



Sandstone Quarrying and Processing: A Life-Cycle Inventory

A Report Prepared for:

The Natural Stone Council

Prepared by:

University of Tennessee
Center for Clean Products

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1 Introduction

The Natural Stone Council (NSC) is a collaboration of businesses and trade associations that have come together to promote the use of Genuine Stone in commercial and residential applications. By pooling resources, their goal is to increase the understanding of, preference for, and consumption of these natural products. Trade associations affiliated with the NSC include Allied Stone Industries, Building Stone Institute, Elberton Granite Association, Indiana Limestone Institute, Marble Institute of America, National Building Granite Quarries Association, and the National Slate Association.

Recognizing that green building was becoming a permanent element of the marketplace, the NSC established a Sustainability Committee made up of key industry members to elevate the issue of sustainability within the industry and provide a body responsible for planning and implementing relevant initiatives. In 2007, the NSC Sustainability Committee engaged in a partnership with the Center for Clean Products (CCP) at the University of Tennessee to assess current industry operations relating to dimensional stone production. Prior to this evaluation, the environmental implications of stone extraction and fabrication processes had received little attention compared to other industries. In particular, life-cycle inventory (LCI) data on natural stone products was limited, not well documented, and out-of-date. This information gap was partially due to the size and varying scale of industry members, the vast diversity of products and materials produced, and the global distribution of stone quarrying activities. As such, this work presents the most comprehensive survey to-date of the natural stone industry's practices.

Provided in the following text are the results of the first phase of a three-year project launched by the NSC to benchmark and improve the environmental profile of the natural stone industry. Specifically, the information that follows is an initial LCI characterizing sandstone extraction and production operations in North America. These data will serve as a baseline from which industry best practices can be identified, comparisons to competing products can be made with regard to environmental considerations, and future research can be prioritized.

2 Sandstone Quarrying and Processing Operations

2.1 Sandstone

Sandstone is a sedimentary rock comprised of lithified sands. Most is primarily quartz sand or a mix of quartz and feldspar sands in conjunction with interstitial cementing materials including calcite, clay, iron oxides, and silica. The lithification process results in a hard, dense material that takes on the color of its components, most commonly tan to yellowish or tinted pink to dark red due to varying levels of iron oxide.

The commercial sandstone category encompasses many variations of texture and color. Common forms of sandstone include arkose which has a high feldspar content, graywacke which contains angular rock fragments, and conglomerate which contains rounded rock fragments. Other common stones included in this category are bluestone, a hard, dense feldspathic sandstone, brownstone, a reddish-brown stone taking its color from its high iron content, and flagstone, a sandstone or sandy slate that is easily split into large, thin slabs.

Sandstone accounts for 15% of the stone produced in the United States, putting it in third place behind limestone and granite. It is quarried in 16 states with Arizona, New York, Ohio, Colorado, and Arkansas leading the industry. Sandstone's primary uses include dressed stone for flagging, ashlar, and partially squared pieces as well as rough blocks for building and construction (Dolley 2007). Two general phases of sandstone production exist: quarrying and processing. Each of these phases is described below.

2.2 Sandstone Quarrying Operations

Extraction (more commonly referred to as quarrying) consists of removing layers or large pieces of stone from an identified and unearthed geologic deposit. Differences in the particular quarrying techniques used often stems from variations in the physical properties of the deposit itself—such as density, fracturing/bedding planes, and depth—financial considerations, and the site owner's preference. Nevertheless, the process is relatively simple: locate or create (minimal) breaks in the stone, remove the stone using heavy machinery, secure the stone on a vehicle for transport, and move the material to storage. A flow diagram of typical quarrying operations is shown in Figure 1.

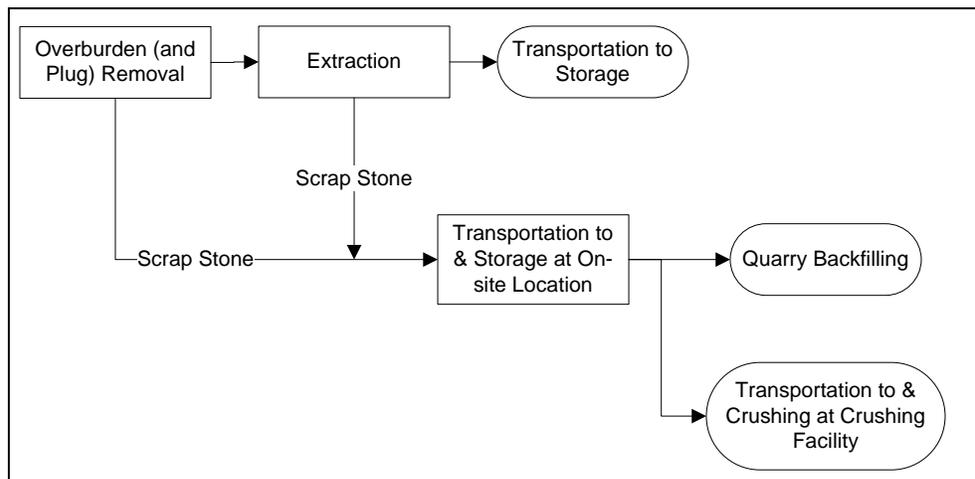


Figure 1. Process flow diagram for quarrying operations.

As shown in Figure 1, the first step in quarrying is to gain access to the sandstone deposit. This is achieved by removing the layer of earth, vegetation, and rock unsuitable for product—collectively referred to as overburden—with heavy equipment and transferring to onsite storage for potential use in later reclamation of the site. Additionally, a “plug” of poor-quality stone may sit atop the material that has commercial value; this plug must also be removed with the overburden. After the face of the deposit is exposed, the stone is removed from the quarry in layers or pieces. If bedding planes are visible, forklifts and/or steel wedges are driven between the strata to pry up the layers. Alternatively, loose pieces are scooped up with front-end loaders, dump trucks, or other equipment. Once the layers or pieces are secured on the heavy machinery, they are transferred to an inspection area for grading, temporary storage, and eventual shipment from the site. Sandstone of insufficient quality or size for current demand is stored on-site for future use, such as for site reclamation activities, or sent to a crushing facility to be used in other applications.

2.3 Sandstone Processing Operations

Processing operations include much more variation than extraction. Nevertheless, the general procedures begin with initial cutting, followed by application of a finish, and conclude with a second cutting or shaping step. Due to the array of stone products, the second and/or third steps may be eliminated, specifically when the product will have a “natural” appearance. Figure 2 depicts the fabrication process.

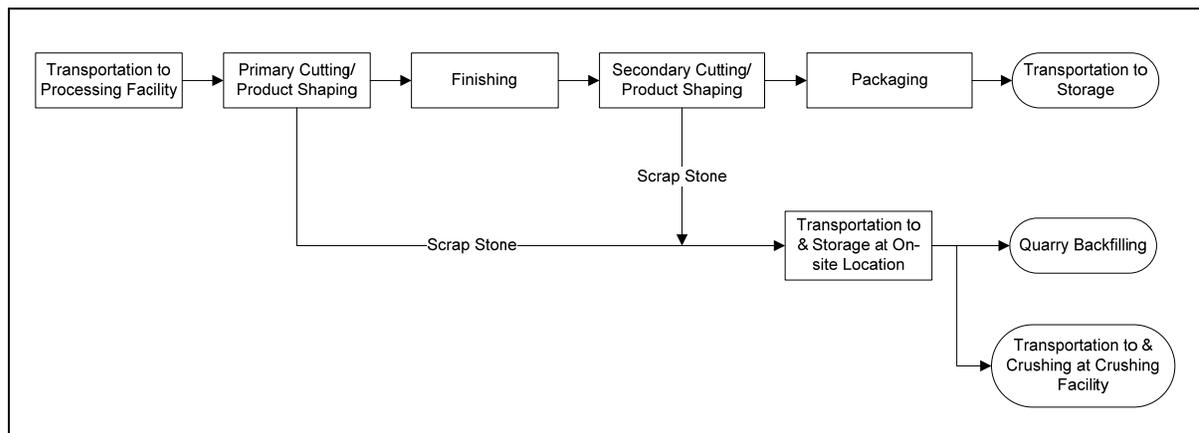


Figure 2. Process flow diagram for processing operations.

The first step in sandstone processing is a primary cutting or shaping of the material. This is often accomplished for sandstone using a circular blade saw, but a splitter or hand tools, such as axes and mauls, can also be implemented. When operating a circular saw, a continuous stream of water over the saw is required in order to dissipate heat generated by the process; sufficiently-elevated temperature can cause major machine and material damage. Natural-faced products, such as veneer or flooring, may be completed with this step, while other products require a finishing application, secondary cutting, or both.

An array of finishing applications exists, and each uses specific types of equipment to accomplish the resulting appearance. Polished or honed finishing as well as a thermal treatment are

frequently given to sandstone products, but others are also possible. The former is applied manually and/or mechanically through the use of polishing pads, while thermal finishes are applied with a flame or blow torch apparatus.

A secondary shaping step may be necessary if the product includes any features or custom size or shape. For this step, a circular saw is again commonly implemented for sandstone. Cooling water is again necessary to maintain an appropriate temperature at the stone-blade interface.

Once a product is completed, it is packaged and stored for shipment or direct sale. Sandstone of insufficient quality or size for current demand is stocked on-site for future use, crushed for use in paving and construction applications, or stored for site reclamation activities.

3 LCI Methodology

3.1 LCI Data Collection

Information for this study was acquired through the distribution of a technical data collection tool. This survey was developed by the Center for Clean Products after touring approximately 15 stone quarries and processing facilities located throughout the United States, and through extensive consultation with industry experts and quarry operators. Choosing a diverse array of facilities was key to this process as a broad understanding of stone industry operations was needed to fashion questions that apply to all members. As such, facilities of diverse magnitudes, locations, and products were toured during the beginning half of 2007.

The survey was distributed to sandstone quarries and processing facilities throughout North America in January of 2008. Responses were received, follow-up conducted, and the resulting data aggregated and analyzed in the period from March to July 2008.

3.2 Quality of LCI Data Set

The dataset presented in this report represents over 62,000 tons of quarried sandstone and nearly 32,000 tons of sandstone products generated in North America; this includes both masonry and landscape products as well as dimensional products. Data also reflects a diversity of operations with respect to size and location. Respondents indicated net annual quarry production ranging from approximately 2,000 tons to 35,000 tons, while processors reported a span of 500-29,000 net tons/year. Quarry data was submitted from companies located in 25% of the 16 states where U.S. sandstone quarries were active in 2006 (Dolley 2007). Reporting processing facilities are located in 4 states.

Due to the limited amount of data able to be supplied by reporting sandstone processors, fabrication data is withheld in order to protect proprietary information.

3.3 LCI Boundaries

3.3.1 Sandstone Quarry Operations

The LCI for quarry operations includes the inputs and outputs for each of the processes depicted in Figure 1. Specifically, processes and operations represented in the inventory presented in this report include:

- Removal of overburden using heavy equipment
- Transfer of overburden to on-site storage
- Quarry operations required to remove stone from deposit including drilling, prying, and use of slight explosive charges.
- On-site transport of stone using heavy equipment.
- Transport of scrap stone to on-site storage
- Onsite generation of energy and compressed air
- Capture and treatment of wastewater
- Upstream production of energy and fuels

Equipment and ancillary materials (e.g. drill bits, maintenance items) are listed in Tables 5 and 6 but have not been included in this inventory.

3.3.2 Sandstone Processing Operations

The LCI for sandstone processing operations includes the inputs and outputs for each of the processes depicted in Figure 2. Specifically, processes and operations represented in this portion of the inventory include:

- Primary shaping of stone into less-refined pieces, such as flagstone or veneer
- Application of a surface finish or texture
- Secondary shaping of stone into specific products
- Packaging of finished sandstone products for shipment
- On-site transport of stone using heavy equipment, such as forklifts
- Transport of scrap stone to on-site storage or reclamation
- Onsite generation of energy and compressed air
- Capture and treatment of wastewater and other waste materials such as dust
- Upstream production of energy and fuels

Equipment and ancillary materials (e.g. drill bits, maintenance items) are listed in Tables 5 and 6 but have not been included in this inventory.

Since a fabrication facility often processes more than one stone type, each facility was categorized as a “sandstone” facility if the majority of their production was indicated to be sandstone. Under this condition, all of respondents who are labeled “sandstone” processors indicate that at least 70% of their production is sandstone.

4 LCI Results

Data have been obtained for the quarrying and processing of 62,000 tons and 32,000 tons of sandstone, respectively. Due to the limited amount of data able to be supplied by reporting sandstone processors, fabrication data is withheld in order to protect proprietary information. Nevertheless, the average gross energy required to quarry one ton of sandstone is 0.217 million BTUs. Table 1 shows the breakdown of this gross energy per ton of sandstone product produced. Table 2 displays the water required for the same production. Table 3 and 4 display the life-cycle inputs and outputs for both the quarrying and stone processing operations, as well as their accumulated totals. Table 5 gives the additional ancillary inputs required for the quarrying and stone processing operations, and Table 6 gives the ancillary outputs for these same processes. (Note that Tables 5 and 6 may be incomplete as level of detail reported for ancillary materials was quite varied.) Each of these tables are available in an excel spreadsheet for your convenience on the Natural Stone Council website.

Note that the abbreviations found in Tables 1-4 imply the following:

- W = Withheld to avoid disclosure of company proprietary information
- N/A = Not applicable due to a lack of data
- NR = Not reported by any facility (i.e., all surveys left this survey question blank)

Table 1. Gross energy to produce one ton of sandstone products.¹

<i>Energy Type</i>	<i>Energy Consumption (Btu/ton)</i>		
	<i>Quarrying</i>	<i>Processing</i>	<i>Total</i>
Electricity	2.04E+03	W	N/A
Natural Gas	0.00E+00	W	N/A
Propane	8.34E+01	W	N/A
Diesel	2.14E+05	W	N/A
Gasoline	1.03E+03	W	N/A
Other Fuel	NR	W	N/A
<i>TOTAL</i>	<i>2.17E+05</i>	<i>W</i>	<i>N/A</i>

¹These values represent the total energy consumption at the quarry and processing sites only. See Table 3 for the complete LCI energy data.

Table 2. Water consumption for sandstone quarrying and processing.²

<i>Energy Type</i>	<i>Water Consumption (gal/ton)</i>		
	<i>Quarrying</i>	<i>Processing</i>	<i>Total</i>
Groundwater	3.20E+00	W	N/A
Surface water	0.00E+00	W	N/A
Public supply	0.00E+00	W	N/A
<i>TOTAL</i>	<i>3.20E+00</i>	<i>W</i>	<i>N/A</i>

²These values represent the total water consumption at the quarry and processing sites only. See Table 3 for the complete LCI water data.

Table 3. LCI inputs for sandstone quarrying and processing.

Input Description	Units	Total Input per Ton of Stone Produced		
		Quarrying	Processing	TOTAL
Air [Renewable resources]	kg	6.67E+00	W	N/A
Barium sulphate [Non renewable resources]	kg	2.36E-13	W	N/A
Basalt [Non renewable resources]	kg	8.36E-04	W	N/A
Bauxite [Non renewable resources]	kg	5.25E-05	W	N/A
Bentonite [Non renewable resources]	kg	3.81E-02	W	N/A
Calcium chloride [Non renewable resources]	kg	2.42E-11	W	N/A
Carbon dioxide [Renewable resources]	kg	2.89E-02	W	N/A
Chromium ore [Non renewable resources]	kg	2.05E-06	W	N/A
Clay [Non renewable resources]	kg	2.51E-03	W	N/A
Colemanite ore [Non renewable resources]	kg	1.09E-07	W	N/A
Cooling water [Operating materials]	kg	W	W	N/A
Copper - Gold - Silver - ore (1,0% Cu; 0,4 g/t Au; 66 g/t Ag) [Non renewable resources]	kg	1.99E-06	W	N/A
Copper - Gold - Silver - ore (1,1% Cu; 0,01 g/t Au; 2,86 g/t Ag) [Non renewable resources]	kg	1.21E-06	W	N/A
Copper - Gold - Silver - ore (1,16% Cu; 0,002 g/t Au; 1,06 g/t Ag) [Non renewable resources]	kg	6.85E-07	W	N/A
Copper - Molybdenum - Gold - Silver - ore (1,13% Cu; 0,02% Mo; 0,01 g/t Au; 2,86 g/t Ag) [Non renewable resources]	kg	1.67E-06	W	N/A
Copper ore (0.14%) [Non renewable resources]	kg	4.07E-05	W	N/A
Copper ore (1.2%) [Non renewable resources]	kg	2.07E-07	W	N/A
Copper ore (4%) [Non renewable resources]	kg	1.38E-14	W	N/A
Copper ore (sulphidic) [Non renewable resources]	kg	1.64E-11	W	N/A
Crude oil Algeria [Crude oil (resource)]	kg	1.74E-02	W	N/A
Crude oil Angola [Crude oil (resource)]	kg	1.93E-01	W	N/A
Crude oil Argentina [Crude oil (resource)]	kg	4.40E-02	W	N/A
Crude oil Australia [Crude oil (resource)]	kg	2.69E-02	W	N/A
Crude oil Austria [Crude oil (resource)]	kg	1.19E-04	W	N/A
Crude oil Bolivia [Crude oil (resource)]	kg	1.35E-09	W	N/A
Crude oil Brazil [Crude oil (resource)]	kg	3.48E-02	W	N/A
Crude oil Brunei [Crude oil (resource)]	kg	3.94E-09	W	N/A
Crude oil Bulgaria [Crude oil (resource)]	kg	7.92E-10	W	N/A
Crude oil Cameroon [Crude oil (resource)]	kg	7.38E-03	W	N/A
Crude oil Canada [Crude oil (resource)]	kg	8.40E-01	W	N/A
Crude oil Chile [Crude oil (resource)]	kg	1.54E-07	W	N/A
Crude oil China [Crude oil (resource)]	kg	1.12E-02	W	N/A
Crude oil CIS [Crude oil (resource)]	kg	6.55E-02	W	N/A
Crude oil Colombia [Crude oil (resource)]	kg	1.44E-01	W	N/A
Crude oil Czech Republic [Crude oil (resource)]	kg	7.96E-06	W	N/A
Crude oil Denmark [Crude oil (resource)]	kg	5.32E-03	W	N/A
Crude oil Ecuador [Crude oil (resource)]	kg	6.47E-02	W	N/A
Crude oil Egypt [Crude oil (resource)]	kg	4.83E-04	W	N/A
Crude oil France [Crude oil (resource)]	kg	1.71E-04	W	N/A
Crude oil Gabon [Crude oil (resource)]	kg	1.03E-01	W	N/A
Crude oil Germany [Crude oil (resource)]	kg	5.40E-04	W	N/A

Crude oil Greece [Crude oil (resource)]	kg	2.38E-05	W	N/A
Crude oil Hungary [Crude oil (resource)]	kg	3.18E-08	W	N/A
Crude oil India [Crude oil (resource)]	kg	3.61E-10	W	N/A
Crude oil Indonesia [Crude oil (resource)]	kg	2.85E-02	W	N/A
Crude oil Iran [Crude oil (resource)]	kg	3.32E-03	W	N/A
Crude oil Iraq [Crude oil (resource)]	kg	2.85E-01	W	N/A
Crude oil Ireland [Crude oil (resource)]	kg	6.07E-10	W	N/A
Crude oil Italy [Crude oil (resource)]	kg	7.56E-04	W	N/A
Crude oil Kuwait [Crude oil (resource)]	kg	1.26E-01	W	N/A
Crude oil Libya [Crude oil (resource)]	kg	5.13E-03	W	N/A
Crude oil Malaysia [Crude oil (resource)]	kg	2.16E-09	W	N/A
Crude oil Mexico [Crude oil (resource)]	kg	8.80E-01	W	N/A
Crude oil Netherlands [Crude oil (resource)]	kg	4.59E-04	W	N/A
Crude oil New Zealand [Crude oil (resource)]	kg	7.77E-06	W	N/A
Crude oil Nigeria [Crude oil (resource)]	kg	3.47E-01	W	N/A
Crude oil Norway [Crude oil (resource)]	kg	2.31E-01	W	N/A
Crude oil Oman [Crude oil (resource)]	kg	9.52E-03	W	N/A
Crude oil Poland [Crude oil (resource)]	kg	2.61E-05	W	N/A
Crude oil Qatar [Crude oil (resource)]	kg	5.18E-03	W	N/A
Crude oil Romania [Crude oil (resource)]	kg	4.76E-05	W	N/A
Crude oil Saudi Arabia [Crude oil (resource)]	kg	8.84E-01	W	N/A
Crude oil Slovakia [Crude oil (resource)]	kg	1.02E-10	W	N/A
Crude oil South Africa [Crude oil (resource)]	kg	5.91E-10	W	N/A
Crude oil Spain [Crude oil (resource)]	kg	3.96E-05	W	N/A
Crude oil Syria [Crude oil (resource)]	kg	4.58E-09	W	N/A
Crude oil Trinidad and Tobago [Crude oil (resource)]	kg	3.89E-02	W	N/A
Crude oil Tunisia [Crude oil (resource)]	kg	2.12E-04	W	N/A
Crude oil Turkey [Crude oil (resource)]	kg	1.42E-14	W	N/A
Crude oil United Arab Emirates [Crude oil (resource)]	kg	5.19E-03	W	N/A
Crude oil United Kingdom [Crude oil (resource)]	kg	2.49E-01	W	N/A
Crude oil USA [Crude oil (resource)]	kg	3.20E+00	W	N/A
Crude oil Venezuela [Crude oil (resource)]	kg	8.64E-01	W	N/A
Dolomite [Non renewable resources]	kg	1.59E-07	W	N/A
Ferro manganese [Non renewable resources]	kg	1.15E-15	W	N/A
Fluorspar (calcium fluoride; fluorite) [Non renewable resources]	kg	7.76E-08	W	N/A
Gypsum (natural gypsum) [Non renewable resources]	kg	1.38E-03	W	N/A
Hard coal Australia [Hard coal (resource)]	kg	1.10E-03	W	N/A
Hard coal Belgium [Hard coal (resource)]	kg	4.46E-07	W	N/A
Hard coal Bosnia and Herzegovina [Hard coal (resource)]	kg	6.39E-08	W	N/A
Hard coal Brazil [Hard coal (resource)]	kg	4.31E-06	W	N/A
Hard coal Canada [Hard coal (resource)]	kg	6.63E-03	W	N/A
Hard coal Chile [Hard coal (resource)]	kg	1.62E-05	W	N/A
Hard coal China [Hard coal (resource)]	kg	2.94E-04	W	N/A
Hard coal CIS [Hard coal (resource)]	kg	2.74E-04	W	N/A
Hard coal Colombia [Hard coal (resource)]	kg	3.50E-03	W	N/A
Hard coal Czech Republic [Hard coal (resource)]	kg	6.44E-05	W	N/A
Hard coal France [Hard coal (resource)]	kg	8.32E-06	W	N/A
Hard coal Germany [Hard coal (resource)]	kg	1.40E-03	W	N/A

Hard coal India [Hard coal (resource)]	kg	1.85E-08	W	N/A
Hard coal Indonesia [Hard coal (resource)]	kg	6.38E-04	W	N/A
Hard coal Italy [Hard coal (resource)]	kg	7.33E-09	W	N/A
Hard coal Japan [Hard coal (resource)]	kg	6.52E-10	W	N/A
Hard coal Malaysia [Hard coal (resource)]	kg	8.58E-11	W	N/A
Hard coal Mexico [Hard coal (resource)]	kg	7.49E-04	W	N/A
Hard coal New Zealand [Hard coal (resource)]	kg	1.31E-05	W	N/A
Hard coal Poland [Hard coal (resource)]	kg	4.18E-04	W	N/A
Hard coal Portugal [Hard coal (resource)]	kg	6.52E-09	W	N/A
Hard coal South Africa [Hard coal (resource)]	kg	8.24E-04	W	N/A
Hard coal Spain [Hard coal (resource)]	kg	4.50E-05	W	N/A
Hard coal Turkey [Hard coal (resource)]	kg	9.21E-11	W	N/A
Hard coal United Kingdom [Hard coal (resource)]	kg	2.02E-04	W	N/A
Hard coal USA [Hard coal (resource)]	kg	2.80E-01	W	N/A
Hard coal Venezuela [Hard coal (resource)]	kg	1.19E-03	W	N/A
Hard coal Vietnam [Hard coal (resource)]	kg	6.52E-06	W	N/A
Heavy spar (barytes) [Non renewable resources]	kg	9.21E-02	W	N/A
Inert rock [Non renewable resources]	kg	3.59E+00	W	N/A
Iron [Non renewable elements]	kg	1.00E-11	W	N/A
Iron ore [Non renewable resources]	kg	2.81E-02	W	N/A
Iron ore (65%) [Non renewable resources]	kg	1.63E-06	W	N/A
Kaolin ore [Non renewable resources]	kg	1.86E-07	W	N/A
Lead [Non renewable elements]	kg	2.30E-15	W	N/A
Lead - zinc ore (4.6%-0.6%) [Non renewable resources]	kg	7.41E-03	W	N/A
Lignite Australia [Lignite (resource)]	kg	4.19E-04	W	N/A
Lignite Austria [Lignite (resource)]	kg	7.48E-06	W	N/A
Lignite Bosnia and Herzegovina [Lignite (resource)]	kg	1.47E-07	W	N/A
Lignite Bulgaria [Lignite (resource)]	kg	8.44E-08	W	N/A
Lignite Canada [Lignite (resource)]	kg	2.63E-03	W	N/A
Lignite CIS [Lignite (resource)]	kg	6.49E-05	W	N/A
Lignite Czech Republic [Lignite (resource)]	kg	3.06E-05	W	N/A
Lignite France [Lignite (resource)]	kg	2.02E-06	W	N/A
Lignite Germany [Lignite (resource)]	kg	0.00E+00	W	N/A
Lignite Germany (Central Germany) [Lignite (resource)]	kg	5.29E-03	W	N/A
Lignite Germany (Lausitz) [Lignite (resource)]	kg	9.28E-04	W	N/A
Lignite Germany (Rheinisch) [Lignite (resource)]	kg	1.72E-03	W	N/A
Lignite Greece [Lignite (resource)]	kg	1.10E-05	W	N/A
Lignite Hungary [Lignite (resource)]	kg	5.06E-07	W	N/A
Lignite India [Lignite (resource)]	kg	3.70E-09	W	N/A
Lignite Macedonia [Lignite (resource)]	kg	2.05E-07	W	N/A
Lignite Poland [Lignite (resource)]	kg	1.32E-05	W	N/A
Lignite Romania [Lignite (resource)]	kg	1.42E-08	W	N/A
Lignite Serbia and Montenegro [Lignite (resource)]	kg	1.21E-06	W	N/A
Lignite Slovakia [Lignite (resource)]	kg	7.28E-08	W	N/A
Lignite Slovenia [Lignite (resource)]	kg	3.70E-07	W	N/A
Lignite Spain [Lignite (resource)]	kg	9.46E-05	W	N/A
Lignite Turkey [Lignite (resource)]	kg	1.77E-12	W	N/A
Lignite USA [Lignite (resource)]	kg	2.86E-02	W	N/A

Limestone (calcium carbonate) [Non renewable resources]	kg	7.86E-02	W	N/A
Magnesit (Magnesium carbonate) [Non renewable resources]	kg	2.71E-08	W	N/A
Magnesium chloride leach (40%) [Non renewable resources]	kg	1.05E-03	W	N/A
Manganese ore [Non renewable resources]	kg	3.88E-07	W	N/A
Manganese ore (R.O.M.) [Non renewable resources]	kg	2.88E-04	W	N/A
Molybdenite (Mo 0,24%) [Non renewable resources]	kg	1.11E-06	W	N/A
Natural Aggregate [Non renewable resources]	kg	7.44E-03	W	N/A
Natural gas Algeria [Natural gas (resource)]	kg	2.02E-03	W	N/A
Natural gas Angola [Natural gas (resource)]	kg	2.36E-02	W	N/A
Natural gas Argentina [Natural gas (resource)]	kg	1.89E-03	W	N/A
Natural gas Australia [Natural gas (resource)]	kg	1.72E-03	W	N/A
Natural gas Austria [Natural gas (resource)]	kg	1.28E-05	W	N/A
Natural gas Bolivia [Natural gas (resource)]	kg	2.72E-06	W	N/A
Natural gas Brazil [Natural gas (resource)]	kg	1.95E-03	W	N/A
Natural gas Brunei [Natural gas (resource)]	kg	3.47E-05	W	N/A
Natural gas Bulgaria [Natural gas (resource)]	kg	6.54E-11	W	N/A
Natural gas Cameroon [Natural gas (resource)]	kg	1.82E-03	W	N/A
Natural gas Canada [Natural gas (resource)]	kg	1.14E-01	W	N/A
Natural gas Chile [Natural gas (resource)]	kg	3.66E-05	W	N/A
Natural gas China [Natural gas (resource)]	kg	5.88E-04	W	N/A
Natural gas CIS [Natural gas (resource)]	kg	4.10E-03	W	N/A
Natural gas Colombia [Natural gas (resource)]	kg	6.55E-03	W	N/A
Natural gas Czech Republic [Natural gas (resource)]	kg	5.87E-07	W	N/A
Natural gas Denmark [Natural gas (resource)]	kg	3.28E-04	W	N/A
Natural gas Ecuador [Natural gas (resource)]	kg	3.96E-03	W	N/A
Natural gas Egypt [Natural gas (resource)]	kg	4.89E-05	W	N/A
Natural gas France [Natural gas (resource)]	kg	1.66E-05	W	N/A
Natural gas Gabon [Natural gas (resource)]	kg	1.47E-02	W	N/A
Natural gas Germany [Natural gas (resource)]	kg	7.24E-04	W	N/A
Natural gas Greece [Natural gas (resource)]	kg	1.56E-06	W	N/A
Natural gas Hungary [Natural gas (resource)]	kg	3.32E-08	W	N/A
Natural gas India [Natural gas (resource)]	kg	1.43E-09	W	N/A
Natural gas Indonesia [Natural gas (resource)]	kg	1.78E-03	W	N/A
Natural gas Iran [Natural gas (resource)]	kg	3.82E-04	W	N/A
Natural gas Iraq [Natural gas (resource)]	kg	1.16E-02	W	N/A
Natural gas Ireland [Natural gas (resource)]	kg	1.35E-06	W	N/A
Natural gas Italy [Natural gas (resource)]	kg	7.52E-05	W	N/A
Natural gas Japan [Natural gas (resource)]	kg	2.09E-10	W	N/A
Natural gas Kuwait [Natural gas (resource)]	kg	4.61E-03	W	N/A
Natural gas Libyan [Natural gas (resource)]	kg	1.35E-04	W	N/A
Natural gas Malaysia [Natural gas (resource)]	kg	3.37E-05	W	N/A
Natural gas Mexico [Natural gas (resource)]	kg	5.06E-02	W	N/A
Natural gas Netherlands [Natural gas (resource)]	kg	2.24E-02	W	N/A
Natural gas New Zealand [Natural gas (resource)]	kg	5.13E-07	W	N/A
Natural gas Nigeria [Natural gas (resource)]	kg	6.30E-02	W	N/A
Natural gas Norway [Natural gas (resource)]	kg	5.00E-03	W	N/A
Natural gas Oman [Natural gas (resource)]	kg	4.91E-04	W	N/A
Natural gas Poland [Natural gas (resource)]	kg	1.71E-06	W	N/A

Natural gas Qatar [Natural gas (resource)]	kg	7.27E-04	W	N/A
Natural gas Romania [Natural gas (resource)]	kg	3.04E-06	W	N/A
Natural gas Saudi Arabia [Natural gas (resource)]	kg	3.01E-02	W	N/A
Natural gas Slovakia [Natural gas (resource)]	kg	1.01E-09	W	N/A
Natural gas South Africa [Natural gas (resource)]	kg	8.23E-08	W	N/A
Natural gas Spain [Natural gas (resource)]	kg	4.28E-06	W	N/A
Natural gas Syria [Natural gas (resource)]	kg	4.92E-10	W	N/A
Natural gas Trinidad and Tobago [Natural gas (resource)]	kg	6.22E-03	W	N/A
Natural gas Tunisia [Natural gas (resource)]	kg	2.77E-05	W	N/A
Natural gas Turkey [Natural gas (resource)]	kg	1.44E-15	W	N/A
Natural gas United Arab Emirates [Natural gas (resource)]	kg	1.97E-04	W	N/A
Natural gas United Kingdom [Natural gas (resource)]	kg	7.10E-03	W	N/A
Natural gas USA [Natural gas (resource)]	kg	3.87E-01	W	N/A
Natural gas Venezuela [Natural gas (resource)]	kg	3.77E-02	W	N/A
Nickel ore [Non renewable resources]	kg	3.04E-10	W	N/A
Nickel ore (1.6%) [Non renewable resources]	kg	1.02E-03	W	N/A
Nitrogen [Renewable resources]	kg	5.80E-10	W	N/A
Olivine [Non renewable resources]	kg	1.27E-14	W	N/A
Oxygen [Renewable resources]	kg	1.88E-14	W	N/A
Peat [Non renewable resources]	kg	4.90E-05	W	N/A
Phosphate ore [Non renewable resources]	kg	4.02E-08	W	N/A
Phosphorus minerals [Non renewable resources]	kg	2.63E-08	W	N/A
Phosphorus ore (29% P2O5) [Non renewable resources]	kg	UA	W	N/A
Pit gas [Natural gas (resource)]	kg	UA	W	N/A
Pit Methane [Natural gas (resource)]	kg	1.16E-03	W	N/A
Potassium chloride [Non renewable resources]	kg	1.24E-08	W	N/A
Precious metal ore (R.O.M) [Non renewable resources]	kg	1.31E-07	W	N/A
Primary energy from geothermics [Renewable energy resources]	MJ	9.97E-02	W	N/A
Primary energy from hydro power [Renewable energy resources]	MJ	5.91E-01	W	N/A
Primary energy from solar energy [Renewable energy resources]	MJ	2.76E-01	W	N/A
Primary energy from wind power [Renewable energy resources]	MJ	3.93E-02	W	N/A
Quartz sand (silica sand; silicon dioxide) [Non renewable resources]	kg	1.04E-03	W	N/A
Raw pumice [Non renewable resources]	kg	1.81E-08	W	N/A
Renewable fuels [Renewable energy resources]	kg	UA	W	N/A
Slate [Non renewable resources]	kg	2.13E-14	W	N/A
Sodium chloride (rock salt) [Non renewable resources]	kg	4.66E-05	W	N/A
Sodium sulphate [Non renewable resources]	kg	5.94E-11	W	N/A
Soil [Non renewable resources]	kg	2.78E-03	W	N/A
Sulphur [Non renewable elements]	kg	3.77E-10	W	N/A
Sulphur (bonded) [Non renewable resources]	kg	1.86E-10	W	N/A
Talc [Non renewable resources]	kg	1.43E-08	W	N/A
Tin ore [Non renewable resources]	kg	2.05E-14	W	N/A
Titanium ore [Non renewable resources]	kg	9.68E-05	W	N/A
Uranium natural [Uranium (resource)]	kg	7.33E-06	W	N/A
Water [Water]	kg	9.53E-04	W	N/A
Water (feed water) [Water]	kg	UA	W	N/A
Water (ground water) [Water]	kg	1.27E+01	W	N/A
Water (sea water) [Water]	kg	7.32E-02	W	N/A

Water (surface water) [Water]	kg	1.39E+01	W	N/A
Water (with river silt) [Water]	kg	UA	W	N/A
Wood [Renewable energy resources]	kg	1.78E-05	W	N/A
Zinc - copper ore (4.07%-2.59%) [Non renewable resources]	kg	1.25E-03	W	N/A
Zinc - lead - copper ore (12%-3%-2%) [Non renewable resources]	kg	5.14E-04	W	N/A
Zinc - lead ore (4.21%-4.96%) [Non renewable resources]	kg	4.72E-15	W	N/A
Zinc ore (sulphide) [Non renewable resources]	kg	3.27E-14	W	N/A

Table 4. LCI outputs for sandstone quarrying and processing.

Output Description	Units	Total Output per Ton of Stone Produced		
		Quarrying	Processing	TOTAL
1,2-Dibromoethane [Halogenated organic emissions to fresh water]	kg	4.98E-14	W	N/A
Acenaphthene [Hydrocarbons to fresh water]	kg	5.65E-09	W	N/A
Acenaphthene [Hydrocarbons to sea water]	kg	9.42E-09	W	N/A
Acenaphthylene [Hydrocarbons to fresh water]	kg	2.19E-09	W	N/A
Acenaphthylene [Hydrocarbons to sea water]	kg	3.64E-09	W	N/A
Acetaldehyde (Ethanal) [Group NMVOC to air]	kg	2.79E-07	W	N/A
Acetic acid [Group NMVOC to air]	kg	4.13E-07	W	N/A
Acetic acid [Hydrocarbons to fresh water]	kg	4.15E-08	W	N/A
Acetic acid [Hydrocarbons to sea water]	kg	1.68E-07	W	N/A
Acetone (dimethylcetone) [Group NMVOC to air]	kg	2.57E-07	W	N/A
Acid (calculated as H+) [Inorganic emissions to fresh water]	kg	1.76E-08	W	N/A
Acrolein [Group NMVOC to air]	kg	9.49E-09	W	N/A
Acrylonitrile [Hydrocarbons to fresh water]	kg	8.56E-12	W	N/A
Adsorbable organic halogen compounds (AOX) [Analytical measures to fresh water]	kg	1.93E-06	W	N/A
Adsorbable organic halogen compounds (AOX) [Analytical measures to sea water]	kg	1.37E-11	W	N/A
Aldehyde (unspecified) [Group NMVOC to air]	kg	7.83E-08	W	N/A
Alkane (unspecified) [Group NMVOC to air]	kg	4.37E-06	W	N/A
Alkene (unspecified) [Group NMVOC to air]	kg	3.96E-06	W	N/A
Aluminium (3+) [Inorganic emissions to industrial soil]	kg	2.74E-07	W	N/A
Aluminum [Inorganic emissions to fresh water]	kg	4.05E-06	W	N/A
Aluminum [Inorganic emissions to sea water]	kg	1.38E-06	W	N/A
Americium (Am241) [Radioactive emissions to fresh water]	Bq	8.64E-03	W	N/A
Ammonia [Inorganic emissions to air]	kg	1.74E-05	W	N/A
Ammonia [Inorganic emissions to fresh water]	kg	2.12E-05	W	N/A
Ammonia [Inorganic emissions to industrial soil]	kg	9.61E-05	W	N/A
Ammonia [Inorganic emissions to sea water]	kg	5.49E-05	W	N/A
Ammonium / ammonia [Inorganic emissions to fresh water]	kg	8.62E-06	W	N/A
Ammonium [Inorganic emissions to air]	kg	4.55E-06	W	N/A
Ammonium nitrate [Inorganic emissions to air]	kg	1.08E-12	W	N/A
Anthracene [Group PAH to air]	kg	1.34E-09	W	N/A
Anthracene [Hydrocarbons to fresh water]	kg	2.72E-09	W	N/A
Anthracene [Hydrocarbons to sea water]	kg	4.04E-09	W	N/A
Antimony (Sb124) [Radioactive emissions to air]	Bq	2.31E-06	W	N/A
Antimony (Sb124) [Radioactive emissions to fresh water]	Bq	6.84E-05	W	N/A
Antimony (Sb125) [Radioactive emissions to fresh water]	Bq	4.73E-05	W	N/A
Antimony [Heavy metals to air]	kg	2.14E-05	W	N/A
Antimony [Heavy metals to fresh water]	kg	1.46E-05	W	N/A
Argon (Ar41) [Radioactive emissions to air]	Bq	1.91E+01	W	N/A
Aromatic hydrocarbons (unspecified) [Group NMVOC to air]	kg	8.51E-08	W	N/A
Aromatic hydrocarbons (unspecified) [Hydrocarbons to fresh water]	kg	1.49E-06	W	N/A
Aromatic hydrocarbons (unspecified) [Hydrocarbons to sea water]	kg	1.09E-07	W	N/A
Arsenic [Heavy metals to air]	kg	1.07E-07	W	N/A
Arsenic [Heavy metals to fresh water]	kg	7.62E-07	W	N/A
Arsenic [Heavy metals to industrial soil]	kg	1.06E-10	W	N/A
Arsenic [Heavy metals to sea water]	kg	9.24E-07	W	N/A

Arsenic trioxide [Heavy metals to air]	kg	5.12E-12	W	N/A
Barium [Inorganic emissions to air]	kg	4.40E-05	W	N/A
Barium [Inorganic emissions to fresh water]	kg	4.90E-06	W	N/A
Barium [Inorganic emissions to sea water]	kg	3.37E-05	W	N/A
Benzene [Group NMVOC to air]	kg	4.70E-06	W	N/A
Benzene [Hydrocarbons to fresh water]	kg	5.98E-06	W	N/A
Benzene [Hydrocarbons to sea water]	kg	5.62E-06	W	N/A
Benzo(a)anthracene [Group PAH to air]	kg	5.03E-10	W	N/A
Benzo(a)anthracene [Hydrocarbons to fresh water]	kg	3.73E-10	W	N/A
Benzo(a)anthracene [Hydrocarbons to sea water]	kg	2.99E-09	W	N/A
Benzo(a)pyrene [Group PAH to air]	kg	3.90E-10	W	N/A
Benzo(ghi)perylene [Group PAH to air]	kg	6.03E-10	W	N/A
Benzofluoranthene [Group PAH to air]	kg	1.89E-09	W	N/A
Benzofluoranthene [Hydrocarbons to fresh water]	kg	1.63E-10	W	N/A
Benzofluoranthene [Hydrocarbons to sea water]	kg	2.49E-09	W	N/A
Beryllium [Inorganic emissions to air]	kg	1.83E-09	W	N/A
Beryllium [Inorganic emissions to fresh water]	kg	1.89E-10	W	N/A
Beryllium [Inorganic emissions to sea water]	kg	1.48E-08	W	N/A
Biological oxygen demand (BOD) [Analytical measures to fresh water]	kg	1.15E-04	W	N/A
Biological oxygen demand (BOD) [Analytical measures to sea water]	kg	1.51E-05	W	N/A
Boron [Inorganic emissions to fresh water]	kg	4.91E-06	W	N/A
Boron [Inorganic emissions to sea water]	kg	2.42E-06	W	N/A
Boron compounds (unspecified) [Inorganic emissions to air]	kg	1.87E-06	W	N/A
Bromide [Inorganic emissions to industrial soil]	kg	3.87E-08	W	N/A
Bromine [Inorganic emissions to air]	kg	5.91E-07	W	N/A
Bromine [Inorganic emissions to fresh water]	kg	1.87E-07	W	N/A
Butadiene [Group NMVOC to air]	kg	2.48E-12	W	N/A
Butane (n-butane) [Group NMVOC to air]	kg	2.02E-04	W	N/A
Butane [Group NMVOC to air]	kg	3.61E-04	W	N/A
Cadmium [Heavy metals to air]	kg	7.31E-09	W	N/A
Cadmium [Heavy metals to fresh water]	kg	1.27E-06	W	N/A
Cadmium [Heavy metals to industrial soil]	kg	1.07E-09	W	N/A
Cadmium [Heavy metals to sea water]	kg	6.38E-07	W	N/A
CaF2 (low radioactive) [Radioactive waste]	kg	8.17E-07	W	N/A
Calcium (2+) [Inorganic emissions to industrial soil]	kg	9.37E-05	W	N/A
Calcium [Inorganic emissions to fresh water]	kg	6.20E-04	W	N/A
Calcium [Inorganic emissions to sea water]	kg	1.71E-04	W	N/A
Carbon (C14) [Radioactive emissions to air]	Bq	8.76E+00	W	N/A
Carbon (C14) [Radioactive emissions to fresh water]	Bq	4.37E-01	W	N/A
Carbon dioxide [Inorganic emissions to air]	kg	4.28E+00	W	N/A
Carbon disulphide [Inorganic emissions to air]	kg	9.26E-12	W	N/A
Carbon monoxide [Inorganic emissions to air]	kg	5.15E-03	W	N/A
Carbon, organically bound [Organic emissions to fresh water]	kg	1.15E-04	W	N/A
Carbonate [Inorganic emissions to fresh water]	kg	6.32E-04	W	N/A
Carbonate [Inorganic emissions to sea water]	kg	9.03E-04	W	N/A
Cesium (Cs134) [Radioactive emissions to air]	Bq	1.07E-01	W	N/A
Cesium (Cs134) [Radioactive emissions to fresh water]	Bq	3.36E-01	W	N/A
Cesium (Cs137) [Radioactive emissions to air]	Bq	9.70E-01	W	N/A

Cesium (Cs137) [Radioactive emissions to fresh water]	Bq	3.09E+00	W	N/A
Chemical oxygen demand (COD) [Analytical measures to fresh water]	kg	1.81E-03	W	N/A
Chemical oxygen demand (COD) [Analytical measures to sea water]	kg	2.45E-04	W	N/A
Chloride (unspecified) [Inorganic emissions to air]	kg	1.04E-02	W	N/A
Chloride [Inorganic emissions to fresh water]	kg	5.43E-02	W	N/A
Chloride [Inorganic emissions to industrial soil]	kg	4.52E-05	W	N/A
Chloride [Inorganic emissions to sea water]	kg	6.29E-02	W	N/A
Chlorinated hydrocarbons (unspecified) [Halogenated organic emissions to fresh water]	kg	1.54E-15	W	N/A
Chlorine (dissolved) [Inorganic emissions to fresh water]	kg	5.40E-06	W	N/A
Chlorine [Inorganic emissions to air]	kg	1.75E-06	W	N/A
Chloromethane (methyl chloride) [Halogenated organic emissions to fresh water]	kg	2.74E-09	W	N/A
Chromium (unspecified) [Heavy metals to air]	kg	6.52E-07	W	N/A
Chromium (unspecified) [Heavy metals to fresh water]	kg	5.22E-07	W	N/A
Chromium (unspecified) [Heavy metals to industrial soil]	kg	1.80E-07	W	N/A
Chromium (unspecified) [Heavy metals to sea water]	kg	1.39E-06	W	N/A
Chromium +III [Heavy metals to air]	kg	1.08E-09	W	N/A
Chromium +III [Heavy metals to fresh water]	kg	1.45E-08	W	N/A
Chromium +III [Heavy metals to industrial soil]	kg	1.00E-11	W	N/A
Chromium +VI [Heavy metals to fresh water]	kg	5.89E-16	W	N/A
Chrysene [Group PAH to air]	kg	1.66E-09	W	N/A
Chrysene [Hydrocarbons to fresh water]	kg	6.51E-09	W	N/A
Chrysene [Hydrocarbons to sea water]	kg	1.11E-08	W	N/A
Cobalt (Co58) [Radioactive emissions to air]	Bq	1.15E-05	W	N/A
Cobalt (Co58) [Radioactive emissions to fresh water]	Bq	2.56E-03	W	N/A
Cobalt (Co60) [Radioactive emissions to air]	Bq	2.90E-04	W	N/A
Cobalt (Co60) [Radioactive emissions to fresh water]	Bq	1.43E+00	W	N/A
Cobalt [Heavy metals to air]	kg	7.99E-04	W	N/A
Cobalt [Heavy metals to fresh water]	kg	3.59E-06	W	N/A
Cobalt [Heavy metals to industrial soil]	kg	4.48E-01	W	N/A
Cobalt [Heavy metals to sea water]	kg	9.09E-05	W	N/A
Cooling water [Waste for recovery]	kg	UA	W	N/A
Copper [Heavy metals to air]	kg	3.02E-08	W	N/A
Copper [Heavy metals to fresh water]	kg	3.99E-06	W	N/A
Copper [Heavy metals to industrial soil]	kg	2.25E-06	W	N/A
Copper [Heavy metals to sea water]	kg	2.44E-06	W	N/A
Cresol (methyl phenol) [Hydrocarbons to fresh water]	kg	4.01E-08	W	N/A
Cresol (methyl phenol) [Hydrocarbons to sea water]	kg	3.72E-08	W	N/A
Curium (Cm alpha) [Radioactive emissions to fresh water]	Bq	1.14E-02	W	N/A
Cyanide (unspecified) [Inorganic emissions to air]	kg	3.02E-07	W	N/A
Cyanide [Inorganic emissions to fresh water]	kg	4.20E-07	W	N/A
Cyclohexane (hexahydro benzene) [Group NMVOC to air]	kg	2.12E-10	W	N/A
Demolition waste (deposited) [Stockpile goods]	kg	2.92E-03	W	N/A
Dibenz(a)anthracene [Group PAH to air]	kg	3.76E-10	W	N/A
Dichloromethane (methylene chloride) [Halogenated organic emissions to air]	kg	9.34E-15	W	N/A
Dichloropropane [Halogenated organic emissions to fresh water]	kg	1.17E-16	W	N/A
Diethyl amine (ethylene ethane amine) [Group NMVOC to air]	kg	6.42E-17	W	N/A
Dioxins (unspec.) [Halogenated organic emissions to air]	kg	4.14E-14	W	N/A
Dust (PM10) [Particles to air]	kg	2.20E-04	W	N/A

Dust (PM2.5) [Particles to air]	kg	1.48E-04	W	N/A
Dust (unspecified) [Particles to air]	kg	2.40E-04	W	N/A
Ethane [Group NMVOC to air]	kg	1.51E-03	W	N/A
Ethanol [Group NMVOC to air]	kg	2.51E-07	W	N/A
Ethene (ethylene) [Group NMVOC to air]	kg	4.77E-08	W	N/A
Ethyl benzene [Group NMVOC to air]	kg	3.96E-06	W	N/A
Ethyl benzene [Hydrocarbons to fresh water]	kg	8.31E-08	W	N/A
Ethyl benzene [Hydrocarbons to sea water]	kg	3.95E-07	W	N/A
Exhaust [Other emissions to air]	kg	5.13E+00	W	N/A
Fluoranthene [Group NMVOC to air]	kg	2.88E-09	W	N/A
Fluoranthene [Hydrocarbons to fresh water]	kg	1.38E-09	W	N/A
Fluoranthene [Hydrocarbons to sea water]	kg	3.83E-09	W	N/A
Fluorene [Group NMVOC to air]	kg	1.39E-08	W	N/A
Fluoride (unspecified) [Inorganic emissions to air]	kg	1.89E-04	W	N/A
Fluoride [Inorganic emissions to fresh water]	kg	6.11E-04	W	N/A
Fluoride [Inorganic emissions to industrial soil]	kg	8.76E-07	W	N/A
Fluorides [Inorganic emissions to air]	kg	5.61E-07	W	N/A
Fluorine [Inorganic emissions to air]	kg	2.05E-08	W	N/A
Fluorine [Inorganic emissions to fresh water]	kg	3.61E-08	W	N/A
Formaldehyde (methanal) [Group NMVOC to air]	kg	2.51E-06	W	N/A
Halogenated hydrocarbons (unspecified) [Halogenated organic emissions to air]	kg	4.61E-15	W	N/A
Hazardous waste (unspec.) [Hazardous waste]	kg	UA	W	N/A
Heavy metals to air (unspecified) [Heavy metals to air]	kg	8.25E-11	W	N/A
Heavy metals to water (unspecified) [Heavy metals to fresh water]	kg	1.23E-09	W	N/A
Helium [Inorganic emissions to air]	kg	2.78E-08	W	N/A
Heptane (isomers) [Group NMVOC to air]	kg	1.93E-05	W	N/A
Hexamethylene diamine (HMDA) [Group NMVOC to air]	kg	1.46E-13	W	N/A
Hexane (isomers) [Group NMVOC to air]	kg	2.86E-05	W	N/A
Hexane (isomers) [Hydrocarbons to fresh water]	kg	4.77E-09	W	N/A
Hexane (isomers) [Hydrocarbons to sea water]	kg	3.67E-09	W	N/A
Highly radioactive waste [Radioactive waste]	kg	2.44E-06	W	N/A
Hydrocarbons (unspecified) [Hydrocarbons to fresh water]	kg	8.01E-08	W	N/A
Hydrogen (H3) [Radioactive emissions to air]	Bq	2.84E+01	W	N/A
Hydrogen (H3) [Radioactive emissions to fresh water]	Bq	1.28E+04	W	N/A
Hydrogen [Inorganic emissions to air]	kg	8.86E+00	W	N/A
Hydrogen arsenic (arsine) [Heavy metals to air]	kg	4.25E-10	W	N/A
Hydrogen bromine (hydrobromic acid) [Inorganic emissions to air]	kg	2.69E-09	W	N/A
Hydrogen chloride [Inorganic emissions to air]	kg	1.91E-05	W	N/A
Hydrogen chloride [Inorganic emissions to fresh water]	kg	1.08E-09	W	N/A
Hydrogen cyanide (prussic acid) [Inorganic emissions to air]	kg	5.65E-10	W	N/A
Hydrogen fluoride (hydrofluoric acid) [Inorganic emissions to fresh water]	kg	1.25E-06	W	N/A
Hydrogen fluoride [Inorganic emissions to air]	kg	2.40E-06	W	N/A
Hydrogen iodide [Inorganic emissions to air]	kg	1.83E-12	W	N/A
Hydrogen phosphorous [Inorganic emissions to air]	kg	4.04E-13	W	N/A
Hydrogen sulphide [Inorganic emissions to air]	kg	1.08E-04	W	N/A
Hydroxide [Inorganic emissions to fresh water]	kg	2.95E-08	W	N/A
Indeno[1,2,3-cd]pyrene [Group PAH to air]	kg	4.49E-10	W	N/A
Industrial waste for municipal disposal [Consumer waste]	kg	UA	W	N/A

Inorganic salts and acids (unspecified) [Inorganic emissions to fresh water]	kg	UA	W	N/A
Iodine (I129) [Radioactive emissions to air]	Bq	3.12E-01	W	N/A
Iodine (I129) [Radioactive emissions to fresh water]	Bq	9.56E-01	W	N/A
Iodine (I131) [Radioactive emissions to air]	Bq	2.16E-03	W	N/A
Iodine (I131) [Radioactive emissions to fresh water]	Bq	7.19E-04	W	N/A
Iron [Heavy metals to air]	kg	1.14E-06	W	N/A
Iron [Heavy metals to fresh water]	kg	5.98E-04	W	N/A
Iron [Heavy metals to industrial soil]	kg	1.90E-04	W	N/A
Iron [Heavy metals to sea water]	kg	4.99E-06	W	N/A
Krypton (Kr85) [Radioactive emissions to air]	Bq	3.23E+05	W	N/A
Krypton (Kr85m) [Radioactive emissions to air]	Bq	3.29E-01	W	N/A
Lanthanides [Heavy metals to air]	kg	2.22E-12	W	N/A
Lead [Heavy metals to air]	kg	1.88E-07	W	N/A
Lead [Heavy metals to fresh water]	kg	1.04E-06	W	N/A
Lead [Heavy metals to industrial soil]	kg	2.05E-07	W	N/A
Lead [Heavy metals to sea water]	kg	9.38E-07	W	N/A
Lead dioxide [Inorganic emissions to air]	kg	2.67E-13	W	N/A
Magnesium (2+) [Inorganic emissions to industrial soil]	kg	4.85E-05	W	N/A
Magnesium [Inorganic emissions to fresh water]	kg	1.30E-04	W	N/A
Magnesium [Inorganic emissions to sea water]	kg	4.30E-05	W	N/A
Magnesium chloride [Inorganic emissions to fresh water]	kg	1.82E-10	W	N/A
Manganese (Mn54) [Radioactive emissions to fresh water]	Bq	2.22E-01	W	N/A
Manganese [Heavy metals to air]	kg	5.54E-08	W	N/A
Manganese [Heavy metals to fresh water]	kg	7.99E-07	W	N/A
Manganese [Heavy metals to industrial soil]	kg	3.17E-07	W	N/A
Manganese [Heavy metals to sea water]	kg	6.94E-02	W	N/A
Medium and low radioactive wastes [Radioactive waste]	kg	2.89E-06	W	N/A
Mercaptan (unspecified) [Group NMVOC to air]	kg	1.92E-07	W	N/A
Mercury [Heavy metals to air]	kg	2.46E-08	W	N/A
Mercury [Heavy metals to fresh water]	kg	2.87E-08	W	N/A
Mercury [Heavy metals to industrial soil]	kg	2.94E-09	W	N/A
Mercury [Heavy metals to sea water]	kg	5.28E-09	W	N/A
Metals (unspecified) [Particles to air]	kg	1.47E-11	W	N/A
Metals (unspecified) [Particles to fresh water]	kg	2.18E-11	W	N/A
Methane [Organic emissions to air (group VOC)]	kg	3.36E-02	W	N/A
Methanol [Group NMVOC to air]	kg	2.16E-07	W	N/A
Methanol [Hydrocarbons to fresh water]	kg	1.15E-06	W	N/A
Mineral waste [Consumer waste]	kg	UA	W	N/A
Molybdenum [Heavy metals to air]	kg	8.85E-08	W	N/A
Molybdenum [Heavy metals to fresh water]	kg	1.42E-07	W	N/A
Molybdenum [Heavy metals to sea water]	kg	6.20E-08	W	N/A
Naphthalene [Group PAH to air]	kg	1.41E-07	W	N/A
Naphthalene [Organic emissions to fresh water]	kg	2.23E-07	W	N/A
Naphthalene [Organic emissions to sea water]	kg	3.56E-07	W	N/A
Neutral salts [Inorganic emissions to fresh water]	kg	2.22E-11	W	N/A
Nickel [Heavy metals to air]	kg	9.82E-07	W	N/A
Nickel [Heavy metals to fresh water]	kg	1.45E-06	W	N/A
Nickel [Heavy metals to industrial soil]	kg	7.21E-08	W	N/A

Nickel [Heavy metals to sea water]	kg	9.59E-07	W	N/A
Nitrate [Inorganic emissions to fresh water]	kg	2.86E-05	W	N/A
Nitrate [Inorganic emissions to sea water]	kg	1.59E-06	W	N/A
Nitrogen (atmospheric nitrogen) [Inorganic emissions to air]	kg	4.22E-04	W	N/A
Nitrogen [Inorganic emissions to fresh water]	kg	2.08E-04	W	N/A
Nitrogen dioxide [Inorganic emissions to air]	kg	1.09E-13	W	N/A
Nitrogen monoxide [Inorganic emissions to air]	kg	1.82E-10	W	N/A
Nitrogen organic bounded [Inorganic emissions to fresh water]	kg	6.69E-05	W	N/A
Nitrogen oxides [Inorganic emissions to air]	kg	1.12E-02	W	N/A
Nitrous oxide (laughing gas) [Inorganic emissions to air]	kg	6.59E-05	W	N/A
NMVOC (unspecified) [Group NMVOC to air]	kg	9.83E-04	W	N/A
non used primary energy from water power [Other emissions to fresh water]	MJ	9.52E-02	W	N/A
non used primary energy from wind power [Other emissions to air]	MJ	8.66E-05	W	N/A
Octane [Group NMVOC to air]	kg	1.06E-05	W	N/A
Oil (unspecified) [Hydrocarbons to fresh water]	kg	1.37E-05	W	N/A
Oil (unspecified) [Hydrocarbons to sea water]	kg	2.61E-05	W	N/A
Oil (unspecified) [Organic emissions to industrial soil]	kg	1.53E-05	W	N/A
Organic chlorine compounds (unspecified) [Organic emissions to fresh water]	kg	5.74E-13	W	N/A
Organic chlorine compounds [Organic emissions to air (group VOC)]	kg	5.56E-13	W	N/A
Organic compounds (dissolved) [Organic emissions to fresh water]	kg	3.33E-13	W	N/A
Organic compounds (unspecified) [Organic emissions to fresh water]	kg	2.84E-23	W	N/A
Organic waste [Consumer waste]	kg	UA	W	N/A
Overburden (deposited) [Stockpile goods]	kg	3.39E+00	W	N/A
Oxygen [Inorganic emissions to air]	kg	1.27E-02	W	N/A
Oxygen [Renewable resources]	kg	9.00E-03	W	N/A
Palladium [Heavy metals to air]	kg	6.69E-16	W	N/A
Paper (unspecified) [Consumer waste]	kg	UA	W	N/A
Pentane (n-pentane) [Group NMVOC to air]	kg	1.93E-04	W	N/A
Phenanthrene [Group PAH to air]	kg	4.43E-08	W	N/A
Phenol (hydroxy benzene) [Group NMVOC to air]	kg	2.77E-06	W	N/A
Phenol (hydroxy benzene) [Hydrocarbons to fresh water]	kg	1.61E-06	W	N/A
Phenol (hydroxy benzene) [Hydrocarbons to sea water]	kg	5.08E-06	W	N/A
Phosphate [Inorganic emissions to fresh water]	kg	5.94E-06	W	N/A
Phosphorus [Inorganic emissions to fresh water]	kg	9.51E-07	W	N/A
Phosphorus [Inorganic emissions to industrial soil]	kg	1.54E-05	W	N/A
Plastic (unspecified) [Waste for recovery]	kg	UA	W	N/A
Plutonium (Pu alpha) [Radioactive emissions to air]	Bq	8.20E-03	W	N/A
Plutonium (Pu alpha) [Radioactive emissions to fresh water]	Bq	2.62E-02	W	N/A
Plutonium as residual product [Radioactive waste]	kg	4.85E-09	W	N/A
Polychlorinated biphenyls (PCB unspecified) [Halogenated organic emissions to air]	kg	9.32E-10	W	N/A
Polychlorinated dibenzo-p-dioxins (2,3,7,8 - TCDD) [Halogenated organic emissions to air]	kg	9.16E-14	W	N/A
Polychlorinated dibenzo-p-dioxins (2,3,7,8 - TCDD) [Halogenated organic emissions to fresh water]	kg	2.24E-20	W	N/A
Polycyclic aromatic hydrocarbons (PAH) [Group PAH to air]	kg	5.65E-06	W	N/A
Polycyclic aromatic hydrocarbons (PAH, unspec.) [Hydrocarbons to fresh water]	kg	1.15E-07	W	N/A
Potassium (+) [Inorganic emissions to industrial soil]	kg	1.99E-05	W	N/A
Potassium [Inorganic emissions to fresh water]	kg	1.10E-05	W	N/A
Propane [Group NMVOC to air]	kg	2.84E-03	W	N/A

Propene (propylene) [Group NMVOC to air]	kg	3.58E-07	W	N/A
Propionic acid (propane acid) [Group NMVOC to air]	kg	9.05E-11	W	N/A
R 11 (trichlorofluoromethane) [Halogenated organic emissions to air]	kg	5.35E-08	W	N/A
R 114 (dichlorotetrafluoroethane) [Halogenated organic emissions to air]	kg	5.48E-08	W	N/A
R 12 (dichlorodifluoromethane) [Halogenated organic emissions to air]	kg	1.15E-08	W	N/A
R 13 (chlorotrifluoromethane) [Halogenated organic emissions to air]	kg	7.22E-09	W	N/A
R 22 (chlorodifluoromethane) [Halogenated organic emissions to air]	kg	1.26E-08	W	N/A
Radioactive tailings [Radioactive waste]	kg	1.43E-03	W	N/A
Radium (Ra226) [Radioactive emissions to fresh water]	Bq	1.42E+02	W	N/A
Radon (Rn222) [Radioactive emissions to air]	Bq	4.70E+03	W	N/A
Rhodium [Heavy metals to air]	kg	6.46E-16	W	N/A
Ruthenium (Ru106) [Radioactive emissions to fresh water]	Bq	8.64E-03	W	N/A
Scandium [Inorganic emissions to air]	kg	1.08E-12	W	N/A
Selenium [Heavy metals to air]	kg	2.54E-07	W	N/A
Selenium [Heavy metals to fresh water]	kg	5.21E-08	W	N/A
Silicate particles [Inorganic emissions to fresh water]	kg	2.31E-10	W	N/A
Silver (Ag110m) [Radioactive emissions to fresh water]	Bq	1.00E-05	W	N/A
Silver [Heavy metals to air]	kg	1.35E-08	W	N/A
Silver [Heavy metals to fresh water]	kg	4.98E-08	W	N/A
Silver [Heavy metals to sea water]	kg	3.15E-06	W	N/A
Slag (deposited) [Stockpile goods]	kg	3.18E-04	W	N/A
Slag (Uranium conversion) [Radioactive waste]	kg	5.41E-06	W	N/A
Sludge [Hazardous waste]	kg	0.00E+00	W	N/A
Sodium (+) [Inorganic emissions to industrial soil]	kg	7.80E-04	W	N/A
Sodium [Inorganic emissions to fresh water]	kg	1.52E-03	W	N/A
Sodium [Inorganic emissions to sea water]	kg	1.92E-04	W	N/A
Sodium chloride (rock salt) [Inorganic emissions to fresh water]	kg	4.00E-11	W	N/A
Sodium hypochlorite [Inorganic emissions to fresh water]	kg	2.67E-11	W	N/A
Soil loss by erosion into water [Particles to fresh water]	kg	1.08E-08	W	N/A
Solids (dissolved) [Analytical measures to fresh water]	kg	9.19E-06	W	N/A
Solids (suspended) [Particles to fresh water]	kg	5.60E-02	W	N/A
Solids (suspended) [Particles to sea water]	kg	3.70E-02	W	N/A
Spoil (deposited) [Stockpile goods]	kg	6.68E-02	W	N/A
Steam [Inorganic emissions to air]	kg	2.61E+00	W	N/A
Strontium (Sr90) [Radioactive emissions to fresh water]	Bq	3.18E-01	W	N/A
Strontium [Heavy metals to fresh water]	kg	3.26E-05	W	N/A
Strontium [Heavy metals to industrial soil]	kg	9.45E-05	W	N/A
Strontium [Heavy metals to sea water]	kg	3.08E-05	W	N/A
Strontium [Inorganic emissions to air]	kg	9.96E-02	W	N/A
Styrene [Group NMVOC to air]	kg	2.35E-13	W	N/A
Sulphate [Inorganic emissions to fresh water]	kg	3.86E-03	W	N/A
Sulphate [Inorganic emissions to industrial soil]	kg	1.85E-04	W	N/A
Sulphate [Inorganic emissions to sea water]	kg	3.36E-04	W	N/A
Sulphide [Inorganic emissions to fresh water]	kg	5.62E-05	W	N/A
Sulphide [Inorganic emissions to industrial soil]	kg	9.56E-05	W	N/A
Sulphide [Inorganic emissions to sea water]	kg	1.54E-04	W	N/A
Sulphite [Inorganic emissions to fresh water]	kg	5.32E-07	W	N/A
Sulphur [Inorganic emissions to fresh water]	kg	1.69E-06	W	N/A

Sulphur [Inorganic emissions to sea water]	kg	1.30E-06	W	N/A
Sulphur dioxide [Inorganic emissions to air]	kg	1.62E-02	W	N/A
Sulphur hexafluoride [Inorganic emissions to air]	kg	1.95E-11	W	N/A
Sulphuric acid [Inorganic emissions to air]	kg	6.79E-08	W	N/A
Sulphuric acid [Inorganic emissions to fresh water]	kg	9.93E-08	W	N/A
Tailings [Stockpile goods]	kg	UA	W	N/A
Tellurium [Heavy metals to air]	kg	1.43E-10	W	N/A
Tetrafluoromethane [Halogenated organic emissions to air]	kg	6.97E-10	W	N/A
Thallium [Heavy metals to air]	kg	1.06E-09	W	N/A
Thallium [Heavy metals to fresh water]	kg	1.79E-10	W	N/A
Tin [Heavy metals to air]	kg	9.39E-08	W	N/A
Tin [Heavy metals to fresh water]	kg	5.46E-08	W	N/A
Tin [Heavy metals to sea water]	kg	5.06E-08	W	N/A
Tin oxide [Inorganic emissions to air]	kg	2.32E-14	W	N/A
Titanium [Heavy metals to air]	kg	1.74E-09	W	N/A
Titanium [Heavy metals to fresh water]	kg	2.45E-08	W	N/A
Titanium [Heavy metals to sea water]	kg	3.06E-09	W	N/A
Toluene (methyl benzene) [Group NMVOC to air]	kg	2.16E-06	W	N/A
Toluene (methyl benzene) [Hydrocarbons to fresh water]	kg	2.08E-06	W	N/A
Toluene (methyl benzene) [Hydrocarbons to sea water]	kg	2.70E-06	W	N/A
Total dissolved organic bounded carbon [Analytical measures to fresh water]	kg	4.90E-12	W	N/A
Total organic bounded carbon [Analytical measures to fresh water]	kg	7.37E-05	W	N/A
Total organic bounded carbon [Analytical measures to sea water]	kg	4.89E-05	W	N/A
Trimethylbenzene [Group NMVOC to air]	kg	2.26E-13	W	N/A
Unused primary energy from geothermal [Other emissions to fresh water]	MJ	5.48E-02	W	N/A
Unused primary energy from solar energy [Other emissions to air]	MJ	1.99E-03	W	N/A
Uranium (total) [Radioactive emissions to air]	Bq	6.80E-01	W	N/A
Uranium (U234) [Radioactive emissions to air]	Bq	3.41E-02	W	N/A
Uranium (U235) [Radioactive emissions to air]	Bq	5.62E-03	W	N/A
Uranium (U238) [Radioactive emissions to air]	Bq	2.50E-02	W	N/A
Uranium [Radioactive emissions to fresh water]	Bq	1.99E+00	W	N/A
Uranium depleted [Radioactive waste]	kg	5.60E-06	W	N/A
Used air [Other emissions to air]	kg	9.85E-03	W	N/A
Used oil [Hazardous waste for recovery]	kg	UA	W	N/A
Vanadium [Heavy metals to air]	kg	1.78E-05	W	N/A
Vanadium [Heavy metals to fresh water]	kg	2.46E-05	W	N/A
Vanadium [Heavy metals to sea water]	kg	3.74E-07	W	N/A
Vinyl chloride (VCM; chloroethene) [Halogenated organic emissions to air]	kg	1.44E-08	W	N/A
Vinyl chloride (VCM; chloroethene) [Halogenated organic emissions to fresh water]	kg	5.99E-14	W	N/A
VOC (unspecified) [Organic emissions to air (group VOC)]	kg	1.39E-05	W	N/A
Waste heat [Other emissions to air]	MJ	1.47E+01	W	N/A
Waste heat [Other emissions to fresh water]	MJ	6.88E+00	W	N/A
Waste radioactive [Radioactive waste]	kg	4.85E-06	W	N/A
Waste water processing residue [Hazardous waste for recovery]	kg	UA	W	N/A
Water (boiler feed water) [Operating materials]	kg	UA	W	N/A
Water (river water) [Water]	kg	1.12E+01	W	N/A
Water (sea water) [Water]	kg	2.90E-04	W	N/A
Wood (dust) [Particles to air]	kg	8.58E-12	W	N/A

Xenon (Xe131m) [Radioactive emissions to air]	Bq	2.64E-01	W	N/A
Xenon (Xe133) [Radioactive emissions to air]	Bq	4.28E+01	W	N/A
Xenon (Xe133m) [Radioactive emissions to air]	Bq	3.44E-01	W	N/A
Xenon (Xe135) [Radioactive emissions to air]	Bq	1.21E+01	W	N/A
Xenon (Xe135m) [Radioactive emissions to air]	Bq	2.13E+00	W	N/A
Xenon (Xe137) [Radioactive emissions to air]	Bq	3.74E-03	W	N/A
Xenon (Xe138) [Radioactive emissions to air]	Bq	4.82E-01	W	N/A
Xylene (dimethyl benzene) [Group NMVOC to air]	kg	1.67E-05	W	N/A
Xylene (isomers; dimethyl benzene) [Hydrocarbons to fresh water]	kg	3.49E-07	W	N/A
Xylene (isomers; dimethyl benzene) [Hydrocarbons to sea water]	kg	1.87E-06	W	N/A
Zinc [Heavy metals to air]	kg	1.38E-06	W	N/A
Zinc [Heavy metals to fresh water]	kg	1.40E-06	W	N/A
Zinc [Heavy metals to industrial soil]	kg	1.92E-06	W	N/A
Zinc [Heavy metals to sea water]	kg	5.29E-06	W	N/A
Zinc oxide [Inorganic emissions to air]	kg	4.65E-14	W	N/A
Zinc sulphate [Inorganic emissions to air]	kg	1.07E-08	W	N/A

Table 5. Other ancillary inputs for sandstone quarrying and processing.

Input Description	<i>Quarrying</i>	<i>Processing</i>
Banding	X	
Banding chips	X	
Chisels	X	X
Corrugated plastic		X
Diamond wire		X
Hydraulic Fluid	X	
Lubricant		X
Polishing pads		X
Shrink/stretch wrap		X
Steel banding straps		X
Tires	X	
Wooden pallets	X	

Table 6. Other ancillary outputs for sandstone quarrying and processing.

Input Description	<i>Quarrying</i>	<i>Processing</i>
Blade cores		X
Diamond wire		X
Hydraulic fluid	X	
Motor Oil	X	
Scrap stone	X	X
Steel drill bits		X

References

Dolley, T.P. 2007. Stone, Dimension. *USGS 2006 Minerals Yearbook*. Vol. 1, Metals & Minerals. <<http://minerals.usgs.gov/minerals/pubs/myb.html>>.