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Report on good practices to promote the transition to circular economy in urban and industrial water management: A new water circularity index

Integrated Water Approach and Urban Water Reuse Project

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Executive summary: This Report is the result of the work of the "Integrated Water Approach and Urban Water Reuse" project team. It intends to present the outcomes of 2019 and includes the development of an indicator to measure the transition of certain installations to the Circular Economy in terms of water use. Therefore is presented an index named Water Circularity Index as a tool to promote a sustainable water use under the goals of the Water Framework Directive (WFD) and the Industrial emissions Directive (IED).	
Disclaimer: This report is the result of a project within the IMPEL network. The content does not necessarily represent the view of the national administrations.	

Introduction to IMPEL

The European Union Network for the Implementation and Enforcement of Environmental Law (IMPEL) is an international non-profit association of the environmental authorities of the EU Member States, acceding and candidate countries of the European Union and EEA countries. The association is registered in Belgium and its legal seat is in Bruxelles, Belgium.

IMPEL was set up in 1992 as an informal Network of European regulators and authorities concerned with the implementation and enforcement of environmental law. The Network's objective is to create the necessary impetus in the European Community to make progress on ensuring a more effective application of environmental legislation. The core of the IMPEL activities concerns awareness raising, capacity building and exchange of information and experiences on implementation, enforcement and international enforcement collaboration as well as promoting and supporting the practicability and enforceability of European environmental legislation.

During the previous years, IMPEL has developed into a considerable, widely known organisation, being mentioned in a number of EU legislative and policy documents, e.g. the 6th Environment Action Programme and the Recommendation on Minimum Criteria for Environmental Inspections.

The expertise and experience of the participants within IMPEL make the network uniquely qualified to work on both technical and regulatory aspects of EU environmental legislation. Information on the IMPEL Network is also available through its website at www.impel.eu.

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Introduction

In a classical context the "transition to the circular economy" is described by the water use efficiency taken into account primarily the quantitative aspects. According this approach the transition should be promoted by the reduction of freshwater consumption, minimization of leaks and losses, through the promotion of reuse practices, such as the use of treated wastewaters and rain waters and also by the valorisation of urban depuration sludge and other solids like manure, namely as sources of organic matter, nutrients and energy.

However, a more complex approach is needed and the real transition to a circular model can only be achieved by the conjunction of above factors with the related processes. Therefore, better and robust assessment could be achieved by following these criteria:

- Reduction of pollution loads by the possibility of the recovery of materials, such as nutrients, metals, fibers, etc. This constituents could be further used as raw materials in other productive processes;
- Development of new technologies and promotion of eco-design to allow the recovery of materials from treated wastewaters and subsequent use;
- Water reuse as a way to:
    - Develop new and more sustainable treatment technologies;
    - Develop new systems and methods for water application (e.g., irrigation systems and methodologies);
    - Improve crops, namely more resilient crops (e.g., increase of salts tolerance or plagues) and consequently with low needs of water and pesticides;
    - Improve seed selection in terms of water needs;
    - Reduce freshwater consumption by the use of new water sources and/or optimization of water use in processes;
    - Develop analytical technologies to improve knowledge on possible hazards;
    - Recover nutrients and consequently reduce consumption of artificial fertilizers;
    - Promote biodiversity and species protection by the promotion of aquatic environments through the maintenance of ecological flows;
    - Promote additional activities, such as eco-tourism or bird-watching activities related with aquatic environments and promotion of natural values;
    - Promote synergies intra and inter processes which could be inter industries or even services (e.g. industrial and urban services) by the production of water that can have multiple uses according location of point of production of this water and surrounding environment (i.e., possible uses);

Water has ubiquitous character and several uses may directly or indirectly interact. Therefore, even if a simple process does not have a direct impact on a specific use it may promote a positive action in a circular system by the creation of synergies and promotion of additional value.

Then, the circular economy can really contribute to more sustainable activities by the promotion of reduction of freshwater consumption according the need of its maintenance and availability in terms of quantity and quality and considering the minimization of risks, in particular for public health and environment.

To ensure a true transition to a circular model, water must be seen under an integrated approach as mean of transport, as source of energy and a service. Other factors that also should be emphasized in this kind of assessment is the energy consumption, the emission of green gases and the content of water in terms of microplastics and compounds of emergent concern.

The development of methodologies that help to understand the interactions needed under the water use assessment and directly related with the promotion of application of European environmental legislation could present an innovative and useful tool to authorities and operators to promote a more sustainable water use.

Main outcomes from the 2017-2018 IWA project

The phase 1 of this IMPEL project (year 2017) brought representatives of a number of EU countries together to consider best practice for water management in the industry sector subject to the Integrated Environmental Permitting regulation. The main aims of this phase were to:

1. Collect and compare the procedures used within Europe for water resources management and protection in the industry sector;
2. Identify new approaches for reducing fresh water consumption and innovative technologies for industrial water treatment able to provide energy saving, sludge production minimization and water reuse for multiple purposes;
3. Use this information for developing a guidance document to share among IMPEL members and other non-IMPEL participants including for example the IPPC Bureau, European Environmental Agency and industry sector associations.

From the responses obtained by a survey, principles, requirements, drivers and barriers in the industrial water management sector were identified and several case studies/experiences were selected.

The Industrial Emission Directive (IED) requirements to Water Framework Directive (WFD) requirements for industrial water management were compared and a guidance document with a check list and suggestions for IED permit writers was developed.

One of the major outcomes of the first phase was that the water management inside industrial sectors, namely pulp and paper and oil refining sectors, should take into account that the water use efficiency must be seen from quantity perspective without jeopardizing the quality of wastewaters and water sources for direct use or reuse.

The phase 2 of this project (year 2018) was the follow-up of the previous phase extended to the sector of Urban Wastewater Reuse i.e., the use of treated urban wastewaters for agriculture irrigation.

The project was carried out by two working groups, related with the industrial water management and the urban treated wastewaters reuse, respectively.

The aim of the first working group was to enhancing best practices included in the guidelines on industrial water management with respect to water reuse inside industry (already developed on first year of the project) and test the application of these guidelines to a real case study, taking into account the complexity of balances needed in terms of quantity and quality of water in the industrial water cycle use.

The aim of the second working group was to exchange current best practices with respect to water reuse of treated urban wastewaters for agriculture irrigation purposes.

The results of this phase were, on the one hand, the development of an addendum of the guidelines on industrial water management best practices testing the guidelines on a selected industrial installation (namely a Pulp & paper industry) and, on the other hand, the development of a report document on the reuse of treated wastewaters for agriculture irrigation purposes, as a tool to achieve the objectives of the WFD in certain areas and enhancing water management best practices.

Aims of the 2019 IWA project

The reuse of treated wastewater can be an important tool to contribute as a local solution to achieving the objectives of the WFD and to contribute to a more resource efficient economy as well as to adapt to climate change, namely in cases where water scarcity is identified as a significant pressure. To transform Europe's economy into a more sustainable one and to implement the ambitious Circular Economy Action Plan, continuous efforts are needed and treated wastewaters can be seen as a new untapped water resource.

However, according the outcomes of the first two phases of this project (year 2017 and 2018), it was noticed that water reuse cannot be seen as single quantitative measure to reduce water abstraction. In the whole water use cycle, at industrial and urban level, quality must be linked with quantity to ensure safety and increasing of value through the chain of use, by the promotion of the natural values and activities directly connected with the emissions receiving environment.

Also, when recycling projects are presented as a solution for circular economy transition, water use is only considered as a quantitative indicator, with no link to quality assessment and therefore without considering the possible impacts on the achievement of the WFD goals.

Therefore, a more integrated and holistic vision for water reuse at industrial and urban level is needed to promote practices that contribute to a real transition to a circular economy.

Furthermore, the reuse of urban wastewater for irrigation purpose can also be an important tool to help ensure that farmers and other land managers comply with environmental rules under EU nature and water laws, as one of the 9-point Action Plan adopted by the European Commission to increase compliance with and improve governance on EU environmental rules on activities.

The aim of Phase 3 of this project (year 2019) is to use the results of the first two phases to find best practices on water use cycle, including water reuse at industrial and urban level, that promote a more realistic transition to the circular economy. At industrial level, besides the sectors appraised on the previous project phases, it is intended to access the water use inside recycling activities to develop new indicator combining quality and quantity. Another related outcome of the work will be improving professional training, spreading knowledge and provide compliance assurance in rural areas as required for the implementation of the ECA 9-point Action Plan.

Introduction and development of the circularity index

In a classic approach the transition to the circular economy is described in terms of water use efficiency, namely the quantitative aspects through the reduction of consumptions and losses, rain waters recovery, water reuse. The use of sludge from wastewater treatment plants and manure can be also considered as a source of organic matter and nutrients and for energy production.

However, to achieve a real transition, the above factors cannot be seen as individual indicators but instead they should be linked with the several possible processes. E.g., instead of looking to the reduction of pollutants loads to reduce pressure over waterbodies should be considered the recovery of substances, like metals, nutrients, cellulose fibers, etc., which can be further reused in distinct processes. In this way, there is the protection of ecosystems by the reduction of pollutant discharges and a promotion of value chain by the reuse of several materials in additional processes. Meanwhile, this new approach leads to the need of use of more sustainable technologies and its development which indirectly increase society knowledge and may promote the creation of new business areas and jobs.

Other aspects to take into account in the transition to a circular model are the reduction of energy consumption and the emission of greenhouse gases.

Water is ubiquitous and the different uses may directly or indirectly interact. For this reason, a certain process may not have a direct action with the water but can promote a positive action on the system creating some additional value.

Therefore, to endorse the transition to the circular economy taking into account the complexity of the systems as previous described, an index was developed as a tool to measure the circularity of a certain process or installation.

The index, named *Circularity Index* (I_C) was developed according the SMART criteria, i.e.

- **Specific**: The index accurately describes what is intended to be measured and does not include multiple measurements;
- **Measurable:** Regardless of who uses the index, consistent results can be obtained and tracked under the same conditions;
- **Attainable:** Collecting data for the index is simple, straightforward, and cost-effective;
- **Relevant:** The index is closely connected with each respective input, output or outcome;
- **Time-bound:** The index includes a specific time frame, i.e., the validity of the environmental/ discharge permit.

Easily accessible and measurable factors that take into account the relationships between the water use patterns, the processes and the environmental systems were considered as as inputs. . These factors are described as key factors.

Key Factors

Taking into account the principles described on the previous section, a following list of relevant key factor was developed:

1. Freshwater consumption
2. Wastewater discharges:
    a. Non-IED installations
    b. IED installations
3. Water reuse
4. Best management practice and technologies
5. Priority substances (PS), priority hazardous substances (PHS) and other pollutants (OP) and specific pollutants (SP)
6. Microplastics and/or compounds of emergent concern
7. Biodiversity
8. Recovery of nutrients
9. Internal industrial symbiosis
10. Sludge
11. Voluntary and incentive instruments

For this task it was appraised the water use cycle and factors were assigned concerning each step of this cycle (figure 1) and these key factors were distributed in three levels of importance.

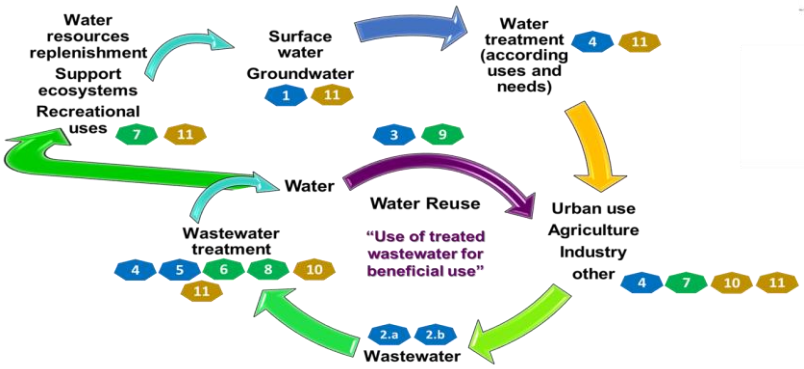

Figure 1: Water use cycle

From this list were excluded factors related with recovery of other substances and external industrial symbiosis since the work in this area is still in an early stage of development and main practices are related with research projects.

As mentioned the key factors were distributed in three levels of importance according their relevance for the circular economy principles, namely:

- High importance: Key factors from 1 to 5
- Medium importance: Key factors 6 to 9
- Low importance: Key factors 10 to 11

The relevance of the key factors was categorised by an importance scale, as the one developed by Saaty[1] and the used attributes were nine (9), five (5) and one (1) which respectively represents an absolute importance, an essential or strong importance and a low importance.

Each key factor was decomposed in simple criteria which intended to be easily, straightforward and cost-effective to assess. According the specifications of each factor some included positive and negative criteria and other only positive criteria. Regarding these conditions, sub-key factors values were appraised by non-linear division of the key factor value (9, 5 or 1) in the number of positive or negative criteria. This way, the sum of the sub-key factors values is equal to zero - when positive and negative criteria are present - or the value of the key-factor when only positive criteria is considered. The final list of key factors, secondary key factors and their values is presented below (tables 1 to 3):

Table 1: List of Key and sub-key factors of high importance

Key Factor	Key and sub-key factors	Key factor value (F_{key})	Sub-Key factor value ($f_{i\ s\text{-}key}$)
1	**Freshwater consumption**	**9**	
	Measures to reduce consumption without linking the impacts on the quality of wastewaters and contributing directly to its degradation		-9,00
	Measures to reduce consumption without linking impacts on the quality of wastewaters (with non-significant variation on wastewater quality, e.g., reduction on groundwater abstraction with low impacts on wastewaters)		1,00
	Measures to reduce consumption with measures to reduce possible effects of effluents concentration		4,00
	Reducing abstraction directly from water body (ex. Rainwater collection and reuse) promoting replenishment		4,00
2.a	**Wastewater discharges non IED installations**	**9**	
	Compliance of ELV without link to the WFD (flat values) and with effects on water status		-9,00
	Compliance of ELV without link to the WFD (flat values) and with no known effects on water status		2,00
	Compliance of ELV with link to the WFD		7,00
2.b	**Wastewater discharges IED installations**	**9**	
	Compliance of BREF-EAV without link to the WFD		-9,00
	Situations where BREF-EAV can be equal to ELV, according check-list		2,00
	Compliance of ELV (ELV defined according WFD principles, where ELV needs to be lower than BREF-EAV, according check-list)		7,00
3	**Water Reuse**	**9**	
	Promotion of water reuse with negative impacts on final concentration of the wastewaters discharged with negative impact on surface water		-6,00
	Promotion of water reuse with negative impacts on final concentration of the wastewaters discharged and no impact on groundwater abstraction		-3,00
	Promotion of water reuse without negative impacts on final concentration of the wastewaters discharged		3,00
	Promotion of water reuse with positive impacts on final concentration of the wastewaters discharged		6,00
4	**Best management practice & Technologies**	**9**	
	Use of lower level than BAT		-9,00
	Use of BAT		1,00
	Promotion of management solutions to reduce CO_2 emissions		3,50
	Use of new technologies (go beyond BAT, with promotion of new developments) (ex. Equipment, maintenance and process improvement to reduce the microplastic release into effluent)		4,50
5	**Priority substances (PS) / priority hazardous substances (PHS) and other substances (OS)/ specific pollutants (SP)**	**9**	
	With PHS and no actions to foreseen the ceasing or phase-out discharges, emissions and losses		-6,00

[1] Saaty, T. L. (1980). The analytic hierarchy process: Planning, priority setting, resource allocation. 1st ed. NY: McGraw-Hill, New York.

	With PS/OS/SP and no actions to foreseen the reduction of discharges, emissions and losses		-3,00
	With PS/OS/SP and actions to foreseen the reduction of discharges, emissions and losses		3,00
	With PHS and actions to foreseen the ceasing or phase-out discharges, emissions and losses		6,00

Table 2: List of Key and sub-key factors of essential or strong importance

Key Factor	Key and sub-key factors	Key factor value (F_{key})	Sub-Key factor value ($f_{i\ s\text{-}key}$)
6	**Microplastics and/or Compounds of emergent concern**	5	
	Promotion of removal solutions to reduce microplastic content in wastewater discharge		2,50
	Promotion of removal solutions to reduce compounds of emergent concern content in wastewater discharge		2,50
7	**Biodiversity**	5	
	Promotion of water reuse with negative impacts on biodiversity (water quality and quantity index)		-5,00
	Promotion of water reuse without negative impacts on biodiversity (water quality and quantity index)		2,00
	Promotion of water reuse with positive impacts on biodiversity (water quality and quantity index)		3,00
8	**Recovery of nutrients**	5	
	Without removal of nutrients with visible negative effects on water bodies (directly linked with the installation)		-5,00
	Removal of nutrients to prevent negative effects on water bodies without further nutrient uses		0,50
	Just recovery of nutrients for further uses (without influence on water bodies)		1,50
	Removal of nutrients to prevent negative effects on water bodies with further nutrient uses (ex. Struvite recovery)		3,00
9	**Internal industrial symbiosis**	5	
	Without promotion of integrated approach for competitive advantages.		-5,00
	Promotion of integrated approach for competitive advantages through the exchange of water, materials and energy between processes (ex. cooling waters, dilution processes, cleanings, etc.)		5,00

Table 3: List of Key and sub-key factors of low importance

Key Factor	Key and sub-key factors	Key factor value (F_{key})	Sub-Key factor value ($f_{i\ s\text{-}key}$)
10	Sludge	1	
	Minimization of sludge production, bio-thermal energy production from anaerobic digestion and reuse of treated sludge from aerobic digestion with impacts on final concentration of the wastewaters discharged		-1,00
	Minimization of sludge production, bio-thermal energy production from anaerobic digestion and reuse of treated sludge from aerobic digestion without impacts on final concentration of the wastewaters discharged		1,00
11	Voluntary and incentive instruments	1	
	Without adoption of regulatory instruments, economic instruments, certification and labelling rules, environmental management systems)		-1,00
	Adoption of regulatory instruments, economic instruments, certification and labelling rules, environmental management systems as measures towards the circular economy		1,00

According to the previous tables it is possible to see that negative values should be used when the non-application of the measure described on the sub-key factor results in a negative impact for water bodies, while the ones that results in positive impacts are classified with positive values.

The circularity index

The circularity index was developed in a knowledge base model, which can be defined as a formally described concept of a certain problem, usually represented by a set of production rules or decision trees, frames, etc. In the current study a set of water usage patterns were used as the input for the model, described as key factors.

Therefore, an algorithm that allows to measure the interactions of water usage concerning the circular economy principle was developed. The outcomes of the model allows to measure the efforts of a certain process or installation in the transition to a circular economy form, which can be defined as the "water" circularity of a certain process or installation. The algorithm weights each sub-key factor and measure how each one contributes for the "water" circularity.

The circularity index (I_c) is determined by the equation 1:

$$I_c = \frac{\sum(f_{i\ s\text{-}key} \times f_{i\ w})}{N_f} \qquad (1)$$

Where,
$f_{i\ s\text{-}key}$ is the sub-key factor value, directly obtained from tables 1 to 3
$f_{i\ w}$ is a weighting factor applicable to each sub-key factor
N_f is a normalization factor

The weighting factor is described by the equation 2:

$$f_{i\ w} = \frac{\left|f_{i\ s\text{-}key_{+++,++or+}}\right|}{F_{key_{+++,\ ++or+}} \times n_{s\text{-}key\ app_{+++,++or+}}} \qquad (2)$$

And,
$|f_{i\ s\text{-}key}|$ is the absolute number of the sub-key factor of the correspondent importance (high – +++, medium – ++ and low – +), i.e., without considering its signal
F_{key} is the key factor value (+++=9, ++=5 or +=1), which correspond to the maximum value of sub-key factors given by the sum of all positive measures
$n_{s\text{-}key\ app}$ is the total number of sub-key factors applicable

It should be noticed that when a key factor is applicable all its sub-key factors are also valid, some as measures in place and others as not in place. Therefore the maximum sub-key factor applicable of high importance (+++) is 19, of medium importance (++) is 11 and of low importance (+) is 4. The weighting factor is calculated per each sub-key factor.

Since not all key factors are applicable to all processes or installations, the algorithm includes a normalization factor to remove its evidence when those are not used. However, the key factor 1 (freshwater consumption) and 2 (wastewater discharges) are always applicable to all cases. The normalization factor is given by equation 3 and also allows to reduce the final scale for the index.

$$N_f = \frac{n_{F_{key+++}} \times F_{key+++} + n_{F_{key++}} \times F_{key++} + n_{F_{key+}} \times F_{key+}}{n_{max\ F_{key+++}} \times F_{key+++} + n_{max\ F_{key++}} \times F_{key++} + n_{max\ F_{key+}} \times F_{key+}} \qquad (3)$$

Therefore, equation 3 can be simplified as:

$$N_f = \frac{n_{F_{key+++}} \times 9 + n_{F_{key++}} \times 5 + n_{F_{key+}} \times 1}{5 \times 9 + 4 \times 5 + 2 \times 1} = \frac{9n_{F_{key+++}} + 5n_{F_{key++}} + n_{F_{key+}}}{67} \quad (4)$$

n_{Fkey} is the number of applicable key factors of high importance (+++), medium importance (++) or low importance (+)
F_{key} as previous mention is the key factor value (+++=9, ++=5 or +=1)

Hence, the information required to determine the circularity index for any kind of installation or process can be directly obtained from the data required for the environmental permitting process, including water abstraction and wastewater discharges. Taking into account the characteristics of the index, its timeframe is directly linked with the permitting cycle and, therefore, is equal to validity period of the environmental permit.

The consistency of the data required for the index determination ensures that all key and sub-key factors are attainable and measurable. So, the methodology allows to obtain consistent results and tracked under the same conditions irrespective of who uses the index.

The measures precluded in the index also allow to identify possibilities for installations improvement namely taking into account the enhancement of the water bodies quality and the goals set on the WFD. On another perspective they allow to improve compliance of measures defined under BAT-BREF documents and subsequently contribute for the compliance of IED. Thus, the circularity index is a tool that allows the use of a holistic approach to understand the water uses in installations, including intra and inter process uses, and its relations with environmental services, such as ecosystems. This way it is possible to measure the efforts made to change from an economic linear model to circular one.

By the application of the current methodology is possible to obtain results between -4,4 and 2,6 according the possible combinations of sub-key factors. Then prioritisation of circularity can be obtained by conversion of the I_c results into a five level qualitative scale as follows:

	Ic <0	Negative Circularity: Negative inputs for the circular economy (negative impacts for water bodies)
	Ic = 0	No inputs for circular economy
	0 < Ic ≤ 0,85	Low Circularity: Low level of inputs for circular economy
	0,85 < Ic ≤ 1,5	Medium Circularity: Medium level of inputs for circular economy
	Ic > 1,5	High Circularity: High level of inputs for circular economy

Guidelines to apply the circularity index

Under this project a tool was developed for the determination of the circularity index for IED and non-IED installations. The tools consists in an excel sheet in which the direct input of data allows the determination of the circularity index. The tool is displayed on annex 1.

To calculate a circularity index of a process or a certain installation the steps required are:

A. Assess information from project or environmental permit regarding the key factors:
   1. Freshwater consumption
   2. Wastewater discharges
   3. Water reuse
   4. Best management practice & technologies
   5. Priority substances (PS) / priority hazardous substances (PHS) and other substances (OS)/ specific pollutants (SP)
   6. Microplastics and/or compounds of emergent concern
   7. Biodiversity
   8. Recovery of nutrients
   9. Internal industrial symbiosis
   10. Sludge
   11. Voluntary and incentive instruments

- To each key factor introduce, in the correspond line, on the row "Key factor value, F_{key}" the number zero (0) or one (1) for not applicable or applicable situations;
- For the key factor 1 (freshwater consumption) and 2 (wastewater discharges) always consider as applicable situations and introduce value one (1).
- For the key factor 2 (wastewater discharges) when multiple cases may apply, sub-key factors should be assessed considering the most critical parameters for the water bodies.

B. Sub-key-factors

- For key factors value, F_{key}, equal to one (1) introduce on the correspond sub-key factors:
  i. One (1) on the row "Sub-key factor";
  ii. Zero (0) or one (1) on the row "Sub-Key factor value" according measures/situations in place.
- When the sum of sub-key factors (inside of the same level of importance is equal to zero, the value displayed on correspondent cell will be 1 and the cell ($f_{i\ s\text{-}Key}$ x $f_{i\ w}$) will be zero. This way, all the terms related with the product (sub-key x factor weighting factor) will be displayed as zero and therefore not considered for the determination of I_c. If the sum is equal or higher than one, the values displayed will be the real sum and the real product.

C. The weighting factor ($f_{i\ w}$), the normalization factor (N_f) and circularity index (I_c) will be automatically produced. The I_c will be displayed according to the colour code range.

Results from real cases

In this paragraph the results of the application of the tool for the determination of the circularity index from real cases are reported. For a detailed overview of the examples of application of the Circularity Index on national cases of participant Member States see Annex II.

The main results can be summerized as follow (table 4):

Table 4: Results from the application of Circularity Index to case-studies

Case study	IED Installation	NON IED Installation	Description of WWTP	Ic
A 1	X		Pulp mill before permit review	-1,24
A 2	X		Pulp mill after permit review	1,19
A 3		X	Urban WWTP	1,91
B 1	X		Pulp and paper industry	0,35
B 2	X		Biorefinery	2,13
B 3	X		Oil refinery	-1,01
C 1		X	Urban WWTP with industrial connections	3,48
C 2	X		Company cleaning and shredders plastic barrels	1,46
D 1	X		Pulp and paper industry and urban wastewater	1,39
D 2	X		Fertilizer production plant	1,00
D 3	X		Large smelter	2,94
E 1	X		Pulp and paper industry	0,52
E 2	X		Brewery	1,09

First of all, the circularity index was applied to a specific case-study used in the previous phase of the current project[2], before and after permit review in a pulp mill, respectively case study A 1 and A 2. This allowed to measure the impact of the actions taken on the transition from a discharge permit only based on the IED principles to a new permit that takes into account the integrated water approach considering directives, i.e., IED and WFD. The index clearly shows that the installation moved from a negative circularity (Ic = -1,24) to a medium circularity (Ic = 1,19).

Then the circularity index was applied to other case-studies from EU countries with also 2 examples of non IED installations (A 3 and C 1) and the obtained results show different Ic values according to different measures and actions taken ranging from negative to low, medium and high circularity index.

To better understand which key-factor and sub-key factor can effectively contribute to a high Ic or low Ic, the following analysis has been carried out.

For each example only the highest values of all sub-key factor have been considered (both positive and negative values) and represented below (table 5).

As can be seen, the worst cases (with negative Circularity Index) are those with:

- Measures to reduce consumption without linking the impacts on the quality of wastewaters and contributing directly to its degradation;
- Compliance of BREF-EAV without link to the WFD;
- Promotion of water reuse with negative impacts on final concentration with negative impact on surface water;
- Without removal of nutrients with visible negative effects on water bodies;

[2] Farabegoli, G. et al (2018). Addendum: Integrated Water Approach – A practical guide for IED permit writers. IMPEL, Brussels.

- Without adoption of regulatory instruments.

The first three are sub-key factors of high importance, one is of essential or strong importance and the last one is of low importance but can contribute to decrease the Ic.

Low circularity cases are those with:

- Compliance of ELV (ELV defined according WFD principles, where ELV needs to be lower than BREF-EAV, according check-list);
- Adoption of regulatory instruments;
- Without promotion of integrated approach for competitive advantages.

While the first two sub-key factors can contribute to increase the Ic the last one can decrease the Ic.

Medium circularity cases are characterized by:

- Compliance of ELV (ELV defined according WFD principles, where ELV needs to be lower than BREF-EAV, according check-list);
- Promotion of water reuse with positive impacts on final concentration;
- With PHS and actions to foreseen the ceasing or phase-out discharges, emissions and losses;
- Promotion of water reuse with positive impacts on biodiversity;
- Removal of nutrients to prevent negative effects on water bodies;
- Minimization of sludge production without impacts on final concentration;
- Adoption of regulatory instruments.

The first three are sub-key factors of high importance, the middle two are of essential or strong importance and the last two are of low importance.

Finally, the best cases (with high circularity index) are those with:

- Compliance of ELV (ELV defined according WFD principles, where ELV needs to be lower than BREF-EAV, according check-list);
- Use of new technologies;
- With PHS and actions to foreseen the ceasing or phase-out discharges, emissions and losses;
- Promotion of water reuse with positive impacts on biodiversity;
- Promotion of integrated approach for competitive advantages;
- Minimization of sludge production without impacts on final concentration;
- Adoption of regulatory instruments.

In this case all the sub key factors, of high importance, essential or strong importance and low importance, are positive values.

Table 5: Assessment of the contribution of key-factors and sub-key factors to the circularity index

Ic	1st Sub-key factor	2nd Sub-key factor	3rd Sub-key factor	4th Sub-key factor	5th Sub-key factor	6th Sub-key factor	7th Sub-key factor	8th Sub-key factor	9th Sub-key factor	10th Sub-key factor	11th Sub-key factor
-1,24	Measures to reduce consumption without linking the impacts on the quality of wastewaters and contributing directly to its degradation −	Compliance of BREF-EAV without link to the WFD −						Without removal of nutrients with visible negative effects on water bodies −	Promotion of integrated approach for competitive advantages +		Without adoption of regulatory instruments −
-1,01		Compliance of BREF-EAV without link to the WFD −	Promotion of water reuse with negative impacts on final concentration with negative impact on surface water −						Without promotion of integrated approach for competitive advantages −	Minimization of sludge production without impacts on final concentration +	Adoption of regulatory instruments +
0,35		Compliance of ELV (ELV defined according WFD principles, where ELV needs to be lower than BREF-EAV, according check-list) +	Promotion of water reuse with negative impacts on final concentration with negative impact on surface water −						Without promotion of integrated approach for competitive advantages −		Adoption of regulatory instruments +

0,52		Compliance of ELV (ELV defined according WFD principles, where ELV needs to be lower than BREF-EAV, according check-list) +							Without promotion of integrated approach for competitive advantages −	Minimization of sludge production without impacts on final concentration +	Adoption of regulatory instruments +
1,00			Promotion of water reuse with positive impacts on final concentration +		With PHS and actions to foreseen the ceasing or phase-out discharges, emissions and losses +		Promotion of water reuse with positive impacts on biodiversity +	Removal of nutrients to prevent negative effects on water bodies +	Without promotion of integrated approach for competitive advantages −	Minimization of sludge production without impacts on final concentration +	Adoption of regulatory instruments +
1,09		Compliance of ELV (ELV defined according WFD principles, where ELV needs to be lower than BREF-EAV, according check-list) +	Promotion of water reuse with positive impacts on final concentration +	Use of new technologies +			Promotion of water reuse with positive impacts on biodiversity +		Without promotion of integrated approach for competitive advantages −	Minimization of sludge production without impacts on final concentration +	Adoption of regulatory instruments +

1,19		Compliance of ELV (ELV defined according WFD principles, where ELV needs to be lower than BREF-EAV, according check-list) +		Use of new technologies +					Promotion of integrated approach for competitive advantages +		Without adoption of regulatory instruments −
1,39		Compliance of BREF-EAV without link to the WFD −			With PHS and actions to foreseen the ceasing or phase-out discharges, emissions and losses +			Removal of nutrients to prevent negative effects on water bodies +	Promotion of integrated approach for competitive advantages +	Minimization of sludge production with impacts on final concentration −	Adoption of regulatory instruments +
1,46		Compliance of ELV (ELV defined according WFD principles, where ELV needs to be lower than BREF-EAV, according check-list) +	Promotion of water reuse with positive impacts on final concentration +		With PHS and actions to foreseen the ceasing or phase-out discharges, emissions and losses +						

1,91		Compliance of ELV with link to the WFD +	Promotion of water reuse with positive impacts on final concentration +	Use of new technologies +	With PHS and actions to foreseen the ceasing or phase-out discharges, emissions and losses −		Promotion of water reuse with positive impacts on biodiversity +			Minimization of sludge production without impacts on final concentration +	
2,13				Use of new technologies +			Promotion of water reuse with positive impacts on biodiversity +		Promotion of integrated approach for competitive advantages +		Adoption of regulatory instruments +
2,94		Compliance of ELV (ELV defined according WFD principles, where ELV needs to be lower than BREF-EAV, according check-list) +			With PHS and actions to foreseen the ceasing or phase-out discharges, emissions and losses +		Promotion of water reuse with positive impacts on biodiversity +		Promotion of integrated approach for competitive advantages +		Adoption of regulatory instruments +
3,48		Compliance of ELV (ELV defined according WFD principles, where ELV needs to be lower than BREF-EAV, according check-list) +						Removal of nutrients to prevent negative effects on water bodies +		Minimization of sludge production without impacts on final concentration +	

From the results obtained it can be observed that the 6th key factor - Microplastics and/or Compounds of emergent concern – even if it is essential or of strong importance, is not present in the table because in all the examples it was not applicable. This is probably due to the fact that there are no regulations currently restricting these kind of compounds. Taking into account this considerations, and the fact that indeed microplastics and compounds of emergent concern are present in all types of urban wastewater, in the three study cases since no measures are being taken, the real Ic values are slightly lower, as can be seen on the below table. However, the introduction of this key factor will not affect the final qualitative result. I.e., the three instalations remain inside the same category of circularity (table 6).

Table 6: Results from the application of Circularity Index to urban wastewater treatment plants considering the application of the sub-key factor "Microplastics and/or Compounds of emergent concern"

Case study	IED Installation	NON IED Installation	Description of WWTP	Ic[1]	Ic[2]
A 3		X	Urban WWTP	1,91	1,69
C 1		X	Urban WWTP with industrial connections	3,48	2,68
D 1	X		Pulp and paper industry and urban wastewater	1,39	1,08

[1] Ic without considering the 6th sub-key factor
[2] Ic considering the 6th sub-key factor

However with the recent media attention and increasing public awareness of the issue, as well as improving technology to detect these substances, regulations may be on the horizon and the European Commission should take them in consideration during the review of the Urban Waste Water Treatment Directive.

Conclusions and future improvement

During this project phase was possible to produce an index applicable to the aspects of the water use and reuse at industrial and urban level. This index was constructed taking into account the main factors of water use cycle linked with the principles of circular economy.

Therefore, the goal of this project was achieved and an indicator able to measure the circular principles linked with the urban and industrial water use cycle was developed and named Water Circularity Index (Ic).

The index was applied to several case studies from several EU countries and clearly illustrated the efforts promoted inside different installations for a sustainable water use, namely in terms of circular principles.

The results from the previous phase of the project showed the importance of defining wastewater industrial discharge permits based on the combined approach that links the WFD and IED principles. The application of the circularity index to the case-study used on the previous phase of the current project[3] allowed to measure the positive impact of the actions taken on the transition from a discharge permit only based on the IED principles to a new permit that takes into account the integrated water approach considering directives, i.e., IED and WFD. The index clearly shows that the installation moved from a negative circularity to a medium circularity. I.e., the index allows to measure the positive impacts from the compliance of environmental legislation, when integrated actions are taken compared with simple compliance of individual directives.

The application of the index to urban cycle also illustrates that the discharges more linked with the WFD principles lead to high circularity values.

On the classical approach of recycling project presented as a solution for circular economy transition, the water use is only considered as a quantitative indicator, with no link to quality assessment and therefore without considering the possible impacts on the achievement of the WFD goals. However, the results of this project clearly shows that the use of a more integrated and holistic vision for water reuse at industrial and urban level can encourage practices with a better contribution to the transition for a circular economy. Furthermore, this index can be seen as tool to promote a better compliance of natural and water laws in line with the 9-point Action Plan adopted by the European Commission to increase compliance with and improve governance on EU environmental rules on activities.

Nevertheless, a deeper knowledge of the best practices is still needed, namely to understand the real impact of the circularity index in the products that are produced with reclaimed water. This way it will be possible to assess the impact of promoting the compliance of environmental legislation on the “reuse markets”. The transition of the Water Circularity Index from the installation to the final product will contribute to a better understanding of the needs to close the loop in terms of water use. This way, instead of having products just assessed in terms of a quantitative water footprint, these can be also evaluated in terms of the qualitative aspects, namely in terms of real impacts over water bodies.

This kind of assessment could be applied to “reuse markets” already in place or to promote new ones by assessing “low circularity” products and identifying possible ways for the transition by the use of circularity indexes.

[3] Farabegoli, G. et al (2018). Addendum: Integrated Water Approach – A practical guide for IED permit writers. IMPEL, Brussels.

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ANNEX I: Tool for the determination of Circularity Index

Non-IED Installations

ID Key Factor	Key and sub-key factors	Key factor value (F_{key})	Sub-Key factor value ($f_{i\ s\text{-}key}$)	Key factor (applicable-1; Non applicable - 0)	Sub-key factor(applicable-1; Non applicable - 0); All sub key factors are applicable when key factor applies	Sub-Key factor value ($f_{i\ s\text{-}key}$) (0 to measures/situations not in place and 1 for measures/situations in place)	Weighting factor ($f_{i\ w}$)	$f_{i\ s\text{-}Key}$ x $f_{i\ w}$
1	**Freshwater consumption**	9						
	Measures to reduce consumption without linking the impacts on the quality of wastewaters and contributing directly to its degradation		-9,00					
	Measures to reduce consumption without linking impacts on the quality of wastewaters (with non-significant variation on wastewater quality, e.g., reduction on groundwater abstraction with low impacts on wastewaters)		1,00					
	Measures to reduce consumption with measures to reduce possible effects of effluents concentration		4,00					
	Reducing abstraction directly from water body (ex. Rainwater collection and reuse) promoting replenishment.		4,00					
2.a	**Wastewater discharges non IED installations**	9						
	Compliance of ELV without link to the WFD (flat values) and with effects on water status		-9,00					
	Compliance of ELV without link to the WFD (flat values) and with no known effects on water status		2,00					
	Compliance of ELV with link to the WFD		7,00					
3	**Water Reuse**	9						
	Promotion of water reuse with negative impacts on final concentration of the wastewaters discharged with negative impact on surface water		-6,00					
	Promotion of water reuse with negative impacts on final concentration of the wastewaters discharged and no impact on groundwater abstraction		-3,00					
	Promotion of water reuse without negative impacts on final concentration of the wastewaters discharged		3,00					
	Promotion of water reuse with positive impacts on final concentration of the wastewaters discharged		6,00					
4	**Best management practice & technologies**	9						
	Use of lower level than BAT		-9,00					
	Use of BAT		1,00					
	Promotion of management solutions to reduce CO2 emissions		3,50					
	Use of new technologies (go beyond BAT, with promotion of new developments) (ex. Equipment, maintenance and process improvement to reduce the microplastic release into effluent)		4,50					
5	**Priority substances (PS) / priority hazardous substances (PHS) and other substances (OS)/ specific pollutants (SP)**	9						
	With PHS and no actions to foreseen the ceasing or phase-out discharges, emissions and losses		-6,00					
	With PS/OS/SP and no actions to foreseen the reduction of discharges, emissions and losses		-3,00					
	With PS/OS/SP and actions to foreseen the reduction of discharges, emissions and losses		3,00					
	With PHS and actions to foreseen the ceasing or phase-out discharges, emissions and losses		6,00					
	∑KF +++			**0**	**0**			

ID Key Factor	Key and sub-key factors	Key factor value (F_{key})	Sub-Key factor value ($f_{i\ s\text{-}key}$)	Key factor (applicable-1; Non applicable - 0)	Sub-key factor(applicable-1; Non applicable - 0); All sub key factors are applicable when key factor applies	Sub-Key factor value ($f_{i\ s\text{-}key}$) (0 to measures/situations not in place and 1 for measures/situations in place)	Weighting factor ($f_{i\ w}$)	$f_{i\ s\text{-}Key}$ x $f_{i\ w}$
6	Microplastics and/or Compounds of emergent concern	5						
	Promotion of removal solutions to reduce microplastic content in wastewater discharge		2,50					
	Promotion of removal solutions to reduce compounds of emergent concern content in wastewater discharge		2,50					
7	Biodiversity	5						
	Promotion of water reuse with negative impacts on biodiversity (water quality and quantity index)		-5,00					
	Promotion of water reuse without negative impacts on biodiversity (water quality and quantity index)		2,00					
	Promotion of water reuse with positive impacts on biodiversity (water quality and quantity index)		3,00					
8	Recovery of nutrients	5						
	Without removal of nutrients with visible negative effects on water bodies (directly linked with the installation)		-5,00					
	Removal of nutrients to prevent negative effects on water bodies without further nutrient uses		0,50					
	Just recovery of nutrients for further uses (without influence on water bodies)		1,50					
	Removal of nutrients to prevent negative effects on water bodies with further nutrient uses (ex. Struvite recovery)		3,00					
9	Internal industrial symbiosis	5						
	Without promotion of integrated approach for competitive advantages.		-5,00					
	Promotion of integrated approach for competitive advantages through the exchange of water, materials and energy between industries (ex. Wastewater with metals reused in a metal factory)		5,00					
	∑KF ++			0	0			
10	Sludge	1						
	Minimization of sludge production, bio-thermal energy production from anaerobic digestion and reuse of treated sludge from aerobic digestion with impacts on final concentration of the wastewaters discharged		-1,00					
	Minimization of sludge production, bio-thermal energy production from anaerobic digestion and reuse of treated sludge from aerobic digestion without impacts on final concentration of the wastewaters discharged		1,00					
11	Voluntary and incentive instruments	1						
	Without adoption of regulatory instruments, economic instruments, certification and labelling rules, environmental management systems)		-1,00					
	Adoption of regulatory instruments, economic instruments, certification and labelling rules, environmental management systems as measures towards the circular economy		1,00					
	∑KF +			0	0			
						$\sum(f_{i\ s\text{-}Key} \times f_{i\ w})$		
						N_f		
						Ic		

IED Installations

ID Key Factor	Key and sub-key factors	Key factor value (F_{key})	Sub-Key factor value ($f_{i\ s\text{-}key}$)	Key factor (applicable-1; Non applicable - 0)	Sub-key factor(applicable-1; Non applicable - 0); All sub key factors are applicable when key factor applies	Sub-Key factor value ($f_{i\ s\text{-}key}$) (0 to measures/situations not in place and 1 for measures/situations in place)	Weighting factor ($f_{i\ w}$)	$f_{i\ s\text{-}Key}$ x $f_{i\ w}$
1	**Freshwater consumption**	9						
	Measures to reduce consumption without linking the impacts on the quality of wastewaters and contributing directly to its degradation		-9,00					
	Measures to reduce consumption without linking impacts on the quality of wastewaters (with non-significant variation on wastewater quality, e.g., reduction on groundwater abstraction with low impacts on wastewaters)		1,00					
	Measures to reduce consumption with measures to reduce possible effects of effluents concentration		4,00					
	Reducing abstraction directly from water body (ex. Rainwater collection and reuse) promoting replenishment.		4,00					
2.b	**Wastewater discharges IED installations**	9						
	Compliance of BREF-EAV without link to the WFD		-9,00					
	Situations where BREF-EAV can be equal to ELV, according check-list		2,00					
	Compliance of ELV (ELV defined according WFD principles, where ELV needs to be lower than BREF-EAV, according check-list)		7,00					
3	**Water Reuse**	9						
	Promotion of water reuse with negative impacts on final concentration of the wastewaters discharged with negative impact on surface water		-6,00					
	Promotion of water reuse with negative impacts on final concentration of the wastewaters discharged and no impact on groundwater abstraction		-3,00					
	Promotion of water reuse without negative impacts on final concentration of the wastewaters discharged		3,00					
	Promotion of water reuse with positive impacts on final concentration of the wastewaters discharged		6,00					
4	**Best management practice & technologies**	9						
	Use of lower level than BAT		-9,00					
	Use of BAT		1,00					
	Promotion of management solutions to reduce CO2 emissions		3,50					
	Use of new technologies (go beyond BAT, with promotion of new developments) (ex. Equipment, maintenance and process improvement to reduce the microplastic release into effluent)		4,50					
5	**Priority substances (PS) / priority hazardous substances (PHS) and other substances (OS)/ specific pollutants (SP)**	9						
	With PHS and no actions to foreseen the ceasing or phase-out discharges, emissions and losses		-6,00					
	With PS/OS/SP and no actions to foreseen the reduction of discharges, emissions and losses		-3,00					
	With PS/OS/SP and actions to foreseen the reduction of discharges, emissions and losses		3,00					
	With PHS and actions to foreseen the ceasing or phase-out discharges, emissions and losses		6,00					
	∑KF +++			**0**	**0**			

ID Key Factor	Key and sub-key factors	Key factor value (F_{key})	Sub-Key factor value ($f_{i\ s\text{-}key}$)	Key factor (applicable-1; Non applicable - 0)	Sub-key factor(applicable-1; Non applicable - 0); All sub key factors are applicable when key factor applies	Sub-Key factor value ($f_{i\ s\text{-}key}$) (0 to measures/situations not in place and 1 for measures/situations in place)	Weighting factor ($f_{i\ w}$)	$f_{i\ s\text{-}Key} \times f_{i\ w}$
6	Microplastics and/or Compounds of emergent concern	5						
	Promotion of removal solutions to reduce microplastic content in wastewater discharge		2,50					
	Promotion of removal solutions to reduce compounds of emergent concern content in wastewater discharge		2,50					
7	Biodiversity	5						
	Promotion of water reuse with negative impacts on biodiversity (water quality and quantity index)		-5,00					
	Promotion of water reuse without negative impacts on biodiversity (water quality and quantity index)		2,00					
	Promotion of water reuse with positive impacts on biodiversity (water quality and quantity index)		3,00					
8	Recovery of nutrients	5						
	Without removal of nutrients with visible negative effects on water bodies (directly linked with the installation)		-5,00					
	Removal of nutrients to prevent negative effects on water bodies without further nutrient uses		0,50					
	Just recovery of nutrients for further uses (without influence on water bodies)		1,50					
	Removal of nutrients to prevent negative effects on water bodies with further nutrient uses (ex. Struvite recovery)		3,00					
9	Internal industrial symbiosis	5						
	Without promotion of integrated approach for competitive advantages.		-5,00					
	Promotion of integrated approach for competitive advantages through the exchange of water, materials and energy between industries (ex. Wastewater with metals reused in a metal factory)		5,00					
	∑KF ++			0	0			
10	Sludge	1						
	Minimization of sludge production, bio-thermal energy production from anaerobic digestion and reuse of treated sludge from aerobic digestion with impacts on final concentration of the wastewaters discharged		-1,00					
	Minimization of sludge production, bio-thermal energy production from anaerobic digestion and reuse of treated sludge from aerobic digestion without impacts on final concentration of the wastewaters discharged		1,00					
11	Voluntary and incentive instruments	1						
	Without adoption of regulatory instruments, economic instruments, certification and labelling rules, environmental management systems)		-1,00					
	Adoption of regulatory instruments, economic instruments, certification and labelling rules, environmental management systems as measures towards the circular economy		1,00					
	∑KF +			0	0			
						$\sum(f_{i\ s\text{-}Key} \times f_{i\ w})$		
						N_f		
						Ic		

ANNEX II: Examples of circularity index applied on national cases of participant Member States

In this annex some examples of application of the Circularity Index on national cases of participant Member States are reported.

CASE STUDY A

Example 1:
The keys factors were applied to a wastewater treatment plant for a pulp mill before the environmental and discharge permit review[4]. The key operation details are:

Before permit review
- Production of pulp using virgin fibres from pine and eucalyptus
- Annual average production: 262800 t/year
- Discharge of treated wastewaters: 15000 m^3/day
- Treatment process: Biological (activated sludge) with prior neutralization and addition of nutrients (phosphoric acid and urea) for biological stabilization

Additional information: The wastewater treatment plant also treats leachates from an old industrial landfill located in the industrial site.

[4] For additional information see: Farabegoli, G. et al (2018). Addendum: Integrated Water Approach – A practical guide for IED permit writers. IMPEL, Brussels.

ID Key Factor	Key and sub-key factors	Key factor value (F_{key})	Sub-Key factor value ($f_{i\ s\text{-}key}$)	Key factor (applicable-1; Non applicable - 0)	Sub-key factor(applicable-1; Non applicable - 0); All sub key factors are applicable when key factor applies	Sub-Key factor value ($f_{i\ s\text{-}key}$) (0 to measures/situations not in place and 1 for measures/situations in place)	Weighting factor ($f_{i\ w}$)	$f_{i\ s\text{-}Key}$ x $f_{i\ w}$
1	Freshwater consumption	9		1				
	Measures to reduce consumption without linking the impacts on the quality of wastewaters and contributing directly to its degradation		-9,00		1	1	0,05	-0,47
	Measures to reduce consumption without linking impacts on the quality of wastewaters (with non-significant variation on wastewater quality, e.g., reduction on groundwater abstraction with low impacts on wastewaters)		1,00		1	0	0,00	0,00
	Measures to reduce consumption with measures to reduce possible effects of effluents concentration		4,00		1	0	0,00	0,00
	Reducing abstraction directly from water body (ex. Rainwater collection and reuse) promoting replenishment.		4,00		1	1	0,02	0,09
2.b	Wastewater discharges IED installations	9		1				
	Compliance of BREF-EAV without link to the WFD		-9,00		1	1	0,05	-0,47
	Situations where BREF-EAV can be equal to ELV, according check-list		2,00		1	0	0,00	0,00
	Compliance of ELV (ELV defined according WFD principles, where ELV needs to be lower than BREF-EAV, according check-list)		7,00		1	0	0,00	0,00
3	Water Reuse	9		1				
	Promotion of water reuse with negative impacts on final concentration of the wastewaters discharged with negative impact on surface water		-6,00		1	0	0,00	0,00
	Promotion of water reuse with negative impacts on final concentration of the wastewaters discharged and no impact on groundwater abstraction		-3,00		1	0	0,00	0,00
	Promotion of water reuse without negative impacts on final concentration of the wastewaters discharged		3,00		1	0	0,00	0,00
	Promotion of water reuse with positive impacts on final concentration of the wastewaters discharged		6,00		1	0	0,00	0,00
4	Best management practice & technologies	9		1				
	Use of lower level than BAT		-9,00		1	0	0,00	0,00
	Use of BAT		1,00		1	1	0,01	0,01
	Promotion of management solutions to reduce CO2 emissions		3,50		1	0	0,00	0,00
	Use of new technologies (go beyond BAT, with promotion of new developments) (ex. Equipment, maintenance and process improvement to reduce the microplastic release into effluent)		4,50		1	0	0,00	0,00
5	Priority substances (PS) / priority hazardous substances (PHS) and other substances (OS)/ specific pollutants (SP)	9		1				
	With PHS and no actions to foreseen the ceasing or phase-out discharges, emissions and losses		-6,00		1	0	0,00	0,00
	With PS/OS/SP and no actions to foreseen the reduction of discharges, emissions and losses		-3,00		1	1	0,02	-0,05
	With PS/OS/SP and actions to foreseen the reduction of discharges, emissions and losses		3,00		1	0	0,00	0,00
	With PHS and actions to foreseen the ceasing or phase-out discharges, emissions and losses		6,00		1	0	0,00	0,00
	∑KF +++			5	19			

ID Key Factor	Key and sub-key factors	Key factor value (F_{key})	Sub-Key factor value ($f_{i\ s\text{-}key}$)	Key factor (applicable-1; Non applicable - 0)	Sub-key factor(applicable-1; Non applicable - 0); All sub key factors are applicable when key factor applies	Sub-Key factor value ($f_{i\ s\text{-}key}$) (0 to measures/situations not in place and 1 for measures/situations in place)	Weighting factor ($f_{i\ w}$)	$f_{i\ s\text{-}Key} \times f_{i\ w}$
6	Microplastics and/or Compounds of emergent concern	5		0				
	Promotion of removal solutions to reduce microplastic content in wastewater discharge		2,50		0	0	0,00	0,00
	Promotion of removal solutions to reduce compounds of emergent concern content in wastewater discharge		2,50		0	0	0,00	0,00
7	Biodiversity	5		1				
	Promotion of water reuse with negative impacts on biodiversity (water quality and quantity index)		-5,00		1	0	0,00	0,00
	Promotion of water reuse without negative impacts on biodiversity (water quality and quantity index)		2,00		1	0	0,00	0,00
	Promotion of water reuse with positive impacts on biodiversity (water quality and quantity index)		3,00		1	0	0,00	0,00
8	Recovery of nutrients	5		1				
	Without removal of nutrients with visible negative effects on water bodies (directly linked with the installation)		-5,00		1	1	0,11	-0,56
	Removal of nutrients to prevent negative effects on water bodies without further nutrient uses		0,50		1	0	0,00	0,00
	Just recovery of nutrients for further uses (without influence on water bodies)		1,50		1	0	0,00	0,00
	Removal of nutrients to prevent negative effects on water bodies with further nutrient uses (ex. Struvite recovery)		3,00		1	0	0,00	0,00
9	Internal industrial symbiosis	5		1				
	Without promotion of integrated approach for competitive advantages.		-5,00		1	0	0,00	0,00
	Promotion of integrated approach for competitive advantages through the exchange of water, materials and energy between industries (ex. Wastewater with metals reused in a metal factory)		5,00		1	1	0,11	0,56
	∑KF ++			3	9			
10	Sludge	1		1				
	Minimization of sludge production, bio-thermal energy production from anaerobic digestion and reuse of treated sludge from aerobic digestion with impacts on final concentration of the wastewaters discharged		-1,00		1	0	0,00	0,00
	Minimization of sludge production, bio-thermal energy production from anaerobic digestion and reuse of treated sludge from aerobic digestion without impacts on final concentration of the wastewaters discharged		1,00		1	0	0,00	0,00
11	Voluntary and incentive instruments	1		1				
	Without adoption of regulatory instruments, economic instruments, certification and labelling rules, environmental management systems)		-1,00		1	1	0,25	-0,25
	Adoption of regulatory instruments, economic instruments, certification and labelling rules, environmental management systems as measures towards the circular economy		1,00		1	0	0,00	0,00
	∑KF +			2	4			
						$\sum(f_{i\ s\text{-}Key} \times f_{i\ w})$		-1,15
						N_f		0,93
						Ic		-1,24

	Ic <0	Negative Circularity: Negative inputs for the circular economy
	Ic = 0	No inputs for circular economy
	0 < Ic ≤ 0,85	Low Circularity: Low level of inputs for circular economy
	0,85 < Ic ≤ 1,5	Medium Circularity: Medium level of inputs for circular economy
	Ic > 1,5	High Circularity: High level of inputs for circular economy

Example 2:

The keys factors were applied to a wastewater treatment plant for a pulp mill after the environmental and discharge permit review. The key operation details are:

After permit review

- Production of pulp using virgin fibres from pine and eucalyptus
- Annual average production: 267180 t/year (732 t/day)
- Discharge of treated wastewaters: 15000 m^3/day
- Treatment process: Membrane bioreactor (MBR) with chemical precipitation of phosphorous

Additional information: The wastewater treatment plant also treats leachates from an old industrial landfill located in the industrial site.

ID Key Factor	Key and sub-key factors	Key factor value (F_{key})	Sub-Key factor value ($f_{i\ s\text{-}key}$)	Key factor (applicable-1; Non applicable - 0)	Sub-key factor(applicable-1; Non applicable - 0); All sub key factors are applicable when key factor applies	Sub-Key factor value ($f_{i\ s\text{-}key}$) (0 to measures/situations not in place and 1 for measures/situations in place)	Weighting factor ($f_{i\ w}$)	$f_{i\ s\text{-}Key}$ x $f_{i\ w}$
1	**Freshwater consumption**	9		1				
	Measures to reduce consumption without linking the impacts on the quality of wastewaters and contributing directly to its degradation		-9,00		1	0	0,00	0,00
	Measures to reduce consumption without linking impacts on the quality of wastewaters (with non-significant variation on wastewater quality, e.g., reduction on groundwater abstraction with low impacts on wastewaters)		1,00		1	0	0,00	0,00
	Measures to reduce consumption with measures to reduce possible effects of effluents concentration		4,00		1	1	0,02	0,09
	Reducing abstraction directly from water body (ex. Rainwater collection and reuse) promoting replenishment.		4,00		1	1	0,02	0,09
2.b	**Wastewater discharges IED installations**	9		1				
	Compliance of BREF-EAV without link to the WFD		-9,00		1	0	0,00	0,00
	Situations where BREF-EAV can be equal to ELV, according check-list		2,00		1	0	0,00	0,00
	Compliance of ELV (ELV defined according WFD principles, where ELV needs to be lower than BREF-EAV, according check-list)		7,00		1	1	0,04	0,29
3	**Water Reuse**	9		1				
	Promotion of water reuse with negative impacts on final concentration of the wastewaters discharged with negative impact on surface water		-6,00		1	0	0,00	0,00
	Promotion of water reuse with negative impacts on final concentration of the wastewaters discharged and no impact on groundwater abstraction		-3,00		1	0	0,00	0,00
	Promotion of water reuse without negative impacts on final concentration of the wastewaters discharged		3,00		1	1	0,02	0,05
	Promotion of water reuse with positive impacts on final concentration of the wastewaters discharged		6,00		1	0	0,00	0,00
4	**Best management practice & technologies**	9		1				
	Use of lower level than BAT		-9,00		1	0	0,00	0,00
	Use of BAT		1,00		1	0	0,01	0,00
	Promotion of management solutions to reduce CO2 emissions		3,50		1	0	0,00	0,00
	Use of new technologies (go beyond BAT, with promotion of new developments) (ex. Equipment, maintenance and process improvement to reduce the microplastic release into effluent)		4,50		1	1	0,03	0,12
5	**Priority substances (PS) / priority hazardous substances (PHS) and other substances (OS)/ specific pollutants (SP)**	9		1				
	With PHS and no actions to foreseen the ceasing or phase-out discharges, emissions and losses		-6,00		1	0	0,00	0,00
	With PS/OS/SP and no actions to foreseen the reduction of discharges, emissions and losses		-3,00		1	0	0,00	0,00
	With PS/OS/SP and actions to foreseen the reduction of discharges, emissions and losses		3,00		1	1	0,02	0,05
	With PHS and actions to foreseen the ceasing or phase-out discharges, emissions and losses		6,00		1	0	0,00	0,00
	∑KF +++			**5**	**19**			

ID Key Factor	Key and sub-key factors	Key factor value (F_{key})	Sub-Key factor value ($f_{i\ s\text{-}key}$)	Key factor (applicable-1; Non applicable - 0)	Sub-key factor(applicable-1; Non applicable - 0); All sub key factors are applicable when key factor applies	Sub-Key factor value ($f_{i\ s\text{-}key}$) (0 to measures/situations not in place and 1 for measures/situations in place)	Weighting factor ($f_{i\ w}$)	$f_{i\ s\text{-}Key} \times f_{i\ w}$
6	Microplastics and/or Compounds of emergent concern	5		0				
	Promotion of removal solutions to reduce microplastic content in wastewater discharge		2,50		0	0	0,00	0,00
	Promotion of removal solutions to reduce compounds of emergent concern content in wastewater discharge		2,50		0	0	0,00	0,00
7	Biodiversity	5		1				
	Promotion of water reuse with negative impacts on biodiversity (water quality and quantity index)		-5,00		1	0	0,00	0,00
	Promotion of water reuse without negative impacts on biodiversity (water quality and quantity index)		2,00		1	1	0,04	0,09
	Promotion of water reuse with positive impacts on biodiversity (water quality and quantity index)		3,00		1	0	0,00	0,00
8	Recovery of nutrients	5		1				
	Without removal of nutrients with visible negative effects on water bodies (directly linked with the installation)		-5,00		1	0	0,00	0,00
	Removal of nutrients to prevent negative effects on water bodies without further nutrient uses		0,50		1	1	0,01	0,01
	Just recovery of nutrients for further uses (without influence on water bodies)		1,50		1	0	0,00	0,00
	Removal of nutrients to prevent negative effects on water bodies with further nutrient uses (ex. Struvite recovery)		3,00		1	0	0,00	0,00
9	Internal industrial symbiosis	5		1				
	Without promotion of integrated approach for competitive advantages.		-5,00		1	0	0,00	0,00
	Promotion of integrated approach for competitive advantages through the exchange of water, materials and energy between industries (ex. Wastewater with metals reused in a metal factory)		5,00		1	1	0,11	0,56
	∑KF ++			3	9			
10	Sludge	1		1				
	Minimization of sludge production, bio-thermal energy production from anaerobic digestion and reuse of treated sludge from aerobic digestion with impacts on final concentration of the wastewaters discharged		-1,00		1	0	0,00	0,00
	Minimization of sludge production, bio-thermal energy production from anaerobic digestion and reuse of treated sludge from aerobic digestion without impacts on final concentration of the wastewaters discharged		1,00		1	0	0,00	0,00
11	Voluntary and incentive instruments	1		1				
	Without adoption of regulatory instruments, economic instruments, certification and labelling rules, environmental management systems)		-1,00		1	1	0,25	-0,25
	Adoption of regulatory instruments, economic instruments, certification and labelling rules, environmental management systems as measures towards the circular economy		1,00		1	0	0,00	0,00
	∑KF +			2	4			
						$\sum(f_{i\ s\text{-}Key} \times f_{i\ w})$		1,10
						N_f		0,93
						Ic		1,19

	Ic <0	Negative Circularity: Negative inputs for the circular economy
	Ic = 0	No inputs for circular economy
	0 < Ic ≤ 0,85	Low Circularity: Low level of inputs for circular economy
	0,85 < Ic ≤ 1,5	Medium Circularity: Medium level of inputs for circular economy
	Ic > 1,5	High Circularity: High level of inputs for circular economy

Example 3:

The keys factors were applied to an urban wastewater treatment plant. The key operation details are:

- Urban wastewater treatment plant without industrial connections but with strong seasonality effect
- Load capacity (p.e): 140000 p.e. (1 p.e. = 60g BOD_5 per day)
- Discharge of treated wastewaters: 25000 m^3/day
- Treatment process: Biological treatment (activated sludge by carrousel) with biological nitrogen removal and phosphorous chemical removal and ultraviolet disinfection system. Since the wastewaters have urban origin some priority, priority hazardous, other pollutants or specific pollutants may be present in low concentrations due to diffuse sources in urban areas (garments washing, cosmetic and cleaning products use, runoffs in urban sites, etc.). The levels of this pollutants are monitored under self-monitoring permit conditions and controlled in water bodies under WFD monitoring programs (e.g. nonylphenols, di-2-ethylhexyl phthalate, trichloromethane, heavy metals, etc.)
- Stabilized sludge is used for agriculture purposes
- At urban level measures to reduce water consumption are taken such as public awareness campaigns, leaks control, urban irrigation control, etc.
- Treated wastewaters are 100% reused to:
    - Support ecosystem, i.e. to keep an ecological flow to a pond classified as protected area according habitats directive. The pond and catchment area are also classified as sensitive areas due to eutrophication risk
    - Irrigation of a golf course
- The company is certified under ISO 14001:2015

ID Key Factor	Key and sub-key factors	Key factor value (F_{key})	Sub-Key factor value ($f_{i\ s\text{-}key}$)	Key factor (applicable-1; Non applicable - 0)	Sub-key factor(applicable-1; Non applicable - 0); All sub key factors are applicable when key factor applies	Sub-Key factor value ($f_{i\ s\text{-}key}$) (0 to measures/situations not in place and 1 for measures/situations in place)	Weighting factor ($f_{i\ w}$)	$f_{i\ s\text{-}Key}$ x $f_{i\ w}$
1	**Freshwater consumption**	9		1				
	Measures to reduce consumption without linking the impacts on the quality of wastewaters and contributing directly to its degradation		-9,00		1	0	0,00	0,00
	Measures to reduce consumption without linking impacts on the quality of wastewaters (with non-significant variation on wastewater quality, e.g., reduction on groundwater abstraction with low impacts on wastewaters)		1,00		1	1	0,01	0,01
	Measures to reduce consumption with measures to reduce possible effects of effluents concentration		4,00		1	0	0,00	0,00
	Reducing abstraction directly from water body (ex. Rainwater collection and reuse) promoting replenishment.		4,00		1	0	0,00	0,00
2.a	**Wastewater discharges non IED installations**	9		1				
	Compliance of ELV without link to the WFD (flat values) and with effects on water status		-9,00		1	0	0,00	0,00
	Compliance of ELV without link to the WFD (flat values) and with no known effects on water status		2,00		1	0	0,00	0,00
	Compliance of ELV with link to the WFD		7,00		1	1	0,04	0,29
3	**Water Reuse**	9		1				
	Promotion of water reuse with negative impacts on final concentration of the wastewaters discharged with negative impact on surface water		-6,00		1	0	0,00	0,00
	Promotion of water reuse with negative impacts on final concentration of the wastewaters discharged and no impact on groundwater abstraction		-3,00		1	0	0,00	0,00
	Promotion of water reuse without negative impacts on final concentration of the wastewaters discharged		3,00		1	0	0,00	0,00
	Promotion of water reuse with positive impacts on final concentration of the wastewaters discharged		6,00		1	1	0,04	0,21
4	**Best management practice & technologies**	9		1				
	Use of lower level than BAT		-9,00		1	0	0,00	0,00
	Use of BAT		1,00		1	0	0,00	0,00
	Promotion of management solutions to reduce CO2 emissions		3,50		1	0	0,00	0,00
	Use of new technologies (go beyond BAT, with promotion of new developments) (ex. Equipment, maintenance and process improvement to reduce the microplastic release into effluent)		4,50		1	1	0,03	0,12
5	**Priority substances (PS) / priority hazardous substances (PHS) and other substances (OS)/ specific pollutants (SP)**	9		1				
	With PHS and no actions to foreseen the ceasing or phase-out discharges, emissions and losses		-6,00		1	1	0,04	-0,21
	With PS/OS/SP and no actions to foreseen the reduction of discharges, emissions and losses		-3,00		1	1	0,02	-0,05
	With PS/OS/SP and actions to foreseen the reduction of discharges, emissions and losses		3,00		1	0	0,00	0,00
	With PHS and actions to foreseen the ceasing or phase-out discharges, emissions and losses		6,00		1	0	0,00	0,00
	∑KF +++			**5**	**19**			

ID Key Factor	Key and sub-key factors	Key factor value (F_{key})	Sub-Key factor value ($f_{i\ s\text{-}key}$)	Key factor (applicable-1; Non applicable - 0)	Sub-key factor(applicable-1; Non applicable - 0); All sub key factors are applicable when key factor applies	Sub-Key factor value ($f_{i\ s\text{-}key}$) (0 to measures/situations not in place and 1 for measures/situations in place)	Weighting factor ($f_{i\ w}$)	$f_{i\ s\text{-}Key} \times f_{i\ w}$
6	Microplastics and/or Compounds of emergent concern	5		0				
	Promotion of removal solutions to reduce microplastic content in wastewater discharge		2,50		0	0	0,00	0,00
	Promotion of removal solutions to reduce compounds of emergent concern content in wastewater discharge		2,50		0	0	0,00	0,00
7	Biodiversity	5		1				
	Promotion of water reuse with negative impacts on biodiversity (water quality and quantity index)		-5,00		1	0	0,00	0,00
	Promotion of water reuse without negative impacts on biodiversity (water quality and quantity index)		2,00		1	0	0,00	0,00
	Promotion of water reuse with positive impacts on biodiversity (water quality and quantity index)		3,00		1	1	0,09	0,26
8	Recovery of nutrients	5		1				
	Without removal of nutrients with visible negative effects on water bodies (directly linked with the installation)		-5,00		1	0	0,00	0,00
	Removal of nutrients to prevent negative effects on water bodies without further nutrient uses		0,50		1	1	0,01	0,01
	Just recovery of nutrients for further uses (without influence on water bodies)		1,50		1	0	0,00	0,00
	Removal of nutrients to prevent negative effects on water bodies with further nutrient uses (ex. Struvite recovery)		3,00		1	0	0,00	0,00
9	Internal industrial symbiosis	5		0				
	Without promotion of integrated approach for competitive advantages.		-5,00		0	0	0,00	0,00
	Promotion of integrated approach for competitive advantages through the exchange of water, materials and energy between industries (ex. Wastewater with metals reused in a metal factory)		5,00		0	0	0,00	0,00
	∑KF ++			2	7			
10	Sludge	1		1				
	Minimization of sludge production, bio-thermal energy production from anaerobic digestion and reuse of treated sludge from aerobic digestion with impacts on final concentration of the wastewaters discharged		-1,00		0	0	0,00	0,00
	Minimization of sludge production, bio-thermal energy production from anaerobic digestion and reuse of treated sludge from aerobic digestion without impacts on final concentration of the wastewaters discharged		1,00		1	1	1,00	1,00
11	Voluntary and incentive instruments	1		1				
	Without adoption of regulatory instruments, economic instruments, certification and labelling rules, environmental management systems)		-1,00		0	0	0,00	0,00
	Adoption of regulatory instruments, economic instruments, certification and labelling rules, environmental management systems as measures towards the circular economy		1,00		0	1	0,00	0,00
	∑KF +			2	1			
						$\sum(f_{i\ s\text{-}Key} \times f_{i\ w})$		1,62
						N_f		0,85
						Ic		1,91

	Ic <0	Negative Circularity: Negative inputs for the circular economy
	Ic = 0	No inputs for circular economy
	0 < Ic ≤ 0,85	Low Circularity: Low level of inputs for circular economy
	0,85 < Ic ≤ 1,5	Medium Circularity: Medium level of inputs for circular economy
	Ic > 1,5	High Circularity: High level of inputs for circular economy

CASE STUDY B

Example 1:
The keys factors were applied to a wastewater treatment plant for pulp and paper industry. The key operation details are:

- Production of tissue paper using virgin fibres
- Annual average production: 30,000 t/year
- Discharge of treated wastewaters: 500 m^3/day
- Treatment process: Chemical-physical and biological

ID Key Factor	Key and sub-key factors	Key factor value (F_{key})	Sub-Key factor value ($f_{i\ s\text{-}key}$)	Key factor (applicable-1; Non applicable - 0)	Sub-key factor(applicable-1; Non applicable - 0); All sub key factors are applicable when key factor applies	Sub-Key factor value ($f_{i\ s\text{-}key}$) (0 to measures/situations not in place and 1 for measures/situations in place)	Weighting factor ($f_{i\ w}$)	$f_{i\ s\text{-}Key}$ x $f_{i\ w}$
1	**Freshwater consumption**	9		1				
	Measures to reduce consumption without linking the impacts on the quality of wastewaters and contributing directly to its degradation		-9,00		1	0	0,00	0,00
	Measures to reduce consumption without linking impacts on the quality of wastewaters (with non-significant variation on wastewater quality, e.g., reduction on groundwater abstraction with low impacts on wastewaters)		1,00		1	1	0,01	0,01
	Measures to reduce consumption with measures to reduce possible effects of effluents concentration		4,00		1	0	0,00	0,00
	Reducing abstraction directly from water body (ex. Rainwater collection and reuse) promoting replenishment.		4,00		1	0	0,00	0,00
2.b	**Wastewater discharges IED installations**	9		1				
	Compliance of BREF-EAV without link to the WFD		-9,00		1	0	0,00	0,00
	Situations where BREF-EAV can be equal to ELV, according check-list		2,00		1	1	0,01	0,03
	Compliance of ELV (ELV defined according WFD principles, where ELV needs to be lower than BREF-EAV, according check-list)		7,00		1	1	0,05	0,36
3	**Water Reuse**	9		1				
	Promotion of water reuse with negative impacts on final concentration of the wastewaters discharged with negative impact on surface water		-6,00		1	1	0,04	-0,27
	Promotion of water reuse with negative impacts on final concentration of the wastewaters discharged and no impact on groundwater abstraction		-3,00		1	0	0,00	0,00
	Promotion of water reuse without negative impacts on final concentration of the wastewaters discharged		3,00		1	0	0,00	0,00
	Promotion of water reuse with positive impacts on final concentration of the wastewaters discharged		6,00		1	0	0,00	0,00
4	**Best management practice & technologies**	9		1				
	Use of lower level than BAT		-9,00		1	0	0,00	0,00
	Use of BAT		1,00		1	1	0,01	0,01
	Promotion of management solutions to reduce CO2 emissions		3,50		1	1	0,03	0,09
	Use of new technologies (go beyond BAT, with promotion of new developments) (ex. Equipment, maintenance and process improvement to reduce the microplastic release into effluent)		4,50		1	0	0,00	0,00
5	**Priority substances (PS) / priority hazardous substances (PHS) and other substances (OS)/ specific pollutants (SP)**	9		0				
	With PHS and no actions to foreseen the ceasing or phase-out discharges, emissions and losses		-6,00		0	0	0,00	0,00
	With PS/OS/SP and no actions to foreseen the reduction of discharges, emissions and losses		-3,00		0	0	0,00	0,00
	With PS/OS/SP and actions to foreseen the reduction of discharges, emissions and losses		3,00		0	0	0,00	0,00
	With PHS and actions to foreseen the ceasing or phase-out discharges, emissions and losses		6,00		0	0	0,00	0,00
	∑KF +++			**4**	**15**			

ID Key Factor	Key and sub-key factors	Key factor value (F_{key})	Sub-Key factor value ($f_{i\ s\text{-}key}$)	Key factor (applicable-1; Non applicable - 0)	Sub-key factor(applicable-1; Non applicable - 0); All sub key factors are applicable when key factor applies	Sub-Key factor value ($f_{i\ s\text{-}key}$) (0 to measures/situations not in place and 1 for measures/situations in place)	Weighting factor ($f_{i\ w}$)	$f_{i\ s\text{-}Key} \times f_{i\ w}$
6	Microplastics and/or Compounds of emergent concern	5		0				
	Promotion of removal solutions to reduce microplastic content in wastewater discharge		2,50		0	0	0,00	0,00
	Promotion of removal solutions to reduce compounds of emergent concern content in wastewater discharge		2,50		0	0	0,00	0,00
7	Biodiversity	5		1				
	Promotion of water reuse with negative impacts on biodiversity (water quality and quantity index)		-5,00		1	0	0,00	0,00
	Promotion of water reuse without negative impacts on biodiversity (water quality and quantity index)		2,00		1	1	0,04	0,09
	Promotion of water reuse with positive impacts on biodiversity (water quality and quantity index)		3,00		1	0	0,00	0,00
8	Recovery of nutrients	5		1				
	Without removal of nutrients with visible negative effects on water bodies (directly linked with the installation)		-5,00		1	0	0,00	0,00
	Removal of nutrients to prevent negative effects on water bodies without further nutrient uses		0,50		1	1	0,01	0,01
	Just recovery of nutrients for further uses (without influence on water bodies)		1,50		1	0	0,00	0,00
	Removal of nutrients to prevent negative effects on water bodies with further nutrient uses (ex. Struvite recovery)		3,00		1	0	0,00	0,00
9	Internal industrial symbiosis	5		1				
	Without promotion of integrated approach for competitive advantages.		-5,00		1	1	0,11	-0,56
	Promotion of integrated approach for competitive advantages through the exchange of water, materials and energy between industries (ex. Wastewater with metals reused in a metal factory)		5,00		1	0	0,00	0,00
	∑KF ++			3	9			
10	Sludge	1		0				
	Minimization of sludge production, bio-thermal energy production from anaerobic digestion and reuse of treated sludge from aerobic digestion with impacts on final concentration of the wastewaters discharged		-1,00		0	0	0,00	0,00
	Minimization of sludge production, bio-thermal energy production from anaerobic digestion and reuse of treated sludge from aerobic digestion without impacts on final concentration of the wastewaters discharged		1,00		0	0	0,00	0,00
11	Voluntary and incentive instruments	1		1				
	Without adoption of regulatory instruments, economic instruments, certification and labelling rules, environmental management systems)		-1,00		1	0	0,00	0,00
	Adoption of regulatory instruments, economic instruments, certification and labelling rules, environmental management systems as measures towards the circular economy		1,00		1	1	0,50	0,50
	∑KF +			1	2			
						$\sum(f_{i\ s\text{-}Key} \times f_{i\ w})$		0,27
						N_f		0,78
						Ic		0,35

	Ic <0	Negative Circularity: Negative inputs for the circular economy
	Ic = 0	No inputs for circular economy
	0 < Ic ≤ 0,85	Low Circularity: Low level of inputs for circular economy
	0,85 < Ic ≤ 1,5	Medium Circularity: Medium level of inputs for circular economy
	Ic > 1,5	High Circularity: High level of inputs for circular economy

Example 2:

The key factors were applied to a biorefinery. The key operation details are:

- Production of the biorefinery: 560,000 t/year
- Primary treatment with sand separation and mechanical oil separator
- The wastewater is transferred to a consortium plant outside the Refinery

ID Key Factor	Key and sub-key factors	Key factor value (F_{key})	Sub-Key factor value ($f_{i\ s\text{-}key}$)	Key factor (applicable-1; Non applicable - 0)	Sub-key factor(applicable-1; Non applicable - 0); All sub key factors are applicable when key factor applies	Sub-Key factor value ($f_{i\ s\text{-}key}$) (0 to measures/situations not in place and 1 for measures/situations in place)	Weighting factor ($f_{i\ w}$)	$f_{i\ s\text{-}Key}$ x $f_{i\ w}$
1	Freshwater consumption	9		1				
	Measures to reduce consumption without linking the impacts on the quality of wastewaters and contributing directly to its degradation		-9,00		1	0	0,00	0,00
	Measures to reduce consumption without linking impacts on the quality of wastewaters (with non-significant variation on wastewater quality, e.g., reduction on groundwater abstraction with low impacts on wastewaters)		1,00		1	0	0,00	0,00
	Measures to reduce consumption with measures to reduce possible effects of effluents concentration		4,00		1	0	0,00	0,00
	Reducing abstraction directly from water body (ex. Rainwater collection and reuse) promoting replenishment.		4,00		1	1	0,03	0,12
2.b	Wastewater discharges IED installations	9		1				
	Compliance of BREF-EAV without link to the WFD		-9,00		1	1	0,07	-0,60
	Situations where BREF-EAV can be equal to ELV, according check-list		2,00		1	0	0,00	0,00
	Compliance of ELV (ELV defined according WFD principles, where ELV needs to be lower than BREF-EAV, according check-list)		7,00		1	0	0,00	0,00
3	Water Reuse	9		1				
	Promotion of water reuse with negative impacts on final concentration of the wastewaters discharged with negative impact on surface water		-6,00		1	0	0,00	0,00
	Promotion of water reuse with negative impacts on final concentration of the wastewaters discharged and no impact on groundwater abstraction		-3,00		1	0	0,00	0,00
	Promotion of water reuse without negative impacts on final concentration of the wastewaters discharged		3,00		1	1	0,02	0,07
	Promotion of water reuse with positive impacts on final concentration of the wastewaters discharged		6,00		1	0	0,00	0,00
4	Best management practice & technologies	9		1				
	Use of lower level than BAT		-9,00		1	0	0,00	0,00
	Use of BAT		1,00		1	1	0,01	0,01
	Promotion of management solutions to reduce CO2 emissions		3,50		1	1	0,03	0,09
	Use of new technologies (go beyond BAT, with promotion of new developments) (ex. Equipment, maintenance and process improvement to reduce the microplastic release into effluent)		4,50		1	1	0,03	0,15
5	Priority substances (PS) / priority hazardous substances (PHS) and other substances (OS)/ specific pollutants (SP)	9		0				
	With PHS and no actions to foreseen the ceasing or phase-out discharges, emissions and losses		-6,00		0	0	0,00	0,00
	With PS/OS/SP and no actions to foreseen the reduction of discharges, emissions and losses		-3,00		0	0	0,00	0,00
	With PS/OS/SP and actions to foreseen the reduction of discharges, emissions and losses		3,00		0	0	0,00	0,00
	With PHS and actions to foreseen the ceasing or phase-out discharges, emissions and losses		6,00		0	0	0,00	0,00
	∑KF +++			4	15			

ID Key Factor	Key and sub-key factors	Key factor value (F_{key})	Sub-Key factor value ($f_{i\ s\text{-}key}$)	Key factor (applicable-1; Non applicable - 0)	Sub-key factor(applicable-1; Non applicable - 0); All sub key factors are applicable when key factor applies	Sub-Key factor value ($f_{i\ s\text{-}key}$) (0 to measures/situations not in place and 1 for measures/situations in place)	Weighting factor ($f_{i\ w}$)	$f_{i\ s\text{-}Key} \times f_{i\ w}$
6	Microplastics and/or Compounds of emergent concern	5		0				
	Promotion of removal solutions to reduce microplastic content in wastewater discharge		2,50		0	0	0,00	0,00
	Promotion of removal solutions to reduce compounds of emergent concern content in wastewater discharge		2,50		0	0	0,00	0,00
7	Biodiversity	5		1				
	Promotion of water reuse with negative impacts on biodiversity (water quality and quantity index)		-5,00		1	0	0,00	0,00
	Promotion of water reuse without negative impacts on biodiversity (water quality and quantity index)		2,00		1	1	0,08	0,16
	Promotion of water reuse with positive impacts on biodiversity (water quality and quantity index)		3,00		1	0	0,00	0,00
8	Recovery of nutrients	5		0				
	Without removal of nutrients with visible negative effects on water bodies (directly linked with the installation)		-5,00		0	0	0,00	0,00
	Removal of nutrients to prevent negative effects on water bodies without further nutrient uses		0,50		0	0	0,00	0,00
	Just recovery of nutrients for further uses (without influence on water bodies)		1,50		0	0	0,00	0,00
	Removal of nutrients to prevent negative effects on water bodies with further nutrient uses (ex. Struvite recovery)		3,00		0	0	0,00	0,00
9	Internal industrial symbiosis	5		1				
	Without promotion of integrated approach for competitive advantages.		-5,00		1	0	0,00	0,00
	Promotion of integrated approach for competitive advantages through the exchange of water, materials and energy between industries (ex. Wastewater with metals reused in a metal factory)		5,00		1	1	0,20	1,00
	∑KF ++			2	5			
10	Sludge	1		0				
	Minimization of sludge production, bio-thermal energy production from anaerobic digestion and reuse of treated sludge from aerobic digestion with impacts on final concentration of the wastewaters discharged		-1,00		0	0	0,00	0,00
	Minimization of sludge production, bio-thermal energy production from anaerobic digestion and reuse of treated sludge from aerobic digestion without impacts on final concentration of the wastewaters discharged		1,00		0	0	0,00	0,00
11	Voluntary and incentive instruments	1		1				
	Without adoption of regulatory instruments, economic instruments, certification and labelling rules, environmental management systems)		-1,00		1	0	0,00	0,00
	Adoption of regulatory instruments, economic instruments, certification and labelling rules, environmental management systems as measures towards the circular economy		1,00		1	1	0,50	0,50
	∑KF +			1	2			
						$\sum(f_{i\ s\text{-}Key} \times f_{i\ w})$		1,49
						N_f		0,70
						Ic		2,13

	Ic <0	Negative Circularity: Negative inputs for the circular economy
	Ic = 0	No inputs for circular economy
	0 < Ic ≤ 0,85	Low Circularity: Low level of inputs for circular economy
	0,85 < Ic ≤ 1,5	Medium Circularity: Medium level of inputs for circular economy
	Ic > 1,5	High Circularity: High level of inputs for circular economy

Example 3:

The key factors were applied to an oil refinery. The key operation details are:

- Production of the oil refinery: 6,500,000 t/year
- The WWTP is divided in 3 sections:

1) TAE A: mechanical pre-treatments (oil separator with API separators, equalization/homogenization, flotation, sand filtration) + biological treatment (biofiltration). The output effluent is reused in the refinery production cycle

2) TAE B: consisting of an oil separator section (API separators) and a lifting section towards the TAE A.

3) TAE C: consisting of an oil separator section (API separators) and a lifting section towards the TAE B.

ID Key Factor	Key and sub-key factors	Key factor value (F_{key})	Sub-Key factor value ($f_{i\ s\text{-}key}$)	Key factor (applicable-1; Non applicable - 0)	Sub-key factor(applicable-1; Non applicable - 0); All sub key factors are applicable when key factor applies	Sub-Key factor value ($f_{i\ s\text{-}key}$) (0 to measures/situations not in place and 1 for measures/situations in place)	Weighting factor ($f_{i\ w}$)	$f_{i\ s\text{-}Key}$ x $f_{i\ w}$
1	Freshwater consumption	9		1				
	Measures to reduce consumption without linking the impacts on the quality of wastewaters and contributing directly to its degradation		-9,00		1	0	0,00	0,00
	Measures to reduce consumption without linking impacts on the quality of wastewaters (with non-significant variation on wastewater quality, e.g., reduction on groundwater abstraction with low impacts on wastewaters)		1,00		1	0	0,00	0,00
	Measures to reduce consumption with measures to reduce possible effects of effluents concentration		4,00		1	1	0,03	0,12
	Reducing abstraction directly from water body (ex. Rainwater collection and reuse) promoting replenishment.		4,00		1	1	0,03	0,12
2.b	Wastewater discharges IED installations	9		1				
	Compliance of BREF-EAV without link to the WFD		-9,00		1	1	0,07	-0,60
	Situations where BREF-EAV can be equal to ELV, according check-list		2,00		1	0	0,00	0,00
	Compliance of ELV (ELV defined according WFD principles, where ELV needs to be lower than BREF-EAV, according check-list)		7,00		1	0	0,00	0,00
3	Water Reuse	9		1				
	Promotion of water reuse with negative impacts on final concentration of the wastewaters discharged with negative impact on surface water		-6,00		1	1	0,04	-0,27
	Promotion of water reuse with negative impacts on final concentration of the wastewaters discharged and no impact on groundwater abstraction		-3,00		1	0	0,00	0,00
	Promotion of water reuse without negative impacts on final concentration of the wastewaters discharged		3,00		1	0	0,00	0,00
	Promotion of water reuse with positive impacts on final concentration of the wastewaters discharged		6,00		1	0	0,00	0,00
4	Best management practice & technologies	9		1				
	Use of lower level than BAT		-9,00		1	0	0,00	0,00
	Use of BAT		1,00		1	1	0,01	0,01
	Promotion of management solutions to reduce CO2 emissions		3,50		1	1	0,03	0,09
	Use of new technologies (go beyond BAT, with promotion of new developments) (ex. Equipment, maintenance and process improvement to reduce the microplastic release into effluent)		4,50		1	1	0,03	0,15
5	Priority substances (PS) / priority hazardous substances (PHS) and other substances (OS)/ specific pollutants (SP)	9		0				
	With PHS and no actions to foreseen the ceasing or phase-out discharges, emissions and losses		-6,00		0	0	0,00	0,00
	With PS/OS/SP and no actions to foreseen the reduction of discharges, emissions and losses		-3,00		0	0	0,00	0,00
	With PS/OS/SP and actions to foreseen the reduction of discharges, emissions and losses		3,00		0	0	0,00	0,00
	With PHS and actions to foreseen the ceasing or phase-out discharges, emissions and losses		6,00		0	0	0,00	0,00
	∑KF +++			4	15			

ID Key Factor	Key and sub-key factors	Key factor value (F_{key})	Sub-Key factor value ($f_{i\ s\text{-}key}$)	Key factor (applicable-1; Non applicable - 0)	Sub-key factor(applicable-1; Non applicable - 0); All sub key factors are applicable when key factor applies	Sub-Key factor value ($f_{i\ s\text{-}key}$) (0 to measures/situations not in place and 1 for measures/situations in place)	Weighting factor ($f_{i\ w}$)	$f_{i\ s\text{-}Key}$ x $f_{i\ w}$
6	Microplastics and/or Compounds of emergent concern	5		0				
	Promotion of removal solutions to reduce microplastic content in wastewater discharge		2,50		0	0	0,00	0,00
	Promotion of removal solutions to reduce compounds of emergent concern content in wastewater discharge		2,50		0	0	0,00	0,00
7	Biodiversity	5		1				
	Promotion of water reuse with negative impacts on biodiversity (water quality and quantity index)		-5,00		1	0	0,00	0,00
	Promotion of water reuse without negative impacts on biodiversity (water quality and quantity index)		2,00		1	1	0,08	0,16
	Promotion of water reuse with positive impacts on biodiversity (water quality and quantity index)		3,00		1	0	0,00	0,00
8	Recovery of nutrients	5		0				
	Without removal of nutrients with visible negative effects on water bodies (directly linked with the installation)		-5,00		0	0	0,00	0,00
	Removal of nutrients to prevent negative effects on water bodies without further nutrient uses		0,50		0	0	0,00	0,00
	Just recovery of nutrients for further uses (without influence on water bodies)		1,50		0	0	0,00	0,00
	Removal of nutrients to prevent negative effects on water bodies with further nutrient uses (ex. Struvite recovery)		3,00		0	0	0,00	0,00
9	Internal industrial symbiosis	5		1				
	Without promotion of integrated approach for competitive advantages.		-5,00		1	1	0,20	-1,00
	Promotion of integrated approach for competitive advantages through the exchange of water, materials and energy between industries (ex. Wastewater with metals reused in a metal factory)		5,00		1	0	0,00	0,00
	∑KF ++			2	5			
10	Sludge	1		1				
	Minimization of sludge production, bio-thermal energy production from anaerobic digestion and reuse of treated sludge from aerobic digestion with impacts on final concentration of the wastewaters discharged		-1,00		1	0	0,00	0,00
	Minimization of sludge production, bio-thermal energy production from anaerobic digestion and reuse of treated sludge from aerobic digestion without impacts on final concentration of the wastewaters discharged		1,00		1	1	0,25	0,25
11	Voluntary and incentive instruments	1		1				
	Without adoption of regulatory instruments, economic instruments, certification and labelling rules, environmental management systems)		-1,00		1	0	0,00	0,00
	Adoption of regulatory instruments, economic instruments, certification and labelling rules, environmental management systems as measures towards the circular economy		1,00		1	1	0,25	0,25
	∑KF +			2	4			
						$\sum(f_{i\ s\text{-}Key} \times f_{i\ w})$		-0,72
						N_f		0,72
						Ic		-1,01

	Ic <0	Negative Circularity: Negative inputs for the circular economy
	Ic = 0	No inputs for circular economy
	0 < Ic ≤ 0,85	Low Circularity: Low level of inputs for circular economy
	0,85 < Ic ≤ 1,5	Medium Circularity: Medium level of inputs for circular economy
	Ic > 1,5	High Circularity: High level of inputs for circular economy

CASE STUDY C

Example 1:
The keys factors were applied to an urban wastewater treatment plant. The key operation details are:

- Urban wastewater treatment plant with industrial connections.
- Load capacity (p.e): 320000 p.e. (1 p.e. = 150 g BOD5 per day)
- Discharge of treated wastewaters: 2500 m3/hour (Dry weather), 12000 m3 Rainy day
- Treatment process: Biological treatment (activated sludge by carrousel) with biological nitrogen removal and phosphorous chemical removal. Recovery of Nitrogen for the agriculture.
- Stabilized sludge is used for the recovery of energy
- At urban level measures to reduce water consumption are taken such as public awareness campaigns.
- Treated wastewaters are 100% discharged to the channel or the river.

ID Key Factor	Key and sub-key factors	Key factor value (F_{key})	Sub-Key factor value ($f_{i\ s\text{-}key}$)	Key factor (applicable-1; Non applicable - 0)	Sub-key factor(applicable-1; Non applicable - 0); All sub key factors are applicable when key factor applies	Sub-Key factor value ($f_{i\ s\text{-}key}$) (0 to measures/situations not in place and 1 for measures/situations in place)	Weighting factor ($f_{i\ w}$)	$f_{i\ s\text{-}Key}$ x $f_{i\ w}$
1	**Freshwater consumption**	9		1				
	Measures to reduce consumption without linking the impacts on the quality of wastewaters and contributing directly to its degradation		-9,00		1	0	0,00	0,00
	Measures to reduce consumption without linking impacts on the quality of wastewaters (with non-significant variation on wastewater quality, e.g., reduction on groundwater abstraction with low impacts on wastewaters)		1,00		1	1	0,01	0,01
	Measures to reduce consumption with measures to reduce possible effects of effluents concentration		4,00		1	0	0,00	0,00
	Reducing abstraction directly from water body (ex. Rainwater collection and reuse) promoting replenishment.		4,00		1	0	0,00	0,00
2.a	**Wastewater discharges non IED installations**	9		1				
	Compliance of ELV without link to the WFD (flat values) and with effects on water status		-9,00		1	0	0,09	0,00
	Compliance of ELV without link to the WFD (flat values) and with no known effects on water status		2,00		1	0	0,02	0,00
	Compliance of ELV with link to the WFD		7,00		1	1	0,07	0,49
3	**Water Reuse**	9		0				
	Promotion of water reuse with negative impacts on final concentration of the wastewaters discharged with negative impact on surface water		-6,00		0	0	0,00	0,00
	Promotion of water reuse with negative impacts on final concentration of the wastewaters discharged and no impact on groundwater abstraction		-3,00		0	0	0,00	0,00
	Promotion of water reuse without negative impacts on final concentration of the wastewaters discharged		3,00		0	0	0,00	0,00
	Promotion of water reuse with positive impacts on final concentration of the wastewaters discharged		6,00		0	0	0,00	0,00
4	**Best management practice & technologies**	9		1				
	Use of lower level than BAT		-9,00		1	0	0,00	0,00
	Use of BAT		1,00		1	1	0,01	0,01
	Promotion of management solutions to reduce CO2 emissions		3,50		1	1	0,04	0,12
	Use of new technologies (go beyond BAT, with promotion of new developments) (ex. Equipment, maintenance and process improvement to reduce the microplastic release into effluent)		4,50		1	0	0,00	0,00
5	**Priority substances (PS) / priority hazardous substances (PHS) and other substances (OS)/ specific pollutants (SP)**	9		0				
	With PHS and no actions to foreseen the ceasing or phase-out discharges, emissions and losses		-6,00		0	0	0,00	0,00
	With PS/OS/SP and no actions to foreseen the reduction of discharges, emissions and losses		-3,00		0	0	0,00	0,00
	With PS/OS/SP and actions to foreseen the reduction of discharges, emissions and losses		3,00		0	0	0,00	0,00
	With PHS and actions to foreseen the ceasing or phase-out discharges, emissions and losses		6,00		0	0	0,00	0,00
	∑KF +++			**3**	**11**			

ID Key Factor	Key and sub-key factors	Key factor value (F_{key})	Sub-Key factor value ($f_{i\ s\text{-}key}$)	Key factor (applicable-1; Non applicable - 0)	Sub-key factor(applicable-1; Non applicable - 0); All sub key factors are applicable when key factor applies	Sub-Key factor value ($f_{i\ s\text{-}key}$) (0 to measures/situations not in place and 1 for measures/situations in place)	Weighting factor ($f_{i\ w}$)	$f_{i\ s\text{-}Key}$ x $f_{i\ w}$
6	Microplastics and/or Compounds of emergent concern	5		0				
	Promotion of removal solutions to reduce microplastic content in wastewater discharge		2,50		0	0	0,00	0,00
	Promotion of removal solutions to reduce compounds of emergent concern content in wastewater discharge		2,50		0	0	0,00	0,00
7	Biodiversity	5		0				
	Promotion of water reuse with negative impacts on biodiversity (water quality and quantity index)		-5,00		0	0	0,00	0,00
	Promotion of water reuse without negative impacts on biodiversity (water quality and quantity index)		2,00		0	0	0,00	0,00
	Promotion of water reuse with positive impacts on biodiversity (water quality and quantity index)		3,00		0	0	0,00	0,00
8	Recovery of nutrients	5		1				
	Without removal of nutrients with visible negative effects on water bodies (directly linked with the installation)		-5,00		1	0	0,00	0,00
	Removal of nutrients to prevent negative effects on water bodies without further nutrient uses		0,50		1	1	0,03	0,01
	Just recovery of nutrients for further uses (without influence on water bodies)		1,50		1	1	0,08	0,11
	Removal of nutrients to prevent negative effects on water bodies with further nutrient uses (ex. Struvite recovery)		3,00		1	1	0,15	0,45
9	Internal industrial symbiosis	5		0				
	Without promotion of integrated approach for competitive advantages.		-5,00		0	0	0,00	0,00
	Promotion of integrated approach for competitive advantages through the exchange of water, materials and energy between industries (ex. Wastewater with metals reused in a metal factory)		5,00		0	0	0,00	0,00
	∑KF ++			1	4			
10	Sludge	1		1				
	Minimization of sludge production, bio-thermal energy production from anaerobic digestion and reuse of treated sludge from aerobic digestion with impacts on final concentration of the wastewaters discharged		-1,00		1	0	0,00	0,00
	Minimization of sludge production, bio-thermal energy production from anaerobic digestion and reuse of treated sludge from aerobic digestion without impacts on final concentration of the wastewaters discharged		1,00		1	1	0,50	0,50
11	Voluntary and incentive instruments	1		0				
	Without adoption of regulatory instruments, economic instruments, certification and labelling rules, environmental management systems)		-1,00		0	0	0,00	0,00
	Adoption of regulatory instruments, economic instruments, certification and labelling rules, environmental management systems as measures towards the circular economy		1,00		0	0	0,00	0,00
	∑KF +			1	2			
						$\sum(f_{i\ s\text{-}Key} \times f_{i\ w})$		1,71
						N_f		0,49
						Ic		3,48

Ic <0	Negative Circularity: Negative inputs for the circular economy
Ic = 0	No inputs for circular economy
0 < Ic ≤ 0,85	Low Circularity: Low level of inputs for circular economy
0,85 < Ic ≤ 1,5	Medium Circularity: Medium level of inputs for circular economy
Ic > 1,5	High Circularity: High level of inputs for circular economy

Example 2:
It is a company which cleans and shredders plastic barrels and plastic IBC's. These barrels originated from both the chemical and food industries. In case the IBC's and plastic drum could be reused, they are cleaned and not shredded.
The shredded plastic and plastic containers are cleaned with collected rainwater, stored in 4 big tanks of 25 m^3. The cleaning machine has a capacity of 8 m^3 per hour. The shredded plastic is reused as raw material for the plastic industry. The contaminated rainwater is treated and reused. If the recycled water is too contaminated, it will be transported to a special company who can process this water. The amount of pollution in the reused water, is measured bases on conductivity. For the process of cleaning the plastics only rainwater is used. The sludge from the cleaning process is discharged as waste
Freshwater consumption is only used by the company employees (coffee, toilet etc). Daily 12 persons are present. The company itself does not discharge industrial waste water.

ID Key Factor	Key and sub-key factors	Key factor value (F_{key})	Sub-Key factor value ($f_{i\ s\text{-}key}$)	Key factor (applicable-1; Non applicable - 0)	Sub-key factor(applicable-1; Non applicable - 0); All sub key factors are applicable when key factor applies	Sub-Key factor value ($f_{i\ s\text{-}key}$) (0 to measures/situations not in place and 1 for measures/situations in place)	Weighting factor ($f_{i\ w}$)	$f_{i\ s\text{-}Key}$ x $f_{i\ w}$
1	Freshwater consumption	9		1				
	Measures to reduce consumption without linking the impacts on the quality of wastewaters and contributing directly to its degradation		-9,00		1	0	0,00	0,00
	Measures to reduce consumption without linking impacts on the quality of wastewaters (with non-significant variation on wastewater quality, e.g., reduction on groundwater abstraction with low impacts on wastewaters)		1,00		1	0	0,00	0,00
	Measures to reduce consumption with measures to reduce possible effects of effluents concentration		4,00		1	1	0,02	0,09
	Reducing abstraction directly from water body (ex. Rainwater collection and reuse) promoting replenishment.		4,00		1	0	0,00	0,00
2.b	Wastewater discharges IED installations	9		1				
	Compliance of BREF-EAV without link to the WFD		-9,00		1	0	0,05	0,00
	Situations where BREF-EAV can be equal to ELV, according check-list		2,00		1	0	0,01	0,00
	Compliance of ELV (ELV defined according WFD principles, where ELV needs to be lower than BREF-EAV, according check-list)		7,00		1	1	0,04	0,29
3	Water Reuse	9		1				
	Promotion of water reuse with negative impacts on final concentration of the wastewaters discharged with negative impact on surface water		-6,00		1	0	0,00	0,00
	Promotion of water reuse with negative impacts on final concentration of the wastewaters discharged and no impact on groundwater abstraction		-3,00		1	0	0,00	0,00
	Promotion of water reuse without negative impacts on final concentration of the wastewaters discharged		3,00		1	0	0,00	0,00
	Promotion of water reuse with positive impacts on final concentration of the wastewaters discharged		6,00		1	1	0,04	0,21
4	Best management practice & technologies	9		1				
	Use of lower level than BAT		-9,00		1	0	0,00	0,00
	Use of BAT		1,00		1	1	0,01	0,01
	Promotion of management solutions to reduce CO2 emissions		3,50		1	0	0,00	0,00
	Use of new technologies (go beyond BAT, with promotion of new developments) (ex. Equipment, maintenance and process improvement to reduce the microplastic release into effluent)		4,50		1	1	0,03	0,12
5	Priority substances (PS) / priority hazardous substances (PHS) and other substances (OS)/ specific pollutants (SP)	9		1				
	With PHS and no actions to foreseen the ceasing or phase-out discharges, emissions and losses		-6,00		1	0	0,00	0,00
	With PS/OS/SP and no actions to foreseen the reduction of discharges, emissions and losses		-3,00		1	0	0,00	0,00
	With PS/OS/SP and actions to foreseen the reduction of discharges, emissions and losses		3,00		1	1	0,02	0,05
	With PHS and actions to foreseen the ceasing or phase-out discharges, emissions and losses		6,00		1	1	0,04	0,21
	∑KF +++			5	19			

ID Key Factor	Key and sub-key factors	Key factor value (F_{key})	Sub-Key factor value ($f_{i\ s\text{-}key}$)	Key factor (applicable-1; Non applicable - 0)	Sub-key factor(applicable-1; Non applicable - 0); All sub key factors are applicable when key factor applies	Sub-Key factor value ($f_{i\ s\text{-}key}$) (0 to measures/situations not in place and 1 for measures/situations in place)	Weighting factor ($f_{i\ w}$)	$f_{i\ s\text{-}Key} \times f_{i\ w}$
6	Microplastics and/or Compounds of emergent concern	5		0				
	Promotion of removal solutions to reduce microplastic content in wastewater discharge		2,50		0	0	0,00	0,00
	Promotion of removal solutions to reduce compounds of emergent concern content in wastewater discharge		2,50		0	0	0,00	0,00
7	Biodiversity	5		0				
	Promotion of water reuse with negative impacts on biodiversity (water quality and quantity index)		-5,00		0	0	0,00	0,00
	Promotion of water reuse without negative impacts on biodiversity (water quality and quantity index)		2,00		0	0	0,00	0,00
	Promotion of water reuse with positive impacts on biodiversity (water quality and quantity index)		3,00		0	0	0,00	0,00
8	Recovery of nutrients	5		0				
	Without removal of nutrients with visible negative effects on water bodies (directly linked with the installation)		-5,00		0	0	0,00	0,00
	Removal of nutrients to prevent negative effects on water bodies without further nutrient uses		0,50		0	0	0,00	0,00
	Just recovery of nutrients for further uses (without influence on water bodies)		1,50		0	0	0,00	0,00
	Removal of nutrients to prevent negative effects on water bodies with further nutrient uses (ex. Struvite recovery)		3,00		0	0	0,00	0,00
9	Internal industrial symbiosis	5		0				
	Without promotion of integrated approach for competitive advantages.		-5,00		0	0	0,00	0,00
	Promotion of integrated approach for competitive advantages through the exchange of water, materials and energy between industries (ex. Wastewater with metals reused in a metal factory)		5,00		0	0	0,00	0,00
	∑KF ++			0	1			
10	Sludge	1		0				
	Minimization of sludge production, bio-thermal energy production from anaerobic digestion and reuse of treated sludge from aerobic digestion with impacts on final concentration of the wastewaters discharged		-1,00		0	0	0,00	0,00
	Minimization of sludge production, bio-thermal energy production from anaerobic digestion and reuse of treated sludge from aerobic digestion without impacts on final concentration of the wastewaters discharged		1,00		0	0	0,00	0,00
11	Voluntary and incentive instruments	1		0				
	Without adoption of regulatory instruments, economic instruments, certification and labelling rules, environmental management systems)		-1,00		0	0	0,00	0,00
	Adoption of regulatory instruments, economic instruments, certification and labelling rules, environmental management systems as measures towards the circular economy		1,00		0	0	0,00	0,00
	∑KF +			0	1			
						$\sum(f_{i\ s\text{-}Key} \times f_{i\ w})$		0,98
						N_f		0,67
						Ic		1,46

Ic <0	Negative Circularity: Negative inputs for the circular economy
Ic = 0	No inputs for circular economy
0 < Ic ≤ 0,85	Low Circularity: Low level of inputs for circular economy
0,85 < Ic ≤ 1,5	Medium Circularity: Medium level of inputs for circular economy
Ic > 1,5	High Circularity: High level of inputs for circular economy

CASE STUDY D

Example 1:
The keys factors were applied to a joint wastewater treatment plant for pulp and paper industry and urban wastewater. Population equivalent of 25 000 - 29 000 from communal sewer line. The treated wastewater has it's outlet to the sea. The WWT has its own environmental permit.

ID Key Factor	Key and sub-key factors	Key factor value (F_{key})	Sub-Key factor value ($f_{i\ s\text{-}key}$)	Key factor (applicable-1; Non applicable - 0)	Sub-key factor(applicable-1; Non applicable - 0); All sub key factors are applicable when key factor applies	Sub-Key factor value ($f_{i\ s\text{-}key}$) (0 to measures/situations not in place and 1 for measures/situations in place)	Weighting factor ($f_{i\ w}$)	$f_{i\ s\text{-}Key}$ x $f_{i\ w}$
1	**Freshwater consumption**	9		1				
	Measures to reduce consumption without linking the impacts on the quality of wastewaters and contributing directly to its degradation		-9,00		1	0	0,00	0,00
	Measures to reduce consumption without linking impacts on the quality of wastewaters (with non-significant variation on wastewater quality, e.g., reduction on groundwater abstraction with low impacts on wastewaters)		1,00		1	0	0,00	0,00
	Measures to reduce consumption with measures to reduce possible effects of effluents concentration		4,00		1	1	0,03	0,12
	Reducing abstraction directly from water body (ex. Rainwater collection and reuse) promoting replenishment.		4,00		1	0	0,00	0,00
2.b	**Wastewater discharges IED installations**	9		1				
	Compliance of BREF-EAV without link to the WFD		-9,00		1	1	0,07	-0,60
	Situations where BREF-EAV can be equal to ELV, according check-list		2,00		1	0	0,00	0,00
	Compliance of ELV (ELV defined according WFD principles, where ELV needs to be lower than BREF-EAV, according check-list)		7,00		1	0	0,00	0,00
3	**Water Reuse**	9		0				
	Promotion of water reuse with negative impacts on final concentration of the wastewaters discharged with negative impact on surface water		-6,00		0	0	0,00	0,00
	Promotion of water reuse with negative impacts on final concentration of the wastewaters discharged and no impact on groundwater abstraction		-3,00		0	0	0,00	0,00
	Promotion of water reuse without negative impacts on final concentration of the wastewaters discharged		3,00		0	0	0,00	0,00
	Promotion of water reuse with positive impacts on final concentration of the wastewaters discharged		6,00		0	0	0,00	0,00
4	**Best management practice & technologies**	9		1				
	Use of lower level than BAT		-9,00		1	0	0,00	0,00
	Use of BAT		1,00		1	1	0,01	0,01
	Promotion of management solutions to reduce CO2 emissions		3,50		1	0	0,00	0,00
	Use of new technologies (go beyond BAT, with promotion of new developments) (ex. Equipment, maintenance and process improvement to reduce the microplastic release into effluent)		4,50		1	0	0,00	0,00
5	**Priority substances (PS) / priority hazardous substances (PHS) and other substances (OS)/ specific pollutants (SP)**	9		1				
	With PHS and no actions to foreseen the ceasing or phase-out discharges, emissions and losses		-6,00		1	0	0,00	0,00
	With PS/OS/SP and no actions to foreseen the reduction of discharges, emissions and losses		-3,00		1	0	0,00	0,00
	With PS/OS/SP and actions to foreseen the reduction of discharges, emissions and losses		3,00		1	1	0,02	0,07
	With PHS and actions to foreseen the ceasing or phase-out discharges, emissions and losses		6,00		1	1	0,04	0,27
	∑KF +++			**4**	**15**			

ID Key Factor	Key and sub-key factors	Key factor value (F_{key})	Sub-Key factor value ($f_{i\ s\text{-}key}$)	Key factor (applicable-1; Non applicable - 0)	Sub-key factor(applicable-1; Non applicable - 0); All sub key factors are applicable when key factor applies	Sub-Key factor value ($f_{i\ s\text{-}key}$) (0 to measures/situations not in place and 1 for measures/situations in place)	Weighting factor ($f_{i\ w}$)	$f_{i\ s\text{-}Key} \times f_{i\ w}$
6	Microplastics and/or Compounds of emergent concern	5		0				
	Promotion of removal solutions to reduce microplastic content in wastewater discharge		2,50		0	0	0,00	0,00
	Promotion of removal solutions to reduce compounds of emergent concern content in wastewater discharge		2,50		0	0	0,00	0,00
7	Biodiversity	5		0				
	Promotion of water reuse with negative impacts on biodiversity (water quality and quantity index)		-5,00		0	0	0,00	0,00
	Promotion of water reuse without negative impacts on biodiversity (water quality and quantity index)		2,00		0	0	0,00	0,00
	Promotion of water reuse with positive impacts on biodiversity (water quality and quantity index)		3,00		0	0	0,00	0,00
8	Recovery of nutrients	5		1				
	Without removal of nutrients with visible negative effects on water bodies (directly linked with the installation)		-5,00		1	0	0,00	0,00
	Removal of nutrients to prevent negative effects on water bodies without further nutrient uses		0,50		1	0	0,00	0,00
	Just recovery of nutrients for further uses (without influence on water bodies)		1,50		1	0	0,00	0,00
	Removal of nutrients to prevent negative effects on water bodies with further nutrient uses (ex. Struvite recovery)		3,00		1	1	0,10	0,30
9	Internal industrial symbiosis	5		1				
	Without promotion of integrated approach for competitive advantages.		-5,00		1	0	0,00	0,00
	Promotion of integrated approach for competitive advantages through the exchange of water, materials and energy between industries (ex. Wastewater with metals reused in a metal factory)		5,00		1	1	0,17	0,83
	∑KF ++			2	6			
10	Sludge	1		1				
	Minimization of sludge production, bio-thermal energy production from anaerobic digestion and reuse of treated sludge from aerobic digestion with impacts on final concentration of the wastewaters discharged		-1,00		1	1	0,25	-0,25
	Minimization of sludge production, bio-thermal energy production from anaerobic digestion and reuse of treated sludge from aerobic digestion without impacts on final concentration of the wastewaters discharged		1,00		1	0	0,00	0,00
11	Voluntary and incentive instruments	1		1				
	Without adoption of regulatory instruments, economic instruments, certification and labelling rules, environmental management systems)		-1,00		1	0	0,00	0,00
	Adoption of regulatory instruments, economic instruments, certification and labelling rules, environmental management systems as measures towards the circular economy		1,00		1	1	0,25	0,25
	∑KF +			2	4			
						$\sum(f_{i\ s\text{-}Key} \times f_{i\ w})$		0,99
						N_f		0,72
						Ic		1,39

Ic <0	Negative Circularity: Negative inputs for the circular economy
Ic = 0	No inputs for circular economy
0 < Ic ≤ 0,85	Low Circularity: Low level of inputs for circular economy
0,85 < Ic ≤ 1,5	Medium Circularity: Medium level of inputs for circular economy
Ic > 1,5	High Circularity: High level of inputs for circular economy

Example 2:
The key factors were applied to a fertilizer production plant. The plant uses seawater cooling water and fresh water (lake) as process water. The leachate of the landfill is also treated at the facility's wastewater treatment plant. The wastewater from the process is reused in either the process or lead to the wastewater treatment plant. The treated wastewater is released to the sea.

ID Key Factor	Key and sub-key factors	Key factor value (F_{key})	Sub-Key factor value ($f_{i\ s\text{-}key}$)	Key factor (applicable-1; Non applicable - 0)	Sub-key factor(applicable-1; Non applicable - 0); All sub key factors are applicable when key factor applies	Sub-Key factor value ($f_{i\ s\text{-}key}$) (0 to measures/situations not in place and 1 for measures/situations in place)	Weighting factor ($f_{i\ w}$)	$f_{i\ s\text{-}Key}$ x $f_{i\ w}$
1	**Freshwater consumption**	9		1				
	Measures to reduce consumption without linking the impacts on the quality of wastewaters and contributing directly to its degradation		-9,00		1	0	0,00	0,00
	Measures to reduce consumption without linking impacts on the quality of wastewaters (with non-significant variation on wastewater quality, e.g., reduction on groundwater abstraction with low impacts on wastewaters)		1,00		1	0	0,00	0,00
	Measures to reduce consumption with measures to reduce possible effects of effluents concentration		4,00		1	1	0,03	0,11
	Reducing abstraction directly from water body (ex. Rainwater collection and reuse) promoting replenishment.		4,00		1	1	0,03	0,11
2.b	**Wastewater discharges IED installations**	9		0				
	Compliance of BREF-EAV without link to the WFD		-9,00		0	0	0,00	0,00
	Situations where BREF-EAV can be equal to ELV, according check-list		2,00		0	0	0,00	0,00
	Compliance of ELV (ELV defined according WFD principles, where ELV needs to be lower than BREF-EAV, according check-list)		7,00		0	0	0,00	0,00
3	**Water Reuse**	9		1				
	Promotion of water reuse with negative impacts on final concentration of the wastewaters discharged with negative impact on surface water		-6,00		1	0	0,00	0,00
	Promotion of water reuse with negative impacts on final concentration of the wastewaters discharged and no impact on groundwater abstraction		-3,00		1	0	0,00	0,00
	Promotion of water reuse without negative impacts on final concentration of the wastewaters discharged		3,00		1	1	0,02	0,06
	Promotion of water reuse with positive impacts on final concentration of the wastewaters discharged		6,00		1	1	0,04	0,25
4	**Best management practice & technologies**	9		1				
	Use of lower level than BAT		-9,00		1	0	0,00	0,00
	Use of BAT		1,00		1	1	0,01	0,01
	Promotion of management solutions to reduce CO2 emissions		3,50		1	0	0,00	0,00
	Use of new technologies (go beyond BAT, with promotion of new developments) (ex. Equipment, maintenance and process improvement to reduce the microplastic release into effluent)		4,50		1	0	0,00	0,00
5	**Priority substances (PS) / priority hazardous substances (PHS) and other substances (OS)/ specific pollutants (SP)**	9		1				
	With PHS and no actions to foreseen the ceasing or phase-out discharges, emissions and losses		-6,00		1	0	0,00	0,00
	With PS/OS/SP and no actions to foreseen the reduction of discharges, emissions and losses		-3,00		1	0	0,00	0,00
	With PS/OS/SP and actions to foreseen the reduction of discharges, emissions and losses		3,00		1	1	0,02	0,06
	With PHS and actions to foreseen the ceasing or phase-out discharges, emissions and losses		6,00		1	1	0,04	0,25
	∑KF +++			**4**	**16**			

ID Key Factor	Key and sub-key factors	Key factor value (F_{key})	Sub-Key factor value ($f_{i\ s\text{-}key}$)	Key factor (applicable-1; Non applicable - 0)	Sub-key factor(applicable-1; Non applicable - 0); All sub key factors are applicable when key factor applies	Sub-Key factor value ($f_{i\ s\text{-}key}$) (0 to measures/situations not in place and 1 for measures/situations in place)	Weighting factor ($f_{i\ w}$)	$f_{i\ s\text{-}Key} \times f_{i\ w}$
6	Microplastics and/or Compounds of emergent concern	5		0				
	Promotion of removal solutions to reduce microplastic content in wastewater discharge		2,50		0	0	0,00	0,00
	Promotion of removal solutions to reduce compounds of emergent concern content in wastewater discharge		2,50		0	0	0,00	0,00
7	Biodiversity	5		1				
	Promotion of water reuse with negative impacts on biodiversity (water quality and quantity index)		-5,00		1	0	0,00	0,00
	Promotion of water reuse without negative impacts on biodiversity (water quality and quantity index)		2,00		1	1	0,04	0,09
	Promotion of water reuse with positive impacts on biodiversity (water quality and quantity index)		3,00		1	1	0,07	0,20
8	Recovery of nutrients	5		1				
	Without removal of nutrients with visible negative effects on water bodies (directly linked with the installation)		-5,00		1	0	0,00	0,00
	Removal of nutrients to prevent negative effects on water bodies without further nutrient uses		0,50		1	0	0,00	0,00
	Just recovery of nutrients for further uses (without influence on water bodies)		1,50		1	0	0,00	0,00
	Removal of nutrients to prevent negative effects on water bodies with further nutrient uses (ex. Struvite recovery)		3,00		1	1	0,07	0,20
9	Internal industrial symbiosis	5		1				
	Without promotion of integrated approach for competitive advantages.		-5,00		1	1	0,11	-0,56
	Promotion of integrated approach for competitive advantages through the exchange of water, materials and energy between industries (ex. Wastewater with metals reused in a metal factory)		5,00		1	0	0,00	0,00
	∑KF ++			3	9			
10	Sludge	1		1				
	Minimization of sludge production, bio-thermal energy production from anaerobic digestion and reuse of treated sludge from aerobic digestion with impacts on final concentration of the wastewaters discharged		-1,00		1	1	0,25	-0,25
	Minimization of sludge production, bio-thermal energy production from anaerobic digestion and reuse of treated sludge from aerobic digestion without impacts on final concentration of the wastewaters discharged		1,00		1	0	0,00	0,00
11	Voluntary and incentive instruments	1		1				
	Without adoption of regulatory instruments, economic instruments, certification and labelling rules, environmental management systems)		-1,00		1	0	0,00	0,00
	Adoption of regulatory instruments, economic instruments, certification and labelling rules, environmental management systems as measures towards the circular economy		1,00		1	1	0,25	0,25
	∑KF +			2	4			
						$\sum(f_{i\ s\text{-}Key} \times f_{i\ w})$		0,79
						N_f		0,79
						Ic		1,00

	Ic <0	Negative Circularity: Negative inputs for the circular economy
	Ic = 0	No inputs for circular economy
	0 < Ic ≤ 0,85	Low Circularity: Low level of inputs for circular economy
	0,85 < Ic ≤ 1,5	Medium Circularity: Medium level of inputs for circular economy
	Ic > 1,5	High Circularity: High level of inputs for circular economy

Example 3:
The key factors were applied to a large smelter located on a riverbank. The wastewater treatment plant treats wastewater from the smelter but also stormwater from the industrial area and wastewater from other industrial production units located on the industrial area. No urban wastewater is lead to the treatment system.

ID Key Factor	Key and sub-key factors	Key factor value (F_{key})	Sub-Key factor value ($f_{i\ s\text{-}key}$)	Key factor (applicable-1; Non applicable - 0)	Sub-key factor(applicable-1; Non applicable - 0); All sub key factors are applicable when key factor applies	Sub-Key factor value ($f_{i\ s\text{-}key}$) (0 to measures/situations not in place and 1 for measures/situations in place)	Weighting factor ($f_{i\ w}$)	$f_{i\ s\text{-}Key}$ x $f_{i\ w}$
1	**Freshwater consumption**	9		1				
	Measures to reduce consumption without linking the impacts on the quality of wastewaters and contributing directly to its degradation		-9,00		1	0	0,00	0,00
	Measures to reduce consumption without linking impacts on the quality of wastewaters (with non-significant variation on wastewater quality, e.g., reduction on groundwater abstraction with low impacts on wastewaters)		1,00		1	0	0,00	0,00
	Measures to reduce consumption with measures to reduce possible effects of effluents concentration		4,00		1	1	0,02	0,09
	Reducing abstraction directly from water body (ex. Rainwater collection and reuse) promoting replenishment.		4,00		1	0	0,00	0,00
2.b	**Wastewater discharges IED installations**	9		1				
	Compliance of BREF-EAV without link to the WFD		-9,00		1	0	0,00	0,00
	Situations where BREF-EAV can be equal to ELV, according check-list		2,00		1	1	0,01	0,02
	Compliance of ELV (ELV defined according WFD principles, where ELV needs to be lower than BREF-EAV, according check-list)		7,00		1	1	0,04	0,29
3	**Water Reuse**	9		1				
	Promotion of water reuse with negative impacts on final concentration of the wastewaters discharged with negative impact on surface water		-6,00		1	0	0,00	0,00
	Promotion of water reuse with negative impacts on final concentration of the wastewaters discharged and no impact on groundwater abstraction		-3,00		1	0	0,00	0,00
	Promotion of water reuse without negative impacts on final concentration of the wastewaters discharged		3,00		1	1	0,02	0,05
	Promotion of water reuse with positive impacts on final concentration of the wastewaters discharged		6,00		1	0	0,00	0,00
4	**Best management practice & technologies**	9		1				
	Use of lower level than BAT		-9,00		1	0	0,00	0,00
	Use of BAT		1,00		1	1	0,01	0,01
	Promotion of management solutions to reduce CO2 emissions		3,50		1	1	0,02	0,07
	Use of new technologies (go beyond BAT, with promotion of new developments) (ex. Equipment, maintenance and process improvement to reduce the microplastic release into effluent)		4,50		1	0	0,00	0,00
5	**Priority substances (PS) / priority hazardous substances (PHS) and other substances (OS)/ specific pollutants (SP)**	9		1				
	With PHS and no actions to foreseen the ceasing or phase-out discharges, emissions and losses		-6,00		1	0	0,00	0,00
	With PS/OS/SP and no actions to foreseen the reduction of discharges, emissions and losses		-3,00		1	0	0,00	0,00
	With PS/OS/SP and actions to foreseen the reduction of discharges, emissions and losses		3,00		1	1	0,02	0,05
	With PHS and actions to foreseen the ceasing or phase-out discharges, emissions and losses		6,00		1	1	0,04	0,21
	∑KF +++			**5**	**19**			

ID Key Factor	Key and sub-key factors	Key factor value (F_{key})	Sub-Key factor value ($f_{i\ s\text{-}key}$)	Key factor (applicable-1; Non applicable - 0)	Sub-key factor(applicable-1; Non applicable - 0); All sub key factors are applicable when key factor applies	Sub-Key factor value ($f_{i\ s\text{-}key}$) (0 to measures/situations not in place and 1 for measures/situations in place)	Weighting factor ($f_{i\ w}$)	$f_{i\ s\text{-}Key}$ x $f_{i\ w}$
6	Microplastics and/or Compounds of emergent concern	5		0				
	Promotion of removal solutions to reduce microplastic content in wastewater discharge		2,50		0	0	0,00	0,00
	Promotion of removal solutions to reduce compounds of emergent concern content in wastewater discharge		2,50		0	0	0,00	0,00
7	Biodiversity	5		1				
	Promotion of water reuse with negative impacts on biodiversity (water quality and quantity index)		-5,00		1	0	0,00	0,00
	Promotion of water reuse without negative impacts on biodiversity (water quality and quantity index)		2,00		1	1	0,08	0,16
	Promotion of water reuse with positive impacts on biodiversity (water quality and quantity index)		3,00		1	0	0,00	0,00
8	Recovery of nutrients	5		0				
	Without removal of nutrients with visible negative effects on water bodies (directly linked with the installation)		-5,00		0	0	0,00	0,00
	Removal of nutrients to prevent negative effects on water bodies without further nutrient uses		0,50		0	0	0,00	0,00
	Just recovery of nutrients for further uses (without influence on water bodies)		1,50		0	0	0,00	0,00
	Removal of nutrients to prevent negative effects on water bodies with further nutrient uses (ex. Struvite recovery)		3,00		0	0	0,00	0,00
9	Internal industrial symbiosis	5		1				
	Without promotion of integrated approach for competitive advantages.		-5,00		1	0	0,00	0,00
	Promotion of integrated approach for competitive advantages through the exchange of water, materials and energy between industries (ex. Wastewater with metals reused in a metal factory)		5,00		1	1	0,20	1,00
	∑KF ++			2	5			
10	Sludge	1		0				
	Minimization of sludge production, bio-thermal energy production from anaerobic digestion and reuse of treated sludge from aerobic digestion with impacts on final concentration of the wastewaters discharged		-1,00		0	0	0,00	0,00
	Minimization of sludge production, bio-thermal energy production from anaerobic digestion and reuse of treated sludge from aerobic digestion without impacts on final concentration of the wastewaters discharged		1,00		0	0	0,00	0,00
11	Voluntary and incentive instruments	1		1				
	Without adoption of regulatory instruments, economic instruments, certification and labelling rules, environmental management systems)		-1,00		1	0	0,00	0,00
	Adoption of regulatory instruments, economic instruments, certification and labelling rules, environmental management systems as measures towards the circular economy		1,00		1	1	0,50	0,50
	∑KF +			1	2			
						$\sum(f_{i\ s\text{-}Key} \times f_{i\ w})$		2,46
						N_f		0,84
						Ic		2,94

Ic <0	Negative Circularity: Negative inputs for the circular economy
Ic = 0	No inputs for circular economy
0 < Ic ≤ 0,85	Low Circularity: Low level of inputs for circular economy
0,85 < Ic ≤ 1,5	Medium Circularity: Medium level of inputs for circular economy
Ic > 1,5	High Circularity: High level of inputs for circular economy

CASE STUDY E

Example 1:
The keys factors were applied to a paper & pulp factory.

The key operation details are:

- Production of paper and pulp
- Average production: 400 t/day
- Discharge of treated wastewaters: 1500 m^3/hour
- The treated wastewater is released to an artificial waterway (canal).

ID Key Factor	Key and sub-key factors	Key factor value (F_{key})	Sub-Key factor value ($f_{i\ s\text{-}key}$)	Key factor (applicable-1; Non applicable - 0)	Sub-key factor(applicable-1; Non applicable - 0); All sub key factors are applicable when key factor applies	Sub-Key factor value ($f_{i\ s\text{-}key}$) (0 to measures/situations not in place and 1 for measures/situations in place)	Weighting factor ($f_{i\ w}$)	$f_{i\ s\text{-}Key}$ x $f_{i\ w}$
1	Freshwater consumption	9		1				
	Measures to reduce consumption without linking the impacts on the quality of wastewaters and contributing directly to its degradation		-9,00		1	0	0,00	0,00
	Measures to reduce consumption without linking impacts on the quality of wastewaters (with non-significant variation on wastewater quality, e.g., reduction on groundwater abstraction with low impacts on wastewaters)		1,00		1	1	0,01	0,01
	Measures to reduce consumption with measures to reduce possible effects of effluents concentration		4,00		1	0	0,00	0,00
	Reducing abstraction directly from water body (ex. Rainwater collection and reuse) promoting replenishment.		4,00		1	0	0,00	0,00
2.b	Wastewater discharges IED installations	9		1	1			
	Compliance of BREF-EAV without link to the WFD		-9,00		1	0	0,00	0,00
	Situations where BREF-EAV can be equal to ELV, according check-list		2,00		1	0	0,00	0,00
	Compliance of ELV (ELV defined according WFD principles, where ELV needs to be lower than BREF-EAV, according check-list)		7,00		1	1	0,04	0,29
3	Water Reuse	9		1				
	Promotion of water reuse with negative impacts on final concentration of the wastewaters discharged with negative impact on surface water		-6,00		1	0	0,00	0,00
	Promotion of water reuse with negative impacts on final concentration of the wastewaters discharged and no impact on groundwater abstraction		-3,00		1	0	0,00	0,00
	Promotion of water reuse without negative impacts on final concentration of the wastewaters discharged		3,00		1	1	0,02	0,05
	Promotion of water reuse with positive impacts on final concentration of the wastewaters discharged		6,00		1	0	0,00	0,00
4	Best management practice & technologies	9		1				
	Use of lower level than BAT		-9,00		1	0	0,00	0,00
	Use of BAT		1,00		1	1	0,01	0,01
	Promotion of management solutions to reduce CO2 emissions		3,50		1	0	0,00	0,00
	Use of new technologies (go beyond BAT, with promotion of new developments) (ex. Equipment, maintenance and process improvement to reduce the microplastic release into effluent)		4,50		1	0	0,00	0,00
5	Priority substances (PS) / priority hazardous substances (PHS) and other substances (OS)/ specific pollutants (SP)	9		1				
	With PHS and no actions to foreseen the ceasing or phase-out discharges, emissions and losses		-6,00		1	0	0,00	0,00
	With PS/OS/SP and no actions to foreseen the reduction of discharges, emissions and losses		-3,00		1	0	0,00	0,00
	With PS/OS/SP and actions to foreseen the reduction of discharges, emissions and losses		3,00		1	1	0,02	0,05
	With PHS and actions to foreseen the ceasing or phase-out discharges, emissions and losses		6,00		1	0	0,00	0,00
	∑KF +++			5	19			

ID Key Factor	Key and sub-key factors	Key factor value (F_{key})	Sub-Key factor value ($f_{i\ s\text{-}key}$)	Key factor (applicable-1; Non applicable - 0)	Sub-key factor(applicable-1; Non applicable - 0); All sub key factors are applicable when key factor applies	Sub-Key factor value ($f_{i\ s\text{-}key}$) (0 to measures/situations not in place and 1 for measures/situations in place)	Weighting factor ($f_{i\ w}$)	$f_{i\ s\text{-}Key}$ x $f_{i\ w}$
6	Microplastics and/or Compounds of emergent concern	5		0				
	Promotion of removal solutions to reduce microplastic content in wastewater discharge		2,50		0	0	0,00	0,00
	Promotion of removal solutions to reduce compounds of emergent concern content in wastewater discharge		2,50		0	0	0,00	0,00
7	Biodiversity	5		0				
	Promotion of water reuse with negative impacts on biodiversity (water quality and quantity index)		-5,00		1	0	0,00	0,00
	Promotion of water reuse without negative impacts on biodiversity (water quality and quantity index)		2,00		1	1	0,04	0,09
	Promotion of water reuse with positive impacts on biodiversity (water quality and quantity index)		3,00		1	0	0,00	0,00
8	Recovery of nutrients	5		1				
	Without removal of nutrients with visible negative effects on water bodies (directly linked with the installation)		-5,00		1	0	0,00	0,00
	Removal of nutrients to prevent negative effects on water bodies without further nutrient uses		0,50		1	1	0,01	0,01
	Just recovery of nutrients for further uses (without influence on water bodies)		1,50		1	0	0,00	0,00
	Removal of nutrients to prevent negative effects on water bodies with further nutrient uses (ex. Struvite recovery)		3,00		1	0	0,00	0,00
9	Internal industrial symbiosis	5		1				
	Without promotion of integrated approach for competitive advantages.		-5,00		1	1	0,11	-0,56
	Promotion of integrated approach for competitive advantages through the exchange of water, materials and energy between industries (ex. Wastewater with metals reused in a metal factory)		5,00		1	0	0,00	0,00
	∑KF ++			2	9			
10	Sludge	1		1				
	Minimization of sludge production, bio-thermal energy production from anaerobic digestion and reuse of treated sludge from aerobic digestion with impacts on final concentration of the wastewaters discharged		-1,00		1	0	0,00	0,00
	Minimization of sludge production, bio-thermal energy production from anaerobic digestion and reuse of treated sludge from aerobic digestion without impacts on final concentration of the wastewaters discharged		1,00		1	1	0,25	0,25
11	Voluntary and incentive instruments	1		1				
	Without adoption of regulatory instruments, economic instruments, certification and labelling rules, environmental management systems)		-1,00		1	0	0,00	0,00
	Adoption of regulatory instruments, economic instruments, certification and labelling rules, environmental management systems as measures towards the circular economy		1,00		1	1	0,25	0,25
	∑KF +			2	4			
						$\sum(f_{i\ s\text{-}Key} \times f_{i\ w})$		0,44
						N_f		0,85
						Ic		0,52

	Ic <0	Negative Circularity: Negative inputs for the circular economy
	Ic = 0	No inputs for circular economy
	0 < Ic ≤ 0,85	Low Circularity: Low level of inputs for circular economy
	0,85 < Ic ≤ 1,5	Medium Circularity: Medium level of inputs for circular economy
	Ic > 1,5	High Circularity: High level of inputs for circular economy

Example 2:
The keys factors were applied to a brewery.

The key operation details are:
- Production of beer
- Average production: 8.000.000 hl/year
- Discharge of treated wastewaters: 650 m^3/hour
- The treated wastewater is released to a river (good water quality).

ID Key Factor	Key and sub-key factors	Key factor value (F_{key})	Sub-Key factor value ($f_{i\ s\text{-}key}$)	Key factor (applicable-1; Non applicable - 0)	Sub-key factor(applicable-1; Non applicable - 0); All sub key factors are applicable when key factor applies	Sub-Key factor value ($f_{i\ s\text{-}key}$) (0 to measures/situations not in place and 1 for measures/situations in place)	Weighting factor ($f_{i\ w}$)	$f_{i\ s\text{-}Key}$ x $f_{i\ w}$
1	Freshwater consumption	9		1				
	Measures to reduce consumption without linking the impacts on the quality of wastewaters and contributing directly to its degradation		-9,00		1	0	0,00	0,00
	Measures to reduce consumption without linking impacts on the quality of wastewaters (with non-significant variation on wastewater quality, e.g., reduction on groundwater abstraction with low impacts on wastewaters)		1,00		1	0	0,00	0,00
	Measures to reduce consumption with measures to reduce possible effects of effluents concentration		4,00		1	1	0,02	0,09
	Reducing abstraction directly from water body (ex. Rainwater collection and reuse) promoting replenishment.		4,00		1	1	0,02	0,09
2.b	Wastewater discharges IED installations	9		1	1			
	Compliance of BREF-EAV without link to the WFD		-9,00		1	0	0,00	0,00
	Situations where BREF-EAV can be equal to ELV, according check-list		2,00		1	0	0,00	0,00
	Compliance of ELV (ELV defined according WFD principles, where ELV needs to be lower than BREF-EAV, according check-list)		7,00		1	1	0,04	0,29
3	Water Reuse	9		1				
	Promotion of water reuse with negative impacts on final concentration of the wastewaters discharged with negative impact on surface water		-6,00		1	0	0,00	0,00
	Promotion of water reuse with negative impacts on final concentration of the wastewaters discharged and no impact on groundwater abstraction		-3,00		1	0	0,00	0,00
	Promotion of water reuse without negative impacts on final concentration of the wastewaters discharged		3,00		1	0	0,00	0,00
	Promotion of water reuse with positive impacts on final concentration of the wastewaters discharged		6,00		1	1	0,04	0,21
4	Best management practice & technologies	9		1				
	Use of lower level than BAT		-9,00		1	0	0,00	0,00
	Use of BAT		1,00		1	0	0,00	0,00
	Promotion of management solutions to reduce CO2 emissions		3,50		1	0	0,00	0,00
	Use of new technologies (go beyond BAT, with promotion of new developments) (ex. Equipment, maintenance and process improvement to reduce the microplastic release into effluent)		4,50		1	1	0,03	0,12
5	Priority substances (PS) / priority hazardous substances (PHS) and other substances (OS)/ specific pollutants (SP)	9		1				
	With PHS and no actions to foreseen the ceasing or phase-out discharges, emissions and losses		-6,00		1	0	0,00	0,00
	With PS/OS/SP and no actions to foreseen the reduction of discharges, emissions and losses		-3,00		1	0	0,00	0,00
	With PS/OS/SP and actions to foreseen the reduction of discharges, emissions and losses		3,00		1	1	0,02	0,05
	With PHS and actions to foreseen the ceasing or phase-out discharges, emissions and losses		6,00		1	0	0,00	0,00
	∑KF +++			5	19			

ID Key Factor	Key and sub-key factors	Key factor value (F_{key})	Sub-Key factor value ($f_{i\ s\text{-}key}$)	Key factor (applicable-1; Non applicable - 0)	Sub-key factor(applicable-1; Non applicable - 0); All sub key factors are applicable when key factor applies	Sub-Key factor value ($f_{i\ s\text{-}key}$) (0 to measures/situations not in place and 1 for measures/situations in place)	Weighting factor ($f_{i\ w}$)	$f_{i\ s\text{-}Key} \times f_{i\ w}$
6	Microplastics and/or Compounds of emergent concern	5		0				
	Promotion of removal solutions to reduce microplastic content in wastewater discharge		2,50		0	0	0,00	0,00
	Promotion of removal solutions to reduce compounds of emergent concern content in wastewater discharge		2,50		0	0	0,00	0,00
7	Biodiversity	5		1				
	Promotion of water reuse with negative impacts on biodiversity (water quality and quantity index)		-5,00		1	0	0,00	0,00
	Promotion of water reuse without negative impacts on biodiversity (water quality and quantity index)		2,00		1	0	0,00	0,00
	Promotion of water reuse with positive impacts on biodiversity (water quality and quantity index)		3,00		1	1	0,07	0,20
8	Recovery of nutrients	5		1				
	Without removal of nutrients with visible negative effects on water bodies (directly linked with the installation)		-5,00		1	0	0,00	0,00
	Removal of nutrients to prevent negative effects on water bodies without further nutrient uses		0,50		1	1	0,01	0,01
	Just recovery of nutrients for further uses (without influence on water bodies)		1,50		1	0	0,00	0,00
	Removal of nutrients to prevent negative effects on water bodies with further nutrient uses (ex. Struvite recovery)		3,00		1	0	0,00	0,00
9	Internal industrial symbiosis	5		1				
	Without promotion of integrated approach for competitive advantages.		-5,00		1	1	0,11	-0,56
	Promotion of integrated approach for competitive advantages through the exchange of water, materials and energy between industries (ex. Wastewater with metals reused in a metal factory)		5,00		1	0	0,00	0,00
	∑KF ++			3	9			
10	Sludge	1		1				
	Minimization of sludge production, bio-thermal energy production from anaerobic digestion and reuse of treated sludge from aerobic digestion with impacts on final concentration of the wastewaters discharged		-1,00		1	0	0,00	0,00
	Minimization of sludge production, bio-thermal energy production from anaerobic digestion and reuse of treated sludge from aerobic digestion without impacts on final concentration of the wastewaters discharged		1,00		1	1	0,25	0,25
11	Voluntary and incentive instruments	1		1				
	Without adoption of regulatory instruments, economic instruments, certification and labelling rules, environmental management systems)		-1,00		1	0	0,00	0,00
	Adoption of regulatory instruments, economic instruments, certification and labelling rules, environmental management systems as measures towards the circular economy		1,00		1	1	0,25	0,25
	∑KF +			2	4			
						$\sum(f_{i\ s\text{-}Key} \times f_{i\ w})$		1,01
						N_f		0,93
						Ic		1,09

	Ic <0	Negative Circularity: Negative inputs for the circular economy
	Ic = 0	No inputs for circular economy
	0 < Ic ≤ 0,85	Low Circularity: Low level of inputs for circular economy
	0,85 < Ic ≤ 1,5	Medium Circularity: Medium level of inputs for circular economy
	Ic > 1,5	High Circularity: High level of inputs for circular economy