro/year) would be even less important.

This is further reinforced by the fact that the legislative proposal required producers to pay 100% of the costs of quaternary treatment, while the adopted legal text allows to limit the coverage to 80%. For the sake of illustration, let us assume the pharmaceutical industry supports 80% of the total costs of quaternary treatment.[21] If the industry passed all the cost on to consumers, the

[20] Feasibility of an EPR system for micro-pollutants - Publications Office of the EU

[21] This scenario is purely hypothetical and provides an upper limit for the contribution of the pharmaceuticals sector. According to the adopted legal text, the contribution is to be split between pharmaceuticals and cosmetics industries

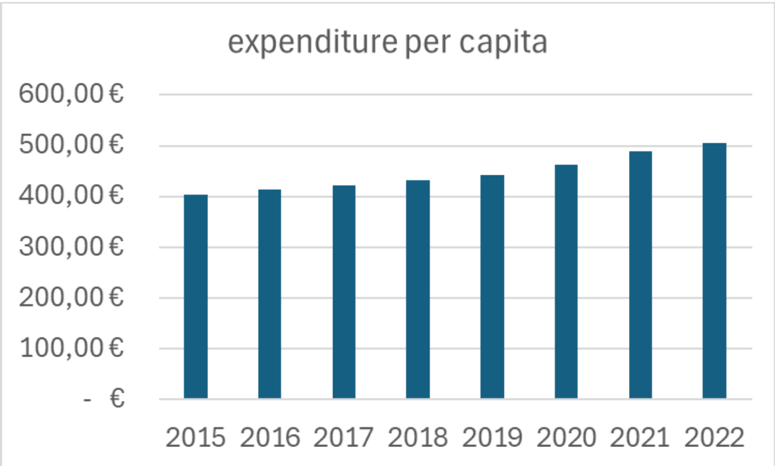
additional cost each of the 449.31 million EU citizens[22] would pay per year in 2045 would be in the range 2,64-3,20 Euro. By comparison, if we consider the nominal cost estimated in the IA and a coverage by EPR of 100% of the quaternary treatment costs, the cost per citizen would be 2,67 Euro per year. These figures represent less than 1% of the expenditure in pharmaceuticals considered in the IA (**Table 7**).

Table 7. Example calculation of costs per EU citizen (see text for details)

Scenario	Total cost (bn Euro/year)	Cost covered by industry (bn Euro/year)	Yearly cost per capita	% of expenditure for medicines from the IA (338 Euro/pers.)	% of expenditure for medicines and other non-durable medical goods (557 Euro/pers.)
IA, nominal value	1,2	1,2 (100%)	2,67 €	0,79%	0,48%
IA, value corrected for inflation	1,56	1,25 (80%)	2,78 €	0,82%	0,50%
lower bound of expected costs	1,48	1,18 (80%)	2,64 €	0,78%	0,47%
upper bound of expected costs	1,8	1,44 (80%)	3,20 €	0,95%	0,58%

Source: JRC

Figure 11. Expenditure in pharmaceuticals and other medical non-durable goods in the EU



Source: JRC based on EuroStat[23]

will be determined in the Producer Responsibility Organisations taking into account quantities and hazardousness of substances placed on the market.

[22] Demography of Europe – 2025 edition - Interactive publications - Eurostat

[23] https://ec.europa.eu/eurostat/databrowser/view/hlth_sha11_hc__custom_18132258/default/table?lang=en and https://ec.europa.eu/eurostat/databrowser/view/tps00001/default/table?lang=en&category=t_demo.t_demo_pop

EuroStat data (last available year 2022) indicate an even higher expenditure per capita in the EU for pharmaceuticals and other medical non-durable goods (**Figure 11**). With an expenditure of 505,11 Euro per capita in 2022, and an inflation of 10,3% from June 2022 to January 2025[24], the current expenditure per capita for pharmaceuticals and other medical non-durable goods can be estimated at 557,31 Euro/person per year. This would make the extra costs just around 0,5% of the expenditure (**Table 7**).

Based on these figures, the increase in the costs of quaternary treatment that we may quantify even at the upper end of the alternative cost models considered above would not substantially change the conclusions of the IA concerning the impacts of the recast UWWTD on the affordability of and accessibility to pharmaceuticals. This conclusion refers only to the expected increase on average. The actual costs per patient or consumer of certain specific pharmaceutical substances will vary depending on how the costs will be redistributed in practice.

[24] https://ec.europa.eu/eurostat/databrowser/view/prc_hicp_midx__custom_18208815/default/table?lang=en

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List of abbreviations

Abbreviations	Definitions
EC	European Commission
EPR	Extended producer responsibility
WWTP	Wastewater treatment plant
EU	European Union
GAC	Granular activated carbon
IA	Impact Assessment (of the UWWTD)
JRC	Joint Research Centre
PAC	Powdered activated carbon
PE	Population equivalent
UBA	Umweltbundesamt (German Environment Agency)
UWWTD	Urban Wastewater Treatment Directive (2024/3019/EU)
VSA	Verband Schweizer Abwasser- und Gewässerschutzfachleute
WRS	(EU) Water Resilience Strategy

List of figures

List of tables

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