D1.1. Comprehensive overview on alternative fertiliser value chains

Check out the FER-PLAY database!

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Deliverable Information Sheet

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Author	Inagro; Inès Verleden [Orcid 0000-0001-5339-1525] & Sander Vandendriessche [Orcid 0000-0003-1096-5861]
Contributing Partners	CETENMA, CIC, EBA, NuReSys, CETAQUA, ACR+, Coldiretti, Naturland, ASAJA
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Keywords list

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- Resource efficiency
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- Agriculture, life cycle assessment
- Sewage sludge
- Bio-waste
- Biological by-products
- Industrial and municipal wastewater
- Digestate
- Treated manure
- Database

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Executive summary

FER-PLAY is working to protect ecosystems, decrease EU dependence on fertiliser imports, and improve resource efficiency through the promotion of alternative fertilisers. The project maps and assesses alternative fertilisers made from secondary raw materials and highlight their multiple benefits to foster their wide-scale production and application.

The main objective of deliverable D1.1 is to showcase the collection of the scientific and practical knowledge about alternative fertilisers from secondary raw materials (both commercially available and under research), as well as to introduce the FER-PLAY database. This provides a comprehensive overview on alternative fertiliser value chains at EU level, covering all phases of alternative fertilisers' life cycle (from secondary raw material production to field application), showing data and figures of alternative fertilising value chains and end products. This is highly valuable since most of the data is available in the references but scattered and not uniformized. The data collection work paves the way to the following phase of the project: deliver clear insights to select those able to better replace conventional fertilisers.

FER-PLAY used a two-step approach to achieve this: first of all, data was collected via an Excel spreadsheet in which project partners were able to add input for several products derived from seven secondary raw materials. This input was then converted into one big table available only for partners, containing 60 identified value chains, which is the base of the public database. This database is differentiated according to the target audience (fertilisers producers, end-users, public administrations, researchers, etc.) or purpose (e.g., assessment, exploitation, etc.) via several information tabs. In the database, it is possible to filter on 'product' and 'secondary raw material' to know more about a specific product the user is looking for. Up to date, not all data have been completed since there are still some knowledge gaps. By simply updating the big table, any new and additional information will become available in the dynamic online database.

In general, it can be concluded that this database is the perfect tool to collect all the available data on alternative fertiliser value chains at EU level in one comprehensive overview. This information will be used for the selection of the seven most promising value chains. Furthermore, it helps to identify knowledge gaps in order to foster their implementation. The public database can be accessed via the project website.

1. Objectives

FER-PLAY is a Horizon Europe project facilitating the uptake of alternative fertilisers, to protect ecosystems, decrease EU dependence on fertiliser imports, foster circularity and improve soil health. The project maps and assesses alternative fertilisers made from secondary raw materials, such as manure, and highlight their multiple benefits in order to promote their wide-scale production and use on field.

There are numerous alternative fertilisers available in the market or under research at EU level. However, most of these and their properties are not widely known yet and the knowledge gap is one of the hinders for a wide market uptake. Therefore, currently available but scattered data and knowledge on alternative fertiliser value chains was collected and refined, considering their whole life-cycle (from production to use). As this data could be valuable for many different stakeholders, the collected data needed to be combined and harmonised in a clear and comprehensive overview to be available in a database.

This database will ensure that the following selection process of the FER-PLAY project can be applied easily, in order to further assess only those seven value chains that are well-characterised and that represent the variability of agricultural applications and practices. Later on in the project, environmental, social and cost effectiveness assessments will be performed on these selected seven value chains through Life Cycle Assessments.

On top of that, **the database is openly available for free** on FER-PLAY's online web page and can be consulted by all interested parties including FER-PLAY's target groups and stakeholders. This will contribute to raise awareness regarding the benefits and viability of the production and use of alternative fertilisers, and consequently contribute to increased sustainability and circularity of the EU food system.

2. Approach and method

As a first step, it was necessary to have an overview on all possible alternative fertiliser value chains across the different secondary raw materials. This task is called the *mapping* and was effectively carried out thanks to the expertise of the Consortium, which counts on alternative fertilisers producers, farmers associations and R&D centres with experience in circular Bioeconomy projects. After a first mapping, resulting in a list of 60 identified value chains, the work proceeded on 48 value chains that had chances to pass the GO/NO-GO selection, according to the criteria that were pre-identified in an early stage of the FER-PLAY project. The project partners provided input on the different value chain parameters and the collected data on the different fertiliser value chains provided the base for the comprehensive overview in the form of a database that is freely accessible online via the project website. The GO/NO-GO selection and the scoring methodologies is briefly described here below in the Work Package structure (see Figure 1).

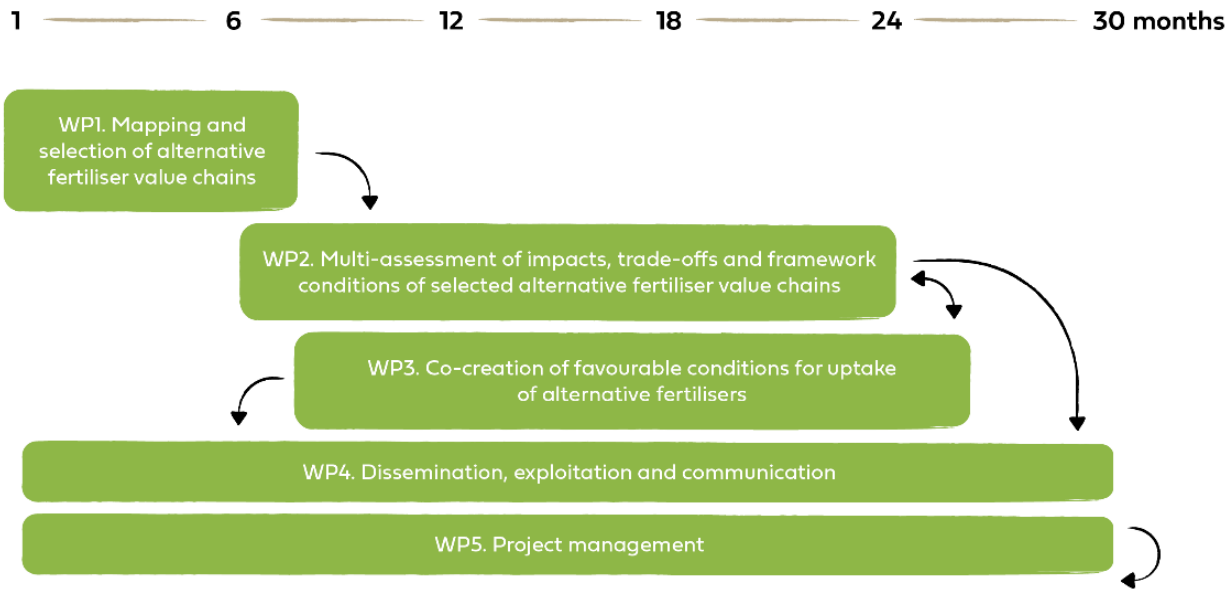


Figure 1. Work package structure of FER-PLAY.

2.1. GO/NO-GO and selection criteria methodology

There are numerous alternative fertilisers available in the market or under research. To ensure geographic representativity, coverage and replicability of the multi-assessment later on, it is crucial to assess only those value chains that are well-characterised and that represent the variability of agricultural applications and practices. To this end, a funnelling process based on a

GO/NO-GO approach will be applied, an agile method that will enable us to be time and resource efficient during this process. The funnelling process facilitates:

- selection of relevant alternative fertiliser value chains from the multitude of existing value chains so that further impact assessment is feasible and resource-effective;
- quickly disregard those value chains that are not viable for industrialisation and/or application due to various problems (e.g., little nutrient content, toxicity, technical nonviability), not considering them for the assessment phase.

The GO/NO-GO approach applies a set of predefined criteria. The value chain will be examined against the first criterion and if the result is positive (GO), it will be analysed against the following one and so on (Figure 2). If the value chain overcomes all the stages, it will be considered as promising and subjected to further selection via a scoring system and assessment.

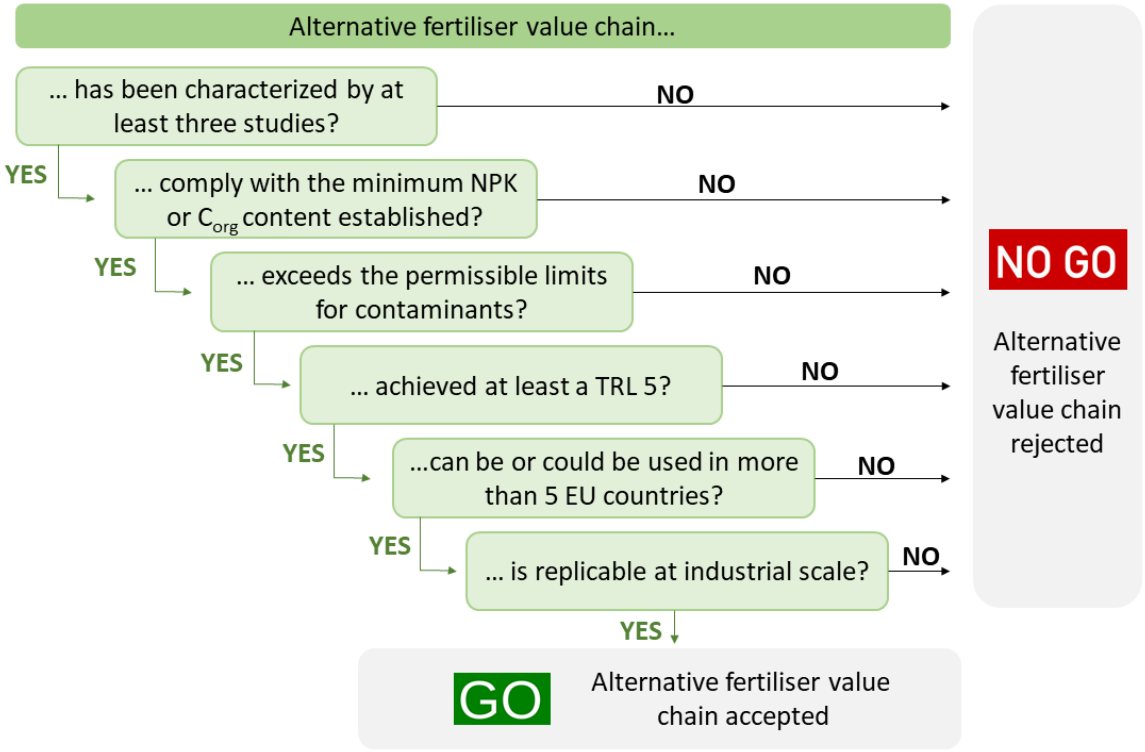


Figure 2. Schematic overview of the GO/NO-GO approach.

2.2. Value chain and parameter template

Alternative fertilisers can be derived from different secondary raw materials. The following were identified:

- urban wastewater: domestic wastewater or the mixture of domestic wastewater with industrial wastewater and/or run-off rain water;
- industrial wastewater: the aqueous discard that results from substances that have been dissolved or suspended in water, typically during the use of water in an industrial manufacturing process or because of the cleaning activities that take place along with that process;
- sewage sludge: a mud-like (solid) residue/by-product resulting from wastewater treatment without anaerobic digestion;
- bio-waste: biodegradable garden and park waste, food and kitchen waste from households, restaurants, caterers and retail premises, and comparable waste from food processing plants;
- biological by-products: organic/biological waste products from other processes;
- digestate: the liquid or solid material processed through anaerobic digestion;
- treated manure: animal manure that has undergone a nutrient recovery treatment.

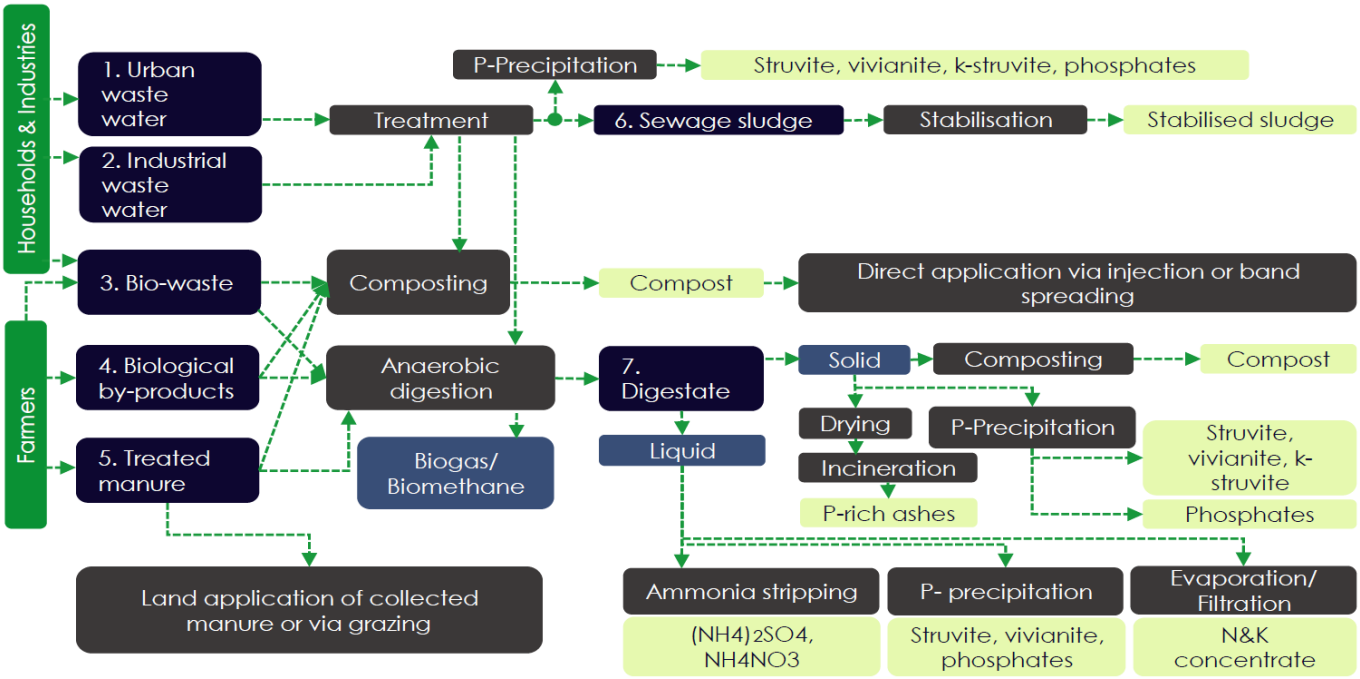


Figure 3. Main alternative fertiliser value chains from secondary raw materials (dark blue) and output products (light green).

Early on, at proposal stage, from within the expertise of the project partners, some alternative fertiliser value chains had been defined across these different secondary raw materials (Figure 3). However, while the data collection was in process, more value chains were identified (Table 1). As a result, the database consists of 60 identified value chains in total, which is twofold higher than the minimum considered at the beginning of the project. The Consortium was able to collect data on 48 of these value chains.

Table 1. Overview of the 60 alternative fertiliser value chains across the seven secondary raw materials.

Urban wastewater
Struvite
Vivianite
K-struvite
Phosphates
Stabilised sludge

Industrial wastewater
Struvite
Vivianite
K-struvite
Phosphates
Stabilised sludge

Bio-waste
Composted bio-waste (green compost from three different geographical regions)
Composted bio-waste (food waste AND green compost)
Struvite
P-rich ashes
Biochar
Hydrochar

Treated manure
Composted animal manure
Ammonium nitate
Ammonium sulphate
Mineral concentrate
Struvite
Vivianite
Phosphates
Biochar
Hydrochar
Liquid fraction of manure (after separation)
Solid fraction of manure (after separation)
K-struvite
Champost
Manure processing effluent

Sewage sludge
Struvite
Vivianite
K-struvite
Phosphates
Stabilised sludge
Composted sewage sludge

Digestate
Untreated (raw) digestate including animal manure
Untreated (raw) digestate without animal manure (plant-based)
Liquid fraction of digestate
Solid fraction of digestate
Liquid and solid equivalent digestate
Composted digestate
Composted digestate from food waste and green waste
Struvite
Enriched biosolids with struvite
Vivianite
K-struvite
Phosphates
P-rich ashes
Tenebrio molitor (insect) frass

Biological by-products
Composted biological by-products
Struvite
Vivianite
K-struvite
Phosphates
P-rich ashes
Hair powder pellets
Feather meal
Horngrit/hornchips
Meat-, bonemeal

For these value chains, data considering all phases of their life cycle needed to be collected. Therefore, the parameters had to be defined per life-cycle phase to fulfill all data requirements and sufficient data to complete the GO/NO GO approach and have data for the selection criteria:

- Production data
- Distribution/trade
- Storage and application on land
- Diffusion into environments
- Product content
- Cost
- Legislation

This breakdown also differentiates the database according to the target audience or purpose. For example, a technology provider will mainly be interested in production data and cost; a famer will mainly be interested in storage and application, product content, legislation and cost; a policy maker will mainly be interested in legislation; a researcher will be interested in all information; a producer will be interested in production data, legislation and cost. This approach and the template to add the information were proposed to all contributing partners, where feedback was taken into account and was incorporated into the template as much as possible.

2.3. Data collection methodology

Once a common template was agreed, the listed alternative fertiliser value chains were divided across the contributing FER-PLAY partners and the searching for and gathering of all relevant data started fractionated according to realistic deadlines with possibilities for extra feedback. This data came from:

- own know-how of partners' and partners' extensive networks;
- consultation of peer-reviewed scientific publications;
- analysis of past and current projects and initiatives developed under the EU funding programmes, including those implemented by partners as well as others relevant to the topic. Some (non-limitative) examples of consulted projects are NUTRIMAN, NUTRI2CYCLE, NITROMAN, WALNUT, RUN4LIFE, INCOVER, …;
- search in databases (e.g. the Nutriman Farmer Platform);
- statistic and market studies for e.g. production and application volumes per country or demand and supply flows (e.g. EUROSTAT);
- feedback from partners' extensive networks and other stakeholders in the value chains.

All partners mentioned the various sources of the data they gathered. These references are kept in the raw data collection excel file instead of on the online database, as this is a massive list

(over 2500 references) scattered throughout the whole file. Adding this to the database would be very complex and most probably result in confusion for the users. However, references can always be requested through the contact details mentioned in the database.

A schematic overview of the various data that was collected can be found in Figure 4. The reader finds the full set of parameters consulting the FER-PLAY online database.

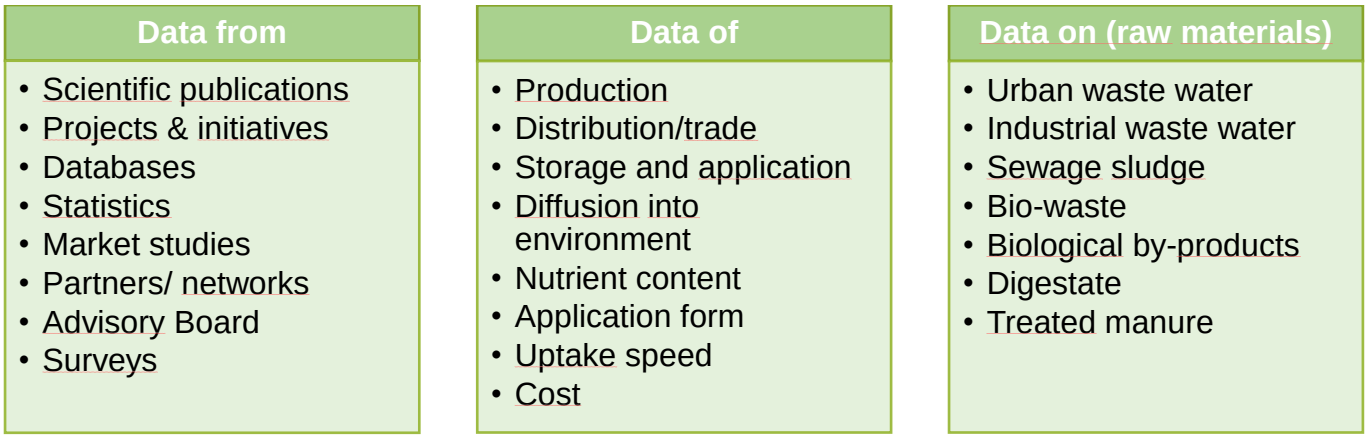


Figure 4. Schematic overview on the data collected within work package 1.

During this process, the data was continuously being revised, gaps and ambiguities were being identified and brought up, to eventually being finalised by the end of February 2023.

2.4. Overview in the form of a database

The collected data feeds an open-access, comprehensive and structured database. Whereas a structured Excel-file was originally envisaged, in the end, the choice was made to utilize Power BI, going further than simply covering the basic requirements. Due to the complex structure of parameters and value chains across different secondary raw materials, it proved quite challenging to easily visualise the available data in a clear overview in Excel without major adjustments and long, complicated formulas. With Power BI, on the other hand, some minor changes in arrangement of the data proved sufficient to provide a clear, complete view, with enough flexibility in the display of columns, filters, groupings, without sacrificing usability.

The database, managed by INAGRO, is public and accessible through the project website and can be easily updated throughout the project time when necessary. This allows different types of stakeholders to have the information organised and displayed adequately for a full vision and overview of the alternative fertiliser value chains.

2.5. Challenges and solutions

Throughout this process, and derived from the complexity, some challenges arose:

- First of all, it became clear that some value chains generated very little to no data. This strongly depends on the secondary raw material and some very specific value chains. This could be due to low technology readiness levels, but makes it clear that knowledge gaps still exist. To try and find solutions for this, partners contact details will be provided with the database so that stakeholders who would be willing to provide missing data can contact the project and the database can be further updated.
- With very various alternative fertiliser value chains from different secondary raw materials, it proved difficult to consistently use the same units for the same parameters across value chains. Further on in the project, these inconsistencies will be taken into account so that an objective scoring process is guaranteed.
- Due to the many different parameters across the whole life-cycle, it was a challenge to find all data within one and the same reference. Therefore, it could be possible that not all data from within one value chain is based upon the exact same fertiliser product. For example, there could be slight differences between the feedstocks across references, which could have an effect on some of the other parameters.
- This database is primarily made in English. So not having a database in the mother language of our various stakeholders can be a major bottleneck. However, due to the large amount of information, providing translations in all EU languages could prove a very time-consuming task. Therefore, the project wants to focus on getting this database and its data across to all stakeholders and the most important intermediaries through various other means that can on their turn get the word across to their target groups. This could also work as an information funnel, where immediately only the most relevant info gets filtered and is readily available and clear for the target groups.

3. Results

All the work described above generated two major outputs. On the one hand, all data that was collected by the partners through the provided template resulted in one big excel file with all raw data, including references on the different alternative fertiliser value chains. On the other hand, there is the public database where this data is displayed in a more structured way, being visually more attractive and user friendly.

3.1. Excel file with collected data

It was made sure that the continuation of the project, more specifically the scoring criteria to filter out the seven most promising value chains, could be met through the defined parameters. A list of 60 parameters across the complete life cycle of the value chains were identified in an Excel template file to be used by the partners for data collection, and organized according to the categories mentioned above (Figure 4). An example of this can be found in Section 5. Annex, Figure 7.

The distribution and cooperation between the various partners ensured that data for 48 out of the 60 identified alternative fertiliser value chains were filled in. The excel was divided in different tabs according to the secondary raw materials. This excel file includes also the references from where the data was gathered, as well as contact persons to get in touch with for more detailed information, in case this value chain is chosen to perform a LCA on and more data is required.

3.2. Database

The data out of the complex data collection Excel file was transformed into raw data more easily structured to feed the Power BI-generated database. With user-friendliness in mind, it was decided to sort all value chains primarily by the fertiliser product rather than the secondary raw material. Due to the large amount of data and parameters, these parameters were also divided into the major life-cycle phases and secondarily visualised per phase as well. Therefore, the user can quickly navigate to the information that is most relevant for them on the home page (Figure 5): production data, distribution and trade, storage and application, product content, cost, legislation. Each category contains several columns. For example, in the category ‘Cost’, there is information on geographical region, CAPEX, OPEX and market price. Using this approach, the database is differentiated according to the target audience or purpose.

As the default value, all products are visible within these life cycle phases. Users could then filter on ‘product’ and/or ‘secondary raw material’ to know more about a specific product they are looking for (Figure 6).

The database can be found through the project website. The content of the database will be updated throughout the project time with any additional information becoming available. Furthermore, contact details of WP1 lead and project coordinator are provided, in order to give users the opportunity to ask questions, provide suggestions, corrections or improvements. Using this approach, the database will be kept up to date based on feedback of project partners and external stakeholders, which will foster the implementation of alternative fertilisers.

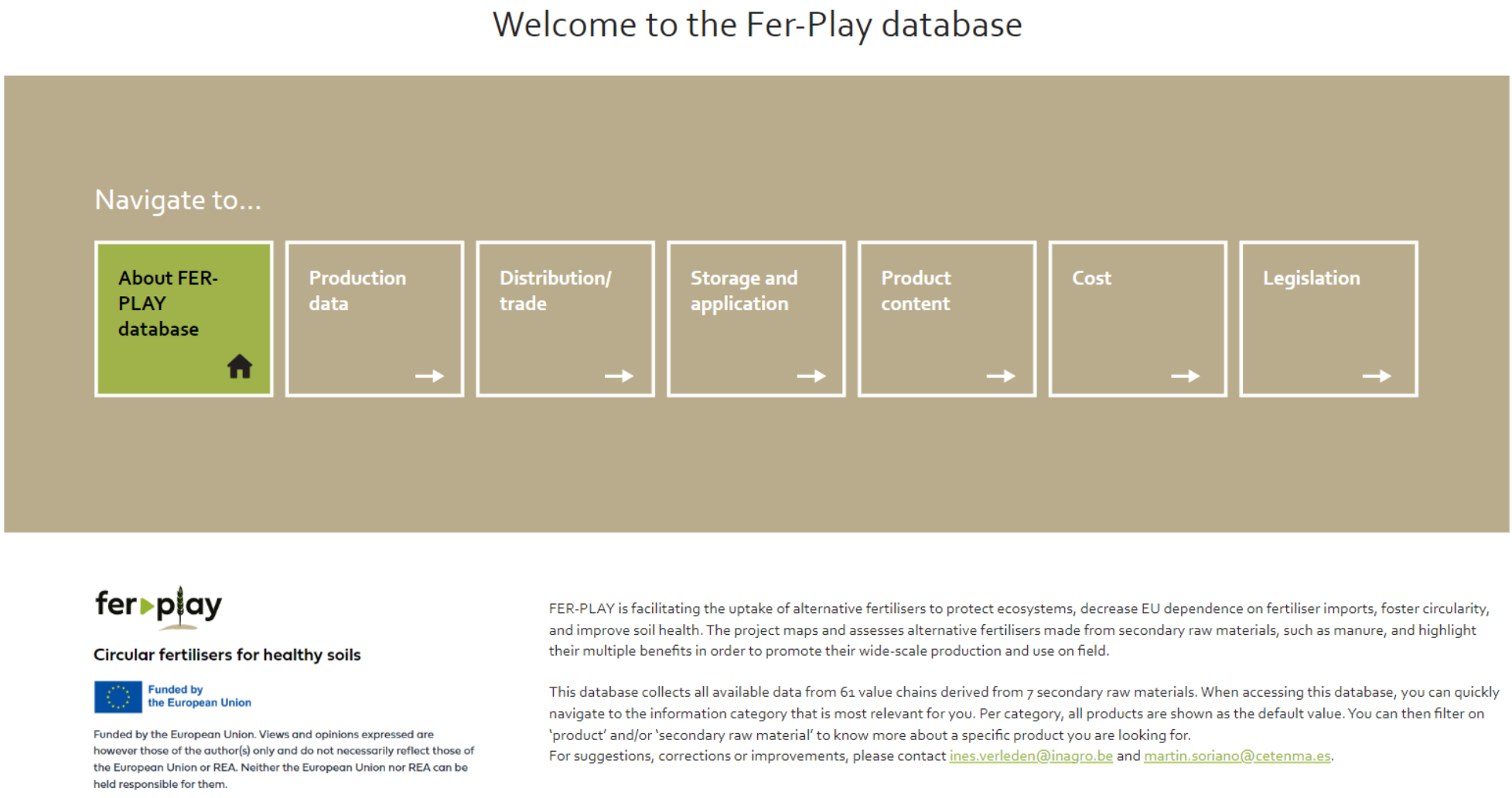
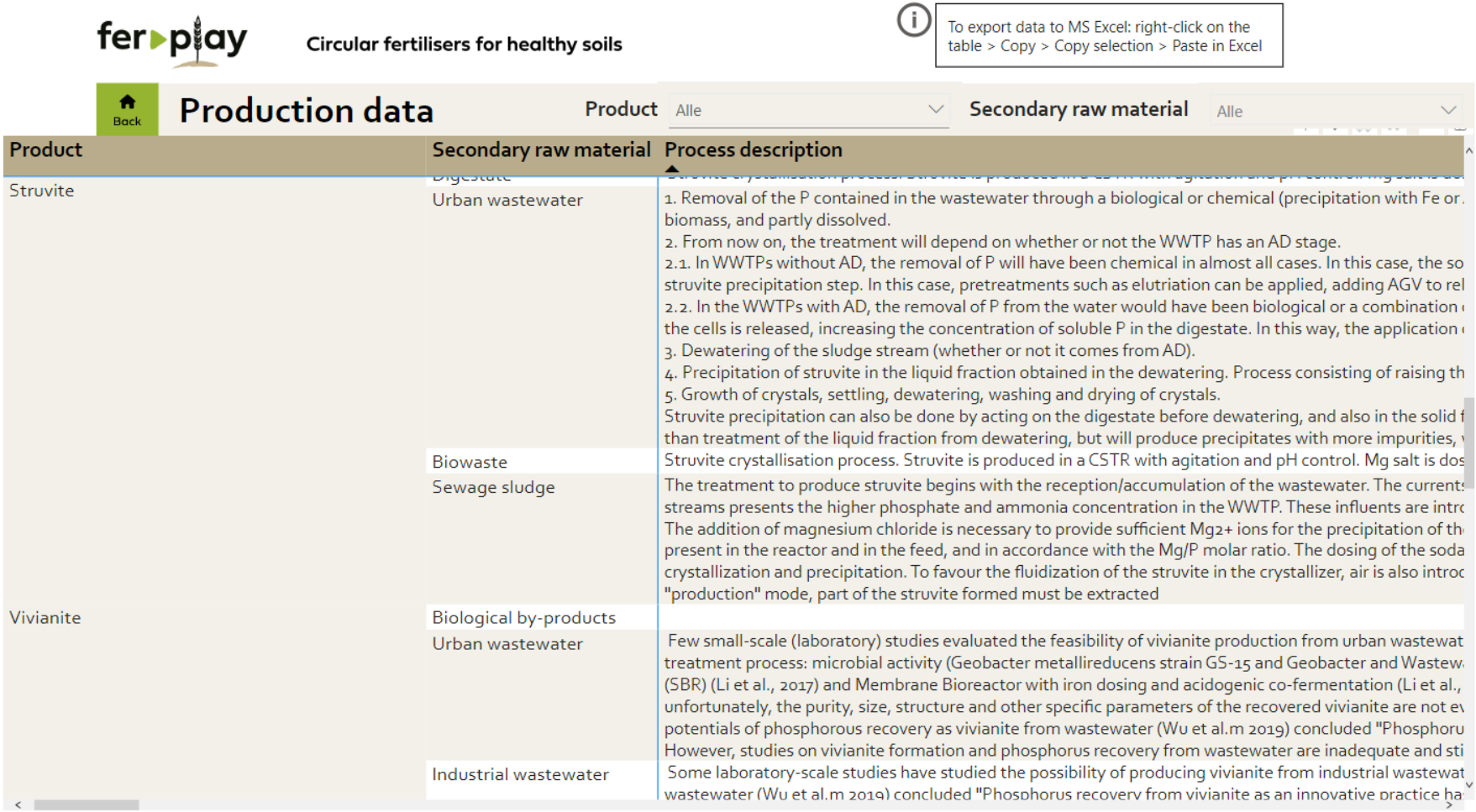


Figure 5. Homepage of the database



fer▸play Circular fertilisers for healthy soils

To export data to MS Excel: right-click on the table > Copy > Copy selection > Paste in Excel

Back **Production data** Product Alle Secondary raw material Alle

Product	Secondary raw material	Process description
Struvite	Urban wastewater	1. Removal of the P contained in the wastewater through a biological or chemical (precipitation with Fe or biomass, and partly dissolved. 2. From now on, the treatment will depend on whether or not the WWTP has an AD stage. 2.1. In WWTPs without AD, the removal of P will have been chemical in almost all cases. In this case, the so struvite precipitation step. In this case, pretreatments such as elutriation can be applied, adding AGV to rel 2.2. In the WWTPs with AD, the removal of P from the water would have been biological or a combination the cells is released, increasing the concentration of soluble P in the digestate. In this way, the application 3. Dewatering of the sludge stream (whether or not it comes from AD). 4. Precipitation of struvite in the liquid fraction obtained in the dewatering. Process consisting of raising th 5. Growth of crystals, settling, dewatering, washing and drying of crystals. Struvite precipitation can also be done by acting on the digestate before dewatering, and also in the solid than treatment of the liquid fraction from dewatering, but will produce precipitates with more impurities,
	Biowaste	Struvite crystallisation process. Struvite is produced in a CSTR with agitation and pH control. Mg salt is dos
	Sewage sludge	The treatment to produce struvite begins with the reception/accumulation of the wastewater. The currents streams presents the higher phosphate and ammonia concentration in the WWTP. These influents are intro The addition of magnesium chloride is necessary to provide sufficient Mg^{2+} ions for the precipitation of th present in the reactor and in the feed, and in accordance with the Mg/P molar ratio. The dosing of the soda crystallization and precipitation. To favour the fluidization of the struvite in the crystallizer, air is also introc "production" mode, part of the struvite formed must be extracted
Vivianite	Biological by-products	
	Urban wastewater	Few small-scale (laboratory) studies evaluated the feasibility of vivianite production from urban wastewat treatment process: microbial activity (Geobacter metallireducens strain GS-15 and Geobacter and Wastew (SBR) (Li et al., 2017) and Membrane Bioreactor with iron dosing and acidogenic co-fermentation (Li et al., unfortunately, the purity, size, structure and other specific parameters of the recovered vivianite are not ev potentials of phosphorous recovery as vivianite from wastewater (Wu et al.m 2019) concluded "Phosphoru However, studies on vivianite formation and phosphorus recovery from wastewater are inadequate and sti
	Industrial wastewater	Some laboratory-scale studies have studied the possibility of producing vivianite from industrial wastewat wastewater (Wu et al.m 2019) concluded "Phosphorus recovery from vivianite as an innovative practice ha

Figure 6. Default production data. Users can filter on 'product' and 'secondary raw material' to learn more about a specific product they are looking for.

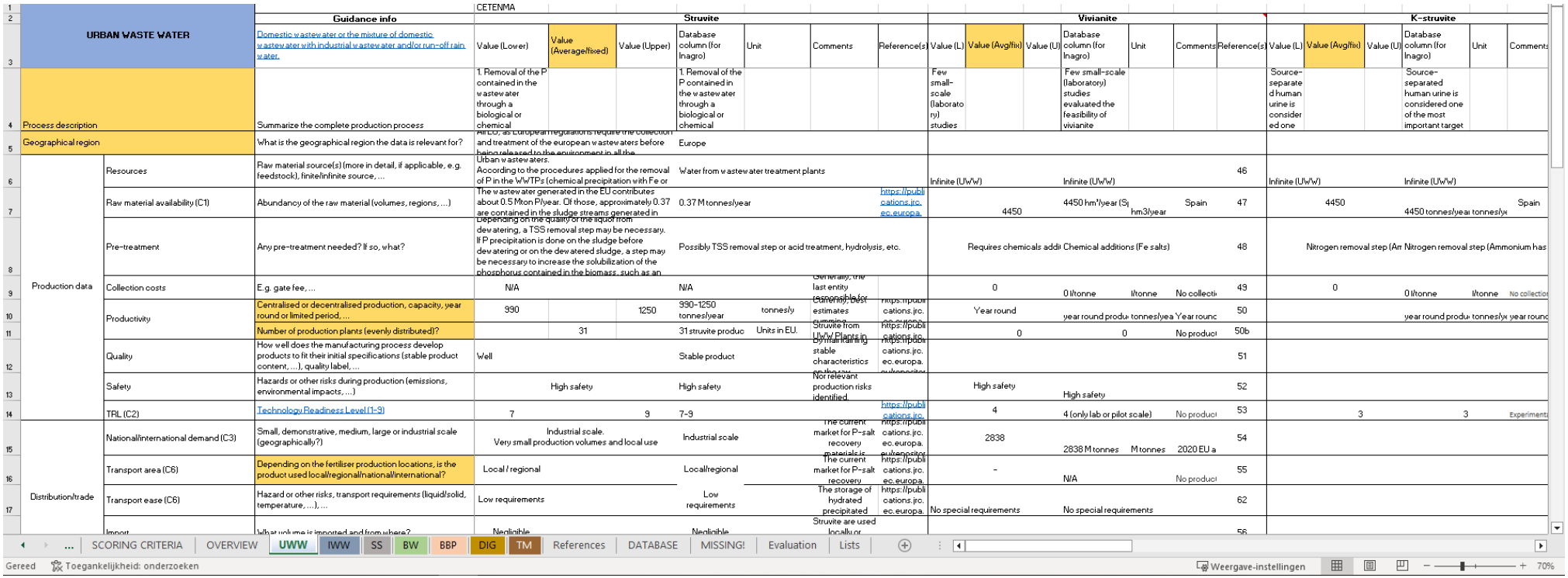
4. Conclusions

A comprehensive overview on alternative fertiliser value chains at EU level is needed to harmonize the scattered available information. Therefore, FER-PLAY created a detailed and user-friendly database containing data and figures of 60 alternative fertilising value chains and end products derived from seven different secondary raw materials (urban waste water, industrial waste water, sewage sludge, bio-waste, biological by-products, digestate, treated manure). The database consists of 49 different parameters providing information on production, distribution/trade, storage and application, product content, cost and legislation.

This database offers an excellent overview of the current state of the art of several alternative fertilising products and helps to identify the knowledge gaps that need to be fulfilled in order to foster their implementation. This overview will feed the subsequent project steps (e.g. selection of the seven most promising value chains and data gathering for LCA) and will be available for consultation by different types of stakeholders.

Since the content of the database can be updated throughout the project, this dynamic overview is a great tool to collect the latest information on several alternative fertiliser value chains.

5. Annex



	URBAN WASTE WATER		Guidance info	CETENMA			Struvite				Vivianite							K-struvite						
3			Domestic wastewater or the mixture of domestic wastewater with industrial wastewater and/or run-off rain water.	Value (Lower)	Value (Average/fixed)	Value (Upper)	Database column (for Inagro)	Unit	Comments	Reference(s)	Value (L)	Value (Avg/fix)	Value (U)	Database column (for Inagro)	Unit	Comments	Reference(s)	Value (L)	Value (Avg/fix)	Value (U)	Database column (for Inagro)	Unit	Comments
4	Process description		Summarize the complete production process	1. Removal of the P contained in the wastewater through a biological or chemical			1. Removal of the P contained in the wastewater through a biological or chemical				Few small-scale (laboratory) studies			Few small-scale (laboratory) studies evaluated the feasibility of vivianite				Source-separated human urine is considered one			Source-separated human urine is considered one of the most important target		
5	Geographical region		What is the geographical region the data is relevant for?	All UC: as European regulations require the collection and treatment of the european wastewaters before being released to the environment in all the			Europe																
6	Production data	Resources	Raw material source(s) (more in detail, if applicable, e.g. feedstock), finite/infinite source, ...	Urban wastewaters. According to the procedures applied for the removal of P in the WWTPs (chemical precipitation with Fe or			Water from wastewater treatment plants				Infinite (UWW)			Infinite (UWW)			46	Infinite (UWW)			Infinite (UWW)		
7		Raw material availability (C1)	Abundancy of the raw material (volumes, regions, ...)	The wastewater generated in the EU contributes about 0.5 Mton P/year. Of those, approximately 0.37 are contained in the sludge streams generated in			0.37 M tonnes/year			https://publications.jrc.ec.europa.	4450			4450 hm³/year (S	hm3/year	Spain	47	4450			4450 tonnes/year	tonnes/y	Spain
8		Pre-treatment	Any pre-treatment needed? If so, what?	Depending on the quality of the liquid from dewatering, a TSS removal step may be necessary. If P precipitation is done on the sludge before dewatering or on the dewatered sludge, a step may be necessary to increase the solubilization of the phosphorus contained in the biomass, such as an			Possibly TSS removal step or acid treatment, hydrolysis, etc.				Requires chemicals addi			Chemical additions (Fe salts)			48	Nitrogen removal step (Am			Nitrogen removal step (Ammonium has		
9		Collection costs	E.g. gate fee, ...	N/A			N/A		Generally, the last entity (currently)		0			0 l/tonne	l/tonne	No collecti	49	0			0 l/tonne	l/tonne	No collectio
10		Productivity	Centralised or decentralised production, capacity, year round or limited period, ...	990		1250	990-1250 tonnes/year	tonnes/y	responsible for current best estimates	https://publications.jrc.	Year round			year round produ	tonnes/yea	Year rounc	50				year round produ	tonnes/y	year rounc
11			Number of production plants (evenly distributed)?		31		31 struvite produc	Units in EU.	Struvite from UWW Plants in	https://publications.jrc.	0			0		No product	50b						
12		Quality	How well does the manufacturing process develop products to fit their initial specifications (stable product content, ...), quality label, ...	Well			Stable product		Dry/containing stable characteristics on the sav	https://publications.jrc.ec.europa.eu/repositor							51						
13		Safety	Hazards or other risks during production (emissions, environmental impacts, ...)	High safety			High safety		No relevant production risks identified.		High safety			High safety			52						
14		TRL (C2)	Technology Readiness Level (1-9)	7		9	7-9			https://publications.jrc.	4			4 (only lab or pilot scale)		No product	53	3		3			Experiment
15	Distribution/trade	National/international demand (C3)	Small, demonstrative, medium, large or industrial scale (geographically?)	Industrial scale. Very small production volumes and local use			Industrial scale		The current market for P-salt recovery	https://publications.jrc.ec.europa.eu/repositor	2838			2838 M tonnes	M tonnes	2020 EU a	54						
16		Transport area (C6)	Depending on the fertiliser production locations, is the product used local/regional/national/international?	Local / regional			Local/regional		The current market for P-salt recovery	https://publications.jrc.ec.europa.	-			N/A		No product	55						
17		Transport ease (C6)	Hazard or other risks, transport requirements (liquid/solid, temperature, ...), ...	Low requirements			Low requirements		The storage of hydrated precipitated	https://publications.jrc.ec.europa.	No special requirements			No special requirements			62						
		Import	What volume is imported and from where?	Negligible			Negligible		Struvite are used locally or								56						

Figure 7. Screenshot as an example of the data collection template with the different life cycle parameters.