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SARMa
ustainable approach to aggregates

Scheme for Life Cycle Inventory data collection

Step 1: Aggregate quarrying

Step 2: Aggregate recycling

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Regione Emilia-Romagna

POLITECNICO DI TORINO 1859

Disclaimer:

The present guidelines are to be used in the SARMa Project by the participants involved in WP 3 activity 3.3 in order to adopt a common LCA methodology and boost use of LCA tools in sustainable production and recycling of aggregates in SEE countries. The information reported is accurate according to the best knowledge of the authors. This publication reflects the views only of the authors, and the South East Europe Programme Managing Authority cannot be held responsible for any use which may be made of the information contained therein.

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Address:	Dimičeva ulica 14, SI-1000 Ljubljana
Project manager:	Slavko V. Šolar
E-mail:	Slavko-Vekoslav.Solar@geo-zs.si
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Author:	Gian Andrea Blengini, Elena Garbarino
E-mail:	blengini@polito.it; elena.garbarino@provincia.torino.it
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Extended Abstract

Overview:

To achieve more sustainable production and consumption patterns, we must consider the environmental implications of the whole supply-chain of products, both goods and services, their use, and waste management, i.e. their entire life cycle from “cradle to grave”.

Life Cycle Thinking (LCT) and Life Cycle Assessment (LCA) are the scientific approaches behind modern environmental policies and business decision support related to Sustainable Consumption and Production (SCP).

The ISO 14040-44 standards and the International Reference Life Cycle Data System (ILCD) of the JRC-European Commission provide a common basis for consistent, robust and quality-assured life cycle data and studies. Such data and studies support coherent SCP instruments, such as Ecolabelling, Ecodesign, Carbon footprinting, and Green Public Procurement.

About Life Cycle Assessment (LCA)

Life Cycle Assessment (LCA) is a structured, comprehensive and internationally standardised method. It quantifies all relevant emissions and resources consumed and the related environmental and health impacts and resource depletion issues that are associated with any goods or services (“products”).

Life Cycle Assessment takes into account a product’s full life cycle: from the extraction of resources, through production, use, and recycling, up to the disposal of remaining waste.

Critically, LCA studies thereby help to avoid resolving one environmental problem while creating others: This unwanted “shifting of burdens" is where you reduce the environmental impact at one point in the life cycle, only to increase it at another point. Therefore, LCA helps to avoid, for example, causing waste-related issues while improving production technologies, increasing land use or acid rain while reducing greenhouse gases, or increasing emissions in one country while reducing them in another.

Life Cycle Assessment is therefore a vital and powerful decision support tool, complementing other methods, which are equally necessary to help effectively and efficiently make consumption and production more sustainable.

Purpose of these guidelines:

This document provides technical guidance for accurate LCA studies in the aggregate quarrying and recycling activities with the overall objective of making the Life Cycle Thinking operational and meaningful to these industries. The present Scheme for Life Cycle Inventory data collection is part of the Life Cycle Assessment (LCA) Guidelines to be used in the SARMa Project by the participants involved in WP 3 activity 3.3 in order to adopt a common LCA methodology and boost use of LCA tools in sustainable production and recycling of aggregates in SEE countries. Both the guidelines and the scheme are based on and conform to the ISO 14040-44 standards on LCA.

Such a common methodological framework can be adapted to various aggregate products (sand, round/crushed gravel, recycled aggregates, manufactured aggregate, etc…), to various quarry typologies (wet/dry) and excavation techniques (blast/mechanical) or different types of recycling facilities (stationary, mobile, etc...).

The main target audience are technical experts in the public and private sectors dealing with environmental decision support in the fields of resources extraction and waste management.

Layout:

This document is made of two chapters, which report the Schemes for Life Cycle Inventory data collection, i.e. tables to be filled in with relevant LCA data, together with recommendations on how to collect data from quarrying/recycling sites.

Such Schemes for Life Cycle Inventory data collection are provided with reference to step 1 (aggregate quarrying) and step 2 (aggregate recycling) of the proposed LCA methodology in the SARMa project, while there is no need of a dedicated chapter for step 3 (integrated quarrying and recycling), as data collection and elaboration can be carried out using the information provided in the chapters 5-6-7 of the Guidelines.

About the authors:

The present guidelines are based on the experience gathered by the LCA research group of the Politecnico di Torino, with emphasis on LCAs of natural aggregates, recycled aggregates, cement, concrete and other construction materials. The LCA research group of Politecnico di Torino is available to assist SARMa participants supplying them any further information needed.

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1. Scheme for Life Cycle Inventory data collection: Step 1

LCI data relevant to **aggregate quarrying** (step 1 of the *Life Cycle Assessment (LCA) Guidelines to be used in the SARMa Project*) should be collected in the field through questionnaires and interviews with operators. Missing data must be estimated and the methodologies for estimation should be reported.

The following tables and comments should be used during data collection. If it is not possible to find the requested data, the proposed tables can be modified (possibly improved) according to the country (or area), operating conditions or participant's experience. Proposed improvements must be reported and justified.

Before to start filling in the tables, LCA practitioners are expected to describe the natural resource to be mined, the natural (or built) environment which hosts the extractive activity, the quarry itself, the quarried products, the quarrying equipments and activities. Templates for Baseline Study Reports (BSR) for both aggregate quarrying and aggregate recycling (BSR-R), available in the SARMa website under Workpackage 3, might be helpful to carry out the description of production sites (quarry/recycling plant) and products (aggregates).

Collected data and information should include a technical description of products and co-products, their selling price and all the information available relevant to their delivery (including average and maximum distance).

The following tables should be filled in according to the example presented in chapter 3 of the *Life Cycle Assessment (LCA) Guidelines to be used in the SARMa Project* .

In case of missing data, the practitioners should (at the very least) give a careful description of the processes, so that hypothesis and assumptions can be undertaken to estimate missing data. A flow sheet describing the main processes, as well as a consistent balance of input materials, final products and rejects must be provided.

Data uncertainty should be estimated according to the approach described in paragraph 2.6 of the *Life Cycle Assessment (LCA) Guidelines to be used in the SARMa Project*.

1.1 Description of the quarry products

In order to standardise the LCI, three types of aggregates should be considered. According to the end-uses, these can be:

- Type A: high quality aggregate for concrete, masonry works and road construction (road sub grade);
- Type B: medium quality aggregate for road, airport and harbour construction;
- Type C: low quality aggregate for environmental filling and rehabilitation of depleted quarries and landfill sites.

If this classification appears to be inconsistent with the case study, changes can be proposed and duly reported and justified.

The final products (aggregates) should be described using the following table.

Table 1.1 – Description of quarry products and delivery distances

Production	Q.ty (t/y)	Unit price (Euro/t)	Average delivery distance (km)	Max delivery distance (km)
Type A				
Type B				
Type C				

Technical quality of aggregates should be provided using, as an example, the following table.

Table 1.2 – Technical properties of aggregates

Aggregates type			A	B	C
Los Angeles Index	LA	(%)			
Shape Index	SI	(%)			
…					

1.2 Quarry development

It is necessary to estimate the total quarry lifetime and the total production over this entire lifetime. This information is necessary to allocate quarry development impacts to the final products.

- quarry lifetime: _____ **years**

- expected total production: _____ **t**

LCI data relevant to quarry development should be provided in Table 1.3.

Table 1.3 – Inventory data for Quarry development (data refer to the whole quarry)

Land use [(2)]	Q.ty		Source [(1)]:
Occupation, industrial area, built up [(3)]		m^2 x y	
Occupation, industrial area, vegetation		m^2 x y	
Occupation, traffic area, road network		m^2 x y	
Transformation, from forest[(3)] (or from other land category)		m^2	
Transformation, to industrial area, built up		m^2	
Transformation, to industrial area, vegetation		m^2	
Transformation, to traffic area, road network		m^2	
Materials/fuels			
Diesel used in building machinery		GJ	
Electricity		GJ	
Steel		t	
Concrete		m^3	
Polyethylene			
(…)			

(1) Source might be one of the following: Communication from operator; estimated from aerial photo; measured on site; estimated on site; estimated from literature, etc…
(2) Land use must be expressed as two components:
- Occupation expressed in Area x Duration
- Transformation "from" (i.e. the state of land before starting quarrying) and transformation "to" (i.e. the state of land after quarrying and rehabilitation)
(3) Land categories reported in the tables of this manual are only examples. They need to be selected from Annex 1. In case it is not clear which type of land use must be selected, please briefly describe the land quality.

Note that Land occupation and Land transformation categories are those available in the Ecoindicator 99 and Impact 2002+ methodologies.

A description of land use (occupation / transformation) categories can be found in the Ecoinvent Manual available at http://www.pre.nl/ecoinvent.

Land categories used in Impact 2002+ and Eco-Indicator 99 are reported in Annex 1.

Note that land use for the cultivation panel (quarry stage) must not be accounted for here, as it will be included in 1.6 Aggregate production. In Table 1.3 only data relevant to quarry development must to be included.

1.3 Quarry closure

All the activities to be run at the end of the mining project have to be forecasted and included (note that recultivation of the quarry stage should not be included here, but in Table 1.6 Aggregate production).

At the very least a description of post-closure activities must be provided, in order to facilitate a possible estimation of LCI data.

Table 1.4 – Inventory data for Quarry closure (data refer to the whole quarry)

Land use	Q.ty		Source:
Transformation, from …[(3)]		m^2	
Transformation, to water bodies, artificial		m^2	
Transformation, to forest		m^2	
Transformation, to traffic area, road network		m^2	
Materials/fuels			
Diesel		MJ	
(…)			
(…)			
(…)			
(…)			

1.4 Quarry infrastructure

Quarry infrastructure should include pre-manufacturing, construction and end-of-life of: excavation equipment, hauling machinery (dumpers, belt conveyors…), processing equipment (crushers, washers, classifiers…), water treatment facilities, dust control, storage, etc.

Infrastructure/equipment with the same life service time will be grouped together, as impacts are allocated to the final products according to the total production delivered during their life time.

At the very list an accurate description of machineries must be provided, in order to allow estimation of LCI data and provide sufficient information to estimate main materials and their quantities (i.e. total mass of crushers, or hoppers…). Brand and model of equipment might allow estimations through manufacturers' manuals and/or websites.

For further support, please consult chapter 3 of the *Life Cycle Assessment (LCA) Guidelines to be used in the SARMa Project*.

Table 1.5 – Inventory data for Quarry infrastructures (data refer to the whole set of infrastructures)

Materials/fuels	Description [(4)]	Q.ty	Unit	Expected life time (years)	Source:
Conveyor belt			m		
Building, office			m^2		
Building, storey/…			m^3		
Industrial machinery (1)					
Industrial machinery (2)					
Industrial machinery (3)					
Industrial machinery (4)					
Industrial machinery (5)					
Industrial machinery (6)					
Industrial machinery (7)					

(4) when no quantitative data are available, please indicate type, brand and model of the machinery. An estimate of main materials and quantities will be made by the LCA task force, according to manuals or literature data.

Note that maintenance of equipment must not be included here, as it is already included in Table 1.6 Aggregate Production.

End-of-life should also be included in the model, according to case specific assumptions.

For guidance see paragraph 2.4.1 of the *Life Cycle Assessment (LCA) Guidelines to be used in the SARMa Project*.

1.5 Aggregate production

Aggregate production should encompass all activities run during cultivation of a quarry stage.

Table 1.6 – Inventory data for Aggregate production (quarry stage) – data per 1 ton of aggregates

Resources & Land use	Q.ty		Source:
Gravel, in ground		t	
Water		m^3	
Occupation, mineral extraction site		m^2 x y	
Transformation, from [(5)] (…)		m^2	
Transformation, to mineral extraction site		m^2	
Materials/fuels			
Explosives		kg	
Diesel		MJ	
Electricity		MJ	
Light fuel oil		MJ	
Jaws/hammers		kg	
Lubricating oil		kg	
Steel		kg	
Synthetic rubber		kg	
Tap water		kg	
(…)		kg	
Air/water/soil emissions			
Dust (PM10)		g	
(…)		mg	
Development/closure/Infrastructure and recultivation			
Quarry development	1/(yearly prod.*mine lifetime)	Unit	
Quarry closure	1/(yearly prod.*mine lifetime)	Unit	
Quarry infrastructure	1/(yearly prod.*equip. lifetime)	Unit	
Recultivation	1/excav. ton per m2	m2	

(5) select appropriate type of Land

See par. 2.4.1 of the *Life Cycle Assessment (LCA) Guidelines to be used in the SARMa Project*.

1.6 Recultivation

Recultivation should encompass all activities run during recultivation of a single quarry stage.

Table 1.7 – Inventory data for recultivation (quarry stage) - data for recultivation of 1 m^2

Land use	Q.ty		Source:
Transformation, from mineral extraction site		m2	
Transformation, to water bodies, artificial (5)		m2	
Transformation, to forest (5)		m2	
Transformation, to traffic area, road network (5)		m2	
Materials/fuels			
Diesel		MJ	
Geo-textile			
Polyethylene			
(…)			
(…)			
(…)			
(…)			

At the very least a description of recultivation activities must be provided, in order to facilitate a possible estimation of LCI data.

For further guidance see paragraph 2.4.1 of the *Life Cycle Assessment (LCA) Guidelines to be used in the SARMa Project*.

2. Scheme for Life Cycle Inventory data collection: Step 2

LCI data relevant to **aggregate recycling** (step 2 of the *Life Cycle Assessment (LCA) Guidelines to be used in the SARMa Project*) should be collected in the field through questionnaires and interviews with operators. Missing data must be estimated and the methodologies for estimation should be reported.

The following tables and comments should be used during data collection. If it is not possible to find the requested data, the proposed tables can be modified (possibly improved) according to the country (or area), operating conditions or participant's experience. Proposed improvements must be reported and justified.

Before to start filling in the tables, LCA practitioners are expected to describe the input material to be recycled, the natural (or built) environment which hosts the recycling activity, the recycling plant itself and the final products. Templates for Baseline Study Reports (BSR) for both aggregate quarrying and aggregate recycling (BSR-R), available in the SARMa website under Workpackage 3, might be helpful to carry out the description of production sites (quarry/recycling plant) and products (aggregates).

Collected data and information should include a technical description of products and co-products, their selling price and all the information available relevant to their delivery (including average and maximum distance).

The following tables should be filled in according to the example presented in chapter 4 of the *Life Cycle Assessment (LCA) Guidelines to be used in the SARMa Project*.

In case of missing data, the practitioners should (at the very least) give a careful description of the processes, so that hypothesis and assumptions can be undertaken to estimate missing data. A flow sheet describing the main processes, as well as a consistent balance of input materials, final products and rejects must be provided.

Data uncertainty should be estimated according to the approach described in paragraph 2.6 of the *Life Cycle Assessment (LCA) Guidelines to be used in the SARMa Project*.

2.1 Description of recycled aggregates

In order to standardise the LCI, three types of aggregates should be considered. According to the end-uses, these can be:

- Type A: high quality aggregate for concrete, masonry works and road construction (road sub grade);
- Type B: medium quality aggregate for road, airport and harbour construction;
- Type C: low quality aggregate for environmental filling and rehabilitation of depleted quarries and landfill sites.

If this classification appears to be inconsistent with the case study, changes can be proposed and duly reported and justified.

The final products (aggregates) should be described using the following table.

Table 2.1 – Description of recycled aggregates and delivery distances

Production	Q.ty (t/y)	Unit price (Euro/t)	Average delivery distance (km)	Max delivery distance (km)
Type A				
Type B				
Type C				

Technical quality of aggregates should be provided using, as an example, the following table.

Table 2.2 – Technical properties of recycled aggregates

Aggregates type			A	B	C
Saturated surface dried specific gravity	γ_{ssd}	(kg/m^3)			
Los Angeles Index	LA	(%)			
Shape Index	SI	(%)			
Flakiness index	FI	(%)			
Sand equivalent	SE	(%)			
Fineness modulus	M_f	-			
Impurity level	-	(%)			

The following information should also be collected:

- Eco-compatibility of recycled aggregates (leaching test - provide the certificate)
- Existence of codes of practice to achieve technical excellence
- Existence of CE Marking (provide the certificate)
- Description of use of recycled aggregates
  - Construction: structural or not structural concrete / road and railways construction / environmental filling / other (specify)
  - chemical industry
  - cement industry
  - Manufactory
  - Other
- Transportation of recycled aggregates
  - Transportation cost according to the delivery distance (€ per ton-km)
  - Maximum delivery distance
  - Average delivery distance

2.2 Inventory data for recycling in mobile, semi-mobile and stationary plants

The following information on the input materials and the recycling facility should be made available:

- Types of raw input material:
  - R1: Recycling of by-products, waste and residues from extractive activities
  - R2: Recycling of Construction and Demolition Waste (CDW)
  - R3: Recycling of excavated soils/rock from civil works
  - R4: Recycling of industrial waste (e.g., slags from civil ferrous metal production, bottom ash from Municipal Solid Waste (MSW) incineration, ashes from coal combustion processes etc.)
  - Others
- Quantity of raw input material (specify per each type of raw input material R1-R2-R3-R4)
  - daily amount (t/d)
  - yearly amount (t/y)
- Classification of raw input material*:
  - EWC code (European Waste Catalogue 2000/532/EC)
  - by-products
  - mining waste
  - others (specify)

  * (provide the input material average composition, i.e. % of different EWC)
- Collection of raw input material
  - direct collection: from work site to treatment plant
    - lorry type and payload
    - average distance
  - indirect collection: from work site to collection centre and from collection centre to treatment plant
    - lorry type and payload
    - average distance
  - in situ recycling through mobile plant: mobile plant transportation
    - lorry type and payload
    - average distance
- Technical information on recycling facility
  - occupied average surface
  - acceptance procedure for the raw input material
  - dimensions of the storage of the different raw input material and of the produced recycled aggregates
  - paved areas
  - areas equipped with a wastewater gathering system
  - energy sources (diesel, electricity from grid, diesel generator, …)
  - environmental controls and monitoring
  - management standards (environment/safety/quality)
- Technical information on recycling infrastructure
  - stationary or mobile plant for the production of recycled aggregates
  - hybrid plant for the production of natural and recycled aggregates

- process units (please provide flowcharts with indication of mass flows and equipment description including treatment capacity and installed power)

unit \ description	Machines description
○ Secondary demolition	
○ Feed	
○ Scalping	
○ Pre-screening	
○ Manual sifting	
○ Primary crushing	○ jaw crusher ○ impact crusher ○ others
○ Magnetic separation	
○ Secondary crushing	○ jaw crusher ○ impact crusher ○ others
○ Screening	
○ Sorting	○ dry ○ wet
○ Water treatment	

- Plant processing capacity for each product (t/h)
- Plant processing throughput for each product (t/y)
- Best available technologies: possible application of new technologies

Recycling infrastructure should include pre-manufacturing, construction and end-of-life of: hauling machinery (dumpers, belt conveyors…), processing equipment (crushers, washers, classifiers…), water treatment facilities, dust control, storage, etc.

Infrastructure/equipment with the same life service time can be grouped together, as impacts are allocated to the final products according to the total production delivered during their life time.

At the very list, an accurate description of machineries must be provided, in order to allow estimation of LCI data and provide sufficient information to estimate main materials and their quantities (i.e. total mass of crushers, or hoppers…). Brand and model of equipment might allow estimations through manufacturers' manuals and/or websites.

Table 2.3 – Inventory data for recycling infrastructures (data refer to the whole set of infrastructures)

Materials/fuels	Description (1)	Q.ty	Unit	Expected life time (years)	Source:
Conveyor belt			m		
Building, office			m^2		
Building, storey/…			m^3		
Industrial machinery (1)					
Industrial machinery (2)					
Industrial machinery (3)					

(1) when no quantitative data are available, please indicate type, brand and model of the machinery. An estimate of main materials and quantities will be made by the LCA task force, according to manuals or literature data.

Data contained in Table 2.3 will be used as an input in Table 2.4, where data relevant to the recycling process should be collected. Note that infrastructure-related burdens must be allocated to the final products (aggregates) according to the overall production during the infrastructure's lifetime.

Table 2.4 Inventory data for recycling (data with reference to 1 year of activity)

Raw input materials		
Quantity processed	t	
Land use		
Occupied area	m^2	
Materials/fuels		
Hammers/jaws	kg	
Water	kg	
Lube oil	kg	
Polyurethane screen	kg	
Steel screen	kg	
Synthetic rubber	kg	
Diesel	l	
Electricity	MJ	
...		
Recycling infrastructure		
Infrastructure 1	Q.ty/(yearly prod.*infrastructure lifetime)	
...		
...		
Outputs		
Recycled aggregate type A	t	
Recycled aggregate type B	t	
Recycled aggregate type C	t	
Steel scrap	t	

For guidance see chapter 4 of the *Life Cycle Assessment (LCA) Guidelines to be used in the SARMa Project*.

Annex 1: Land categories according to Eco-Indicator99 and Impact 2002+

arable
arable, non-irrigated
arable, non-irrigated, diverse-intensive
arable, non-irrigated, fallow
arable, non-irrigated, monotone-intensive
arable, organic
construction site
dump site
forest
forest, extensive
forest, intensive
forest, intensive, clear-cutting
forest, intensive, normal
forest, intensive, short-cycle
heterogeneous, agricultural
industrial area
industrial area, built up
industrial area, vegetation
mineral extraction site
pasture and meadow
pasture and meadow, extensive
pasture and meadow, intensive
pasture and meadow, organic
permanent crop
permanent crop, fruit
permanent crop, fruit, extensive
permanent crop, fruit, intensive
permanent crop, vine
permanent crop, vine, extensive
permanent crop, vine, intensive
shrub land, sclerophyllous
traffic area
traffic area, rail embankment
traffic area, rail network
traffic area, road embankment
traffic area, road network
unknown
urban, continuously built
urban, discontinuously built
urban, green areas