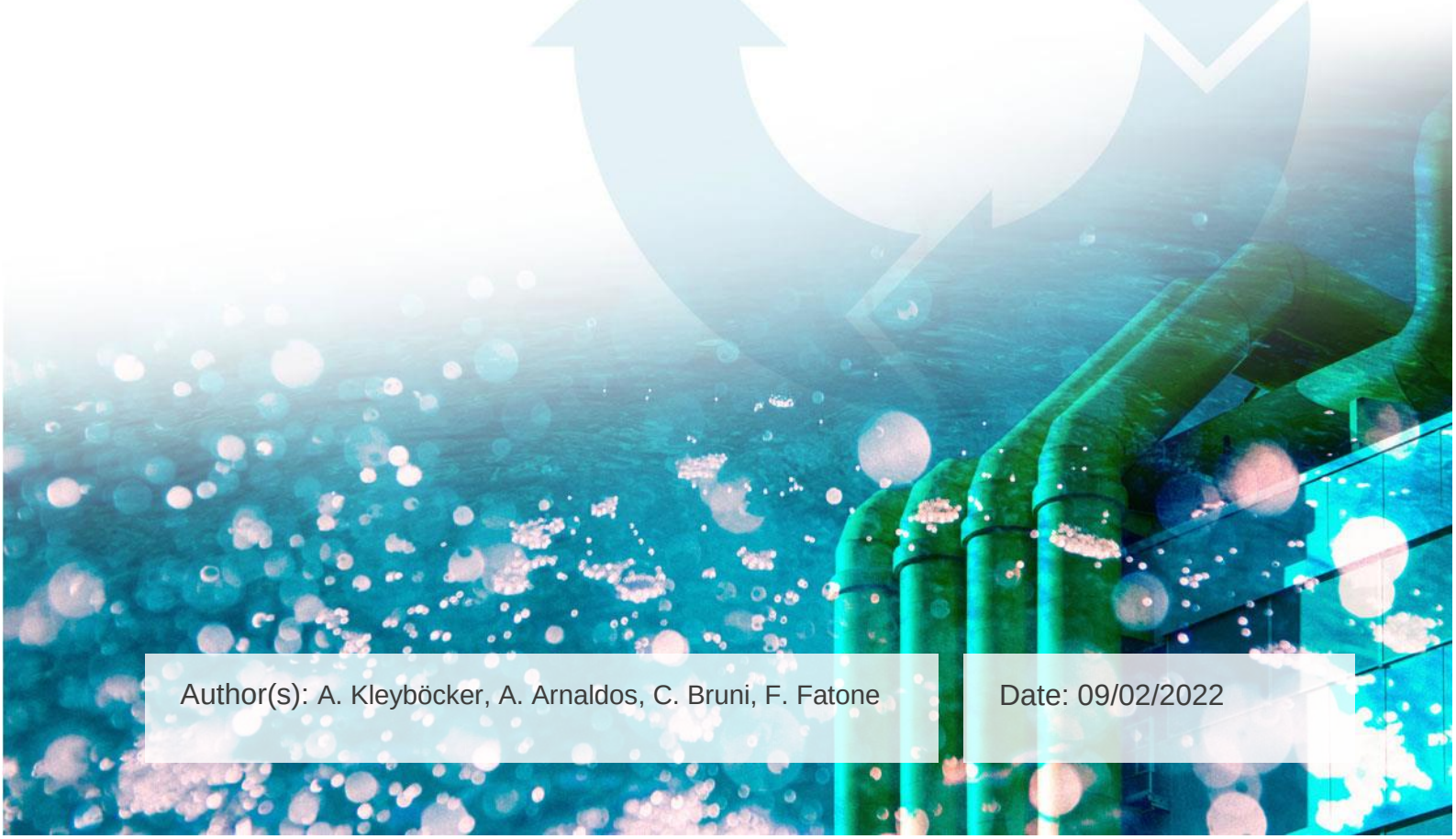
ULTIMATE

WATER SMART INDUSTRIAL SYMBIOSIS

Accompanying document to

D1.6 Technology Evidence Base concept and integration



Author(s): A. Kleyböcker, A. Arnaldos, C. Bruni, F. Fatone

Date: 09/02/2022

The project leading to this application has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 869318

Technical References

Project Acronym	ULTIMATE
Project Title	ULTIMATE: indUstry water-utiLiTy symbiosis for a sMarter wATer society
Project Coordinator	Gerard van den Berg KWR
Project Duration	01.06.2020 – 31.05.2024 (48 months)

Deliverable No.	D1.6
Dissemination level [1]	PP
Work Package	WP1
Task	T1.1
Lead beneficiary	KWB
Contributing beneficiary(ies)	EUR, UNIVPM, UNEXE
Author(s)	A. Kleyböcker, A. Arnaldos, C. Bruni, F. Fatone
Quality Assurance	J. van den Broeke, A. Rubini & S. Casas Garriga
Due date of deliverable	30.11.2021
Actual submission date	18.11.2021

[1] PU = Public
PP = Restricted to other programme participants (including the Commission Services)
RE = Restricted to a group specified by the consortium (including the Commission Services)
CO = Confidential, only for members of the consortium (including the Commission Services)

The project leading to this application has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 869318

Document history

V	Date	Author(s) /Reviewer(s) (Beneficiary)	Description
0.1	15.09.2021	A. Kleyböcker, A. Arnolds, C. Bruni, F. Fantone	Send to J. van den Broeke for internal review
0.2	30.09.2021	J. van den Broeke	Reviewed document
0.3	06.10.2021	A. Kleyböcker	Review addressed and send to project partners for feedback and confirmation of the concept (MS14)
0.4	20.10.2021	Project partners	Feedback and confirmation provided by the project partners
0.5	28.10.2021	A. Kleyböcker	Document supplemented with the feedback of the project partners and send to A. Rubini for external review
0.6	28.10.2021	A. Rubini (Water Europe)	External review
0.7	02.11.2021	A. Kleyböcker	Feedback of the external review addressed
0.8	11.11.2021	S. Casas Garriga, G. van den Berg	Quality Control
1	18.11.2021	A. Kleyböcker	Feedback of quality control addressed → final document
2	09.02.2022	A. Kleyböcker	Feedback of EC addressed

The project leading to this application has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 869318

Executive Summary

Background and objective of the TEB

In the frame of the H2020 project NextGen (Grant Agreement No. 776541), a technology evidence base (TEB) has been set up. It is a database that will contain the results of the NextGen demo cases and generic information on the demonstrated circular economy technologies in NextGen. The aim of the TEB is to unify the results and to allow for an easy access to relevant information needed for setting up new circular economy schemes in the water sector. The TEB will be accessible via the NextGen Marketplace. In the long term, Water Europe will host the TEB along with the Marketplace. Up to now, the TEB contains 26 factsheets prepared by the NextGen consortium. In NextGen, the technologies are applied mainly for water, material and energy recovery from municipal wastewater.

Ultimate focuses on water smart industrial symbioses and demonstrates circular economy based technologies applied in the industrial, water and energy sectors. Ultimate supplements very well the industrial aspect in the TEB and provides new information on symbiotic cooperation opportunities between the industry and the water sector. Hence, the Ultimate technologies are very suitable to extend the TEB.

TEB concept and integration of the Ultimate technologies

The TEB is structured in three domains focusing on technologies to recover and reuse (1) water, (2) material and (3) energy. Each domain consists of different subdomains for example wastewater treatment for water reuse, nutrient recovery technologies or biomass production technologies. Each subdomain provides a collection of technology factsheets. The concept explains the taxonomy of the NextGen technologies and the integration of the Ultimate technologies in this taxonomy. The technology factsheets contain mainly generic information, while the case study factsheets will contain case study specific information and will be accessible via the technology factsheets, but also directly through the knowledge portal. Finally, the TEB concept considers aspects regarding the assurance of a good data quality and provides an outlook for its future maintenance.

Exploitation and EU-added value of the TEB

The EU-added value of the TEB (D1.6 and D1.7) will be a very broad collection of evidence-based data from circular economy related technologies. Besides NextGen and Ultimate, also B-WaterSmart (Grant Agreement No. 869171) will deliver factsheets for the TEB. The sister project Water-Mining (Grant Agreement No. 869474) already indicated its interest to contribute to the TEB. Ultimate will promote further the TEB in order to gain more projects to present their results in the TEB. The collection and open access presentation of the technologies will support decision makers and investors to gain a fast overview of the opportunities and proven concepts of circular economy.

The project leading to this application has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 869318

Together with the Marketplace (D5.5), the TEB will severely contribute to the transition from a linear to a circular economy in Europe.

The TEB promotes technologies that are in line with the ambitions of the European Green Deal (European Commission 2019) to reduce strongly our greenhouse gas emissions, to provide clean water, to maintain healthy soil, make industry resilient and produce cleaner energy. The TEB presents technologies that can be applied in the frame of the Regulation (EU) 2020/741 on minimum requirements for water reuse, the Regulation (EU) 2019/1009 laying down rules on the making available on the market of EU fertilising products and the Directive (EU) 2018/2001 on the promotion of the use of energy from renewable sources.

The project leading to this application has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 869318

Disclaimer

This publication reflects only the author's views and the European Union is not liable for any use that may be made of the information contained therein.

The project leading to this application has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 869318

Table of Contents

Abbreviations

AAT	Advanced anaerobic technology
AOP	Advanced oxidation processes
AnMBR	Anaerobic membrane bioreactor
ASR	Aquifer storage recovery
CAPEX	Capital expenditures
CEA	Cost-effectiveness analysis
GAC	Granular activated carbon
HFMC	Hollow fibre membrane contactor
KPI	Key performance indicator
LCA	Life cycle assessment
LCC	Life cycle costing
MBR	Membrane bioreactor
MELiSSA	Micro-ecological life support system alternative
MNR	Metabolic network reactor
OPEX	Operational expenditures
QCRA	Quantitative chemical risk assessment
QMRA	Quantitative microbial risk assessment
RO	Reverse osmosis
TEB	Technology evidence base
WWTP	Wastewater treatment plant

Table of figures

The project leading to this application has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 869318

1. Introduction

In the frame of the H2020 project NextGen (Grant Agreement No. 776541), a technology evidence base (TEB) has been set up. It is a database that will contain the results of the NextGen demo cases and generic information on the demonstrated circular economy technologies in NextGen. The aim of the TEB is to unify the results and to allow for an easy access to relevant information needed for setting up new circular economy schemes in the water sector. The TEB will be accessible via the NextGen Marketplace. In the long term, Water Europe will host the TEB along with the Marketplace. Up to now, the TEB contains 26 factsheets prepared by the NextGen consortium. In NextGen, the technologies are applied mainly for water, material and energy recovery from municipal wastewater.

Ultimate focuses on water smart industrial symbioses and demonstrates circular economy based technologies applied in the industrial, water and energy sectors. Ultimate supplements very well the industrial aspect in the TEB and provides new information on symbiotic cooperation opportunities between the industry and the water sector. Hence, the Ultimate technologies are very suitable to extend the TEB.

The concept of the TEB is explained in the following chapter and the link to the first version of the TEB is provided. The concept includes the structure and taxonomy of the circular economy technologies from NextGen as well as the integration of the Ultimate technologies into the existing taxonomy. Each technology is presented via a factsheet. The technology factsheets contain mainly generic information, while the case study factsheets will contain case study specific information and will be accessible via the technology factsheets, but also directly through the knowledge portal. Finally, the TEB concept considers aspects regarding the assurance of a good data quality and provides an outlook for its future maintenance.

The project leading to this application has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 869318

2. Concept of the TEB

The concept of the TEB comprises the structure and organization of the TEB, its contents, aspects regarding the assurance of a good data quality and an outlook for its future maintenance.

2.1. Structure and organisation of the NextGen TEB

The first version of the TEB is already open accessible via the NextGen and Ultimate webpages at:

- https://mp.nextgenwater.eu/teb/
- https://ultimatewater.eu/
- https://ultimatewater.eu/results/

Figure 1 illustrates the entrance of the TEB with the three cycles concerning the recovery and reuse of water, material and energy. The nexus between the three cycles emphases the potential for synergies of the circular economy technologies and the figure explains the circular economy character of the technologies supporting the TEB users to easily discover new opportunities for creating their own circular economy concepts.

After clicking on one of the cycles, the next webpage provides an overview of the technology domains that are relevant for the selected cycle.

For the water cycle:

- Wastewater treatment for water reuse
- Rainwater harvesting systems
- Surface water and infiltration systems
- Groundwater systems
- Desalination technologies

For the nutrient and material cycle:

- Nutrient recovery technologies
- Material recovery technologies
- Food/fodder production technologies

For the energy cycle:

- Biomass production technologies
- Heat recovery & storage systems

Each domain of technology contains subdomains and factsheets. Figure 2 shows an example for the material cycle.

The project leading to this application has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 869318

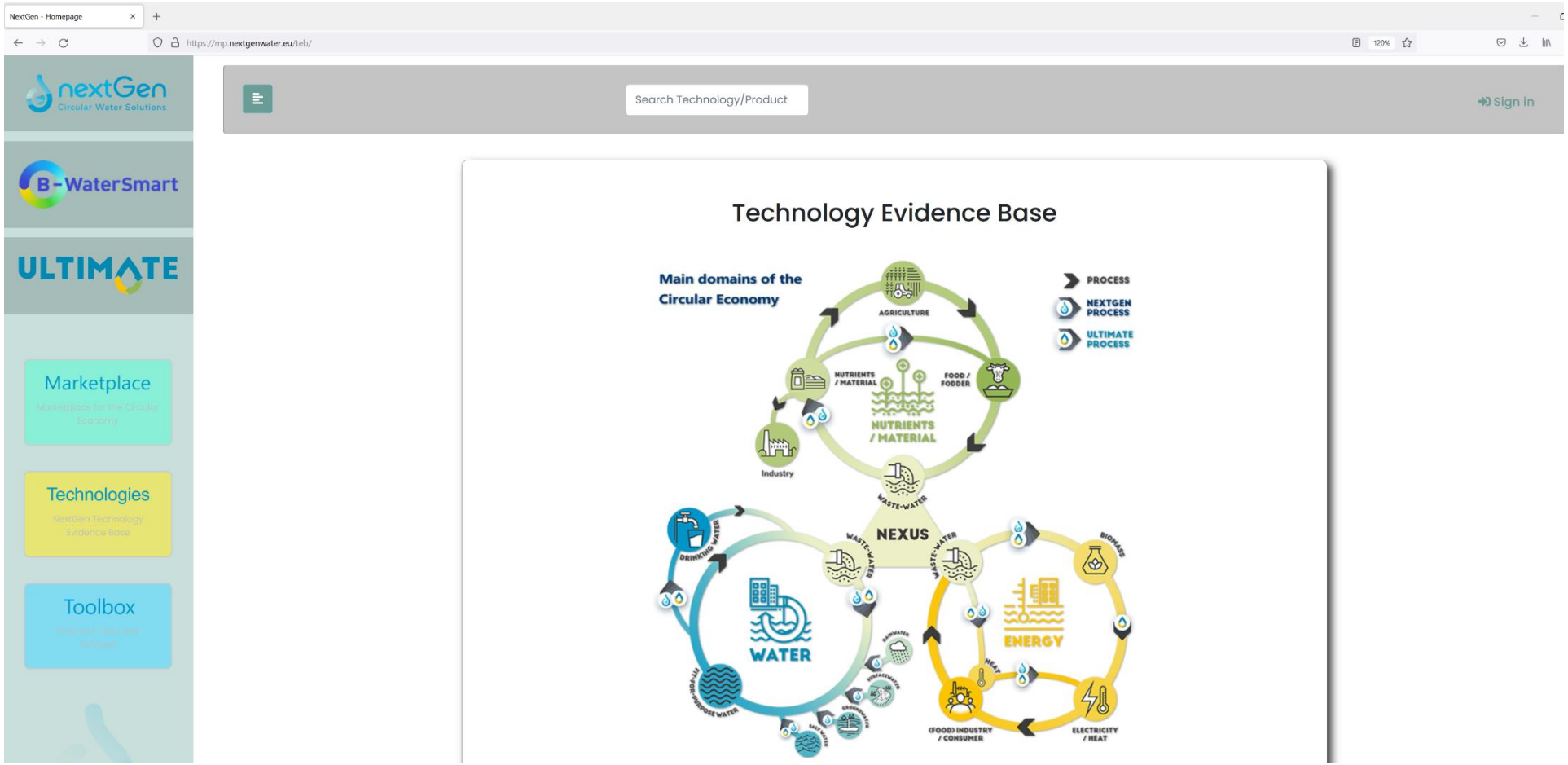


Figure 1 Overview figure of the TEB and starting point to enter the TEB

The project leading to this application has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 869318

Figure 2 *Example for the display of the nutrients/material cycle*

Via the “Overview of Technologies” button (Figure 1), all factsheets sorted by their subdomains and broader domains can be accessed as shown in Figure 3. This structure is also called *taxonomy of the technologies*.

The project leading to this application has received funding from the European Union’s Horizon 2020 research and innovation programme under grant agreement No 869318

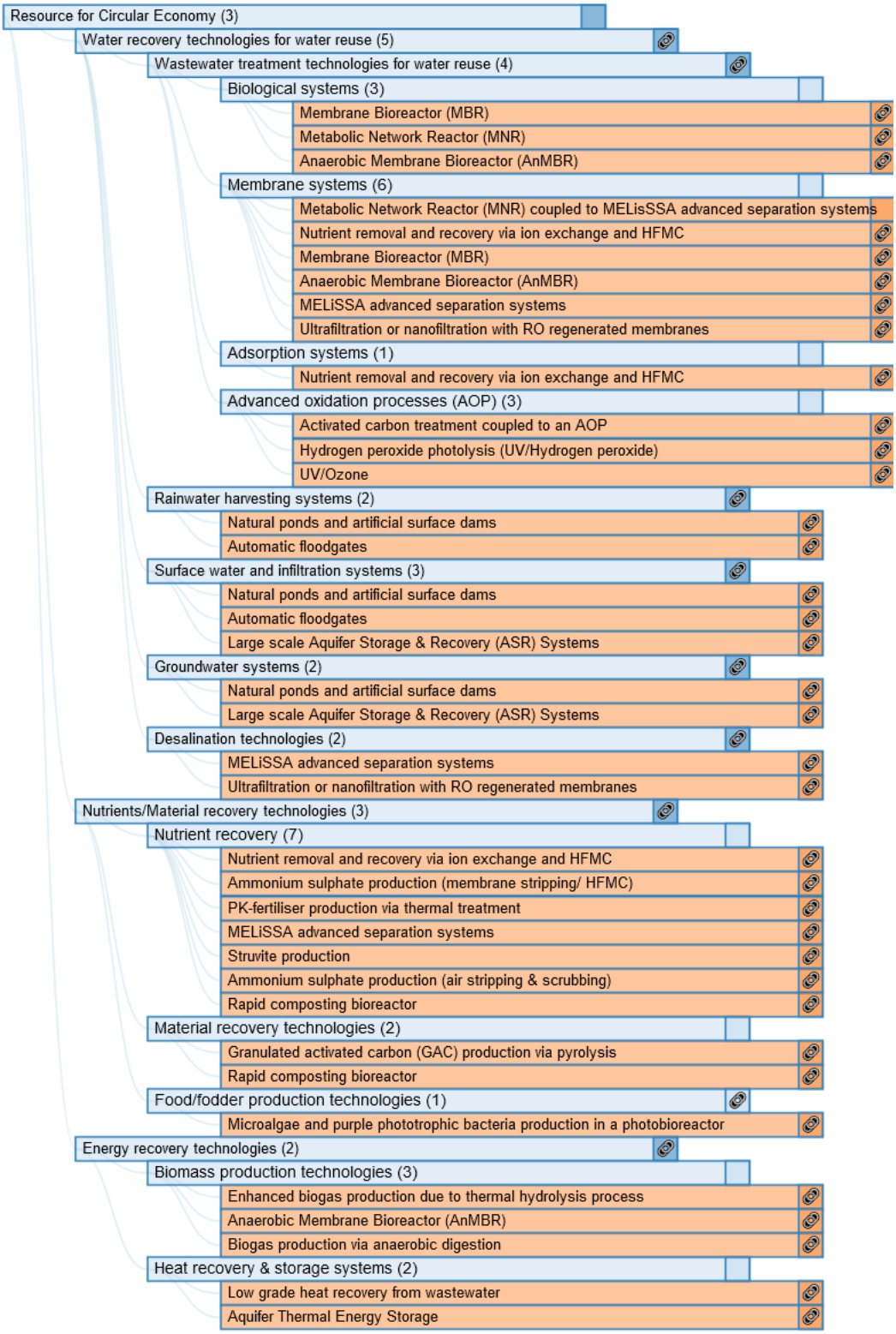


Figure 3 *Overview on the taxonomy of the technologies consisting of technology domains (blue), subdomains (blue) and factsheets (orange) of the NextGen technologies*

Via the search function in the upper part of the TEB webpage, the user can search directly for a technology or product as shown in Figure 4 and marked with a red circle.

The project leading to this application has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 869318

Just below the search function, the path of the domain, subdomain and factsheet is displayed. By clicking on the domain or subdomain, the user can navigate back to the overview pages. The same navigation can be done by clicking on the blue button of the broader domain and the orange buttons of the subdomains (Figure 4, black circles).

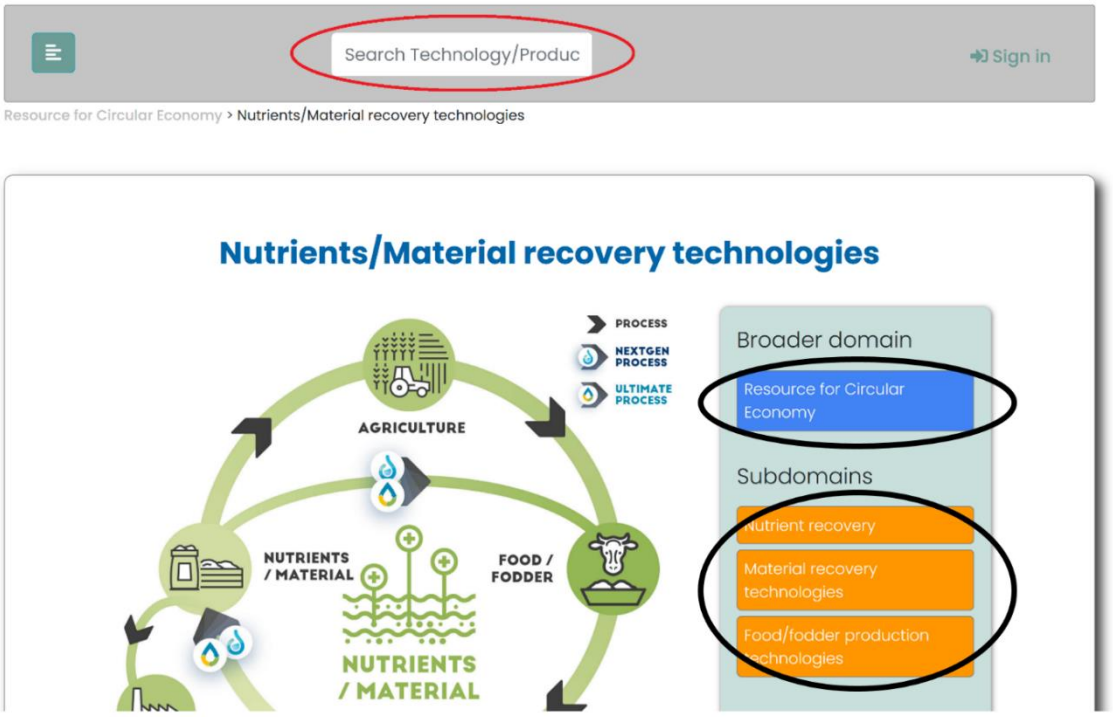
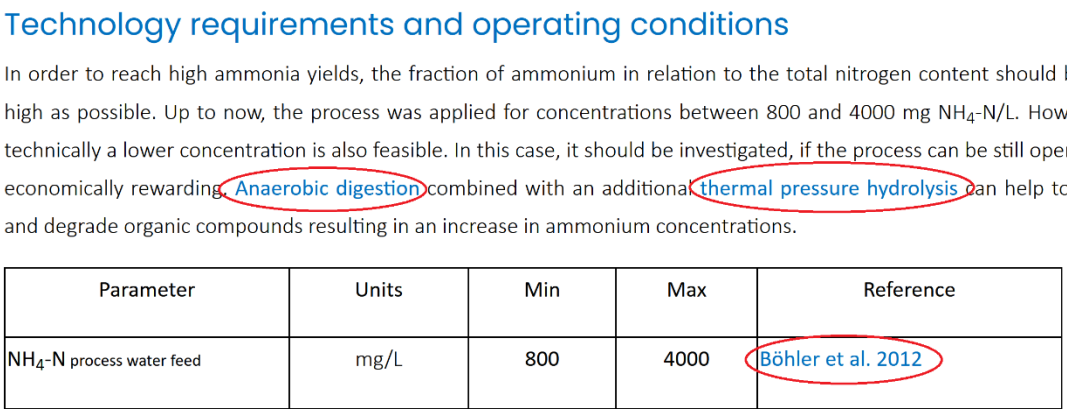


Figure 4 *Search function in the upper part of the TEB webpage marked with a red circle and buttons to access the broader domain and subdomains are marked with black circles*

Between the different factsheets, links are provided in order to easily switch between pages and to easily find information (Figure 5). Those links are further explained in the next paragraph “Content of the factsheets”.



Technology requirements and operating conditions

In order to reach high ammonia yields, the fraction of ammonium in relation to the total nitrogen content should be as high as possible. Up to now, the process was applied for concentrations between 800 and 4000 mg NH_4-N/L. However, technically a lower concentration is also feasible. In this case, it should be investigated, if the process can be still operated economically rewarding. Anaerobic digestion combined with an additional thermal pressure hydrolysis can help to lyse and degrade organic compounds resulting in an increase in ammonium concentrations.

Parameter	Units	Min	Max	Reference
NH_4-N process water feed	mg/L	800	4000	Böhler et al. 2012

Figure 5 *Example for links to other factsheets presenting technologies which are related to the described technology and for links to cited publications: all marked with red circles.*

The project leading to this application has received funding from the European Union’s Horizon 2020 research and innovation programme under grant agreement No 869318

2.2. Content of the factsheets

Each factsheet has the same structure (Figure 6). The basic information in the factsheets of the technologies is and will be generic. For each aspect (see bullet points below), easy-to-understand with summarised information content is presented together with a link to more detailed information such as literature references. For references the first choice shall be open access literature.

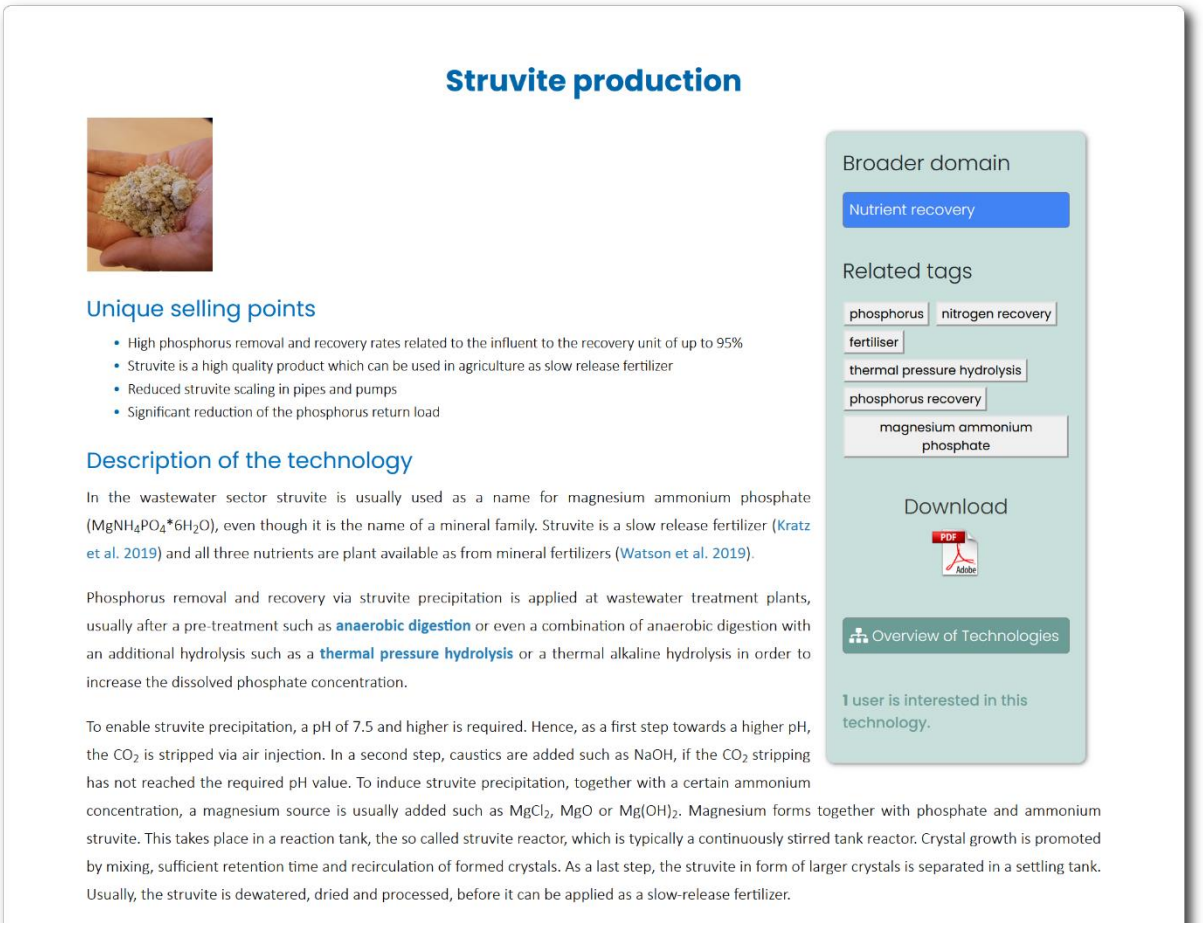


Figure 6 Example of the first part of a factsheet

Each factsheet will contain the following elements:

Generic information about the technology:

- Name of the technology
- Unique selling points
- Description of the technology (point of application, capacity, explanation of the process with literature references, type of product produced by the technology)
- Flow scheme of the technology
- Pictures of the technology and if available short videos
- Synergetic effects and motivation to implement this technology

The project leading to this application has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 869318

- Key performance indicators (KPIs) & technical parameters: data for the performance of the technology (e.g. nutrient recovery rate, biogas yield, log removal rate of pathogenic organisms),
- Requirements for the implementation of the technology and operating conditions
- Link to the case study where the technology is applied (here the case study specific information will be presented)
- Links to similar related technologies or other technologies producing the same product
- Literature references

The results of the Ultimate related technologies will be presented as case study specific information. This part is not yet integrated in the online version of the TEB and will be presented on a separate web page that will be accessible via the related technology factsheet or directly via the button “Living Labs – Case Studies” on the Knowledge Portal, where also the button for the TEB “Technologies” is found (Figure 7).

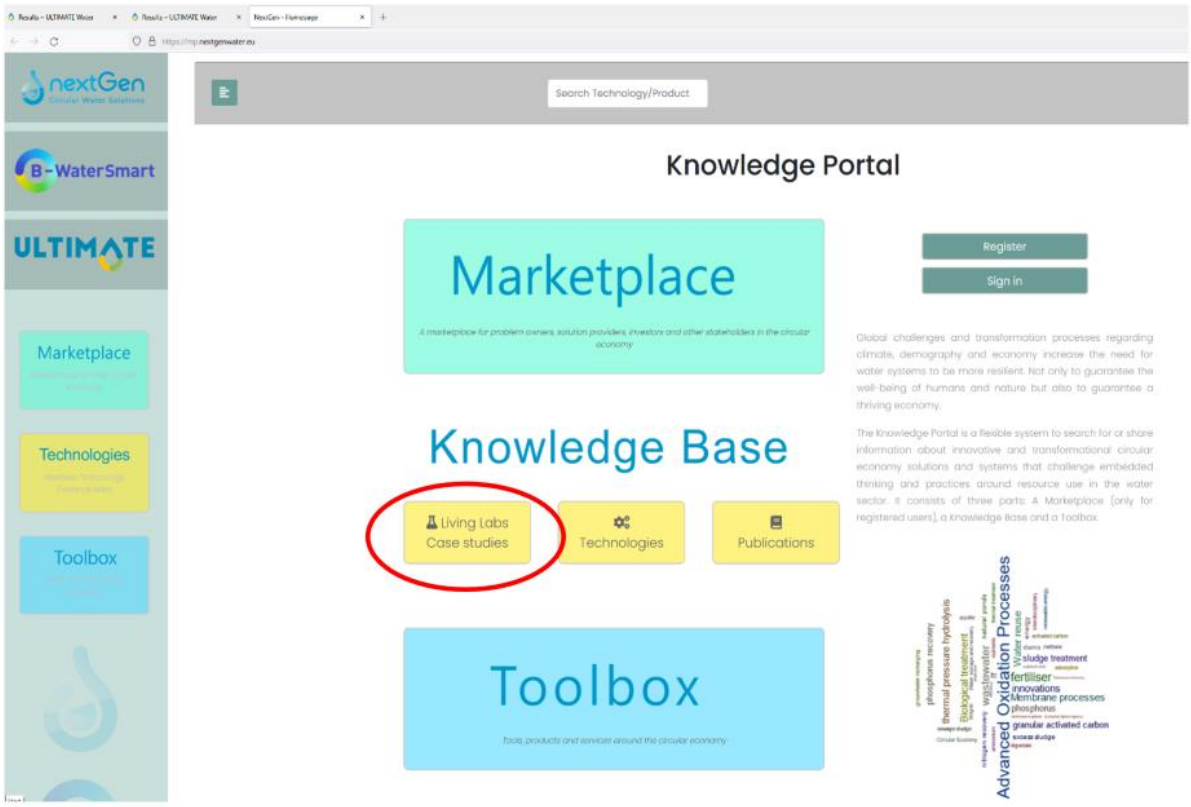


Figure 7 *Knowledge portal of the projects NextGen, B-WaterSmart and Ultimate: the red circle marks the button to access the future case study factsheets*

Case study specific information:

- Info graphic of the relevant case study (already prepared by WP6)

The project leading to this application has received funding from the European Union’s Horizon 2020 research and innovation programme under grant agreement No 869318

- Description of the case study
- Abstract of operational challenges and lessons learned from WP1 and link to the corresponding deliverables D1.3, D1.4, D1.5 (New approaches and best practices for the optimal operation of the technologies and explaining the success of the symbioses)
- Abstract of the outcomes of the assessments from WP2 (e.g. LCA (CO_2 footprint, energy consumption/production), QMRA, QCRA, LCC incl. CAPEX, OPEX, return rate, distribution costs, etc. and CEA),
- Legal and regulatory information regarding the value chain concerning the technology (→link to the corresponding case study results in WP4),
- Business opportunities (→link to the corresponding case study results in WP5)

Each technology factsheet and case study factsheet are and will be downloadable as a pdf-files as shown in Figure 6.

2.3. Integration of the Ultimate technologies in the existing TEB

In Ultimate, 20 different technologies/ treatment trains will be investigated. In the TEB, they will be categorised in the same structure as in NextGen, differentiating between water, material and energy recovery and reuse. In order to integrate the Ultimate technology taxonomy in the NextGen technology taxonomy, the TEB has to be extended with a few subdomains.

Figure 8 shows the new technology taxonomy for the water cycle including both the NextGen and the Ultimate technologies. “Electrostimulated systems” and “Monitoring and control systems” are the new subdomains, which will be added in the TEB together with 17 new factsheets and the update of three already existing factsheets with data from Ultimate.

The material cycle will be extended by four additional factsheets and two already existing factsheets will be supplemented with data resulting from the Ultimate project (Figure 9).

The project leading to this application has received funding from the European Union’s Horizon 2020 research and innovation programme under grant agreement No 869318

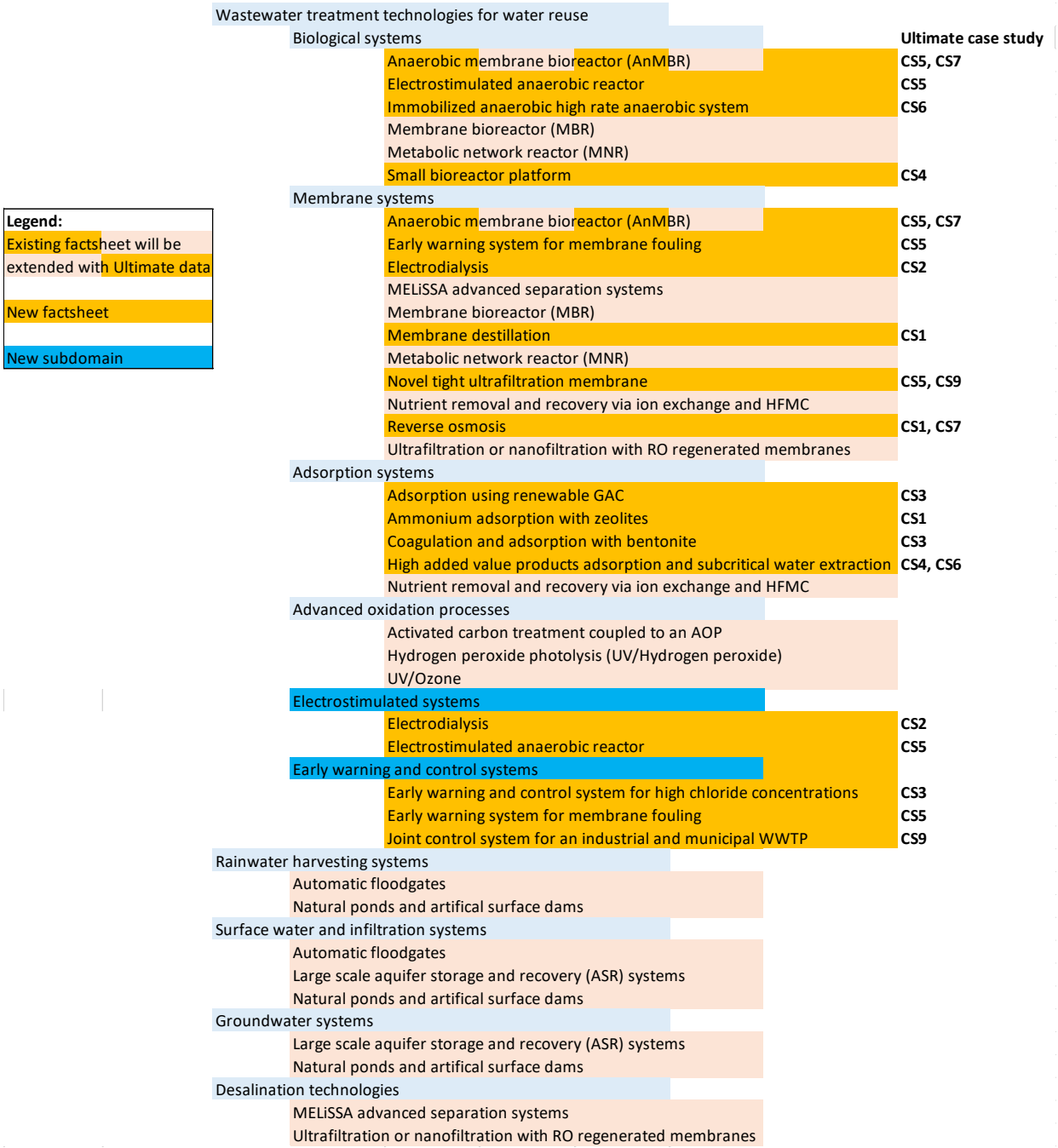


Figure 8 *Extension of the NextGen technology taxonomy with the Ultimate technologies for the water cycle*

The project leading to this application has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 869318

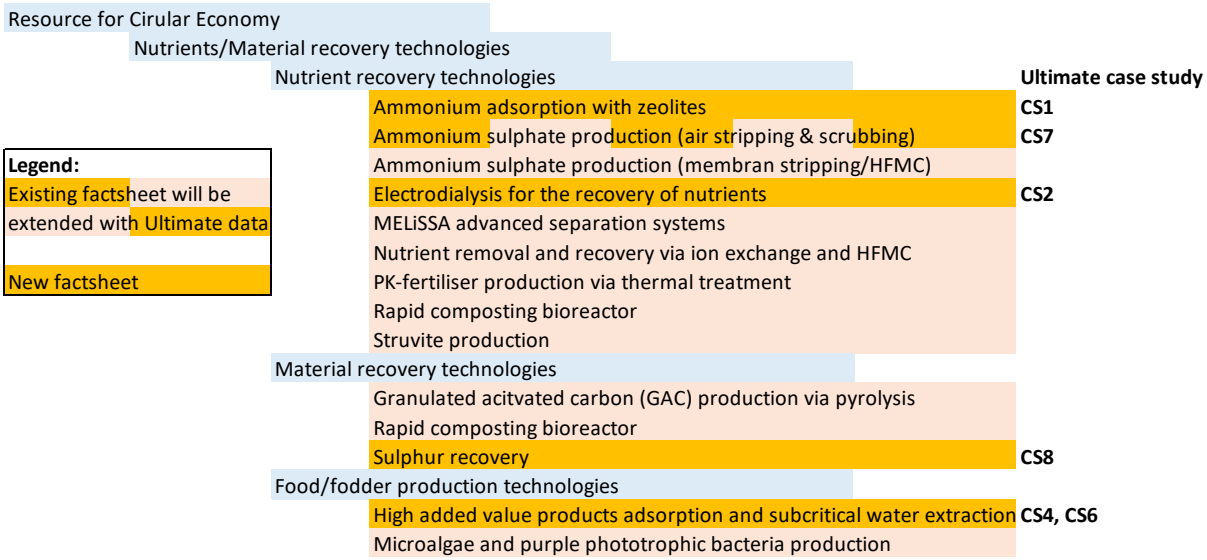


Figure 9 *Extension of the NextGen technology taxonomy with the Ultimate technologies for the material cycle*

As shown in Figure 10, the two new subdomains “Electrical power and heat generation systems” and “Monitoring and control systems” will be added to the energy cycle. Four new factsheets will be produced and three existing factsheets will be supplemented with Ultimate data.

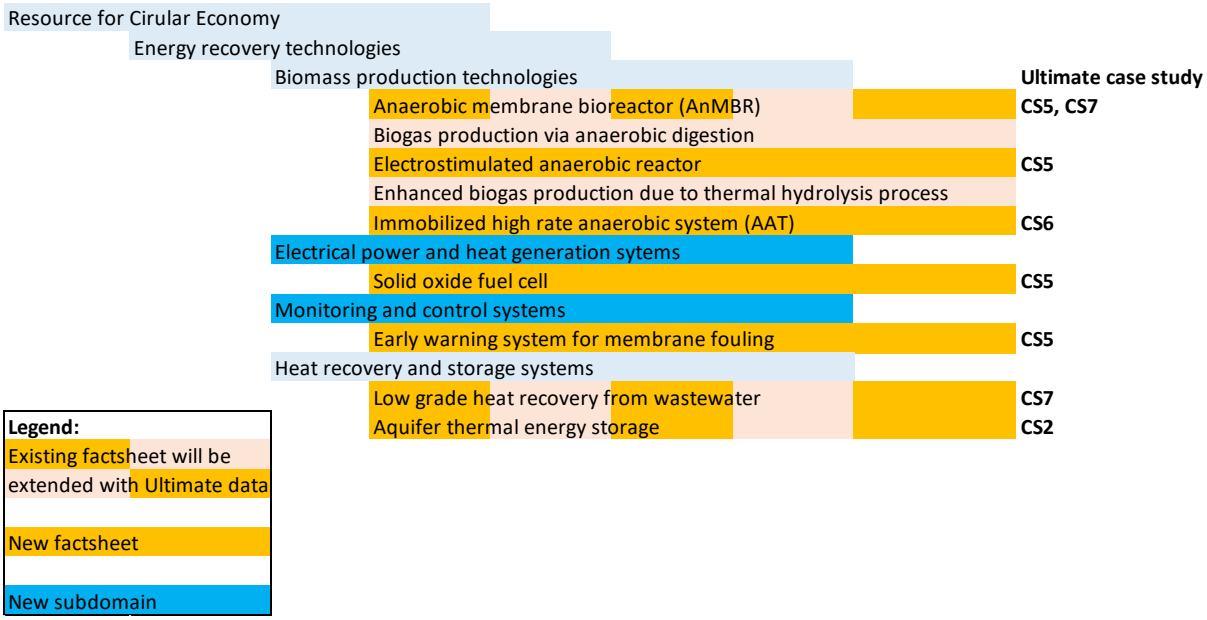


Figure 10 *Extension of the NextGen technology taxonomy with the Ultimate technologies for the energy cycle*

Some technologies fit to more than only one domain or subdomain. To make it more user friendly to search for a certain technology, the corresponding factsheet fitting in multiple subdomains will be accessible in every subdomain it fits to.

The project leading to this application has received funding from the European Union’s Horizon 2020 research and innovation programme under grant agreement No 869318

Specific attention was given to the subdomain “monitoring and control systems” because of the following: the TEB is connected to the *Toolbox* (https://mp.nextgenwater.eu/-l/Product/; Figure 11) which presents software and tools in the context of circular economy. There, for example, tools to assess the circular economy technologies such as an online tool for quantitative microbial risk assessments or the description of the tool for life cycle assessments can be found. As the monitoring and control systems can be also categorised as tools, they will be presented in the *Toolbox* in addition to the TEB, too.

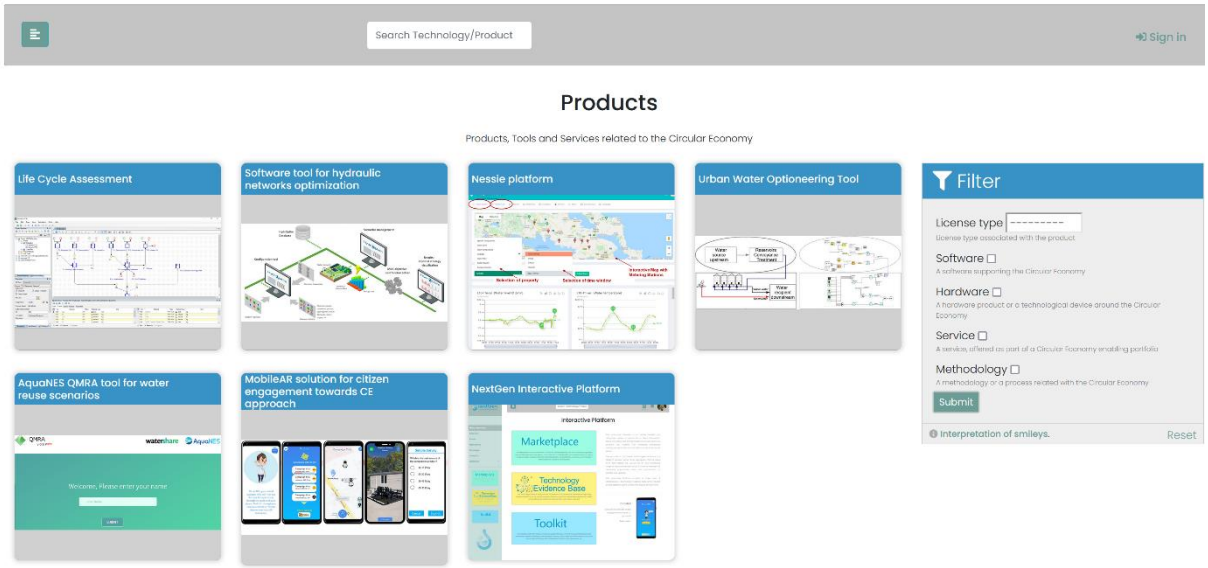


Figure 11 *Toolbox: consisting of different tool and services which can be used in in the context of circular economy solutions*

2.4. Data quality and future of the TEB

In order to cover a wider technology spectrum, the TEB is planned to be extended with further technologies from collaborative research projects such as B-WaterSmart, a sister project of Ultimate or with interested other research projects and parties providing validated information such as Water-Mining. To gain more scientifically validated data for the TEB, the consortium members of Ultimate will promote the TEB and present it to other research projects.

To approve a new factsheet or a contribution to an already existing factsheet, several requirements should be met as summarised in Figure 12.

The project leading to this application has received funding from the European Union’s Horizon 2020 research and innovation programme under grant agreement No 869318

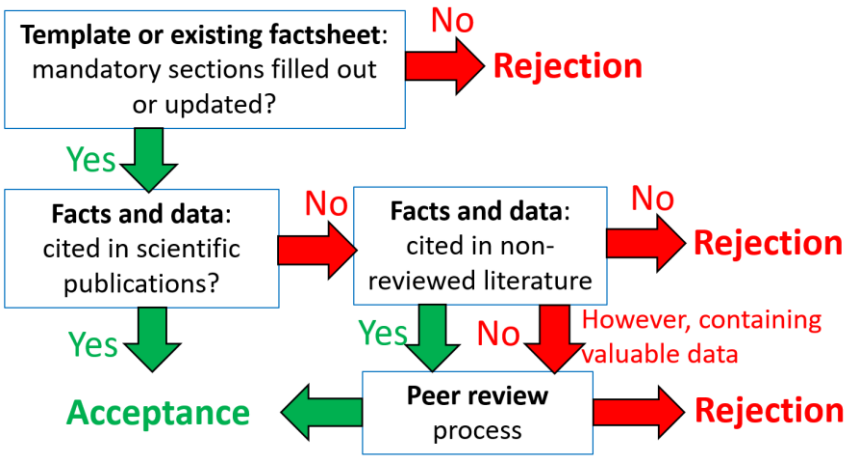


Figure 12 Decision tree to approve a new factsheet or an update of a factsheet

Template or existing factsheet: mandatory sections filled out or updated?

A template for a new factsheet will be provided to be filled out. This template will consist of different sections, which are mandatory to be filled out. If those are not filled out, the contribution will be rejected and needs to be revised.

Mandatory sections will be:

- Classification of the technology group indicating the position of the technology in the infographic and taxonomy
- 3 tags (keywords)
- Unique selling points
- Description of the technology (incl. capacity and level of competence for its operation)
- Flow scheme
- Pictures and (if available) videos
- Synergetic effects and motivation to implement the technology
- Requirements of the technology and operating conditions
- Key performance indicators
- References to case studies or similar projects
- Literature references (including links to publications with DOI, ISBN etc.)

In the case the factsheet exists already, the new contributor uses the already existing factsheet and updates it with his/her own data. The updated factsheet will be shared with the authors of the original factsheet and reviewed by them (in the pdf-version of each factsheet, the authors are indicated). The original authors will have the opportunity to update their contributions in this frame, too. So, they can make sure, that their old data are up to date in the case the technology has been further optimised. In the case the original authors are not available anymore, an alternative is needed. Currently, different options are being investigated and discussed among the core team

The project leading to this application has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 869318

of the TEB task. For example, one option might be to involve other organisations such as the Biorefine Cluster Europe. Ultimate recently joined the cluster (https://www.biorefine.eu/), which aims to interconnect biobased research and innovation projects dealing with circular economy and to disseminate and promote their results.

Optional sections of the factsheet will be the case study specific information:

- Lessons learned from the first implementation and operation of the technology
- Outcome of assessments such as life cycle assessment, cost assessment and risk assessment
- Legal and regulatory information concerning the technology and its products
- Business opportunities

Facts and data cited in scientific publications?

Important facts and data must be cited. If the used literature comprises mainly peer reviewed scientific publications, the contribution to the TEB can be accepted, because this indicates good data quality. In this case, the links to the publications and the DOIs or ISBN must be provided in the literature reference section. Therefore, if available, open access publications shall be preferred to cite the facts.

Facts and data cited in non-reviewed literature or not cited at all?

If no peer-reviewed publications were used to cite facts and data, a peer-review process is required to decide, if the contribution can be accepted for publication in the TEB.
In the case, the contribution contains no citation at all, but provides valuable data, a peer review process will help to better assess the quality of the contribution and the suitability for the TEB. The quality of the factsheet depends highly on the reliability of the shown data.
The choice of the reviewers is still under discussion among the core team of the TEB task. In this case, the cooperation with a certain organisation such as the Biorefine Cluster Europe might also be a good option.

In addition, the TEB might also be interesting for technology providers who want to present their technology in the context of the marketplace, but have not done an independent evaluation or assessment of their technologies by scientific parties. If there is no evidence that the provided data and facts were produced in a reliable way, the contribution can be directly rejected. However, if the evaluator considers the contribution as highly valuable, it can be peer reviewed as well. In the case the reviewer decides to accept the contribution, a label with the statement “data quality is uncertain” has to be implemented.

The project leading to this application has received funding from the European Union’s Horizon 2020 research and innovation programme under grant agreement No 869318

Maintenance and hosting of the TEB

If there will not be a new update of a certain factsheet within two years, all authors of this factsheet will be automatically asked to update their factsheet. For the case, the authors won't be available anymore after the project lifetimes, an alternative is needed. Different options for the alternative will be discussed in the coming months in the core team.
The TEB will be hosted by Water Europe and be linked to the NextGen and Ultimate online marketplace. Its access shall be free of charge.

The project leading to this application has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 869318

3. Summary and conclusions

In the projects NextGen and Ultimate, a technology evidence base (TEB) is developed as a “Wikipedia” for circular economy related technologies. The aim of the TEB is to unify the project results and to allow for an easy access to relevant information needed for setting up new circular economy schemes in the water sector.

The TEB is structured in three domains focusing on technologies to recover and reuse (1) water, (2) material and (3) energy. Each domain consists of different subdomains for example wastewater treatment for water reuse, nutrient recovery technologies or biomass production technologies. Each subdomain provides a collection of technology factsheets. The concept explains the taxonomy of the NextGen technologies and the integration of the Ultimate technologies in this taxonomy. The technology factsheets contain mainly generic information, while the case study factsheets will contain case study specific information and will be accessible via the technology factsheets, but also directly through the knowledge portal. Finally, the TEB concept considers aspects regarding the assurance of a good data quality and provides an outlook for its future maintenance.

The EU-added value of the TEB (D1.6 and D1.7) will be a very broad collection of evidence-based data from circular economy related technologies. Besides NextGen and Ultimate, also B-WaterSmart (Grant Agreement No. 869171) will deliver factsheets for the TEB. The sister project Water-Mining (Grant Agreement No. 869474) already indicated its interest to contribute to the TEB. Ultimate will promote further the TEB in order to gain more projects to present their results in the TEB. The collection and open access presentation of the technologies will support decision makers and investors to gain a fast overview of the opportunities and proven concepts of circular economy. Together with the Marketplace (D5.5), the TEB will severely contribute to the transition from a linear to a circular economy in Europe.

The TEB promotes technologies that are in line with the ambitions of the European Green Deal (European Commission 2019) to reduce strongly our greenhouse gas emissions, to provide clean water, to maintain healthy soil, make industry resilient and produce cleaner energy. The TEB presents technologies that can be applied in the frame of the Regulation (EU) 2020/741 on minimum requirements for water reuse, the Regulation (EU) 2019/1009 laying down rules on the making available on the market of EU fertilising products and the Directive (EU) 2018/2001 on the promotion of the use of energy from renewable sources.

The project leading to this application has received funding from the European Union’s Horizon 2020 research and innovation programme under grant agreement No 869318

4. Literature references

Böhler, M., Büttner, S., Liebi, C., Siegrist, H. (2012). Ammoniakstrippung mittels Luft zur Behandlung von Faulwasser und Urin auf der auf der Kläranlage Kloten/Opfikon. Aqua & Gas, 1, 1-7.

European Commission (2019). Communication from the Commission to the European Parliament, the European Council, the Council, the European Economic and Social Committee and the Committee of the Regions. The European Green Deal COM/20197640 final (https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:52019DC0640) accessed on Feb. 8th 2022.

EU (2018/2001) Directive of the European Parliament and of the Council of 11 December 2018 on the promotion of the use of energy from renewable sources https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A32018L2001&qid=1630937219623) accessed on Feb. 8th 2022

EU (2019/1009) Regulation of the European Parliament and of the Council of 5 June 2019 laying down rules on the making available on the market of EU fertilising products and amending Regulations (EC) No 1069/2009 and (EC) No 1107/2009 and repealing Regulation (EC) No 2003/2003 (https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A32019R1009) accessed on Feb. 8th 2022

EU (2020/741) Regulation on minimum requirements for water reuse (https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32020R0741&from=EN) accessed on Feb. 8th 2022

Kratz, S., Vogel, C., Adam, C. (2019). Agronomic performance of P recycling fertilizers and methods to predict it: a review, Nutrient Cycling in Agroecosystems, 115, 1-39.

Watson, C., Clemens, J., Wichern, F. (2019). Plant availability of magnesium and phosphorus from struvite with concurrent nitrification inhibitor application. Soil Use and Management, 35, 4, 675-682.

The project leading to this application has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 869318