Estimation of the Terminal Value of the hydropower plant's components

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Introduction

Assessing the economic value of an asset is essential for informed decision-making, such as purchasing, selling, or investing. Accurate asset evaluation enables companies to gain a comprehensive understanding of their assets' worth, which in turn supports effective business planning and risk management.
Within the asset evaluation the estimation of the Terminal Value (TV) allows to determine the residual value of the asset referring to a specific point in time (year of interest) e.g. the year in which the plant is to be bought or sold. This process can be applied to a variety of assets, including real estate, investments, businesses, and intangible assets.
Evaluation of the TV in the hydropower field has been increased its importance, in Italy, in correlation with the set of the procedure issued for the reassignment of hydroelectric concession of large hydropower plants.
Italian law stipulates that the power plant components are divided into "non-freely transferable works" or "dry works" and "freely transferable works" or "wet works". Wet works correspond to those works that capture, accumulate, regulate and convey water. The State, once the concession expires, takes possession of them without paying any sum of money to the outgoing concessionaire.
The so-called "non-freely transferable works" or "dry works", i.e. any building, owned land, machinery, utilization, transformation, and distribution plant related to the concession, are also acquired by the State, which promises to compensate the rightful owners with a price equal to the estimated value of the materials in place.
In light of the cited law, TV has been included, by many Regions, in the set of the document (End of Concession Report - ECR) that the outgoing concessionaries should submit to the Authorities before concession expires.
The compensation for dry works to rightful owners, according to Italian law, must be "a price equal to the estimated value of the materials in place, calculated at the time of possession, irrespective of any assessment of income derivable therefrom" without any other specification. As the reallocation of the hydroelectric concession, about the non-freely transferable works, amounts to a sale transaction overseen by the granting Authority, it is deemed appropriate that the exchange price of the assets be determined through a certified expert valuation.
The model developed by Frosio Next for TV determination complies with the latter description, as it does not rely on the expected energy production of the assets. It was decided to disregard the TV with respect to the accounting book value of the assets, as it does not reflect their actual technical functional condition. For example, the residual value of a turbine estimated based on accounting records corresponds to its book value, which is zero in all those cases—frequent in large plants—where the turbine is still the original one from the time of plant construction. This occurs because such components are subject to an ordinary depreciation rate of 7%[1] and are fully depreciated—under simplified assumptions—within approximately 15 years. Since available data on hydroelectric groups indicates that turbines have a useful life longer than 15 years[2], the asset, although fully depreciated, remains fully functional and therefore resalable at a price (as is the case with any industrial machinery) that does not correspond to the book value but rather to an expert appraisal or a market-dependent value.
There is also no real hydroelectric secondhand market to take as it is too site-specific to take the quotation as reference. Therefore, FN concentrates its methodology for an estimation of the TV that is highly dependent on the technical and functional properties of the works being assessed.
In the industrial context, the value of a component is gauged by its ability to perform the function for which it was designed and installed. Furthermore, following the instructions of some of the Authorities, the developed model enables the TV to be estimated based on judgments expressed through numerical values concerning the state of conservation, efficiency, and functioning of the hydropower plant (a method for the assessment of this parameter has been presented

by Frosio Next in Hydro 2023). These judgments are assigned to each main component of the plant and describe, using various indicators, the actual condition of functionality and preservation of the assessed component.
In the proposed model, the TV is calculated for each component of the hydropower plant from the reconstruction value as new, appropriately depreciated as will be explained in the following paragraphs. The model incorporates the effects of the useful life of the component, the maintenance work performed on it, the percentage of the component subject to degradation, the inflation and the current condition of the item. The latter effect is represented by the key element of this method: the *Cert* parameter. The *Cert* parameter is a numerical coefficient between 0 and 1, with no units of measurement, specially designed by Frosio Next to represent the consistency status (condition at the time of the official assessment) of each major component of the plant and it's based on the numerical values about the state of conservation, efficiency and functioning as defined and calculated during the assessment activities.
The method created by Frosio Next to calculate the terminal value divides the dry works into i) electromechanical components, ii) buildings and iii) land. More in detail the terminal value of land is mainly based on changes in its market value, unlike the other two, to which the specially devised method applies instead. Electromechanical components and buildings are subject to wear and tear, so it has been necessary to define a method that considers this fact. Evaluation of this phenomenon is even more difficult considering that two item levels are present in the model i) main component level (referred to as first-level item), for which the TV is estimated and ii) sub-components (referred to as second-level items) each with its own wear rate.

1.Estimation process for electromechanical components and buildings

1.1 Generalities
As already done for the assessment of the state of conservation, efficiency, and functioning in the ECR, which is an unavoidable precondition for the method, the outgoing concessionaire inventory is used as the basis.
The plant components for which the residual value is to be estimated are the first-level items in inventory.
The method incorporates the effects of:

- the age of the component
- maintenance work carried out to extend the useful life of the component
- the percentage of the component subject to degradation
- the consistency state of the component at the time of the assessment (*Cert* parameter)

The age of the component must be provided by the customer as initial data and is used in reference to the Average Expected Life to calculate progressive degradation year by year.
Likewise, the maintenance list is a key input for defining residual value, as it can lead to an increase in the useful life of the component and thus to an increase in its residual value. The list must be provided by the customer and must include both past interventions, which determine the residual value in the initial year (year of the asseveration), and planned future interventions, which determine the residual value in future years.
The *Cert* parameter used in the following formulas for estimating residual value is calculated using the numerical values assigned during the assessment phase, as they best describe the actual condition of the components. The *Cert* is essential to apply the initial depreciation, i.e. that from which the rebuild-to-new value allows to obtain the residual value in the year of the assessment the state of conservation, efficiency and functioning. From this residual value, it is possible to obtain the projection of the terminal value into the future by making use of a second coefficient for additional depreciation: Z coefficient. Z, as will be explained later, is calculated for each year following the assessment year and it estimates the future component's health status under the assumption that its condition deteriorates over time and it's used in particular when a replacement intervention of the whole component or a part of it is planned.

1.2 Components subject to wear and tear
For the estimation of useful life, a distinction was introduced between portions of a component that are subject to degradation and those that are not. In other words, an effort was made to account for the different rates of degradation of the various elements making up a component, and consequently, for the differing impact each element's value has on the overall value of the main component, depending on its level of degradation.
A typical example is the turbine. It consists of fixed parts and rotating or moving parts. The fixed parts are generally subject to much less degradation than the rotating and moving ones, and therefore also experience a smaller reduction in useful life (and thus in value).
The implemented model seeks to reflect these differing degradation rates.
For convenience, each component subject to evaluation was assigned to a category based on its type, as defined by FN in a preliminary phase.
The percentage of each component subject to degradation was then assigned according to its category (Tab. 1.) to be used within the terminal value calculation formula in order to depreciate only the portion of the component subject to wear and tear.

	Percentage of component subject to wear and tear [%]
Turbine	70%
Pump	70%
Generator	75%
Automation and protection	100%
Transformer	90%
Panels	100%
Overhead crane	50%
Electrical station AT	70%
Ancillary services	80%
Hydraulic systems	90%
Power generator	100%
Cavern power station	70%
External building	100%

Tab. 1. Components subject to wear and tear and loss of useful life

1.3 Input parameters of the method

The following are the input parameters of the method, along with their definitions and purposes:

1. **Rebuild-to-new Value for Electromechanical Components**:
   Used to determine residual value; it is mainly estimated based on budgetary offers from major manufacturers. Where such offers are unavailable, the estimate is obtained using a parametric model developed by interpolating data extracted from Frosio Next's database.
2. **Rebuild-to-new Value for Buildings**:
   Used to determine their residual value. This has been estimated either by analogy with similar buildings recently assessed by Frosio Next or by applying a unit value per m³ to the total building volume. The unit reconstruction value differs depending on the building type: above-ground masonry structures, above-ground steel structures, or cavern structures.
3. **Average Expected Life (or Useful Life) of the Component**:
   Derived from technical literature is used to calculate progressive degradation year by year ($Deg_{i\_\Delta j}$). Specifically, one of the most authoritative publications in the field was considered[2].
   Where the literature provides a range, the value was chosen based on Frosio Next's experience.
4. **Percentage of the Component Subject to Degradation (Deg_i)** and consequently the percentage not subject to degradation (1 – Deg_i):
   As previously explained, this is a key parameter to reflect the impact of differing degradation rates of the various elements comprising a component on its residual value.
5. **Coefficient Values Related to the State of Preservation, Efficiency, and Functioning of Each Component**, as defined and calculated during the assessment activities:
   These are used to compute the ***Cert*** parameter, which defines the health status of the component in the year of the assessment (year *a*).
   $Cert_i$ is a value between 0 and 1: the closer it is to 1, the lower the overall degradation of the element.
   Based on the *Cert* parameter, a **Z coefficient** is calculated for each year following the assessment year. This coefficient estimates the component's health status under the assumption that—if no maintenance is carried out—its condition deteriorates over time.
   This parameter also ranges from 0 to 1 and is assumed that decreases linearly over time (Fig. 1).
6. **Estimated Maintenance Expenditure Aimed at Extending the Component's Useful Life**:
   This refers to partial or total replacement interventions planned through to the *j-th* year of interest.
   This data was provided directly by the Client, based on the investment plan.

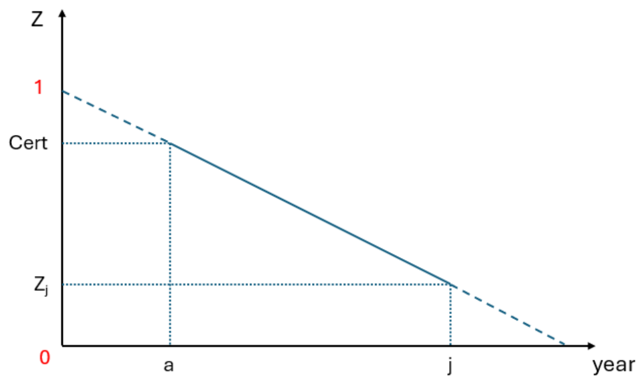

Fig. 1. Trend of parameter Z over time: in year 0 (component equal to the new) Z is equal to the maximum value; in year a (year of assessment activities) Z is equal to Cert parameter; in year j Z is equal to Z_j < Cert.

1.5 Maintenance contribution

Regarding interventions, whose financial value and timing are provided by the Client, a distinction was necessary between two categories:

- Replacement Interventions (partial or full), where a part or the entire component is replaced.
- Maintenance Interventions, where the component undergoes inspection, adjustment, calibration, etc., which do not fully restore the useful life of individual elements but undeniably help ensure correct interaction between subcomponents and partially restore residual life.

This distinction allows for the calculation of two different contributions depending on the type of intervention:
In replacement interventions, the residual value of the component—calculated at the year of the intervention using the previously described method—is adjusted by subtracting the residual value of the replaced element and adding the value of the new element. Specifically, the residual value of the worn element is computed as the replacement cost (S) degraded by the specially calculated Z coefficient, while the value of the new element is the actual purchase cost.
In maintenance interventions, the value is simply added to the residual value at the year of the intervention.

1.4 Implementation

The method begins with the estimate of the rebuilt-to-new value, as outlined above. In combination with the *Cert* parameter and the percentage of the component subject to degradation, this enables the calculation of the residual value in the assessment year.
To ensure consistency with the formula presented in paragraph 3.2, reconstruction values must be expressed in currency of the assessment year.
If requested by the client, the first phase is followed by a projection to a future year of interest (j-th year) of the residual value, starting from that calculated in the initial year. This projection takes into account further degradation over time and any maintenance interventions. The value is adjusted to year j values through proper monetary revaluation.
The monetary revaluation is calculated using the ISTAT (Italian public organization that diffuse statistical information on economic and social aspects) consumer price index for years up to 2024[3] and applying an estimated 2% inflation rate for future years[4].
It is important to note that the calculation of the residual value in year j is an iterative process. To reach the value in year j, it must be calculated the residual values for all preceding years (j–1, ..., j–n, ..., a+1).
As a result, the method provides a year-by-year timeline of the residual value from the year of certification up to the year of interest (Fig. 2).

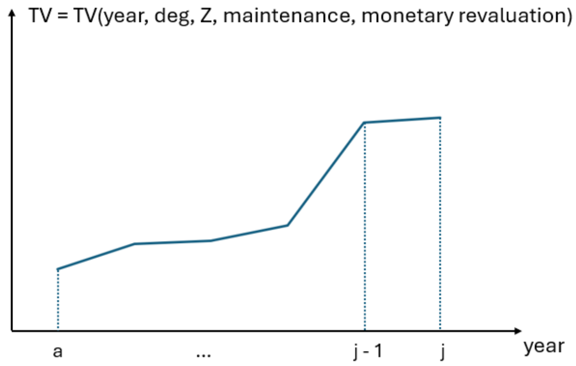

Fig. 2. Trend of the TV of a powerplant component over time: the value is calculated as a function of useful life (year), percentage of the component subject to degradation, Z parameter, maintenance interventions, monetary revaluation. The trend in the example is positive thanks to numerous maintenance interventions and increasing inflation.

2.Estimation process for land

Unlike electromechanical components and buildings, the residual value estimate for land is not based on the method described in the previous paragraphs, but solely on changes in its market value.
Residual values were calculated using unit prices per square meter, depending on the type of land asset (e.g., vineyard, meadow, uncultivated land, building plot, etc.). These unit values were obtained from the expropriation value tables of the specific country.
If the values found in official databases refer to a previous year, the residual value of each parcel of land must be updated to the year of interest through a revaluation process.
It is also emphasized that, because land prices vary significantly depending on the municipality and the specific area in which the land is located, an average price per land type was used.

3.Equations

3.1 Symbols

TV_j =	Terminal value of a component in year *j* [€]
TV_{j_cap} =	Terminal value of a component in year j with maintenance [€]
$€_j$ =	Actualisation to year j [€]
t_j =	inflation rate from year a to year j [€]
RV_{i_j} =	Rebuilt-to-new value of component i in year j [€]
$Cert_i$ =	Parameter defining the health status of the component in accordance with the assessment by Frosio Next
Deg_i =	Portion of component i that is subject to degradation and therefore depreciation [% of degrading part cost out of total cost]
CR_i =	Conservation status of component i in accordance with the assessment
ER_i =	Efficiency status of component i in accordance with the assessment
FR_i =	Functioning status of component i in accordance with the assessment
L_i =	Conventional service life of the component i [years]
Z_j =	Degradation of the component projected for year j starting from the *Cert* in accordance with the assessment by Frosio Next
i =	Component category according to the classification made in the assessment
j =	Future year to which the Termina Value refers
a =	Year in which the assessment was carried out
Dj =	Difference between year j and the current year [years]
$Deg_{i\_\Delta j}$ =	Degradation factor between the current year and year j [dimensionless]
$S_{s\_j\_i}$ =	Expected annual expenditure j for extending the useful life of component i, referring to partial or total replacement [€]
$S_{r\_j\_i}$ =	Expected annual expenditure j for extending the useful life of component i, referring to maintenance intervention [€]
$\Delta TV_{s\_j\_i}$ =	Variation in residual value due to replacement work in year j
$\Delta TV_{r\_j\_i}$ =	Variation in residual value resulting from maintenance in year j;
n =	Total number of components assessed in the certification

3.2 Terminal value in year *a*

$$TV_a^{€a} = \sum_{i=1}^{n} RV_{i\_a} \cdot [1 - Deg_i \ \cdot (1 - Cert_i)]$$

$$Cert_i = \frac{CR_i \cdot ER_i \cdot FR_i}{1.000.000}$$

3.3 Terminal value in year *j*

3.3.1 Without maintenance interventions

$$TV_j^{€a} = \sum_{i=1}^{n} TV_{j\_i}^{€a} \ = \sum_{i=1}^{n} \left(TV_{ElMec\_a\_i}^{€a} - RV_{i\_a} \cdot Deg_i \cdot Deg_{i\_\Delta j}\right)$$

$$TV_j^{€j} = TV_j^{€a} \cdot (1 + t_j)$$

$$Deg_{i\_\Delta j} = \frac{\Delta j}{L_i} = \frac{j - a}{L_i}$$

3.2.2 With maintenance interventions

General rule

$$TV_{j\_cap} = \sum_{i=1}^{n} \ TV_{j\_cap\_i} = \sum_{i=1}^{n} \ (TV_{j\_i} + \ \Delta TV_{s\_j\_1} + \Delta TV_{r\_j\_i})$$

Variation of terminal value due to a replacement intervention

$$\Delta TV_{s\_j\_i} = \sum_{j=1}^{n} S_{s\_j\_i} - Z_{j\_i} \cdot \sum_{j=1}^{n} S_{s\_j\_i}$$

$$Z_{j\_i} = \ \ Cert_i \ \cdot (1 - Deg_{i_{\Delta j}})$$

Variation of terminal value due to a maintenance intervention

$$\Delta TV_{r\_j\_i} = \sum_{j=1}^{n} S_{r\_j\_i}$$

4.Example

To facilitate understanding of the method, an example of estimating the terminal value of a turbine is provided below. Let the assumption be made that the residual value of a turbine dated 1940 is to be determined in 2027. The scores assigned in the assessment of the state of conservation, efficiency and functioning carried out in 2024 are available. It is also assumed that the inflation rate will be 2% per year from 2024 onwards.

4.1 Input data

In the first phase, it is very important to find the input data (Tab. 2).

Type	*Value*		
Reconstruction Value as New (*RV_{2024}*)	5.000.000 €		
Average Expected Life of a turbine (*L*)	60 years		
Percentage of the turbine Subject to Degradation (*Deg*)	70%		
Coefficient Values Related to the State of Preservation, Efficiency, and Functioning (*CR, ER, FR*)	CR = 62	ER = 100	FR = 91,5
Maintenance interventions (*S_r, S_s*)	Impeller overhaul in 2025 S_{r_2025} = 80.000 €	New rotary valve in 2026 S_{s_2026} = 1.000.000 €	
Inflation rate (*t*)	2%		

Tab. 2. Input data

Through which the other parameters are calculated (Tab. 3):

Type	*Value*
Cert	0,57
Z_{2024}	0,57
Z_{2025}	0,56
Z_{2026}	0,55
Z_{2027}	0,54
Progressive degradation year by year ($Deg_{\Delta j}$)	2%

Tab. 3. Parameters

4.2 Implementation

Using the data reported and the formulas in paragraph 3, the following values are obtained (Tab. 4, Fig. 3):

RV_{2024}	*Deg*	*Cert*	TV_{2024}	S_{r_2025}	S_{s_2026}	*t*	TV_{2025}	TV_{2026}	TV_{2027}
5.000.000 €	70%	0,57	3.485.550 €	80.000 €	1.000.000 €	2%	3.575.761 €	4.038.039 €	4.056.896 €

Tab. 4. Implementation of the method to obtain the TV in 2027 with maintenance interventions

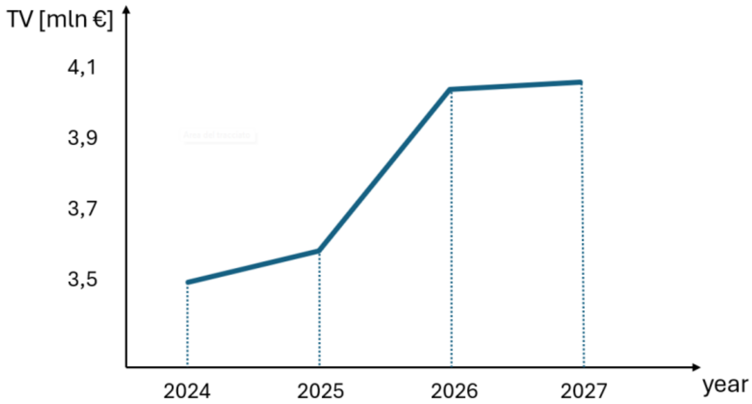

Fig. 3. Trend of the TV over time: it can be noticed that the TV increase over the years thanks to the contribution of the two maintenance interventions and the increasing inflation.

It is interesting to compare the previous results with the values obtained by calculating the residual value without maintenance interventions (Tab. 5, Fig. 4).

RV_{2024}	*Deg*	*Cert*	TV_{2024}	*t*	TV_{2025}	TV_{2026}	TV_{2027}
5.000.000 €	70%	0,57	3.485.550 €	2%	3.495.761 €	3.504.986 €	3.513.182 €

Tab. 5. Implementation of the method to obtain the TV in 2027 without maintenance interventions

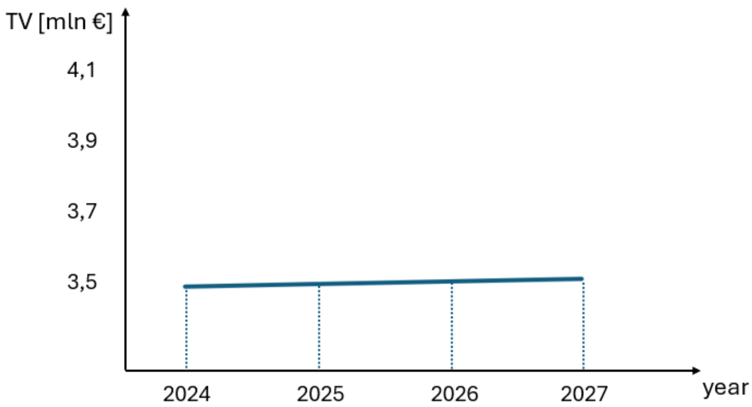

Fig. 4. Trend of the TV over time: the slight positive trend is due to the fact that, although the component deteriorates and loses value over time, inflation counteracts this effect, causing the value to increase.

5.Conclusion

FN implemented an objective, replicable and numerical method based to estimate the Termina Value of a hydropower plant component based on the judgments made during the Assessment of the state of conservation, efficiency and functioning. This method, applied to each component of the plant to obtain their residual value in the year of interest, incorporates the effects of the useful life of the component, the maintenance work performed on it, the percentage of the component subject to degradation, the inflation and the current condition of the item.
Thanks to the example given in the previous paragraph, it is possible to see how inflation influences fluctuations in residual value. This effect is a limitation of the method, as the monetary revaluation is the result of a forecast and may therefore be inaccurate. In fact, if inflation instead of increasing were to collapse in the future, the trend would be different.
However, the change in value resulting from the use of this parameter is negligible compared to that obtained when maintenance interventions are considered. The latter concept emphasizes the importance of maintenance for hydropower plants to increase the useful life of components and therefore their monetary value. It should also be noted that the most significant loss in value occurs in the transition from the rebuilt-to-new value to the terminal value in the year of the assessment.
The described loss of value is due to the *Cert* parameter, which records the condition of the component, and it is significantly affected by age (more than 60 years). This is an important consideration, as large hydropower plants in Italy are frequently based on the original components from the time of plant construction.
In conclusion, the method is objective and emphasizes that a plant, even an old one, can retain a good percentage of its monetary value if maintained with proper care.

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