

Calculation manual for LCI calculation tools for regionalised waste treatment



**Updated calculation Manual
Zurich, June 2021**

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- Review** Ivan Muñoz of 2.-0 LCA consultants (2017 version)
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1 Summary

This report presents the calculation tools created to calculate waste-specific inventories of waste disposal. Process inventories of advanced disposal technologies like municipal incineration and sanitary landfilling are possible, but also more rudimentary disposal technologies like open burning and open dumping are possible. The latter represent important waste pathways in developing countries.

The underlying process models are built upon the existing models already used for waste disposal in ecoinvent (Doka 2003) and the updates (Doka 2013, 2015). The technical details of the disposal models themselves are presented in separate reports.

The tools allow calculation of inventories and produce Ecospol2 XML-Files (ES2) which can be read into EcoEditor(EE) and via that route become part of the ecoinvent database.

Waste-specific inventories are complex as

- they inventory a part attributable to a specific waste material of a disposal process (so they do subdivision of multi-input processes)
- they can produce usable recyclates or usable energy (so they can be multi-output processes, even when subdivided)
- they can incorporate further downstream disposal of secondary wastes, e.g. bottom ash landfilling from waste incineration (so they encompass more than one real-world activity)
- they can address complex wastes consisting of heterogeneous waste fractions

Apart from information *characterising the waste* (composition, heating values, degradabilities, burnabilities), the regionalisation requires that a range of different disposal sites are described using local parameters like *climate* – e.g. temperature, precipitation – and *technical parameters* like landfill height or gas collection rates. A simplified overview of the general process structure is shown below. This increases the complexities and raw data demand necessary for disposal inventory calculation even more than with the previous tools (Doka 2003). The new tools present a vehicle to apply all these different aspects in a structured and consistent manner. Nevertheless it is recommended that for transparency authors not only create inventories, but write also conventional reports detailing the raw data and sources.

The manual text by Gabor Doka was in large parts written for a 2016/2017 project for Sustainable Recycling Industries SRI, financed by the Swiss State Secretariat for Economic Affairs SECO, commissioned by the Swiss Federal Laboratories for Materials Science and Technology EMPA, mandated by the ecoinvent Association. All reports of 2017 were reviewed by Ivan Muñoz of 2.-0 LCA consultants.

In 2020 the manual text was expanded to include the new landfill models for construction waste landfills and excavation material landfills, which allow also creation of EcoSpold1 files. **Added steps in the manual are prefixed with "(new)".**

In 2021 the manual text was expanded to include the updated rationalised model of wastewater disposal. **Added steps in the manual are prefixed with "(new2)".**

Thanks to Ivan Muñoz of 2.-0 LCA consultants (Aalborg, Denmark) for his review of the first version of this manual in 2017. Thanks to Andreas Ciroth of GreenDelta (Berlin, Germany) for his testing of tool-generated EcoSpold1 files in OpenLCA. Thanks to Mischa Zschokke of carbotech (Zurich, Switzerland) for his testing of tool-generated EcoSpold1 files in SimaPro software.

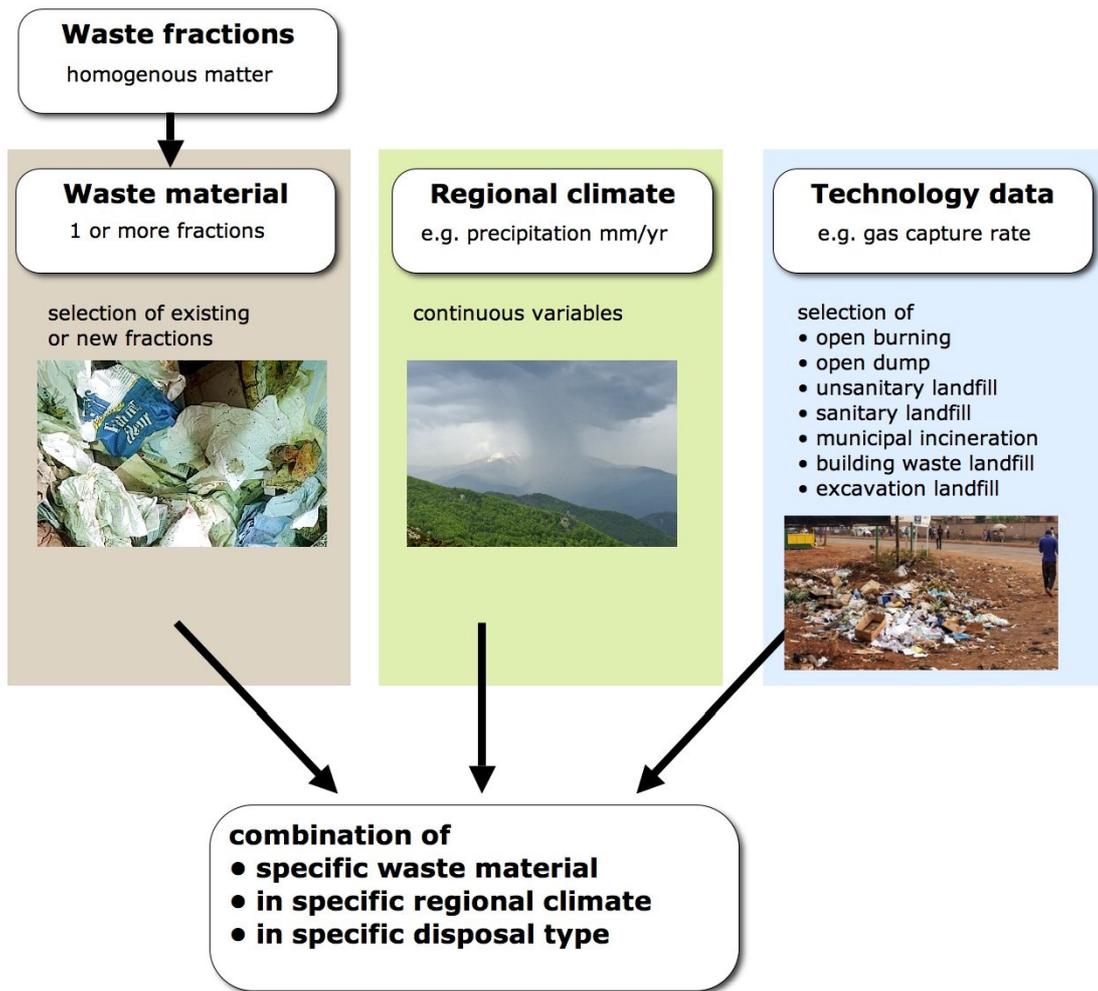


Fig. 1.1 Overview of the general process structure for the regionalised waste tools. A more technical representation is shown at the end of this manual in Fig. 11.1 on page 43.

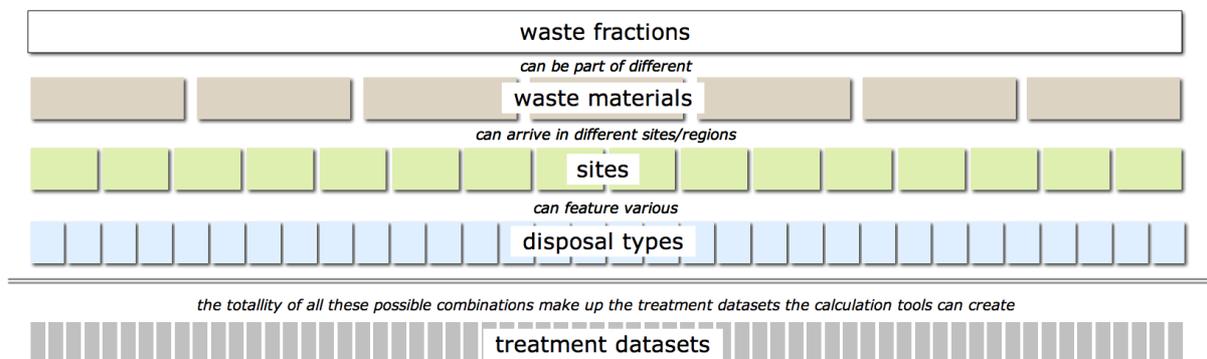


Fig. 1.2 A schematic illustration of the combination possibilities offered by the tool structure.

2 First steps and creating a result file

The calculation tools are made up by following Excel workbooks:

Central Repository 2020.xlsm	contains waste definitions and geographic/site/climate information
Landfill 2020.xlsm	model for unsanitary landfill, open dumps and sanitary landfill
Open Burning 2020.xlsm	model for open burning
Municipal Incineration 2020.xlsm	model for municipal incineration
Tailings Impoundment 2020.xlsm	model for tailings impoundment
Construction waste landfill 2020.xlsm	(new) model for mineral construction waste landfill (C&D)
Excavation material landfill 2020.xlsm	(new) model for clean excavation material landfill
Wastewater 2021.xlsm	(new2) model for wastewater disposal

2.a Preliminary remarks



Keep a ***backup copy*** of the original Excel workbooks. Be sure *not* to save the original workbooks under different names from within Excel, or rename files on the desktop, as this will corrupt functionality. If you want to have different versions of the workbooks, make *copies of the whole folder* containing the workbooks.

provide data:	500		
calculated	12.345		

Only ever enter anything or change ***cells with a white background***. Anything else is not designed to be changed by the user.



The workbooks contain ***macros (VBA)***, which are a standard feature of Excel. Please make sure your computer allows the execution of macros. Some security settings especially in on Windows computers are suspicious of documents with macro content. So you need to tell Office/Windows that execution of these workbooks is OK.

Otherwise you are free to use the features of Excel: Zooming and splitting windows, checking formulas, exploring precedent cells etc. The spreadsheet cells are not protected, which allows maximum flexibility, but also requires you not to overwrite or delete content.

2.b Setting up

1. Open the workbook "Central Repository 2020.xlsm" first. It is the central information hub. Open any of the other workbooks, as you require.
2. Allow execution of macros in all the workbooks. They are needed (see remark on VBA above).
3. Do not update links to other sheets. There is no need. Choose 'No' in the dialog box. You might get a warning "Data might have been lost". This happens when Excel is not able to add any additional customized number formats. This is at worst a cosmetic issue and does not

interfere with the proper functioning of the tool. Once you resaved the workbooks in Excel this error dialog should not appear anymore.

- You might want to disable automatic calculation. Choose the menu command 'Extras/Preferences', choose 'calculation' and set the calculation to 'manual'.

2.c Choosing a dataset

- Go to the workbook "Central Repository 2020.xlsm" and there to sheet "DS info" (Dataset info)
- Have a look at the datasets already defined in the list starting at cell C22.
- On the same sheet in row B a number is given to each dataset. Pick a number.
- Go to the top part, to cell B12, and there type in the number of the dataset you want to calculate. Choose a dataset existing in the list.

The screenshot shows the 'Central Repository 2020.xlsm' spreadsheet. The 'Data used for inventoried dataset' section is highlighted in purple and contains the following data:

chosen dataset	(a) Treated waste material	(b) Disposal site	(c) Disposal type	Region code	Text comment on waste origin, use & application (and any restrictions) of this treatment dataset
12	waste polypropylene	ecoinvent 2013	municipal incineration (m)	GLO	Recommended use of this dataset: For PP, which goes to disposal as part of communal waste mixture.

Below this is the 'Dataset Information repository' section, which is a table for defining datasets. It includes columns for 'dataset number', 'Treated waste material', 'Disposal site', 'Disposal type', 'Region code', and 'Text comment'. A list of datasets is provided below, including:

dataset number	(a) Treated waste material	(b) Disposal site	(c) Disposal type	Region code	Text comment on waste origin, use & application (and any restrictions) of this treatment dataset
1	scrap aluminium	ecoinvent 2013	municipal incineration (m)	GLO	For disposal of bulky, non-dust aluminium, which goes to
2	waste emulsion paint	ecoinvent 2013	municipal incineration (m)	GLO	For small amounts of dried waste emulsion paint, which
3	municipal solid waste for incineration only	ecoinvent 2013	municipal incineration (m)	GLO	For average municipal/communal waste mixture. Not su
4	waste newspaper	ecoinvent 2013	municipal incineration (m)	GLO	For newspaper, which goes to disposal as part of commu
5	waste paperboard	ecoinvent 2013	municipal incineration (m)	GLO	For cardboard, which goes to disposal as part of commu
6	waste packaging paper	ecoinvent 2013	municipal incineration (m)	GLO	For packaging paper, which goes to disposal as part of c
7	waste paint	ecoinvent 2013	municipal incineration (m)	GLO	For disposal of small amounts of dried paint, which go to
8	waste graphical paper	ecoinvent 2013	municipal incineration (m)	GLO	For paper, which goes to disposal as part of communal w
9	waste plastic, mixture	ecoinvent 2013	municipal incineration (m)	GLO	For plastic, mixture, which goes to disposal as part of c
10	waste polyethylene	ecoinvent 2013	municipal incineration (m)	GLO	For PE, which goes to disposal as part of communal wa
11	waste polyethylene terephthalate	ecoinvent 2013	municipal incineration (m)	GLO	For PET, which goes to disposal as part of communal wa
12	waste polypropylene	ecoinvent 2013	municipal incineration (m)	GLO	For PP, which goes to disposal as part of communal wa
13	waste polystyrene	ecoinvent 2013	municipal incineration (m)	GLO	For PS, which goes to disposal as part of communal wa
14	waste polyurethane	ecoinvent 2013	municipal incineration (m)	GLO	For PU, which goes to disposal as part of communal wa
15	waste polyvinylchloride	ecoinvent 2013	municipal incineration (m)	GLO	For PVC, which goes to disposal as part of communal wa

2.d Calculation of a disposal inventory

- Be sure the workbook for the defined type of disposal (column E) is open. If you want to calculate for instance landfills, the workbook "Landfill 2020.xlsm" needs to be open.
- With the dataset chosen in cell B12, just left of that cell press the grey button named "save ES2". This starts a calculation and saves an EcoSpold2 XML-File. You will be prompted as to where. Whatever name is given in the dialog, the saved file will have the suffix ".xml" (So don't worry if the save dialog says ".xlsx" or something else).
- Be patient. The calculation and file creation might take a few seconds. The first calculation just after opening the workbooks can take a bit longer than subsequent inventory calculations and export. Do not click into the workbook windows during calculation. When the XML file export is finished, the Central Repository workbook will be brought back into the foreground.
- (new) Alternatively, it is possible to create an EcoSpold1 XML-file, by pressing the button named "save ES1". For an accurate EcoSpold1 file, you might want to review some additionally required fields, described in chapter 10 'Additional information for EcoSpold1-Files' on page 37.

And that's it. You got an EcoSpold2 inventory file, which you can open in EcoEditor and submit to review.¹

But the tool is very flexible and is designed to create your own datasets based on your own waste compositions, site and disposal technology data.

In the following sections you are guided through examples of such procedures, going from easier to more difficult cases.

3 A new activity inventory

In ecoinvent/ES2 an activity is defined

- by the name of the activity, e.g. "treatment of waste paperboard, sanitary landfill"
- by its geographic location, e.g. "South Africa" (ZA)
- by a time period e.g. from 1-1-2010 to 31-12-2015

These three items together decide if an activity is different from another.² If all are the same, it is meant to be the same activity. If one or more of these items are different, then you have a different activity.

The ecoinvent database needs to distinguish and keep track of different activities and this is done by assigning each activity a **unique identification number**. Ecospold2 employs so called universally unique identifiers or UUIDs, which might look like this: "f40939cd-6058-470c-ab3a-fc45d44f8cea". All already defined activities in the ecoinvent database are contained in an ActivityIndex, which lists all the Activities and their UUIDs.

When you create a new activity – new in the above sense that the specific combination of name/geography/time does not already exist within ecoinvent – you need to assign this new activity its own new UUID (the tool will help you create new UUIDs).³ And this will lead to a new entry in the ActivityIndex.

But let's go through the steps for creating a new activity in the tool column by column:

3.a Choosing a waste material

13. Open the workbooks as described in §2.b on page 7.
14. Go to the workbook "Central Repository 2020.xlsm" and there to sheet "DS info".
15. Scroll past the already defined activities and down to an empty row (Excel row 508+, or dataset number 487+)

¹ ES1-Files can be used as is. They cannot be uploaded to EcoEditor. For use of EcoSpold1 in the SimaPro software see chapter 10.e.1 on page 41.

² Strictly speaking there is also a distinction by something called "specialActivityType" which in our case is always zero (0) which stands for "ordinary transforming activity" and the SystemModel, which in our case is always "undefined".

³ This UUID needs to be provided for new activities, as the Ecospold2 format requires that new entries are catalogued in a special appended section of the file (usedUserMasterData). So any ES2-File needs to *announce by itself*, whether it carries any new entries or not. It is not enough to create the new entries and let the database decide whether this represents something new or if it already exists.

16. Column C has the header "*(a) Treated waste material*" and here you select the waste material. On the empty row click on the cell in column C.

		(a) Treated waste material	(b) Disposal site
20			
21	dataset number		
253	232		
254	233		
255	234		
256	235		

		(a) Treated waste material	(b) Disposal site
18			
19	different countries		
20			
21	dataset number		
253	232		
254	233		
255	234		
256	235		
257	236		
258	237		
259	238		
260	239		

17. This displays a handle for a selection list. If you click on the double arrow  a selection list pops up from which you can select a waste.
18. The list is large and can be navigated with arrow keys and page keys, but unfortunately cannot be searched.⁴ If you prefer the list to be alphabetical, go to the top cell at C21, where you can select if the dropdown list will be displayed simply alphabetically, or in the sequence and groupings they were entered in the table of waste material definitions. If you change this setting and have switched off automatic calculation in Excel, do a manual calculation to get the chosen type of listing (recalculate the workbook by pressing 'Alt = ' or 'F9' in Windows machines or  = ' on Macs).
19. Select a waste you want (don't select "Null" values, these are empty lines). For a first, easy run choose "waste polyethylene".

3.b Choosing a disposal site/geographic location

20. On the same row, go one cell to the right (column D) under the header "*(b) Disposal site*". In this column there is a similar, but much smaller selection list for disposal sites.
21. Here you select the disposal site/location. This will define the geographic region, the time period, and several technology parameters. Choose what you like (not "Null"). For a first, easy run choose "ecoinvent GLO 2015". All the site names displayed are the names given in the same workbook on sheet "site" at cell G11 rightward. You should control there, whether the site's parameters are actually suitable to your application. Descriptions of the parameters are given in chapter 4 on page 15.

3.c Choosing a treatment/disposal type

22. Still on the same row, go one cell to the right (column E) under the header "*(c) Disposal type*". At one location/geography various disposal types are possible. Here you can select from a short list of different waste treatment types. For a first, easy run choose "sanitary landfill (s)".⁵

⁴ All the waste material names displayed are the names given in the same workbook on sheet "waste input" at cell C86 downward. But don't concern yourself with that yet.

⁵ Some default data for sanitary landfills is given for all sites in sheet "site". You should check, whether the provided parameters of disposal technology are appropriate for your application case and year. If not, create a new site entry, using the guidance of chapter 4 'Creating a new disposal site entry' on page 15.

With the last step you have defined the disposal process: a specific waste material goes into a certain disposal technology at a certain location. ***But a word of caution: The tool will calculate any combination of those three items, regardless if this is realistic or makes sense in the real world.*** You will not be warned if you enter a combination which is unrealistic today. Such a warning is beyond the capabilities of the tools. It is you—the user of the tool—who must ascertain that a combination of waste/location/technology is sensible for your purposes. Those purposes might also be scenario analyses: "What would be the result if location X had disposal technology Y?" which is a good reason to wanting results for combinations not existing today.

An example of an unrealistic combination is gold mining tailings in Colombia (Doka 2018:8). The climate at the mining sites is extreme in as it has very large precipitation and rather small evaporation. In the real world this means that surface runoff is very large and the surface heaps will be eroded mechanically. A impoundment for waste on the *surface* is therefore less likely in the real world, and it is more probable that tailings waste is backfilled into the disused *underground* mining shafts. But the tools will calculate gold mining tailings disposal in Colombian impoundments, when asked to do that, implying a surface impoundment.

3.d Additional information

23. In essence, with this you have defined a new activity. But some additional information is required. Some information is mandatory, some is good practice to provide other users of your dataset with some additional information.
24. In the next column (F) the short geographic name is displayed automatically, based on what you entered as disposal site. If you have switched off automatic calculation in Excel, do a manual calculation to see this (recalculate the workbook by pressing 'Alt = ' or 'F9' in Windows machines or '⌘ = ' on Macs).
25. And just as a reminder: column F has non-white cells, so *do not type anything there*. If you accidentally overwritten the formula in there, copy a formula from above or below.

3.e Text on "Recommended use of this dataset"

26. In the next row right you can write some *helpful text comment* on waste origin, use & application (and any restrictions) of this treatment dataset. Example: *"For cardboard, which goes to disposal as part of communal waste mixture. Larger amounts of separated cardboard will likely not be disposed in incinerators or landfills, but rather go to recycling."* The aim of this text is a quick orientation for the user and avoiding improper uses of the dataset. For instance even though an inventory for municipal incineration of metallic copper is available, this dataset should not be used for large amounts of separated copper, but only for minor amounts as part of other waste flows, e.g. small amounts of electrical wires. The tool will automatically preface your text given here with *"Recommended use of this dataset: "*

3.f Activity name

27. The next two automatic cells (columns H and I) are headed "waste exchange". They are displaying the Ecospol2 waste material exchange.
28. *Activity names are generated automatically.* The Ecospol2 name of the waste exchange (e.g. "waste polyethylene") is repeated in the name of the activity, as in "treatment of waste

polyethylene,...". The last part is defined by the treatment type "...municipal incineration", "...open burning", "...sanitary landfill" etc. Which is determined by what you typed earlier under "Disposal type" (see §3.c on page 10). The normal name an activity should have based on this common structure is automatically given in column J ("Suggested Automatic Base Name").

start	waste name, comma	treatment type
"treatment of"	scrap aluminium,	sanitary landfill"

Tab. 3.1 Standard structure of activity names for solid waste treatment processes in ecoinvent v3. Start is always "treatment of", the waste name is always followed by a comma (and not "to" or "in"), last part depends on treatment type.

29. The next two columns allow you to modify this common automatic name. Please only use that with good reason.
30. The text under the header "*Optional Activity Name suffix*" (column K) allows you to give a optional text which will be appended to the usual name. E.g. the database has the activity "treatment of waste polyethylene, municipal incineration//CH//2006-2012" but also "treatment of waste polyethylene, municipal incineration *with fly ash extraction*//CH//2006-2012". So this suffix allows you to discern processes, which otherwise would result identical Ecospod2 activities. Please use this with restraint and if you use it, do it systematically and be consistent in phrasing choices. ⁶
31. (new2) In case you are modelling wastewater disposal, and are creating inventories with and without residential sewer infrastructure (see point 109 on page 24), to discern the two datasets, include a name suffix in the dataset with residential sewer ", from residence". See other examples in the list of datasets. Without this suffix, the default is without residential sewer infrastructure, and the suffix denotes a deviation from the default.
32. The next column (L) allows an override of all the foregoing and freely define an activity name. This fully ignores the automatic name (column J) and any given suffix (column K). You should not use this for new datasets at all. ⁷
33. The next two automatic columns (M & N) give the ultimately used activity name and the UUID for this activity name. Recalculate the workbook by pressing 'Alt – =' or 'F9' in Windows machines or '⌘ – =' on Macs.
34. If you have not followed the "first run" tips given in points 19 and 22: If #NV! is displayed in column N, then this ActivityName has not yet any MasterData. This means that your chosen combination of waste name and disposal type has lead to an ActivityName unknown to the database up to this point. You need to define new Master Data for this ActivityName, see §5 'Creating a new ActivityName MasterData entry' on page 26 for how to do this.

⁶ It is cumbersome for database control and search to have slight, but meaningless and unnecessary differences in activity names. For instance some authors in the past created treatment activities that ended in "..municipal *waste* incineration", while most other MSWI activities simply spell "..municipal incineration". Incineration already implies waste burning.

⁷ This feature was introduced to have backward compatibility with already existing dataset names. This was necessary for instance for unnecessary irregularities in activity names like "treatment of waste aluminium, sanitary landfill", where the actual waste exchange name is "scrap aluminium" which would result in the slightly different automatic name "treatment of scrap aluminium, sanitary landfill".

3.g Production volume

35. The *annual production volume* (APV) is a mandatory information for each dataset. The APV refers to the activity with its geographic and temporal constraints. The number (column O) is for the reference product, i.e. the waste input. The physical unit for solid wastes is always "kilogram per year" in these tools, while for wastewaters, where it's "m³ per year" (new2).

Please note that for some already listed legacy datasets (of site "legacy ...") do not list any production volumes here, as they were not defined in the original work and report, but added later by an anonymous entity without any report on this.

36. Annual production volumes are used in the ecoinvent database to construct market activities, which represent technology mixtures of processes delivering the same product or service. If there is only one treatment type for a certain material within a geography and time period, the "technology mixture" will always be 100%. In such a case the given production volume does not have to be accurate, but can be a dummy, non-zero value.
37. In column P a production volume comment must be given. Comment on the source or calculations to derive the production volume amount.

For the legacy EcoSpold1 format, the figure and comment given for annual production volume is written into the technology comment text field, as there is no separate tag for production volume as such (see Doka 2020:27 for an explanation).

3.h Documentation source

38. Later, when creating datasets which contain more information generated by the inventory author, the amount of background, literature or raw data to document and comment on can become too large to be reasonably documented within the dataset itself. It is therefore recommended that the inventory author, in case datasets are published, produces also a *ordinary text report* documenting the choices and assumptions in applied raw data in more detail. If possible, this report should be made available on the internet for convenience.
39. Under the header "Source (Report)" you can enter/paste the the UUID of such a conventional report. Columns R, S, and T show you (after a recalculation) the first author, year, and title you have selected.
40. Naturally, for new reports, you will have to create a new "source" entry for Ecospold2. This information is compiled in *another sheet*. In row 18 of the sheet "DS info" there is a link that takes you to that sheet, "MD sources" (MD stands for "MasterData"). There you can list (on a free row) all the pertinent information (firstAuthor, year, title, additionalAuthors, placeOfPublications, etc) and assign a new UUID to this new report. See section 7 on page 30 below for a detailed description on how to enter new sources.

3.i Activity Index UUID

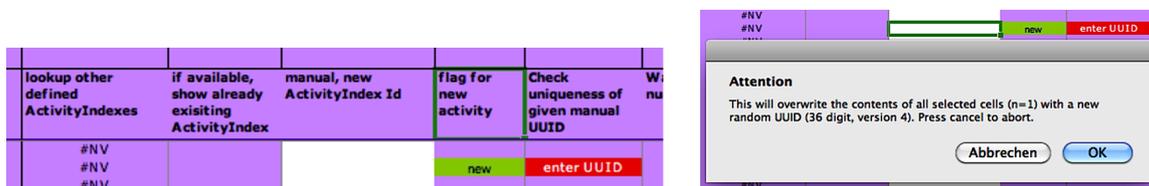
41. As explained at the beginning of this section, with a new activity a *new Ecospold2 ActivityIndex entry* must be created. Most of the pertinent information is already given in previous rows:

- The *Activity Name* was defined in Columns J to N (see §3.f'Activity name' on page 11).

- The *Time Period* was set implicitly by choosing a disposal site and
- likewise the *Geographic Region* is set by the chosen disposal site (see §3.b on page 10).

What remains to be done is to define a new UUID. The reason for this was explained at the beginning of this section on page 9.

- In columns U and V the given information is checked against the already defined Activities. If you have switched off automatic calculation in Excel, do a manual calculation to see this (recalculate the workbook by pressing 'Alt – =' or 'F9' in Windows machines or '⌘ – =' on Macs).
- If this particular combination defining the activity is available as a Master Data entry, the already established UUID will be used. You can skip to point 51 on page 15.
- If this particular combination represents a new activity, you get a text flag "new" in green indicating this in column X (under the header "flag for new activity")



- What you also get at this point is a text warning "enter UUID" in red in column Y, to provide a new UUID for this new Activity.
- In the white cell in column W you can provide this new UUID. Click on the one appropriate cell for your activity and press the three keys 'CTRL + Alt + u' on your keyboard simultaneously ('Alt' is sometimes labelled 'option' or '⌘'). This command will fill all the currently selected cells with new, random UUID.⁸
- Recalculate again, to make the "enter UUID" warning go away.

lookup other defined ActivityIndexes	if available, show already existing ActivityIndex	manual, new ActivityIndex Id	flag for new activity	Check uniqueness of given manual UUID
#NV			new	
#NV		0930726-8117-4cf5-b7e-22fa119e2		
#NV				
#NV				

With this step you have associated a particular waste treatment activity with a particular UUID. At this point to avoid confusion you should not go back to changing waste material input, disposal site, or treatment type (§3.a – 3.c) on this row. One UUID should only refer to one particular activity. If you want another disposal activity, start with a *new line* and point 13 on page 9.

⁸ You will get a warning beforehand, as this command overwrites all selected cells with UUIDs without a possibility to undo. The pop-up dialog states the number of cells you selected. Press cancel to abort. The command is only available when the workbook "Central Repository 2017.xlsm" is open.

3.j Author Name

48. While the Excel tool was created by Gabor Doka, the datasets you create with it are yours and you should properly identify yourself as the author of these datasets. This is done at one central place and applied for all datasets you create. So you only need to do this once.
49. In the Central Repository workbook go to the sheet "General Data". In cell F16 you can enter a person UUID. A list of all available persons is in sheet "MD persons". In case you are not already on that list, you can use the entry for "[System]".
50. When you later load the datasets intoecoinvent's EcoEditor software and save them, the datasets will be carrying the user's name as data generator anyway. In this case, instead of entering your own person UUID you can also use a default name here like "[System]" with the ID c4597934-ecac-422c-b431-382e85fdbc83 (listed to the right). This procedure is also possible for persons not already included in the list of available persons in sheet "MD persons".

3.k File creation

51. With the last step you have provided all the required information for a new activity inventory. You can now create an Ecospold2 XML-File for this activity by the procedure already described in §2.c 'Choosing a dataset' on page 8 onwards. Basically you need to change the number in cell B12 to contain the number of this new activity you defined. In a first run, have the workbook "Landfill 2020.xlsm" open, since in point 22 you chose "sanitary landfill".
52. Also you might want to save the "Central Repository" workbook in Excel at this point, for safekeeping all the information you have entered.

4 Creating a new disposal site entry

The disposal site carries the information pertinent to a specific disposal location and regional differences in disposal technology. For consistency all different disposal sites are listed in the sheet "site" in the workbook "Central Repository 2020.xlsm". All site entries listed on sheet "site" become available to choose from when creating a new activity, i.e. §3.b 'Choosing a disposal site/geographic location' on page 10. The first five columns contain the information pertinent to previously created treatment datasets. You should not change the information there (which is why cells are not white), but you can consult the values used there for comparison. You can create your own site which what this chapter is about.

If you use a particular disposal technology, make sure to check the relevant information given for the particular site you will be using. Not all information is already provided, e.g. no waste incinerators exist in South Africa in 2011. So trying to calculate an activity for South African waste incinerators will result in a faulty inventory, since parameters for this type of disposal technology are missing for this site. Maybe listed information is not necessarily suitable for your application so be sure to check the parameters given for the technology type and the site you will be using.

Information in §4.a is mandatory for all activities. You are free to only fill out the technologies you are interested in or will be using.

4.a General site information

53. In the workbook "Central Repository 2020.xlsm" go to sheet "site"
54. Split the window and arrange the left hand side that you can see the row headers in column D-F. Also split the window horizontally and make sure you see row 11, where the names of your site is given, as to be sure you are working on the same site entry.
55. Find a column with an empty, white cell in row 11 (row is headed "site unique name"). In that cell type in a *short unique name for the location*. Unique means that this name should not be occurring anywhere else on row 11. This can be any unique string, but it is recommended to include a reference to geographic location and the year of elaboration of the project. This string will be used to select a site when creating datasets (see point 21 on page 10).

Please note that for some already listed sites the year given in the site name refers to the *date of publication*, but you are free to use any unique name that makes sense to you here. Actual time period data will be given below (point 57).

Please do not alter site names in non-white cells. Altering existing names will disrupt the calculation of already defines dataset entries in sheet "DS info".

56. Go down to row 13 (headed "*Region long name*"). Click on the cell and see the double arrow  of the selection list appear. Click on the double arrow and select a geographic region/country name from the list. Your entry must be a valid, canonised ecoinvent geography name. After a recalculation ('Alt = ' or 'F9') the cell just beneath will contain the appropriate short name for your choice of region.
57. In Rows 17 + 18 the *start and end date for this site* must be entered. The format is "YYYY-MM-DD", i.e. year-month-day. These dates will be used to define the time period of any Activity referring to this disposal location.⁹

4.b Climate data for landfills/dumps/impoundments

58. Next we come to *climate data*. Strictly this is required only for calculation of landfills. If you do not need to calculate any landfills, open dumps or tailings impoundments as disposal technologies, you can skip to section 4.c below.
59. In row 23, the *mean annual precipitation* (MAP) of the site must be given in millimetres per year (mm/yr). Fig. 4.1 gives a map for mean annual precipitation values around the world. You can use any other data source as well, but the data should represent a long-term annual mean. Water availability will influence decomposition processes in landfills/dumps especially in arid regions and overall weathering speed.
60. In row 25, the *mean annual temperature* (MAT) of the site must be given in millimetres per year (mm/yr). Fig. 4.2 shows a map for mean annual temperature for the world. You can use other data sources as well. The purpose of providing a temperature is to discern regions with probability of permafrost conditions in the soil. Such conditions are also slowing down landfill development.

⁹ Excel might want to enforce automatically one of its own, different date formats. The cells should be formatted as text (not dates). Don't worry if the format of the date in the white cell is not the prescribed one. The cells just beneath will convert the date into a valid text string.

61. In row 27, the *mean annual actual evapotranspiration* (ETa) of the site must be given. Fig. 4.3 shows a world map of ETa values. You can use other data sources as well. But please note that the *actual* evapotranspiration ETa is required, not the potential evapotranspiration (PET). PET figures are theoretical values of total evapotranspiration, if water availability is not limited, while actual evapotranspiration ETa is limited by the actually present water. ETa is low in hot and arid regions (e.g. Sahara desert), while the PET in such regions is large.
62. In the model the evapotranspiration ETa from above is used to determine leachate flow direction. In arid regions leachate flow might actually be upward towards the surface, leading to leachate evaporation and partially to windblown emissions. In row 29 the *weight share of windblown leachate evaporites* at such locations with reversed leachate flow must be entered. This value will only come into effect in "reversed dry sites". A default value of 10% is commonly used. The remainder of the leachate solids is assumed to stay on ground.
63. (new) Usually the water infiltration into landfills in the model is determined by the difference of precipitation MAP minus the evapotranspiration ETa. This assumes a zero surface runoff, as surface runoff of water would erode landfills mechanically. For some combinations of precipitation and evaporation very large infiltrations can result, which are probably unrealistic, e.g. in Colombia with 5800 mm precipitation and evaporation of 840 mm. To avoid unrealistically high infiltrations, and thus very fast landfill weathering in the model, a "**soft capping**" was introduced in 2018 (Doka 2018:8). With this soft capping any raw infiltrations above 1000 mm per year are exponentially reduced to stay below 2000 mm/year. Without soft capping the raw infiltration rate is used without change. If soft capping has an influence on the infiltration rate, a comment is included in the geography metatext. The soft capping is activated by default (for all landfill models), but can be switched off consistently for all landfill models in the workbook "Central Repository", sheet "General Data", cell F82 (1= soft capping, 0 = no soft capping). In reality, a decreased infiltration rate would mean surface runoff is not zero and this in turn increases risks of erosion of the landfill body. The effects of this risk are presently not included in the models, but discussed in (Doka 2018:9).

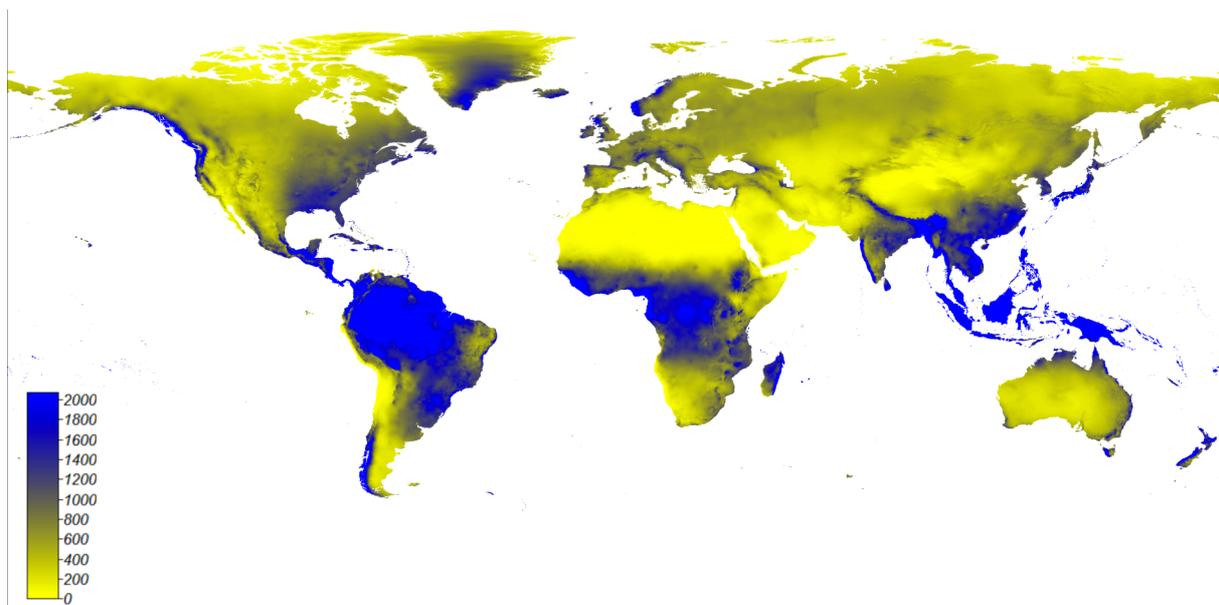


Fig. 4.1 Mean annual precipitation (MAP) [mm/year] (from www.worldgrids.org)

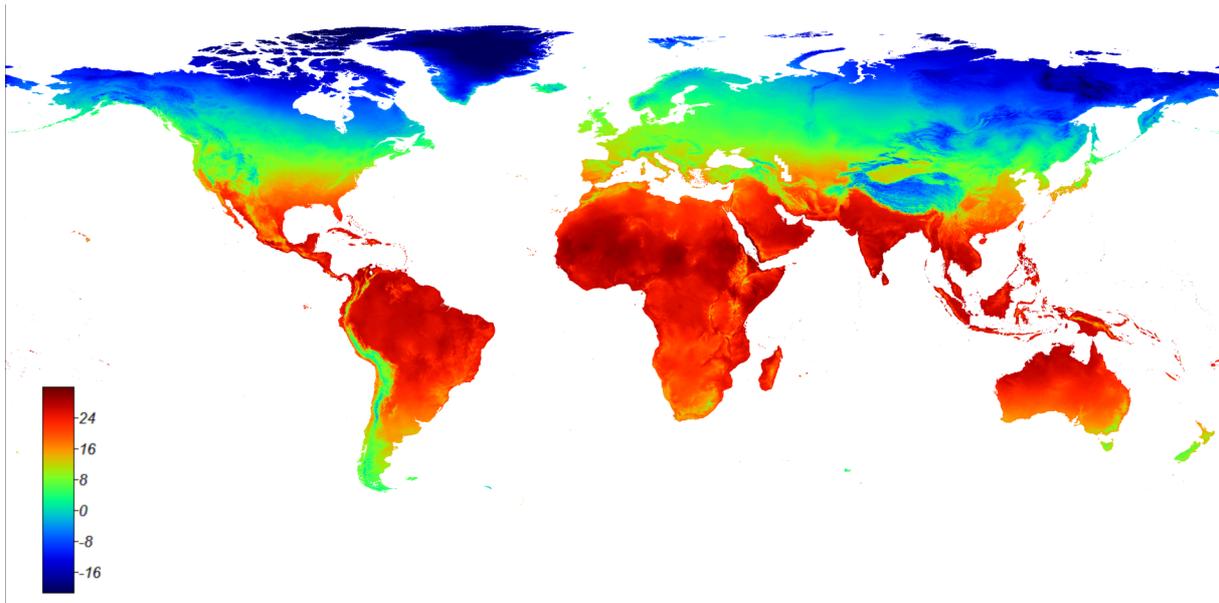


Fig. 4.2 Mean annual temperature (MAT) [°C] (from www.worldgrids.org)

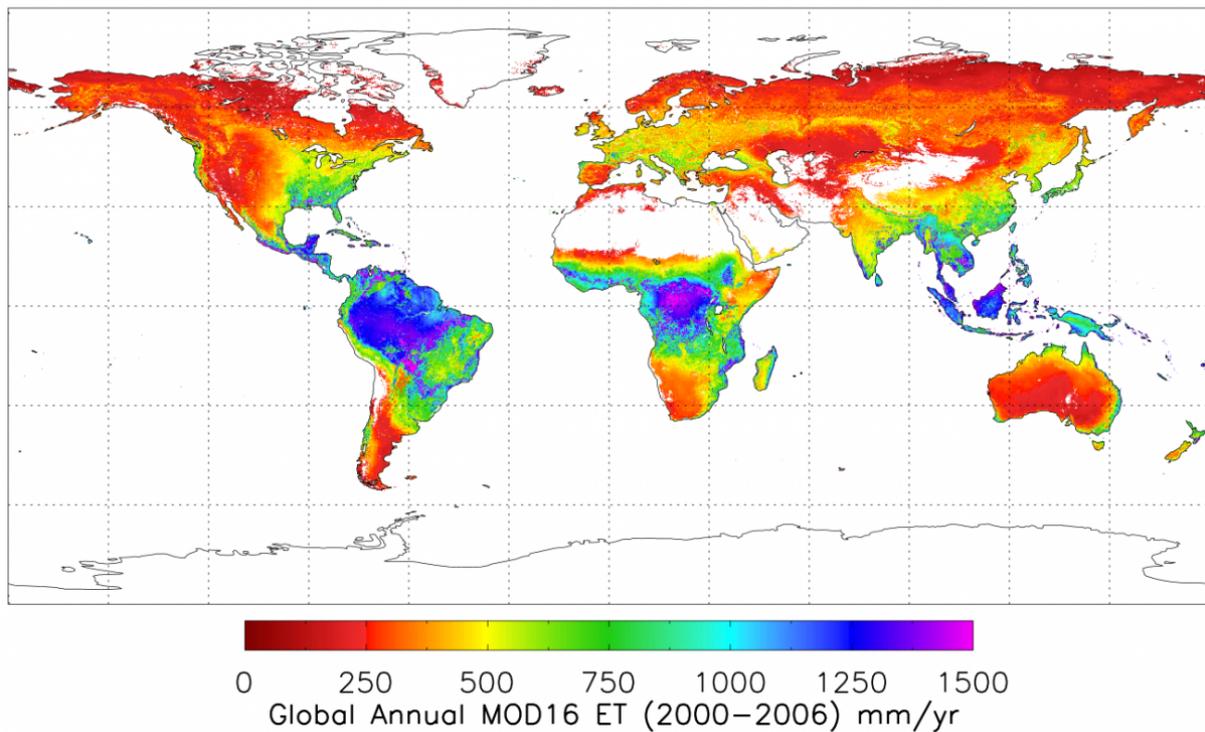


Fig. 4.3 Mean *actual* annual evapotranspiration (ETA) [mm/year] From Mu et al. 2001. An interactive, zoomable online map for this data is available at <http://www.arcgis.com/apps/OnePane/main/index.html?appid=b1a0c03f04994a36b93271b0c39e6c0f> (Feb 2017)

4.c Technology Data for Municipal Incineration

The incinerator model is for mixed municipal waste. The model is described in (Doka 2003-II, 2013, 2015).

64. Some incinerators can produce usable heat and electricity from waste incineration. In row 33 and 34 the gross electrical and thermal efficiency of the municipal incinerators at our site can be entered. These are gross figures I.e. *without any subtraction of energy used internally by the incinerator itself*. The figures tell how much of the energy contained in waste is converted to usable energy. In the model the lower heating value of the waste material will be used as incinerators utilising condensation energy are scarce.
65. In rows 36-38 the actual recycling rates for iron, aluminium and copper can be given. This is the counterpart to specifying the *recyclable* metal contents in the descriptions of waste fractions (see point 171 on page 34). Here it is specified how much of the metals that can potentially be recycled (recyclable) are *actually* recycled from bottom ash. A figure of 100% signifies that all of the element present in bulk metallic form is separated.
66. An example: a waste has a total copper content of 1 gram per kg. Of that copper only 50% is in bulk metallic form. The rest is in oxides and distributed in traces of materials. So maximally only 0.5 gram of copper metal can be gained from this waste. Recycling rates are usually not perfect and small bits or devalued items cannot be recycled. If the recycling rate is set for instance at 70% it means that in this case 0.35 gram of copper metal will be separated from residues ($=0.5 \text{ g} \cdot 70\%$). See also Fig. 8.1 on page 34 for this.
67. In rows 41-44 the technology mixture for the DeNOx stage in flue gas treatment are given. This influences NOx emissions and auxiliaries consumption. The sum of all four shares must equal 100%.
68. The rows 48 and 49 currently pertain only to *Switzerland*, where MSWI filter ash is extracted with the scrubber liquid and a zinc concentrate is produced (cf. Doka 2015). This procedure is called FLUWA. In row 48 you can specify how much of the filter ash is treated with this filter ash treatment. 100% is for all of the filter ash produced by incineration, and a current value in Switzerland is 46%.
- Some of the filter ash is hauled to other MSWIs to perform FLUWA on them, which leads to an additional transport. In row 49 the fraction of filter ash treated externally can be specified. Again, 100% stands for all of the filter ash produced by incineration.
69. In row 53 a code on how to calculate matrix element IDs is given. Always use 2. The option 1 is only present for backwards compatibility. The difference between the options 1 and 2 for calculation of matrix element IDs are explained in chapter 9 'Base number for Matrix Element IDs' on page 35.
70. In case you do use option 1, in row 52 you can enter a so called matrix element id base number. This number is unique to municipal incineration at this location. Select the cell and press the three keys 'CTRL + Alt + u' on your keyboard simultaneously. This command will fill all the currently selected cells with new, random UUIDs. Do not overwrite values you have already created process inventories with.

4.d Open burning parameters

Open burning is uncontrolled burning of waste on open areas without any control or management. The model is described in (Doka 2017b).

71. The open burning process itself is in large parts independent of location. There are nevertheless some aspects where differences between locations can occur.

72. In row 56 you can choose the *air emission category*, i.e. whether the air pollutants are released in high-population (urban) air, or in low-population (rural) air. A choice of high-population air will not depict health burdens imposed on workers in close proximity to the open burning site. Entering the code "hi" chooses high-population air, anything else the default low-population air.
73. In row 59 you can choose the *soil emission category*, i.e. whether the solid incineration remains are released to industrial soil, or in agricultural soil. Agricultural soil can – depending on the Impact Assessment method – lead to larger human health burdens. Entering the code "agri" chooses agricultural soil, anything else the default industrial soil.
74. For the attribution of thermal NO_x emissions, the *share of thermal NO_x* must be given in row 62. This is the ratio of (thermal NO_x to total NO_x). A default of 30% is suggested. The function of this parameter in this model is explained in the chapter 'Thermal-NO_x' of the accompanying report describing the open burning model (Doka 2017b).
75. For iron, aluminium and copper you can specify *recycling rates* in rows 64,66,68. Similar to the recycling rates for municipal incineration (point 65, page 19) these determine how much of the maximally recyclable bulk metal is actually recycled from burn residues. A figure of 100% signifies that all of the element present in bulk metallic form is separated. The maximally recyclable bulk metal is part of the waste material definition.
76. In row 71 a *code on how to calculate matrix element IDs* is given. Always use 2. The option 1 is only present for backwards compatibility. The difference between the options 1 and 2 for calculation of matrix element IDs are explained in chapter 9 'Base number for Matrix Element IDs' on page 35.
77. In case you do use option 1, in row 70 you can enter a so called *matrix element id base number*. This number is unique to open burning at this location. Select the cell and press the three keys 'CTRL + Alt + u' on your keyboard simultaneously. This command will fill all the currently selected cells with new, random UUIDs. Do not overwrite values you have already created process inventories with.

4.e Technology Data for Sanitary Landfill

A sanitary landfill is a managed and controlled landfill for mixed municipal waste. The model is described in (Doka 2003-III).

78. To use the sanitary landfill model, be sure to fill out the rows pertaining to climate data, cf. §4.b 'Climate data for landfills' on page 16.
79. In row 75 give the ultimate average *final height of the sanitary landfill* in meters. This influences how much infiltration water is available per kilogram of waste and landfill infrastructure.
80. In row 77 enter the duration of the *sanitary landfill operation phase* in years. This will influence land occupation duration.
81. An important parameter is on row 79, the *fraction of landfill gas captured*. This should be a figure covering the whole methane phase of the landfill of ca. 50 years, not only a single year. Values around 50% are typical for modern landfills. 100% means all of the generated landfill gas is captured. Not captured landfill gas is assumed to be emitted untreated.

82. In row 81 a figure can be given describing how much of the *captured landfill gas is flared*. Flare means incineration without energy utilisation. 100% means all captured landfill gas is flared and 0% is utilised. The remainder of captured landfill gas is assumed to be utilised for energy production.
83. In rows 84 and 85 the *gross conversion efficiencies for landfill gas utilisation* to electricity and heat, respectively can be given. These can be technology mixtures across several sites. As with municipal incineration, these efficiencies include all energy produced, i.e. are gross efficiencies. Any energy used internally by the landfill itself subsequently is *not* taken away here. Electricity required internally for gas pumping is specifically subtracted in the landfill model calculation.
84. In row 88 a *code on how to calculate matrix element IDs* is given. Always use 2. The option 1 is only present for backwards compatibility. The difference between the options 1 and 2 for calculation of matrix element IDs are explained in chapter 9 'Base number for Matrix Element IDs' on page 35.
85. In case you do use option 1, in row 87 you can enter a so called *matrix element id base number*. This number is unique to sanitary landfilling at this location. Select the cell and press the three keys 'CTRL + Alt + u' on your keyboard simultaneously. This command will fill all the currently selected cells with new, random UUIDs. Do not overwrite values you have already created process inventories with.

4.f Unsanitary Landfill management data

An unsanitary landfill is a basic landfill without landfill gas capture or leachate treatment, but a earthen cover on deposited waste, which influences landfill gas releases. The model is described in (Doka 2017a).

86. To use the unsanitary landfill model, be sure to fill out the rows pertaining to climate data, cf. §4.b 'Climate data for landfills' on page 16.
87. In row 93 give the ultimate average *final height of the unsanitary landfill* in meters. This influences how much infiltration water is available per kilogram of waste.
88. In row 95 enter the duration of the *unsanitary landfill operation phase* in years. This will influence land occupation duration.
89. In row 99 a *code on how to calculate matrix element IDs* is given. Always use 2. The option 1 is only present for backwards compatibility. The difference between the options 1 and 2 for calculation of matrix element IDs are explained in chapter 9 'Base number for Matrix Element IDs' on page 35.
90. In case you do use option 1, in row 98 you can enter a so called *matrix element id base number*. This number is unique to unsanitary landfilling at this location. Select the cell and press the three keys 'CTRL + Alt + u' on your keyboard simultaneously. This command will fill all the currently selected cells with new, random UUIDs. Do not overwrite values you have already created process inventories with.

4.g Open Dump parameters

An open dump is a landfill without any formal or consistent management or control. The model is described in (Doka 2017a).

91. To use the open dump model, be sure to fill out the rows pertaining to climate data, cf. §4.b 'Climate data for landfills' on page 16.
92. In row 103 give the ultimate average *final height of the dump* in meters. This influences how much infiltration water is available per kilogram of waste.
93. In row 105 enter the duration of the *dump operation phase* in years. This will influence land occupation duration.
94. In shallow and/or uncompacted landfills the methane in landfill gas can become oxidised to CO₂. The *methane correction factor* accounts for this effect. A value of 1 means there is no further methane oxidation before release, a value of 0.5 means that half of the methane is oxidised to CO₂ before release. A default methane correction factor is calculated in row 108. But you can enter an *override value* in row 109 (except 0, which prompts the use of the automatically calculated value). Override values should be justified in the documentation.
95. In row 109 a *code on how to calculate matrix element IDs* is given. Always use 2. The option 1 is only present for backwards compatibility. The difference between the options 1 and 2 for calculation of matrix element IDs are explained in chapter 9 'Base number for Matrix Element IDs' on page 35.
96. In case you do use option 1, in row 108 you can enter a so called *matrix element id base number*. This number is unique to open dumping n at this location. Select the cell and press the three keys 'CTRL + Alt + u' on your keyboard simultaneously. This command will fill all the currently selected cells with new, random UUIDs. Do not overwrite values you have already created process inventories with.

4.h Technology Data for Tailings Impoundment

Tailings are the unwanted remains from refining of metal ores (beneficiation). It is a ground up powder or sludge of unwanted inorganic minerals from ore processing. Tailings are stacked in large impoundments. This model should not be used for other types of waste. The model is described in (Doka 2018).

97. To use the tailings impoundment model, be sure to fill out the rows pertaining to climate data, cf. §4.b 'Climate data for landfills' on page 16.
98. In row 118 give the ultimate average *final height of the impoundment* in meters. This influences how much infiltration water is available per kilogram of waste. Tailings impoundments are often very large and a default value is 50 m.
99. In row 120 enter the *duration of the impoundment operation phase* in years. This will influence land occupation duration.

4.i Technology Data for Construction Waste Landfill

This landfill is for *mostly mineral* construction and demolition waste a.k.a. building waste, but without burnable materials, though traces of non-mineral material can end up in such a landfill (i.e. biomass fibres in reinforced gypsum boards). The model is described in (Doka 2020).

100. (new) To use the construction waste landfill model, be sure to fill out the rows pertaining to climate data, cf. §4.b 'Climate data for landfills' on page 16.

101. (new) In row 125 give the ultimate average *final height of the landfill body* in meters. This influences how much infiltration water is available per kilogram of waste. A default value for Switzerland is 11 m.
102. (new) In row 127 enter the duration of the *dump operation phase* in years. This will influence land occupation duration.

4.j Technology Data for Excavation Material Landfill

This landfill is for not reused, but clean excavation material. The model is described in (Doka 2020).

103. (new) To use the excavation material landfill model, be sure to fill out the rows pertaining to climate data, cf. §4.b 'Climate data for landfills' on page 16.
104. (new) In row 132 give the ultimate average *final height of the landfill body* in meters. This influences how much infiltration water is available per kilogram of waste. A default value for Switzerland is 11 m.
105. (new) In row 134 enter the duration of the *dump operation phase* in years. This will influence land occupation duration.

4.k Technology Data for Wastewater Disposal

This is for a regionalised model of wastewater disposal. Depending on the chosen region this can encompass a mixture of a large range of activities: direct emission of untreated wastewater, sewerage, treatment, digestion, biogas utilization, and sewage sludge disposal. All these steps are calculated as waste-specific flows, i.e. dependent on the initial wastewater composition, and combined in one inventory. Thus, the model is complex and requires quite a range of parameters, apart from the initial wastewater definition. The model is described in (Doka 2021).

106. (new2) fill out the rows pertaining to climate data, cf. §4.b 'Climate data for landfills' on page 16, which will play a role in water evaporation in treatment and emissions from sludge spreading on agriculture.
107. (new2) Apart from the region chosen in point 56 on page 16, for wastewater disposal three types of subregions, or territories can be chosen in row 139: a) the national average (default), b) a rural territory, c) an urban territory. In rural settings, treatment rates are commonly lower and sewer lengths are longer. Chose here the type of territory set in this site definition.
108. (new2) In many regions of the world, level of wastewater treatment is rudimentary and often not even sewerage exists. The next three parameters characterise the coarse level of the technology mix of wastewater disposal technology in the set region/territory. The three parameters are the *share of wastewater emitted directly* (% emitted directly), the *share of wastewater sewerage and emitted untreated* (%sewerage and emitted untreated) , and lastly the *share of wastewater sewerage and treated* (%sewerage and treated). These three parameters must add up to 100% (100% signifying here all wastewater *generated* in a country or territory). If you have entered a geographic region in point 56 and recalculate ('Alt – =' or 'F9'), rows 142, 145, 148 display suggested parameters for this region/territory, based on available statistics or estimates.¹⁰ Suggestions are provided for 313 different geographic

¹⁰ The entire country list of parameters used here and in subsequent points is accessible on sheet "GNIWWT" of "CentralRepository 201.xlsm". Given are the suggested parameters for a country/region, the estimated uncertainty of the

regions. In rows 143, 146, and 149 you have the possibility to *manually override* these suggested values. If no suggested values are available, an *error value* will be displayed instead, and you are then *required* to manually provide a valid set of parameters yourself for a correct model calculation. Please note that an empty cell provides no override. To override a value with zero enter a zero value (0%). Row 151 contains a control formula expressing the *difference* of the sum of the three parameters to 100%. To be correct, this value must be zero.

109. (new2) Sewering can include the *pipes from a building to the public network*. In row 152 you can choose if in this site, the residence sewers shall be included in the inventory (yes=1) or not (no=0). With 'yes' a building sewer infrastructure will be added to the fraction of sewered wastewater (sum of the two '%sewered...' parameters from point 108). To include the residential sewer makes only sense in particular circumstances. In most cases the residential sewer will be counted in wastewater-generating activity infrastructure, e.g. a household, or a factory, and counting the residential sewer again here bears a risk of double counting.
110. (new2) The wastewater being sewered into a wastewater treatment facility can encounter different levels of treatment sophistication in different countries. The *level of treatment* is typified in this next section by expressing the technology mix as fraction of wastewater treated in Single Stage Treatment (mechanical), fraction in Two Stage Treatment (mechanical+biological), and fraction in Three Stage Treatment (mechanical+biological+chemical). These three parameters must add up to 100% (100% signifying here all wastewater *treated* in a country). If you have entered a geographic region in point 56 and recalculate ('Alt = =' or 'F9'), rows 154, 157, and 160 display suggested parameters for this region, based on statistics or estimates. Suggestions are provided for 313 different geographic regions. In rows 155, 158, and 161 you have the possibility to *manually override* these suggested values. If no suggested values are available, an *error value* will be displayed instead, and you are then *required* to manually provide a valid set of parameters yourself for a correct model calculation. Row 163 contains a control formula expressing the *difference* of the sum of the three parameters to 100%. To be correct, this value must be zero.
111. (new2) Treatment sludge produced in wastewater treatment can be digested anaerobically, producing biogas and reducing sludge mass. The *frequency of generated sludge being digested* is selected next. 100% represents the sludge generated in WWTs of the chosen territory. Entering 100% means that all of the generated treatment sludge is being digested anaerobically. If you have entered a geographic region in point 56 and recalculate ('Alt = =' or 'F9'), row 165 displays a suggested frequency for this region, based on statistics or estimates. Suggestions are provided for 313 different geographic regions. In row 166 you have the possibility to manually override the suggested value. If no suggested value is available, an error value will be displayed instead, and you are then required to manually provide a valid parameter yourself for a correct model calculation.
112. (new2) Biogas during sludge digestion (see point above) can be utilised for energy. The *share of generated digester biogas going into combined heat–power plant (CHP)* is selected next. Entering 100% means that all of the generated biogas from sludge digestion is being fed into energy utilization. This step can be skipped, if 0% digestion is entered in the previous point. Biogas not being utilized for energy is assumed to be *flared* without energy gain. If you have entered a geographic region in point 56 and recalculate ('Alt = =' or 'F9'), row 168 displays a suggested share for this region, based on statistics or estimates. Suggestions are provided for

parameter and a numerical flag indicating if a value is from survey/statistics (=1) or estimated (=2). The latter flag determines the magnitude of parameter uncertainty. An abridged overview is in Tab. 14.1 on page 48.

313 different geographic regions. In row 169 you have the possibility to manually override the suggested value. If no suggested value is available, an error value will be displayed instead, and you are then required to provide a valid share yourself for a correct model calculation.

113. (new2) The combined heat–power plant (CHP) converts biogas with various efficiencies. Next the *mean gross efficiencies of conversion to electricity and heat* must be entered. This step can be skipped, if 0% biogas energy utilisation is entered in the previous point. The efficiencies entered here should refer to the mean, current technological mixture of all facilities converting wastewater treatment sludge digestion biogas. This can be a mixture of facilities producing only heat, only electricity, or both. It usually represents a mixture of several facilities, not a particular single facility nor a best case. The 100% basis is the lower heating value of biogas entering an energy utilization. The maximum value for either parameters *and* their sum is 100%. Commonly the electric gross efficiency is smaller than the thermal gross efficiency, and for Switzerland the values are 26% and 48%. The efficiencies are gross values, i.e. without deductions from internal use of energy. No suggestions are provided here based on the region, so appropriate data must be researched by the user, for instance from national energy statistics. If no values are entered, an efficiency of 0% will be used.
114. (new2) The remaining sludge from treatment needs to be disposed. The next three parameters define the technology mix of *disposal of the remainder sludge*. Sludge can either be spread on agricultural fields, landfilled in sanitary landfills, or go to municipal waste incineration. These three parameters must add up to 100% (100% signifying here all sludge generated in a country or territory). If you have entered a geographic region in point 56 and recalculate ('Alt = ' or 'F9'), rows 173, 176, 179 display suggested parameters for this region/territory, based on statistics. Suggestions are only provided for 31 European countries and corresponding regions. In rows 174, 177, and 180 you have the possibility to *manually override* these suggested values. If no suggested values are available, an *error value* will be displayed instead, and you are then *required* to provide a valid set of parameters yourself for a correct model calculation. Agricultural spreading, or landfilling is prohibited in some countries. The user must research appropriate disposal mix parameters.

Several groups of percentages given to characterise the wastewater fate must sum up to 100% to produce a valid inventory.

	Initial fate of wastewater		
	% emitted directly % sewerage and emitted untreated % sewerage and treated	}	must sum up to 100% (wastewater generated)
	Technology in treatment		
	% WWTP with 1 stage only % WWTP with 2 stages % WWTP with 3 stages	}	must sum up to 100% (wastewater treated)
	Sludge disposal		
	% sludge to agriculture % sludge to landfill % sludge to municipal incineration	}	must sum up to 100% (treatment sludge generated)

Remark on uncertainty

The data on site climate, technology and management choices can influence the elemental transfer coefficients used in the disposal models. Uncertainty of transfer coefficients is calculated using a formula (Doka 2003-II:30, Doka 2003-II:36, Doka 2017b:14).

This heeds the fact that transfer coefficients approaching 100% cannot have very large uncertainty without violating principles of mass conservation. A transfer coefficient of 105% does not make sense on a physical level and its existence can be excluded for chemical elements.¹¹ Transfer coefficients must remain within the bracket of 0% to 100% to be sensible. For instance a transfer coefficient with a mean value of 95% *cannot* possibly have a GSD of 130%, as this would suggest an upper boundary value of 161%, which in turn would signify that we consider it a possibility that 61% more of an element leaves the disposal process than was in the waste input, which would be a clear violation of mass conservation. Uncertainties of transfer coefficients are determined with the indicated formulas to assure mass conservation is not violated.

On the other hand small transfer coefficients can display large relative uncertainty: they describe infrequent emissions and relatively minor pathways that can be influenced by many stochastic events of which there are many in the heterogeneous milieu of a waste body. The formulas used assign larger uncertainty to small resulting transfer coefficients.

Similar remarks apply to technology mixes and similar. For instance if 95% of a wastewater is treated in a 3-stage wastewater treatment plants (cf. point 110) the uncertainty of that parameter must be restrained so the upper boundary value does not exceed 100%, since not more than 100% wastewater should be inventoried.

The Excel tools use the Geometric Standard Deviation (GSD) for error propagation calculations. The ES2 XML requires however a tag "variance". This is (for lognormal distributions) derived from the Geometric Standard Deviation (GSD). Variance is equal to $[\ln(\text{GSD})]^2$. Conversely $\text{GSD} = \exp(\sqrt{\text{variance}})$.

5 Creating a new ActivityName MasterData entry

If the activity you want to inventory leads to an ActivityName unknown to the database up to this point, you need to provide a new MasterData entry for it. That basically means that you need to associate this new ActivityName with a new UUID. As explained in footnote 3 on page 9, this is based on the need in Ecospold2 to clearly separate new entries from already existing ones.

115. Go to the *sheet "DS info"* and to column M (under the header "Eiv3 Activity Name").
116. Find the pertinent line(s) for your new dataset(s).
117. The names given in column M should be following the naming conventions explained in §3.f 'Activity name' on page 11. Please use the automatically generated names for consistency.
118. If column M displays errors on your row, you probably have used a new waste material. In this case you need to define a new IntermediateExchange and its associated master data, see §6 'Creating a new waste material' on page 27.
119. From column M copy the standard ActivityName(s) into the clipboard.

¹¹ Please note that topic here is uncertainty of transfer coefficients – i.e. the behaviour of the landfill – not uncertainty of the waste material input.

120. Goto the *sheet "MD ActName"*.
121. Under the header "name Tag" in column E on a free range of white cells, paste the new ActivityName(s) *as values* from the clipboard. "As values" means you want to paste the text strings alone, not the formulas that created them.
122. Select the white cell(s) immediately to the left (header "suggested ActivityName Id").
123. Press the three keys 'CTRL + Alt + u' on your keyboard simultaneously ('Alt' is sometimes labelled 'option' or '⌥'). This command will fill all the currently selected cells with new, random UUID. ¹² With this step you have associated a particular waste treatment activity name with a particular UUID. At this point to avoid confusion you should not go back to changing waste material input, or treatment type (§3.a or 3.c) on this row. One UUID should only refer to one particular activity name. If you need another disposal activity, start with a *new line* and step 13 on page 9.
124. Recalculate the workbook by pressing 'Alt – =' or 'F9' in Windows machines or '⌘ – =' on Macs.
125. If all your names are really new, you get a text flag in column C saying so, plus the UUID you just created will be appearing in column F, which is the place the tool looks for ActivityName IDs.

not already canonized	suggested ActivityName Id	name Tag	ActivityName Id
new	4e259ea5-361e-4746-9b6c-abfa11	treatment of waste packaging paper, open burning	4e259ea5-361e-4746-9b6c-abfa114c9688

126. If the ActivityName already exists, column C and F remain empty. You don't need to remove this entry as it does not interfere with the tool. It can be handy to have frequently used names available in one contiguous list.
127. When going back to sheet "DS info", the column N under the header "ES2 Activity Name ID" should now display the correct UUIDs for your ActivityNames.

6 Creating a new waste material

128. In "Central Repository 2020.xlsm" go to the *sheet "waste input"*.
129. In columns K onward between rows 31 and 69 the *available waste fractions* are listed. A waste fraction is best imagined as a uniform material with homogenous properties.
130. A waste material – as input to a treatment – can be a *mixture of different fractions* – e.g. you can have a glass bottle with paper label as a single waste material, i.e. a waste material composed of two very different fractions. In the tools these two different fractions will lead to different emissions not only because of different composition, but also because of different behaviour regarding burnability or degradability. Waste materials with more than one fraction are called "complex wastes". A waste material can however also be composed of only one single waste fraction.

¹² You will get a warning beforehand, as this command overwrites all selected cells with UUIDs without a possibility to undo. The pop-up dialog states the number of cells you selected. Press cancel to abort. The command is only available when the workbook "Central Repository 2017.xlsm" is open.

131. Clarify what waste material you want to create. Is it a complex waste? Is it a single, homogenous fraction? Identify if the required fractions are available and in what proportions the different fractions are present in your waste. If a required fraction is missing, you can create one, see chapter 8 'Creating a new waste fraction' on page 31. Compile the data needed for this.
132. Now go to column C of the sheet "waste input" and find an empty white row (Excel row 250+).
133. In row C type in a *waste name for your orientation*. This is the name that will be displayed in the list of available waste materials in sheets "DS info", see §3.a 'Choosing a waste material' on page 9. This is not the ES2 Exchange name, but an informal name which will also be mentioned in the General Comment of the dataset.¹³
- Please do not alter waste material names in non-white cells. Altering existing names will disrupt the calculation of already defined dataset entries in sheet "DS info".
134. Split the window and arrange the panes so that you can see the row you worked on and the headers of the defined waste fractions. Let's call the row you worked on X.

Waste material lookup and mixture calculation			Waste fraction composition database				
Enter name for waste			Enter data into the white background cells only. All data				
Name for waste:			0	0	1	0	0
			0	1	1	1	1
			average residual materials from MSWI	PE	PP	PS	PVC
210	waste nr 125	PL hard coal ash					
211	waste nr 126	PT hard coal ash					
212	waste nr 127	SK hard coal ash					
213	waste nr 128						
214	waste nr 129	my brand new waste					
215	waste nr 130						
216	waste nr 131						
217	waste nr 132						
218	waste nr 133						

135. In the right half scroll to the fractions of your interest and enter in row X the *weight share* this fraction has for your waste. So for a simple, single-fraction waste that means somewhere on row X you type in 1. For a complex waste you can enter two or more numbers, which however must add up to 1. For this you can check column D, where a control sum over all fractions is calculated (after a recalculation of the sheet).
136. After you have defined the weight share of all the fractions in your waste, go to the right end to column HG. Make sure you see the column headers in row 15 or the copy on row 85.

¹³ It might seem superfluous to have an informal name alongside the canonised waste exchange name. In certain circumstances it is however useful to also have a flexible informal name and reference that name in a comment. There are for instance several datasets for the disposal of hard coal ash *in various countries*. Their geographic location is distinguished in the dataset definition. But their reference product exchange name is always the same: "hard coal ash", even though different, country-specific waste compositions are used as inputs. The informal name in row C allows to specify that composition in more detail (e.g as "German hard coal ash") than the waste exchange name would be able to. The mention of the informal name in the General Comment allows for verification of proper dataset calculation and tracability of the given information.

137. Go to the column HM under the header "*ES2 Exchange name*". Here you must enter a name for the waste material exchange.
138. You can copy an already existing waste name here (see waste entries above row X). For example, if you want to inventory a specific, new biowaste composition you have for Brazil you *can* use the existing "biowaste" name here, but you can alternatively also choose to create a distinct name or a more specific one, e.g. "yard waste". The waste input is an IntermediateExchange in Ecospol2 parlance. A list of *all* already available (canonised) IntermediateExchange names is directly below starting on row 273. If you use an already existing name (which you preferably copy as value from an existing entry), skip to point 142 on page 29.
139. Otherwise, type in the new name for your new waste material exchange in column HM, row X. All IntermediateExchange names start with small letters. Please keep in mind that the name you use will become available to allecoinvent authors, so look at naming conventions in other similar exchanges. Also avoid abbreviations and consider that not everybody might know technical jargon used in a branch (you can use more specific terms in synonyms). Also the name will become part of the treatment activity name, see §3.f 'Activity name' on page 11. So avoid unnecessary repetitions. Be specific, but concise.
140. If you use a new Exchange name, you need to create a Master Data entry for it. That basically means that you need to associate this new name with a new UUID.
141. Go to the cell *to the left* (column HL) under the header "*new manual UUID for exchange*". Select the cell. Create a new UUID by pressing the three keys 'CTRL + Alt + u' on your keyboard simultaneously.
142. At this point you might want to recalculate with 'Alt – =' or 'F9' and check if everything is correct. If you entered a completely new Exchange name, the text label "new" in column HK will say so. If the name already exists, HK remains empty.

HG	HH	HI	HJ	HK	HL	HM
check canonised names	check unique names	check unique UUID	manual UUID given?	new, un-canonised exchange names	new manual UUID for new exchange name	ES2 Exchange name
752 #NV 2231				new	2c7f34d5-da2e-4eb7	waste cement in concrete and mortar excavation material, clean wastewater, average

143. The next column to the right (HN) contains the physical unit of the waste. This is always kilogram for solid waste, but m³ for wastewater (new2). Although the waste composition definition—also for wastewater—was based on a kilogram element per kilogram wet mass basis, for wastewater the f.u. of the created inventory will be automatically upscaled to an m³ input in the inventory calculation. Since this column contains the physical unit of the Intermediate Exchange master data, the appropriate unit must be entered here: kg for solid waste materials, m³ for wastewaters.
144. The next cell to the right (column HO) under the header "Synonyms ES2" allows optionally you to enter synonyms. These can be reasonably similar phrases for this waste. Here you can enter technical jargon for the waste material or frequent abbreviations. If appropriate, you can also enter chemical formulas for the waste, like "Ca(SO4).2H2O" for gypsum, or "Fe" for iron. You can enter multiple synonyms in the same cell. Separate individual synonyms with a two normal slashes (//) as delimiter.

145. On the next cell to the right (column HP) under the header "CAS number" you can enter a CAS number. This is rather unlikely for waste materials, but an optional part of the Ecospld2 Intermediate Exchange MasterData. For instance gypsum has the CAS number 13397-24-5.

With this you have given all the relevant information to create a new waste material. You can use now this waste material in calculations of new treatment activities §3.a 'Choosing a waste material' on page 9.

7 Creating a new Source MasterData entry (Documentation report)

The datasets created here are complex and intricate processes, as outlined in the Summary on page 5. It is possible for a dataset to include new raw data on a wide range of aspects:

- new waste fractions can be used
- new complex waste materials (combinations of fractions) can be employed
- climate data specific to a region or location can be used
- as can region-specific technology parameters.

None of these various raw data items do show up directly in the created process inventories¹⁴. To make the inventories more transparent it is advised therefore that the author compiles any sources and results of such raw data research in normal text reports. This allows to comment on sources, conversion, assumptions used to derive the raw data and finally present the raw data employed by the author in the tools in a form that other users can consult in an efficient and transparent manner. If you are documenting several datasets, their raw data can of course be presented in one report.

To reference your text report within the dataset, you should make a source reference when creating new datasets, see §3.h 'Documentation source' on page 13. Any new report needs a new Master Data entry in the list of sources. To create one, do the following.

146. Go to the workbook "Central Repository 2020.xlsm" and there to sheet "MD sources".

147. On a free row with white cells, go to column E under the header "firstAuthor". Type in the name of the first author of the new report you are going to reference. Only write out the family name (surname). Append given name (first name) only as initials. In case of measurement on site, oral communication, personal written communication and questionnaires ('sourceType'=4, 5, 6, 7) the name of the supplying person is given here (not the name of the person receiving information).

148. On the next cell to the right (column F) give the year the report is published.

149. On the next cell to the right (column G) give the main title of the report. Enter a title that clearly identifies a single report.¹⁵

¹⁴ Though some of them are mentioned in comment fields in produced Ecospld2 XML-Files.

¹⁵ Don't write the name of a project, when this project has issued *several* reports. You can identify such projects in the tag "titleOfAnthology" four columns to the right. For measurement on site: write 'Measurement documentation of company XY'. For oral communication: write 'Oral communication, company XY'. For personal written communication: write: 'personal written communication, Mr./Mrs. XY, company Z'. For questionnaires: write 'Questionnaire, filled in by Mr./Mrs. XY, company Z'.

150. On the next cell to the right (column H) enter a code for the *type of source* this represents. Following are the possible codes. '3' is probably most appropriate for your type of compilation report.

0	Undefined (default)
1	Article
2	Chapters in anthology
3	Separate publication/web-site
4	Measurement on site
5	Oral communication
6	Personal written communication
7	Questionnaires

151. Skip the yellow column and go to the next over (Column J). There you can list any *additional authors*. Use the same format as for the first author. Separate co-authors with a comma (,).
152. The next column (K) is called "Title of Anthology". Here you can enter the title of any overarching project this report has been published from. If the publication is a chapter in an anthology, the title of the anthology is reported here.
153. In column L names of any editors can be given.
154. In the next column (M) the *place of publication* is given. This is actually a twofold field. You give the geographic location of publisher (place name, country). For reports available on the internet you give the full URL web-address (deep link, give the address to the specific report you are recording, not only general main-domain addresses).
155. Finally in the last column you can give the name of the publisher/publishing body or organisation.
156. Now if this represents a new report, it needs to be associated with an identification number. To do this *select* the left-most, white cell in column D (under the header "source Id"). With this cell selected, press the three keys 'CTRL + Alt + u' on your keyboard simultaneously. This will generate a new UUID for this report.
157. You can copy/paste this UUID number to reference your report, i.e. point 13 in §3.h 'Documentation source' on page 13 .

8 Creating a new waste fraction

Waste materials are the input to a waste treatment. A waste *material* can be composed of one or several waste *fractions*. A waste fraction is best described by a uniform material with homogenous properties, especially regarding burnability or degradability. The reason to separate heterogeneous materials into several waste fractions is *better waste specificity in the created inventories*.

To explain: Consider a waste composed of burnable and un-burnable parts, for instance a plastic part with metal screws. During an incineration the plastic will burn away, but metal screws will go to bottom ash. In the incinerator and open burning models the behaviour of burnable parts is discerned from un-burnable parts. Otherwise you'd have either the unrealistic case of the plastic part of the example waste go to bottom ash or the also unrealistic case of bulk metal parts going into flue gas. So

heterogeneous parts of waste materials need to be distinguished. This also goes for materials with dissimilar behaviour regarding degradation in a biologically active landfill (sanitary landfill or similar): easily degradable fractions must be recorded as different from less degradable fractions. Recording different waste fractions independently achieves this necessary separation. It is possible to have several differently behaving waste fractions in a single disposal inventory of a waste material. A waste material composed of several fractions is called a "complex waste". This makes it for instance possible to have one inventory dataset for the burning of electric cables (plastic + copper metal).

In large parts the requirements to define a waste fraction are the same as for the previous tools from (Doka 2003, cf. part II, page 14ff.). New parameters are the share of recyclable aluminium and copper. You will need to research the required data from literature measurements or theoretical considerations. Setting waste composition equal to factory-new materials is acceptable, if contamination (or decontamination) during use is negligible. Purely theoretical compositions are to be avoided, like assuming a polyethylene plastic (C₂H₄) consists only of carbon and hydrogen. In all materials pollutant traces of heavy metals and other elements are present—even for factory new materials—and they often are crucial for the disposal inventory.

(new2) Also wastewater definitions are entered in this mask for solid waste. Common in literature are wastewater definitions as concentrations, e.g. mass per volume, like milligram per litre. This must be converted into a kg per kg wet waste. E.g. a concentration like 5 mg cadmium per litre will be entered as 0.000005 kg cadmium per kg wet mass. I.e. the assumption is made that one m³ of wastewater is 1000 kg of wet waste. Pollutants like COD, BOD, DOC need to be converted into a value for organic carbon (TOC). A guideline on how to convert these parameters is given in chapter "*Appropriate pollutant parameters*" in (Doka 2021:55). As with solid wastes, the sum total of the given contents must equal 1 kg wet waste, here water being the usual lionshare. Some parameters can be skipped for wastewaters, like heating values, degradability and share of theoretically recyclable metals.

(new 2) It is possible to have two or more different wastewaters within one disposal datasets, i.e. the analogue to a complex solid waste consisting of several fractions. Wastewaters mix well and one single definition is possible and sensible. Depending on the wastewater-producing activity it can however be convenient to keep separate wastewater definitions from separate sections of the facility, and only merge them in one inventory calculation. It is also possible to make two separate datasets for two separate wastewaters from the same activity. In either case make sure the activity names and wastewater names are clear, unambiguous and understandable to practitioners not necessarily familiar or even interested with your specific wastewater-producing activity. Consider, that users of the database who might have to search through a large list of disposal activities to find an appropriate one are not necessarily interested in or informed about your activity in the foreground. So clear, generally understandable names are advantageous.

158. In "Central Repository 2020.xlsm" go to the sheet "waste input".

159. In columns K onward between rows 31 and 69 the available waste fractions are listed.

160. Find an empty, white column right of column K. Lots of room right of column FR. Do not change the information given for already existing fractions, to remain consistent with previous publications. But you can of course *copy* information from existing entries to derive your own fractions.

161. Split the window, so you can see the row headers in columns A–D.

162. In row 15 a descriptive name for this fraction must be given¹⁶ (row 16 for a German translation can be left blank).
163. Row 17 can contain some optional additional internal notes or details regarding the fraction.
164. In row 13 (top) enter a number 1 or 0, for burnable or inert waste fractions. Burnable (=1) are materials like plastic or paper, biowaste, all wastewaters etc. Inert (=0) are bulk metals, bulk glass, bulk ceramics, stones etc. For thin metal laminates, for instance in drinks cartons, a burnable flag can however be appropriate.¹⁷
165. Got to row 21–61. The concentration of different chemical elements found in your fraction can be entered. The composition here is always for wet waste. The physical unit is kilogram element per kilogram of wet waste.¹⁸ Water content is entered in row 20. The data given for hydrogen and oxygen (rows 22 and 21) excludes the H and O in water (row 20). Please be diligent in inventorying real world toxic traces, like for instance heavy metals. You mustn't merely consider theoretical compositions (like C₆H₆O₁₂ for "biomass"). Usually toxic traces matter *a lot* in the inventory result of waste disposal.
- Please note that uncertainty of composition data will be heeded using the procedure described in Doka 2003-II, chapter "Uncertainty of waste composition data". So uncertainty of composition will be heeded without using Pedigree scores.
166. The sum total of all chemical elements plus water must equal to 100%. The sum is calculated on row 62. An error message will be displayed in row 14 just above the fraction name, if the sum is not 100%. Recalculate the sheet to see this ('Alt = ' or 'F9'). Please note that unnecessary rounding to significant digits in element concentrations can lead to 'mass gaps', resulting in an error message. Since 1 kg is the basis for the composition definition here, later used for the functional unit¹⁹, your composition must meet the 100%, otherwise you are ignoring mass or creating mass from nothing. To arrive at a 100% composition, it is usually best to keep toxic elements as found in literature and adjust some large and non-toxic part, like H₂O, oxygen, silicon. What is suitable to adjust depends on the waste fraction.
167. In rows 18 and 19 the upper and lower heating values (calorific values) must be entered – for wastewaters this can be left empty. The unit is megajoules per kg of wet waste (MJ/kg). If you don't have literature data on this, rows 75 and 76 calculate theoretical heating values based on the given elemental composition (elements O,H,C,S,N and water must be given for this). If you only have a lower heating value from literature, row 73 calculates a corresponding upper heating value based on hydrogen and water content. Likewise row 74 calculates a lower heating value from a given upper heating value. Heating values will be used in energy production in municipal waste incinerators, but its good practice to record a heating value for all fractions.
168. In row 64 the share of biogenic carbon in the waste is defined. As biogenic and fossil materials likely have different degradabilities, i.e. are heterogenous, mixtures of both should

¹⁶ This name will be used in the GeneralComment of a dataset when describing the composing fractions of the treated waste material.

¹⁷ For borderline cases it might be appropriate to create *two* separate factions of identical composition, but with different burnability flags, as done for the fine-grained metal residues from automotive shredder residues (ASR).

¹⁸ (new2): Also for wastewaters the composition definition must be given as kg element *per kg wet waste* for consistency. I.e. a wastewater concentration of 123 mg per litre must be entered as 0.00123 (kg/kg). The f.u. of wastewater activities is m³ and this will be automatically upscaled.

¹⁹ 1 kilogram for solid waste disposal, 1m³ for wastewater.

in most cases best be separated in two or more different fractions. So the share of biogenic carbon will be either 0% or 100%, but in-between values are possible.

169. In row 65 the *degradability in a landfill* within the first 100 years are given. These are values for temperate climates. Influence of climate on degradability will be heeded in the landfill model. A list of suitable degradability values for some fractions is given in Tab. 8.1 on page 35 below. For wastewaters, this can be left empty.
170. Row 66 (solidification with cement in residual landfill) is not used in the present models. A separate inventory of disposal in residual material landfill will be possible in planned updated models.
171. Rows 68-70 give the share of metals that are *theoretically recyclable*. Bulk iron, aluminium and copper are discerned, in that order. Give a number from 0% to 100% for each. 100% refers to the total given elemental content in the fraction. For example a waste containing 0.12 kg iron per kg (row 56), can have a 30% recyclable share, which means that a 100% efficient recycling can isolate 36 grams of iron metal from this waste ($= 0.12 \cdot 30\%$). Please note the different meaning of 'recyclable' and 'recycled'. You are *characterising a waste material* here; you are not giving recycling efficiencies of a treatment technology (see point 65 on page 19 for this). For the theoretically recyclable parts exclude very small, thin, or oxidised metal parts (unless they stick to bulk metal parts). The relation between a content, the theoretically recyclable metal, and the actually recycled metal is shown schematically in Fig. 8.1 below.

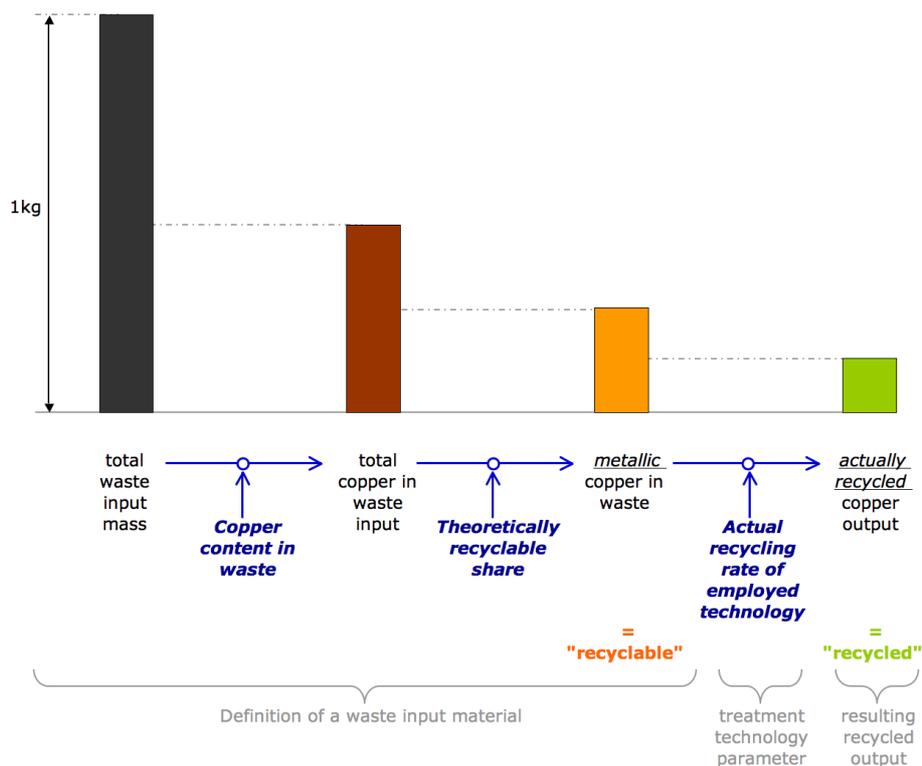


Fig. 8.1 Scheme of relations of content, theoretically recyclable metal and actually recycled metal.

You now have a new waste fraction which you can use in a new waste material (see §6 'Creating a new waste material' on page 27).

Tab. 8.1 Waste degradability in landfill in the first 100 years

Material	Waste degradability rate D in 100 years for temperate climate
Office Paper, tissue paper, towels	39.34% ¹
Cardboard boxes	32.44% ¹
Paper average	26.99% ¹
Coated paper	18.02% ¹
Newsprint/newspaper	16.17% ¹
Wood	0% to 3.30% ¹
Plastics, Paints	1% ²
Compostable materials	27% ²
Textiles	12% ²
Bulk metals	50% ³
Gypsum	100% ⁴
Wood ash	5% ²
Sludges	60% ²

1 Derived from (Micales & Skog 1997:151), cf. (Doka 2003-III:44)

2 Estimate

3 Estimate base on high corrosion rates. Re-precipitation of metals diminishes the actual emissions.

4 Estimate based on gypsum solubility. Re-precipitation of sulfur diminishes the actual emission.

9 Base number for Matrix Element IDs

9.a The Matrix Element ID

Ecospold2 requires for each occurrence of an exchange within a dataset a unique UUID number. This is not the UUID number that defines the exchange itself (like 'cadmium to rural air'). It is another unique number that identifies that exchange *within that particular dataset* (like 'cadmium to rural air' in the activity 'open burning of paper in India 2006-2012'). This UUID number therefore represents a single matrix element in the matrix of [activities × exchanges] of the whole database. I named this unofficially "Matrix Element ID".²⁰ In order to consistently create ecospold2 files of disposal datasets also these matrix element IDs need to be called up by the tool in a consistent manner. It is not enough to define a particular exchange in a particular process, also the correct matrix element must be written out for a valid Ecospold2 file. As with other ID challenges in Ecospold2, this could theoretically be solved with a lookup table of already defined or newly created IDs. Since disposal datasets have often hundreds of exchanges, this list would grow quickly and create large and unwieldy Excel files.

²⁰ In the Ecospold 2 schema documentation this element is simply given the name "id" (field 1005) accompanied by following scant description "Unique identifier for this exchange. The intermediateExchangeId or the elementaryExchangeId can not be used to identify an exchange because one master data entry can be referenced by more than one exchange of a dataset." (Ecoinvent Association 2017)

9.a.1 Deriving consistent Matrix Element IDs (variant A)

The problem was solved in (Doka 2013) not by simply assigning fully random numbers as UUIDs in a long list, but *calculating* these matrix element UUIDs. For each particular disposal process, e.g. municipal incineration in Switzerland 2012, a 36-digit base number was defined, whose first 30 characters represent the front part of the 36-digit matrix element UUID. Such a base number might be for instance fe3bf381-fa09-41c4-964f-4dd64c. Each base number therefore stood for a particular disposal practice in a particular country, in which various waste materials can be disposed, resulting in *several* activity datasets.

The end part of the matrix ID was calculated from the waste number (row number in the list of defined waste in the central repository) plus the number of the exchange times 3. The result was converted to hexadecimal values, padded to 6 digits with leading zeros, and added to the front end to result in the completed matrix element UUID. This is variant A of calculating Matrix Element IDs, as shown in Fig. 9.1 on the left. With this calculation for each dataset the matrix element IDs of each exchange can be *calculated* in a reproducible manner. Initially though a base number must be provided which stands for a particular treatment type, i.e. disposal practice in a particular country and time period. This variant was employed in the municipal waste incineration updates of 2013 and 2015 (Doka 2013, 2015).

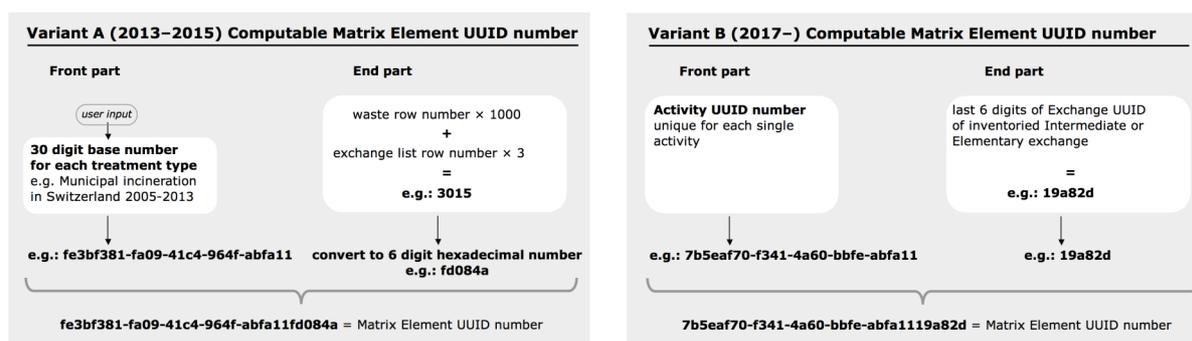


Fig. 9.1 The two schemes of calculation of Matrix Element IDs. Variant A (2013-2015) on the left and variant B (2017-) on the right.

9.a.2 Assuring consistency among several users (variant B)

This first solution A of 2013 works well for a single user. When the Excel tool is duplicated and several users start using the tool in parallel, a problem can ensue from the use of the row number from the waste list to derive Matrix Element IDs. When new wastes in the list are defined, non-identical waste materials might be defined with the same waste number. It can become impossible to reproduce the matrix element IDs correctly when other users try to calculate inventories with waste definitions on a different row. Therefore a second variant of the calculation of the matrix element IDs was introduced in 2017 (variant B, see Fig. 9.1). The base number (front part) is replaced by simply using the Activity UUID, which must already be defined for an activity (see point 46 on page 14).

For the end part, the last 6 digits of the UUID of the inventoried exchange are used. This number is defined for exchange (irrespective of the user or table layouts).²¹

²¹ In some rare cases an inventory can feature the same exchange as input and output simultaneously. An example is the sanitary landfill which might produce usable electricity from captured landfill gas, so there is an electricity output. At the

Thus also in the second variant matrix element IDs can be *calculated* for each exchange in any activity (instead of being looked up in a huge list of random IDs) but with the added ease that no additional user input of a base number is required and that these calculations are not dependent on the position rows of a waste material in the defining Excel sheet.²²

10 Additional information for EcoSpold1-Files

10.a Introduction

The current version of the ecoinvent database (version 3+, since 2011) uses the EcoSpold2 file format for inventory files (ES2). Ecoinvent has abandoned the earlier EcoSpold1 format used in previous database versions (2003-2010). In the LCA world however the EcoSpold1 file format (ES1) keeps on being used, for instance in the KBOB-UVEK database²³, in the OpenLCA application²⁴, or in the SimaPro software²⁵.

Commissioned by BAFU (the Swiss EPA) the newly created calculation tools in 2020 for inorganic building waste landfill and excavation material landfills were given the ability to export EcoSpold1 directly (Doka 2020). This functionality was also introduced into the rest of the tools. Most of the required information for EcoSpold1 can be derived from the information already present in EcoSpold2. Details on the exact implementation can be found in (Doka 2020, chapter "Implementation remarks").

Additional data is required for some EcoSpold1-fields. This required data is described below.

The following fields must only be filed, when creating EcoSpold1 files, but are not required for EcoSpold2 files.

10.b ES1 waste material names

The waste names used in EcoSpold1 files (ES1) usually are different from the waste exchange names used in EcoSpold2 files (ES2). In ecospoldv3+ and ES2 certain waste names were changed, due to the fact that in ES2 a waste-producing activity would only state a technosphere flow as an *output exchange* of a waste material ("waste polyethylene") and not request an *activity* for waste treatment (like "treatment of polyethylene, municipal incineration") as in ES1. For referencing a waste material

same time the activity includes the off-site treatment of leachate and disposal of treatment sludge, where electricity is consumed, so there is an electricity input. To still be able to calculate Matrix Element IDs in this case and obtain different IDs although the Exchanges (and their Exchange IDs) are identical, simply a value of 16 is added to one of the two instances.

²² Another difference is that in variant A all treatment activities originating from a particular treatment type (e.g. all possible different waste materials treated in municipal incineration in Switzerland 2012) will have the same initial 30 digits in all their Matrix Element IDs. In variant B the Matrix Element IDs only within a certain activity will have the same front part, derived from the activity's UUID.

²³ See (KBOB et al. 2018).

²⁴ See www.openlca.org

²⁵ See <https://simapro.com>

alone, as in the new ES2 procedure, it is clearer to have a distinct exchange name which labels a waste like "waste polyethylene" (and not a name like "polyethylene", which could be mistaken for a pre-consumer polyethylene mass output). For this reason in ES2 waste names are clearly signified as "waste", "scrap", "used", "spent" etc. especially in cases where the material without such a qualification could be mistaken for a new, pre-consumer product. Also in ES2 waste names do not carry information about water content as previously in ES1.

In ES1 a waste-producing activity would always link to a *disposal activity* by referencing the entire activity name. So the waste name is never used on its own, but always in combination with a disposal type. A waste name is used to construct a disposal's activity name, e.g. "disposal, polyethylene, 0.4% water, to municipal incineration".

When creating new ES1 disposal datasets, for consistency, it is best to adhere to the *naming conventions* used in the seminal ecoinvent v1.0-2.2 (2003-2010). A speciality there is that the waste names were accompanied by their *water content*. This allows practitioners to check compatibility with the waste their inventoried process is producing, e.g. waste wood has a water content of 20% (corresponding to a humidity or moisture content of $u=25\%$). But giving a water content is not compulsory in ES1, merely advised for consistency.

In case you are creating a **new waste material**, perform the steps in chapter 6 on page 27 first. Then, for creating an ES1 file, additionally follow the steps below.

172. (new) In "Central Repository 2020.xlsm" go to the sheet "waste input".
173. (new) Go to the column IA under the header "ES1 waste name". Here you must enter a name for the waste material on the respective row of that waste material. You can look at the names in the same column to assure consistency. Except for wastewater compositions, it is advised to include a water content in the waste's name, rounded to three digits. Water content is water mass in wet waste divided by total wet waste mass, expressed in percent. A waste material's water content is calculated in row HJ. Waste material and water content is always separated by a comma, e.g. "*polypropylene, 15.9% water*". Don't make the name too long, as it will be used in the creation of the disposal dataset's name, which can't be longer than 80 characters overall.
174. (new) In the column to the right (IB) with the header "ES1 local waste name (German)" you can enter the waste material's name in German. This will be used to construct a local name for the disposal activity in German. You can look at the names in the same column to assure consistency. Also here—except for wastewater compositions—it is advised to include a water content in the waste's name (% Wasser), separated by a comma, e.g. "*Polypropylen, 15.9% Wasser*". Also the local dataset name should ultimately not become longer than 80 characters. A local name is a *required part* of an ES1 dataset inventory, and in practice this has always been in German. Non-German speaking users are advised to try to find the proper German terminology for a waste; the author can be contacted for this, if need be (ecoinvent@doka.ch).
175. (new) EcoSpold1 has an extra spot for entering chemical formulas of an exchange (unlike EcoSpold2, that only has synonyms and CAS numbers, but no formulas anymore). It is rather rare for *waste* materials to have a proper or approximate chemical formula, but if appropriate or helpful you can enter a formula in column HZ to the left. If you have already supplied a chemical formula previously in the synonyms section (see step 144 on page 29), you need to *repeat it* here, if you want that formula being also shown in the separate formula element of ES1. For instance you can enter $(CH_2-CH_2)_n$ for polyethylene, or $Ca(SO_4) \cdot 2H_2O$ for gypsum, or Pb for a lead scrap. Chemical formulas should not be taken literally, as they do not reflect the actual real world composition with traces and grime, but the idealised composition of the material's bulk mass (cf. step 165 on page 33).

10.c ES1 dataset name

The English and German waste names given above will be used to automatically create a disposal activity's name and local name. The naming conventions in ES1 are a bit different from those in ES2 (see Tab. 3.1 on page 12). In ES1 a disposal activity is always prefixed with "disposal, " (or "Entsorgung, " for the local name), followed by a comma and the waste materials name (usually with comma-separated water content), followed by ", to" and the disposal type.

	start, comma	waste name + water content	comma, treatment type
Activity name	"disposal,	polyethylene, 0.4% water	, to municipal incineration"
Local name	"Entsorgung,	Polyethylen, 0.4% Wasser	, in Kehrrechtverbrennung"

Tab. 10.1 Standard structure of activity names for solid waste treatment processes in ecoinvent v1-2.2/EcoSpold1. Start is always "disposal, " with a comma, then the waste name which is followed by ", to" and the treatment type.

In existing datasets, the standard structure is sometimes abandoned. This can occur for several reasons.

- The standard name would exceed 80 characters, which is the limit for dataset names in EcoSpold1. So a *shorter name* needs to be provided.²⁶
- The dataset author *deviated* from the standard structure. E.g. the dataset "disposal, LCD module, to municipal waste incineration" ends with "municipal waste incineration" instead of the standard "municipal incineration".
- The dataset author accidentally had a *typo* in the dataset name, e.g. "disposal, coatings in CRT screens, to municipal waste incineration" has an unnecessary double space in front of "to ".

If *updates* of these datasets are to be created, the dataset names need to be reproduced to the letter in order to replace the old datasets. In order to allow for such deviations from standard dataset names to be included, the Central Repository workbook allows for entering an *override dataset name*, which will then be used with priority.

For *new datasets* it is advised to keep the automatic standard name, except when it exceeds 80 characters (cf. steps 0–181 below).

First make sure all the required information for the desired disposal dataset is compiled, by following the steps in chapter 3 'A new activity inventory' on page 9, respectively making sure the information given is appropriate for your desired application.

176. (new) Make sure you have given waste material names (English, German) as described in the previous §10.b).
177. (new) Recalculate the workbook by pressing 'Alt – =' or 'F9'.
178. (new) In "Central Repository 2020.xlsm" go to the *sheet "DS info"*. Spilt the window vertically so you can see the chosen waste, site and disposal type in columns C-E; and columns AY and AZ. Split the window horizontally, so you can see the row of your target datasets, and the column headers on row 11.

²⁶ In some contexts, EcoSpold1 dataset names longer than 80 characters have been encountered, for instance in the Swiss KBOB database (KBOB et al. 2018).

B	C	D	E	AU	AV	AW	AX	AY	AZ
chosen dataset	(a) Treated waste material	(b) Disposal site	(c) Disposal type	ES1 override English dataset name	ES1 override German dataset name	ES1 used English dataset	ES1 used German dataset	name length	
57	coatings in CRT screens	ecoinvent 2013	municipal incineration (m)			disposal, coatings in CRT	Entsorgung, Beschichtung in CRT	67	66
	check	check	check						
56 used liquid crystal display module	ecoinvent 2013	ecoinvent 2013	municipal incineration (m)	disposal, LCD module, to municipal waste incineration		disposal, LC	Entsorgung,	54	45
57 coatings in CRT screens	ecoinvent 2013	ecoinvent 2013	municipal incineration (m)	disposal, coatings in CRT screens, to municipal waste incineration		disposal, co	Entsorgung,	57	66

179. (new) In the appropriate row and columns AY and AZ check if the length of the dataset name is longer than 80 characters (if so, the cells will be red).
180. (new) When the names are shorter than 80 characters, you don't need to do anything. If the names are longer than 80 characters, then start by shortening the waste names given in previous §10.b.
181. (new) If shortening the waste names does not lead to names shorter than 80 characters (or you want to reproduce an already existing non-standard dataset name) go to the columns AU and AV to the left. Enter English and/or German override names for datasets. Overrides should continue to be as close to the standard name structure as possible (see Tab. 10.1 above). Overrides can be used to create compliant shorter datasets names, e.g. by abbreviating the treatment type.²⁷

10.d Reviewer and reviewer comment

EcoSpold1 files can optionally contain a reference to a reviewer person and their review comment.

182. (new) In the case a neutral review of the inventory has actually been performed, a reviewer person can be specified in the workbook "Central Repository", sheet "General Data", cell F26 you can enter a person's UUID. A list of all available persons is in sheet "MD persons". This procedure is similar to specifying the dataset author in point 49 on page 15.
183. (new) In the case a neutral review of the inventory has actually been performed, a reviewer's comment text can be entered in cell F28 as plain text. Without a specified reviewer person (see point above) a review comment will not be included.

The default setting in the tool is to have both these fields empty. If specified, the reviewer person and reviewer text will be used for *all created datasets* alike. This is not very flexible to use in several datasets when different review comments are desired. This scant approach was chosen due to the often very limited information in those fields encountered in actual practice of the past, when used at all (see comments in Doka 2020).

10.d.1 Country information for persons

For each person specified in a dataset (author, reviewer) EcoSpold1 requires that the country of their postal address is defined explicitly as a country code (2-letter ISO, like CH, DE, US, NL etc.). In EcoSpold2 a person's country may or may not be specified in the field "address" in free text. This information cannot be parsed dependably into a country code.

²⁷ For instance, when a name like "disposal, residues, mechanical treatment, desktop computer, to municipal incineration" would be too long (85 characters), it is acceptable to shorten it to "disposal, residues, mechanical treatment, desktop computer, to MSWI". Unfortunately, for this activity the author has chosen a non-standard phrasing, by making the name end in "... in MSWI", instead of the more standard "... to MSWI". Thus to reproduce this non-standard name, the override name in column AU is needed.

184. (new) The *2-letter country code* associated with a data generator person should be entered in the workbook "Central Repository", sheet "General Data", cell F25 (2-letter ISO, like CH, DE, US, NL etc.)

To avoid creation of invalid ES1 files, the country code for Switzerland (CH) is already entered as a default value in the tool, but can be overwritten by the user. The same country code is also used for the reviewer's person for simplicity.

10.e EcoSpold1 mutated "dialects"

EcoSpold1 (ES1) is a data format created by the ecoinvent association (ecoinvent 2002). As such, the naming conventions of the ecoinvent database (versions 2003-2010) should be adhered to when creating an ES1 file. In spite of this some mutated 'dialects' of ES1 have emerged, with changed or deleted exchanges and changed exchange subcategory names. For instance in ES1 for SimaPro, exchange names have been changed (e.g. from "Phosphorus" to "Phosphorus, total") or category/subcategory names have been changed (from "water/ground-" to "water/groundwater"). Unfortunately those changes and idiosyncrasies are not publicly documented, which makes it difficult to create valid ES1 files for a particular application or software.

10.e.1 EcoSpold1 import in SimaPro

The generated EcoSpold1 files (see step 12 on page 8) can be imported into SimaPro. This was tested in July 2020 with SimaPro 9.1 Developer version (thanks to Mischa Zschokke of Carbotech for this).

The datasets provided from the Excel waste tools are unit process inventories (UPR, or U) with direct emissions and direct consumptions of technosphere products and services. So the cumulated (rolled-up) life cycle inventory (S) of these datasets rely on the required technosphere processes, which need to be provided by an *appropriate backgrounds database*. A suitable backgrounds database must therefore be present for the datasets to be used properly in LCA work. In SimaPro the database(s) needed in a project are to be chosen first by the user. Here it is important that the correct databases are chosen so that the required technosphere processes in the UPR can be found and linked up to the correct processes. The Excel tools produce EcoSpold1 files adhering to the official EcoSpold1 naming conventions, which were used in the official ecoinvent v2.2 released in 2010.

The appropriate steps for an import into SimaPro are described below.

185. (new) Backup your projects in SimaPro.
186. (new) Create a new project in SimaPro.
187. (new) In the Libraries tab, select the suitable background databases. Successful testing was done with the databases KBOB:2016 and UVEK:2018 which are unofficial extensions of the official ecoinvent v2.2 of 2010.
188. (new) In the File/Import dialog (see picture below), select the file format EcoSpold1 (top radio button)
189. (new) Next, press the 'Add' button and select the EcoSpold1 file of the process you want to import.
190. (new) Below that, press the 'Select' button and then choose the mapping file. A mapping file 'Doka2020.SPMMapping' is provided together with the Excel tools. You can also use other

mapping files that succeed to translate the original EcoSpold1/ecoinvent v2.2 names into local name dialects.

191. (new) In the object link method, choose the third option (link to existing objects first). The disposal datasets generated by the tools commonly do not link to each other.
192. (new) In other options, reproduce the check marks given in the picture below.

Import files

File format: SimaPro CSV EcoSpold v1

Import files 1 file selected

C:\Users\mischa\Desktop\vers b Drei Varainten ES1SP\1b leanest\woneu2 235C_WasteCementFibreSlabDismantledConstructionAndDemolitionWastCH3h26m.xml

Mapping file: C:\Users\mischa\Desktop\vers b Drei Varainten ES1SP\1b leanest\1leanestDoka.SPMMapping

Object link method

Link imported objects only to other imported objects

Try to link imported objects to existing objects first

Try to link imported objects to other imported objects first

CSV format separator

Tab Comma Semicolon

Other options

Replace existing processes with equal identifiers or product names Skip process identifier

Apply 'U' and 'S' suffixes for product names of unit and system processes

Use SimaPro requirements (less strict checking) Use EcoSpold v1 product name format

Use local names

Default settings

OK Cancel

193. (new) Click OK to import.
194. (new) You might receive an import *warning* at this point. A warning will allow the import to continue. You should investigate and consider warnings, as the might deteriorate datasets from their original content.
195. (new) If you get a an import *alert*, there is an error that prevents the import at this point. This first needs to be fixed. It might be that required exchanges cannot be found in the background database selected by you in step 187 and therefore the imported dataset is not linked fully.
196. (new) If no alerts occur, you get an 'import overview' that shows you the recognized elements that are intended to be added with this import.
197. (new) Please check the various tabs in the 'import overview' window and make sure this is consistent with your expectations. For instance if new 'Substances' (Elementary Exchanges) are to be imported, you should consider an extension of the characterisation factors in the LCIA methods.

11 Overview of the calculation tool structure

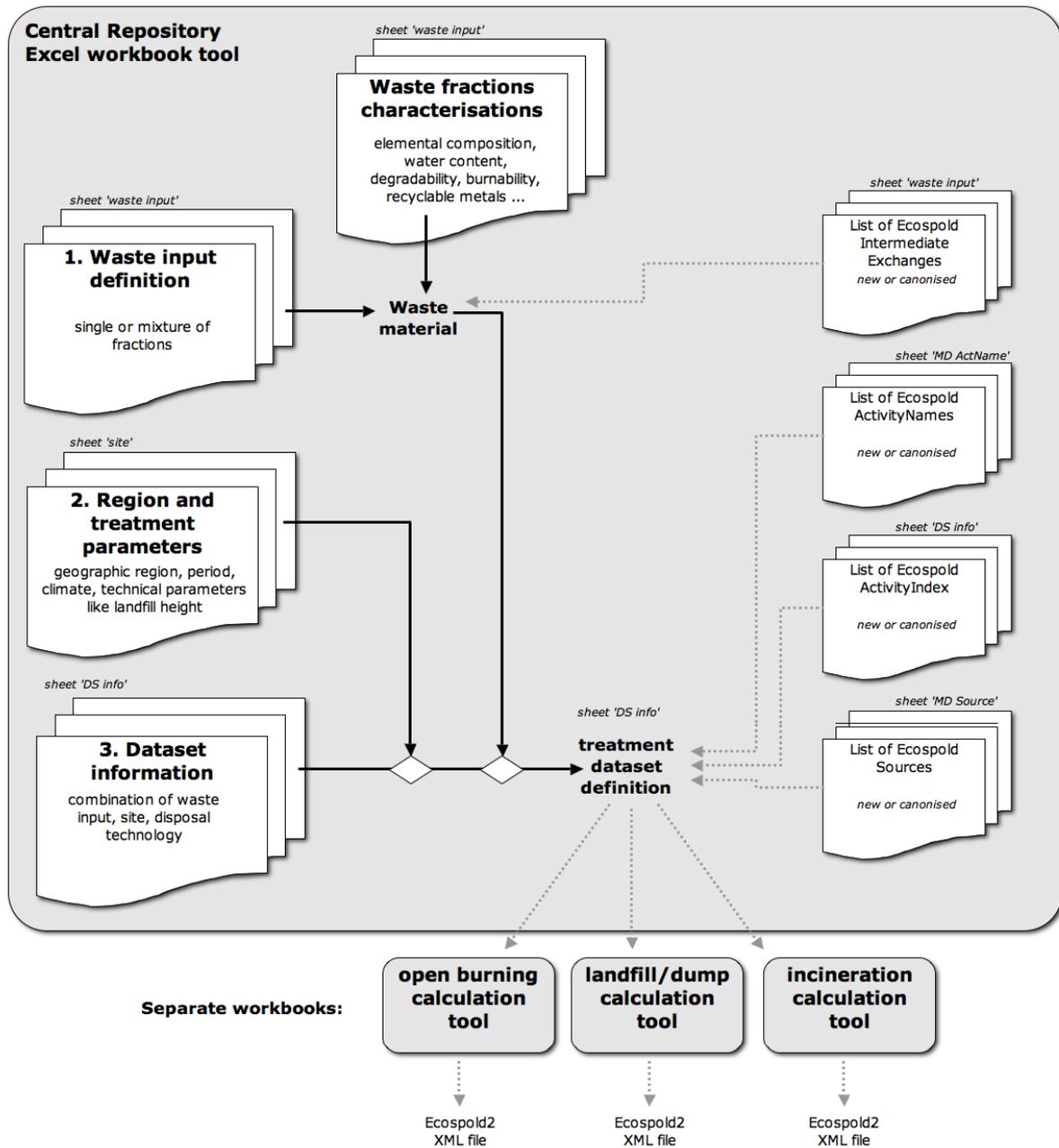


Fig. 11.1 Overview of the process structure for the waste calculation tools described here. A simpler scheme is shown in Fig. 1.1 on page 6.

12 VBA code

New code from 2020 includes VBA routines to export EcoSpold1-Files

Public Function NewUUID() As String

```
'creates a new (version 4) UUID of the form (8-4-4-4-12)
' xxxxxxxx-xxxx-4xxx-Yxxx-xxxxxxxxxxxx
' where x is a hexadecimal digit (1-9,a-f), and Y is either (8,9,a,b)
uuid$ = ""
For i = 1 To 32
  rn = Int(Rnd() * 15.999999)
  If i = 17 Then rn = 8 + Int(Rnd() * 3.999999) ' make 17th place either (8,9,a,b)
  If rn > 9 Then
    uuid$ = uuid$ & Chr$(87 + rn) ' add character (a,b,c, ...)
  Else
    uuid$ = uuid$ & Chr$(48 + rn) ' add number string (a,b,c, ...)
  End If
Next i
' make 13h place a 4
uuid$ = Left(uuid$, 12) & "4" & Right(uuid$, 19)
' add hyphens
uuid$ = Left(uuid$, 8) & "-" & Mid(uuid$, 9, 4) & "-" & Mid(uuid$, 13, 4) & "-" & Mid(uuid$, 17, 4) & "-" & Right(uuid$, 12)
NewUUID = uuid$
End Function
```

Sub FillRangeWithNewUUID()

```
' fill range of selected cells with a new UUID
' a new (version 4) UUID of the form (8-4-4-4-12)
' xxxxxxxx-xxxx-4xxx-Yxxx-xxxxxxxxxxxx
' where x is a hexadecimal digit (1-9,a-f), and Y is either (8,9,a,b)
nc = ActiveWindow.Selection.Cells.Count
ans = MsgBox("This will overwrite the contents of all selected cells (n=" & nc & ") with a new random UUID (36 digit, version 4). Press cancel to abort.", vbOKCancel, "Attention")
If ans <> 1 Then End
Randomize (Hour(Now) * 10000 + Minute(Now) * 100 + Second(Now))
For Each c In Selection.Cells
  u$ = NewUUID()
  c.Value = Left(u$, 24) & "abfa11" & Right(u$, 6) ' insert "abfa11" in last dodecet
Next c
End Sub
```

Public Function VarianceWithPedigree(VarianceWithout As Range, PedigreeString As Range) As Double

```
' converts as given variance and a PedigreeString (e.g. 12345)
' in to a value of variance including Pedigree uncertainty
VarianceWithPedigree = VarianceWithout.Value
PGv = PedigreeString.Value
MsgBox PedigreeString.Value & vbTab & PedigreeString.Formula & vbTab & PedigreeString.Address
If Len(PGv) <> 5 Then End "Pedigree String must contain exactly 5 digits!"
Dim PM(5, 5)
PM(1, 1) = 0: PM(1, 2) = 0.0006: PM(1, 3) = 0.002: PM(1, 4) = 0.008: PM(1, 5) = 0.04 ' scores for Reliability
PM(2, 1) = 0: PM(2, 2) = 0.0001: PM(2, 3) = 0.0006: PM(2, 4) = 0.002: PM(2, 5) = 0.008 ' scores for Completeness
PM(3, 1) = 0: PM(3, 2) = 0.0002: PM(3, 3) = 0.002: PM(3, 4) = 0.008: PM(3, 5) = 0.04 ' scores for Temporal correlation
PM(4, 1) = 0: PM(4, 2) = 2.5e-05: PM(4, 3) = 0.0001: PM(4, 4) = 0.0006: PM(4, 5) = 0.002 ' scores for Geographical correlation
PM(5, 1) = 0: PM(5, 2) = 0.0006: PM(5, 3) = 0.008: PM(5, 4) = 0.04: PM(5, 5) = 0.12 ' scores for Further technological correlation
For i = 1 To 5
  scv = Val(Mid$(PGv, i, 1))
  VarianceWithPedigree = VarianceWithPedigree + PM(i, scv)
Next i
' round to 5 significant digits of pedigree addition
Padd = VarianceWithPedigree - VarianceWithout.Value
If Padd > 0 Then
  pal = Application.WorksheetFunction.Log(Abs(Padd))
  VarianceWithPedigree = Application.WorksheetFunction.Round(VarianceWithPedigree, 5 - Int(pal) - 1) ' rounding to 5 digits
End If
End Function
```

Public Function digit(SourceValue As Variant, RoundingDigits As Double) As Variant

```
' rounds a number (cell content) to a specified number of significant digits
' e.g. 12'345'678 is rounded to 12'340'000; 0.00123456 is rounded to 0.001234 (@ 4 significant digits)
' (No, this is not the same as Excel's ROUND(num, 4) function, which would yield 12'345'678 and 0.0012 for these two numbers)
```

```

If Application.WorksheetFunction.IsText(SourceValue) Then
    digit = SourceValue
Elseif Application.WorksheetFunction.IsError(SourceValue) Then
    digit = SourceValue
Else
    If SourceValue = 0 Then digit = 0: GoTo skipit
    digit = Application.WorksheetFunction.Round(SourceValue, RoundingDigits) -
    Int(Application.WorksheetFunction.Log(Abs(SourceValue))) - 1
End If
skipit:
End Function

```

Public Function RemoveXMLcharsFromString(SourceString As String) As String

```

' removes unsuitable characters from comments that shall go into XML tags
MsgBox SourceString
R$ = SourceString
R$ = Application.WorksheetFunction.Substitute(R$, "&", "&amp;") ' & any ampersands must be replaced first
R$ = Application.WorksheetFunction.Substitute(R$, ">", "&gt;") ' > greater than
R$ = Application.WorksheetFunction.Substitute(R$, "<", "&lt;") ' < less than
' unrequired replacements in ES2
R$ = Application.WorksheetFunction.Substitute(R$, Chr$(34), "&quot;") ' &quot; quotation mark
R$ = Application.WorksheetFunction.Substitute(R$, "&auml;", "&auml;") ' &auml;
R$ = Application.WorksheetFunction.Substitute(R$, "&ouml;", "&ouml;") ' &ouml;
R$ = Application.WorksheetFunction.Substitute(R$, "&uuml;", "&uuml;") ' &uuml;
R$ = Application.WorksheetFunction.Substitute(R$, "&Auml;", "&Auml;") ' &Auml;
R$ = Application.WorksheetFunction.Substitute(R$, "&Ouml;", "&Ouml;") ' &Ouml;
R$ = Application.WorksheetFunction.Substitute(R$, "&Uuml;", "&Uuml;") ' &Uuml;
RemoveXMLcharsFromString = R$
End Function

```

Public Function RemoveSpecialCharsFromES1String(SourceString As String) As String

```

' removes unsuitable characters from text that goes into Ecospol1 elements
R$ = SourceString
R$ = Application.WorksheetFunction.Substitute(R$, "&", "&amp;") ' any ampersands must be replaced first
R$ = Application.WorksheetFunction.Substitute(R$, ">", "&gt;") ' > greater than
R$ = Application.WorksheetFunction.Substitute(R$, "<", "&lt;") ' < less than
R$ = Application.WorksheetFunction.Substitute(R$, Chr$(34), "&#34;") ' &#34; quotation mark
R$ = Application.WorksheetFunction.Substitute(R$, Chr$(13) & Chr$(10), "&#xA;") ' &#xA; carriage return & line feed
R$ = Application.WorksheetFunction.Substitute(R$, Chr$(13), "&#xA;") ' &#xA; carriage return
R$ = Application.WorksheetFunction.Substitute(R$, Chr$(10), "&#xA;") ' &#xA; line feed
R$ = Application.WorksheetFunction.Substitute(R$, "&#252;") ' &#252; ü
R$ = Application.WorksheetFunction.Substitute(R$, "&#228;") ' &#228; ä
' presumed codes (Not encountered in ES1 XML)
R$ = Application.WorksheetFunction.Substitute(R$, "&#246;") ' &#246; ö
R$ = Application.WorksheetFunction.Substitute(R$, "&#214;") ' &#214; Ö
R$ = Application.WorksheetFunction.Substitute(R$, "&#220;") ' &#220; Ú
R$ = Application.WorksheetFunction.Substitute(R$, "&#196;") ' &#196; Ä
R$ = Application.WorksheetFunction.Substitute(R$, "&#248;") ' &#248; ø
R$ = Application.WorksheetFunction.Substitute(R$, "&#224;") ' &#224; à
R$ = Application.WorksheetFunction.Substitute(R$, "&#225;") ' &#225; á
R$ = Application.WorksheetFunction.Substitute(R$, "&#176;") ' &#176; °
R$ = Application.WorksheetFunction.Substitute(R$, "&#233;") ' &#233; é
RemoveSpecialCharsFromES1String = R$
End Function

```

Public Function SynonymTag(SynonymString As String) As String

```

' creates fully specified series of XML tags for synonyms, based on a string of synonyms with // delimiter
' a string like 'pasta//noodles//spaghetti' will be converted to
' <synonym xml:lang="en">pasta</synonym><synonym xml:lang="en">noodles</synonym><synonym
xml:lang="en">spaghetti</synonym>
If SynonymString = "0" Or SynonymString = "" Then R$ = "": GoTo skipit
ot$ = "<synonym xml:lang=" & Chr$(34) & "en" & Chr$(34) & ">" ' opening tag
ct$ = "</synonym>"
R$ = "" ' building result string
sc = 1 ' position of searching delimiter in source string
ls = Len(SynonymString) ' length of source string
On Error GoTo outa ' no (further) delimiters found
finddelimiter:
nd = Application.WorksheetFunction.Search("//", SynonymString, sc)
' pick portion up to next delimiter
R$ = R$ & ot$ & RemoveXMLcharsFromString(Mid$(SynonymString, sc, nd - sc)) & ct$
sc = nd + 2
GoTo finddelimiter ' repeat search
outa:

```

```

R$ = R$ & ot$ & RemoveXMLcharsFromString(Right$(SynonymString, ls - sc + 1)) & ct$
skipit:
SynonymTag = R$
End Function

```

Public Function FileCreaTime() As String

```

' gives the creation date of this workbook file in time ES2 format (yyyy-mm-ddThh:mm:ss)
Dim fdat As Date
fdate = ActiveWorkbook.BuiltinDocumentProperties("Creation Date")
y$ = Year(fdate)
m$ = Month(fdate)
d$ = Day(fdate)
h$ = Hour(fdate)
mi$ = Minute(fdate)
s$ = Second(fdate)
' fill up with zeros where necessary
m$ = String(2 - Len(m$), "0") & m$
d$ = String(2 - Len(d$), "0") & d$
h$ = String(2 - Len(h$), "0") & h$
mi$ = String(2 - Len(mi$), "0") & mi$
s$ = String(2 - Len(s$), "0") & s$
'MsgBox y$ & vbCr & m$ & vbCr & d$ & vbCr & h$ & vbCr & mi$ & vbCr & s$
' create ES2 timestamp value
FileCreaTime = y$ & "-" & m$ & "-" & d$ & "T" & h$ & ":" & mi$ & ":" & s$
End Function

```

Private Sub Workbook_Open()

```

Application.OnKey "^%u", "FillRangeWithNewUUID" ' assign macro FillRangeWithNewUUID to keyboard sequence ctrl + option
+ u
Application.Calculation = xlCalculationManual
End Sub

```

Private Sub Workbook_BeforeClose(Cancel As Boolean)

```

Application.OnKey "^%u", "" ' unassign ctrl + option + u
End Sub

```

13 Abbreviations

DS Dataset, in this work commonly a unit process inventory for a treatment activity

EC, or EA Ecoinvent Centre, since 2013 Ecoinvent Association

EE EcoEditor, the official software to manually author ecoinvent inventories since 2011. Uses the EcoSpold2 format.

ei3 (or eiv3) ecoinvent version 3 or later (since 2011)

EIExch / ElemExch ElementaryExchange, i.e. biosphere exchanges in Ecospold2 (terminal exchanges)

ES1 EcoSpold version 1, the predecessor of → ES2, used in ecoinvent v1-2.2 (2003-2010)

ES2 EcoSpold version 2, the standardised syntax for the → EE inventory data structure. Used in ecoinvent 3+ (since 2011)

ImExch IntermediateExchange, i.e. technosphere exchanges in Ecospold2

PV, APV Production Volume = Annual Production Volume

UUID Universally unique identifier. A 36-character identifier string with a particular format:
 xxxxxxxx-xxxx-4xxx-Yxxx-xxxxxxxxxxxx
 where x is a hexadecimal digit (1-9,a-f), and Y is either (8,9,a,b)

- UUMD** Used User Master Data. A portion of a → ES2 XML file, which specifies new user-defined master data, which is used in the datasets of the file, but has not yet become part of the regular database definitions. All UUMD info is appended at the bottom part of the → XML file.
- XML** Extensible Markup language. A very large family of document formats (includes also HTML). EE uses plain text → XML files to save datasets in Ecospold2-syntax (alternatively also .spold).

14 Appendix A

Tab. 14.1 251 countries and nations with data on wastewater fate. * denotes countries where national average treatment rates were estimated. All other entries have available JMP data.

* Afghanistan	AF	* Aland Is.	AX	Albania	AL
Algeria	DZ	American Samoa	AS	Andorra	AD
* Angola	AO	* Anguilla	AI	* Antarctica	AQ
* Antigua & Barbuda	AG	* Argentina	AR	Armenia	AM
Aruba	AW	Australia	AU	Austria	AT
Azerbaijan	AZ	* Bahamas	BS	Bahrain	BH
* Bangladesh	BD	Barbados	BB	Belarus	BY
Belgium	BE	* Belize	BZ	* Benin	BJ
Bermuda	BM	* Bhutan	BT	Bolivia	BO
* Bonaire, Sint Eustatius & Saba	BQ	Bosnia Herzegovina	BA	* Botswana	BW
* Bouvet Is.	BV	Brazil	BR	* British Indian Ocean Territory	IO
* Brunei	BN	Bulgaria	BG	* Burkina Faso	BF
* Burundi	BI	* Cabo Verde	CV	* Cambodia	KH
* Cameroon	CM	Canada	CA	* Cayman Is.	KY
* Cent. Afr. Rep.	CF	* Chad	TD	Chile	CL
China	CN	* Christmas Is.	CX	* Cocos Is.	CC
Colombia	CO	* Comoros	KM	* Congo (Brazzaville)	CG
* Congo (Kinshasa)	CD	* Cook Is.	CK	Costa Rica	CR
* Cote d'Ivoire	CI	Croatia	HR	Cuba	CU
* Curacao	CW	Cyprus	CY	Czech Rep.	CZ
Denmark	DK	Djibouti	DJ	* Dominica	DM
Dominican Rep.	DO	Ecuador	EC	Egypt	EG
* El Salvador	SV	Emirates	AE	* Equatorial Guinea	GQ
* Eritrea	ER	Estonia	EE	Eswatini	SZ
* Ethiopia	ET	* Falkland Is.	FK	* Faroe Is.	FO
* Fiji	FJ	Finland	FI	France	FR
* French Guiana	GF	* French Polynesia	PF	* French Southern Territories	TF
* Gabon	GA	* Gambia	GM	Georgia	GE
Germany	DE	* Ghana	GH	* Gibraltar	GI
Greece	GR	Greenland	GL	* Grenada	GD
* Guadeloupe	GP	* Guam	GU	* Guatemala	GT
* Guernsey	GG	* Guinea	GN	* Guinea-Bissau	GW
* Guyana	GY	* Haiti	HT	* Heard & McDonald Is.	HM
Honduras	HN	Hong Kong	HK	Hungary	HU
Iceland	IS	India	IN	* Indonesia	ID
Iran	IR	Iraq	IQ	Ireland	IE
* Isle of Man	IM	Israel	IL	Italy	IT
Jamaica	JM	Japan	JP	* Jersey	JE
Jordan	JO	Kazakhstan	KZ	* Kenya	KE
* Kiribati	KI	* Kosovo	XK	Kuwait	KW
Kyrgyzstan	KG	Laos	LA	Latvia	LV
Lebanon	LB	* Lesotho	LS	* Liberia	LR
Libya	LY	Liechtenstein	LI	Lithuania	LT
Luxembourg	LU	* Macao	MO	* Madagascar	MG
* Malawi	MW	Malaysia	MY	* Maldives	MV

Mali	ML	Malta	MT	* Marshall Is.	MH
* Martinique	MQ	* Mauritania	MR	Mauritius	MU
* Mayotte	YT	Mexico	MX	* Micronesia FSM	FM
Moldova	MD	Monaco	MC	Mongolia	MN
Montenegro	ME	* Montserrat	MS	Morocco	MA
* Mozambique	MZ	* Myanmar	MM	* Namibia	NA
* Nauru	NR	* Nepal	NP	Netherlands	NL
* New Caledonia	NC	New Zealand	NZ	* Nicaragua	NI
Niger	NE	Nigeria	NG	* Niue	NU
* Norfolk Is.	NF	* North Korea	KP	North Macedonia	MK
* Northern Mariana Is.	MP	Norway	NO	Oman	OM
* Pakistan	PK	* Palau	PW	Palestine	PS
* Panama	PA	Papua New Guinea	PG	Paraguay	PY
Peru	PE	Philippines	PH	* Pitcairn Is.	PN
Poland	PL	Portugal	PT	Puerto Rico	PR
Qatar	QA	* Reunion	RE	Romania	RO
Russia	RU	* Rwanda	RW	Samoa	WS
San Marino	SM	* Sao Tome & Principe	ST	Saudi Arabia	SA
Senegal	SN	Serbia	RS	* Seychelles	SC
Sierra Leone	SL	Singapore	SG	* Sint Maarten (NL)	SX
Slovakia	SK	Slovenia	SI	* Solomon Is.	SB
* Somalia	SO	* South Africa	ZA	* South Georgia & South Sandwich Is.	GS
South Korea	KR	* South Sudan	SS	Spain	ES
* Sri Lanka	LK	* St Barthelemy	BL	* St Helena, Ascension & Tristan da Cunha	SH
* St Kitts & Nevis	KN	* St Lucia	LC	* St Martin (Fr)	MF
* St Pierre & Miquelon	PM	* St Vincent & Grenadines	VC	* Sudan	SD
* Suriname	SR	* Svalbard & Jan Mayen	SJ	Sweden	SE
Switzerland	CH	* Syria	SY	* Taiwan	TW
* Tajikistan	TJ	Tanzania	TZ	* Thailand	TH
* Timor-Leste	TL	* Togo	TG	* Tokelau	TK
* Tonga	TO	* Trinidad & Tobago	TT	Tunisia	TN
Turkey	TR	* Turkmenistan	TM	* Turks & Caicos	TC
Tuvalu	TV	Uganda	UG	Ukraine	UA
United Kingdom	GB	United States	US	* Uruguay	UY
* US Minor Outlying Is.	UM	* Uzbekistan	UZ	* Vanuatu	VU
* Vatican	VA	Venezuela	VE	* Viet Nam	VN
* Virgin Is. (Brit)	VG	* Virgin Is. (US)	VI	* Wallis & Futuna	WF
* Western Sahara	EH	Yemen	YE	* Zambia	ZM
Zimbabwe	ZW				

Tab. 14.2 Supra-national regions, where wastewater fate data was compiled from the countries above:

* Global	GLO
Ecoinvent global regions:	
* Europe	RER
* Western Europe	WEU
* Northern America	RNA
* Middle East	RME
* Asia	RAS
* South Asia	SAS
* Latin America and the Caribbean	RLA
* Africa	RAF
UN global regions:	
* Americas	UN-AMERICAS
* Asia, UN Region	UN-ASIA
* Australia and New Zealand	UN-AUSTRALIANZ
* Caribbean	UN-CARIBBEAN
* Central America	UN-CAMERICA
* Eastern Asia	UN-EASIA
* Eastern Europe	UN-EEUROPE
* Europe, UN Region	UN-EUROPE
* Northern Africa	UN-NAFRICA
* Oceania	UN-OCEANIA
* South America	UN-SAMERICA
* Southern Africa	UN-SAFRICA
* South-Eastern Asia	UN-SEASIA

15 References

- Baloyi et al. 2012 Baloyi O, Sehaswana D, Maringa M, Sibande J, Oelofse S, Schubert M, Swanepoel H, Godfrey L, Wakaba L, Muswema A, Graasboll S, Norby E (2012). National Waste Information Baseline Report. Draft 6 of 5. Sept 2012, Department of Environmental Affairs DEA, Pretoria, South Africa. <http://sawic.environment.gov.za/documents/1567.docx> (20 Feb 2017)
- Doka 2003-I Doka G (2003) Life Cycle Inventories of Waste Treatment Services, part I: General Introduction Waste Material Compositions Municipal Waste Collection. ecoinvent report No. 13, part I. Swiss Centre for Life Cycle Inventories, Dübendorf, 2003. http://www.doka.ch/13_I_WasteTreatmentGeneral.pdf (15 Dec 2003)
- Doka 2003-II Doka G (2003) Life Cycle Inventories of Waste Treatment Services, part II: waste incineration. ecoinvent report No. 13, part III. Swiss Centre for Life Cycle Inventories, Dübendorf, 2003. http://www.doka.ch/13_II_WasteIncineration.pdf
- Doka 2003-III Doka G (2003) Life Cycle Inventories of Waste Treatment Services, part III: Landfills - Underground Deposits - Landfarming. ecoinvent report No. 13, part III. Swiss Centre for Life Cycle Inventories, Dübendorf, 2003. http://www.doka.ch/13_III_Landfills.pdf
- Doka 2013 Doka G. (2013) Updates to Life Cycle Inventories of Waste Treatment Services - part II: waste incineration. Doka Life Cycle Assessments, Zurich, 2013. Available at <http://www.doka.ch/ecoinventMSWIupdateI.CI2013.pdf>
- Doka 2015 Doka G. (2015) Life cycle inventories of municipal waste incineration with residual landfill & FLUWA filter ash treatment. Doka Life Cycle Assessments, Zurich, Switzerland. Commissioned by BAFU Bundesamt für Umwelt, Berne. Available at <http://www.doka.ch/ecoinventMSWIupdateI.CI2015.pdf>
- Doka 2017a Doka G. (2017) A model for waste-specific and climate-specific life cycle inventories of open dumps and unsanitary landfilling of waste. For Sustainable Recycling Industries, mandated by ecoinvent Association, Zurich. By Doka Life Cycle Assessments, Zurich, Switzerland. Available at <http://www.doka.ch/publications.htm>
- Doka 2017b Doka G. (2017) A model for waste-specific life cycle inventories of open burning of waste. For Sustainable Recycling Industries, mandated by ecoinvent Association, Zurich. By Doka Life Cycle Assessments, Zurich, Switzerland. Available at <http://www.doka.ch/publications.htm>
- Doka 2018 Doka G. (2018) A model for waste-specific and climate-specific life cycle inventories of tailings impoundments. Report Version 2. Doka Life Cycle Assessments, Zurich, Switzerland. Available at <http://www.doka.ch/publications.htm>

- Doka 2020 Doka G. (2020) Two models for waste-specific and climate-specific life cycle inventories of excavation material landfills and construction & demolition waste landfills. Doka Life Cycle Assessments, Zurich, Switzerland. Commissioned by Swiss Federal Office for the Environment (FOEN). Available at <http://www.doka.ch/publications.htm>
- Doka 2021 Doka G. (2021) A model for composition-specific life cycle inventories of regionalised wastewater fates. Doka Life Cycle Assessments, Zurich, Switzerland. Commissioned by Swiss Federal Office for the Environment (FOEN). Available at <http://www.doka.ch/publications.htm>
- DWAF 1998 DWAF (1998) Waste Generation in South Africa: Baseline Studies. Waste Management Series. Department of Water Affairs and Forestry, Pretoria. Cited in (Fiehn & Ball 2005)
- Ecoinvent 2002 Ecoinvent (2002) EcoSpold01 Schema Documentation - EcoSpold01Dataset_Simple.html. Swiss Centre for Life Cycle Inventories. Version of 29. Oktober 2002 http://www.ecoinvent.org/download/EcoSpoldSchema_v1.0.zip (29 Oct 2008) and identical at https://www.ecoinvent.org/files/ecospold1_data_exchange_format.zip (1 March 2016, 27 Apr 2020)
- Ecoinvent Association 2017 Authors not indicated (2017) EcoSpold02 Schema Documentation: v1.0.2. Document EcoSpold02.html dated 15 September 2011. <http://www.ecoinvent.org/data-provider/data-provider-toolkit/ecospold2/ecospold2.html> http://www.ecoinvent.org/files/documentation_on_ecospold2_format.zip (8 Apr 2017)
- ESU 1994 Frischknecht R, Knoepfel I, Hofstetter P, Dones R, Zollinger E, Attinger N, Baumann T, Doka G, Gränicher HP, Grassler C, Müller H, Vollmer M, Walder E (ESU 1994) Ökoinventare für Energiesysteme; Grundlagen für den ökologischen Vergleich von Energiesystemen und den Einbezug von Energiesystemen in Ökobilanzen für die Schweiz. Gruppe Energie Stoffe Umwelt (ESU), ETH Zurich, Schweiz, ESU-Reihe Nr. 1/94 (in German), März 1994 <http://www.bfe.admin.ch/dokumentation/energieforschung/index.html?lang=de&publication=3559>
- Fiehn & Ball 2005 Fiehn H, Ball J (2005). Integrated Waste Management – Background Research Paper produced for the South Africa Environment Outlook report. National State of the Environment Project. Department of Environmental Affairs and Tourism, Pretoria http://soer.environment.gov.za/dm_documents/Waste_-_Background_Paper_QX0NS.pdf (20 Feb 2017)
- Hoorweg et al. 2012 Hoorweg D, Bhada-Tata P, Joshi- Ghani A, Allaoua Z, Peterson C (2012) What A Waste – A Global Review of Solid Waste Management. Urban Development Series Knowledge Papers No. 15, World Bank, Urban Development & Local Government Unit, Washington, USA, March 2012, http://siteresources.worldbank.org/INTURBANDEVELOPMENT/Resources/336387-1334852610766/What_a_Waste2012_Final.pdf (31 Mar 2015)
- KBOB et al. 2018 KBOB (2018) KBOB-Ökobilanzdatenbestand 2016 und UVEK-Ökobilanzdatenbestand 2018. Koordinationskonferenz der Bau- und Liegenschaftsorgane der öffentlichen Bauherren KBOB, und eco-bau Nachhaltigkeit im öffentlichen Bau, und IPB Interessengemeinschaft Privater Bauherren, 7 Nov 2018. http://www.dflca.ch/inventories/Kommunikation_Oekobilanzdatenbestand_KBOB-2016_UVEK-2018.pdf (25 Nov 2018) see databases at https://db.ecoinvent.org/download/KBOB%20DQRv2_2016.zip?area=3e2c0806caa3c (25 Nov 2018) and https://db.ecoinvent.org/download/UVEK%20LCI%20Data_2018_20191003.zip?area=3e2c0806caa3c (2 Mai 2020)
- Micales & Skog 1997 Micales JA, Skog KE (1997): The Decomposition of Forest Products in Landfills. International Biodeterioration and Biodegradation, Elsevier, Vol. 39, No. 2-3, p. 145-158. <http://www.fpl.fs.fed.us/documnts/pdf1997/mical97a.pdf> (31 Jul 2009)
- MOEF 2012 Indina Ministry of Environment & Forests (MOEF 2012) India – Second National Communication to the United Nations Framework Convention on Climate Change. Ministry of Environment & Forests (MOEF), Government of India, 2012, New Delhi. <http://unfccc.int/resource/docs/natc/indnc2.pdf> (25 Dec 2016)
- Mu et al. 2011 Mu Q, Zhao M, Running SW (2011) Improvements to a MODIS global terrestrial evapotranspiration algorithm. Remote Sensing of Environment, Volume 115, Issue 8, 15 August 2011, Pages 1781–1800. ftp://secure.nts.gov.umt.edu/pub/MODIS/Mirror/MOD16/Mu_etal_RSE_2011.pdf (23 Jun 2015) , see also <http://www.nts.gov.umt.edu/project/mod16>