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"$LCCO_2$ of GEOLAM ",

Geolam Management
Zurich , Switzerland
www.geolam.com

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1. Calculating $LCCO_2$ of GEOLAM

1-1. System boundaries and scenarios

In this analysis, we have adopted the evaluation scope proposed by Wada et al[1] for the purpose of assessing how the use of recycled materials in GEOLAM production affects the $LCCO_2$ value for GEOLAM. Figure 1 shows the system boundaries. In the case of recycled products, the process of generating raw production materials from original products that were themselves produced from raw materials is included within the system boundaries as a raw material procurement process.

Fig1: System boundaries

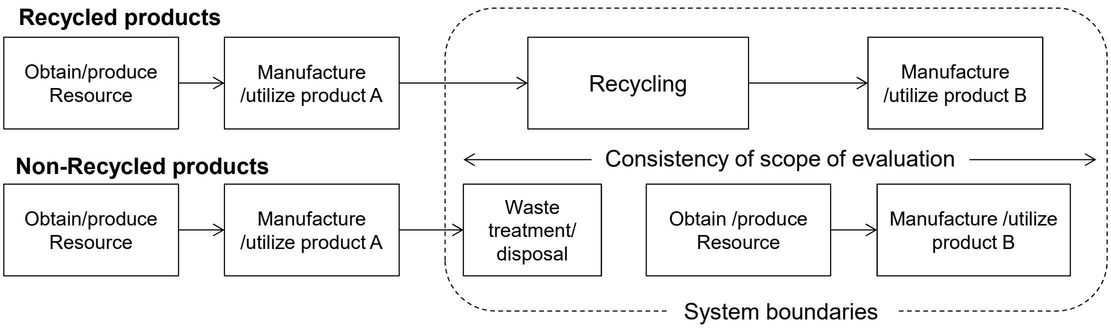
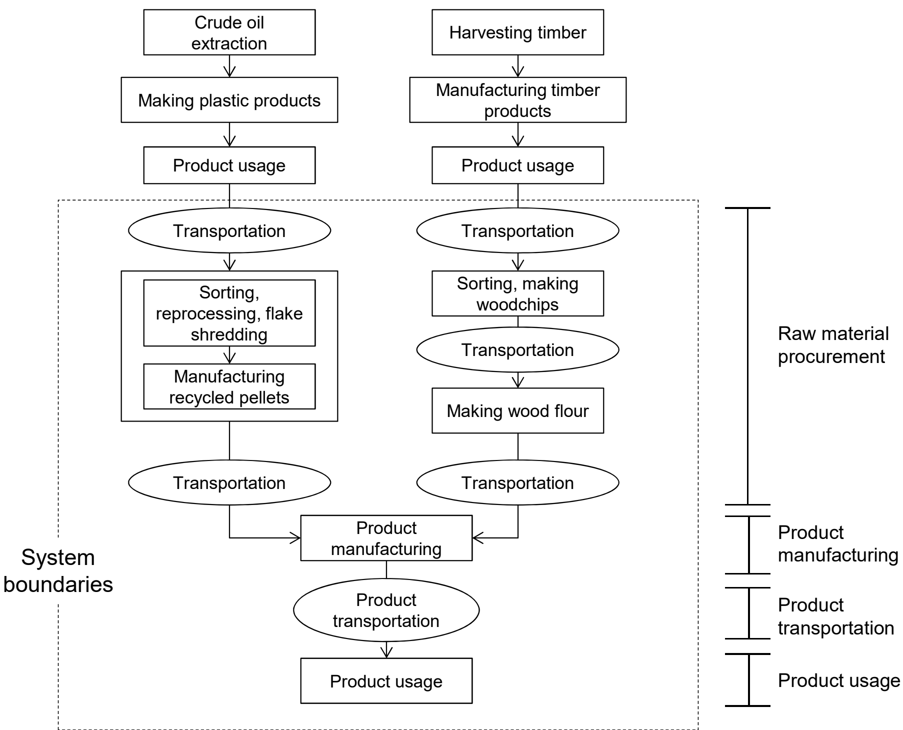


Figure 2 shows the GEOLAM scenario discussed in this analysis.



Plastic materials are typically recycled from plastic containers and packaging as well as industrial waste. Wood flour from wood material is timber scrap derived from recycled construction scrap.

Product manufacturing processes consist of mixing the raw materials and casting or molding the materials into the finished product. The ratio of plastic to wood material is an average based on figures supplied by the manufacturers we interviewed. Although GEOLAM products can take a variety of forms, our discussion here will be restricted to standard hollow panels.

In terms of product usage, we assume that the panels are deployed in outdoor settings.

Our analysis does not include capital goods production (such as building factories and processing facilities) associated with the various processes.

1-2. Calculation conditions for individual processes

This analysis employs bottom-up calculations using foreground data wherever possible. Where process data was unavailable, we have used what we consider to be representative data taken from previous reports and research papers.

1-2-1. Raw material procurement—plastic

From Figure 2, raw material procurement processes for plastics (in the form of recycled pellets) consist of transporting used plastic, sorting, reprocessing, flake shredding, manufacturing recycled pellets, and transporting recycled pellets.

Since all of the GEOLAM licensee purchase recycled plastic pellets through trading firms, we were unable to obtain foreground data on the sorting, reprocessing, and flake shredding process or the pellet manufacturing process. Instead, we calculated CO_2 emissions for these processes based on data provided in past literature.

We used past literature to determine the criteria for calculating CO_2 emissions associated with transportation of used plastic products. Based on the scenario of a 10-t truck[2] loaded at 62%[2] capacity and traveling a distance of 500 km[2], unit CO_2 emissions were calculated at 0.1300 kg-CO_2/t-km[2.3] and CO_2 emissions per kilogram carried were 0.0650 kg-CO_2/kg.

CO_2 emissions from sorting, reprocessing and flake shredding were 0.0857 kg-CO_2/kg. This figure is based on emissions for manual sorting and disassembly of waste plastic products as stated in past literature[7]. CO_2 emissions from recycled pellet manufacturing were 0.0838 kg-CO_2/kg, based on emissions figures for melting and extrusion in the literature[7]. Product yields were 98.5% for sorting, reprocessing and flake shredding and 99.7% for recycled pellet manufacturing, based on the same literature[7].

Once again, CO_2 emissions associated with transportation of recycled pellets were calculated on the basis of the criteria stated in past literature. For a 10-t truck[2] loaded at 62%[2] capacity and traveling a distance of 500 km[2], unit CO_2 emissions were 0.1300 kg-CO_2/t-km[2,3] and CO_2 emissions per kilogram carried were 0.0650 kg-CO_2/kg.

1-2-2. Raw material procurement—wood

From Figure 2, raw material procurement processes for wood (in the form of wood flour) consist of transporting timber scrap, sorting, making woodchips, transporting woodchips, manufacturing wood flour, and transporting wood flour.

We used past literature to determine the criteria for calculating CO_2 emissions associated with transportation of timber scrap. Based on the scenario of a 4-t truck[5] loaded at 62%[2] capacity and traveling a distance of 10 km[5], unit CO_2 emissions were calculated at 0.2178 kg-CO_2/t-km[2,3] and CO_2 emissions per kilogram carried were 0.0022 kg-CO_2/kg.

None of the GEOLAM licensee manufactures their woodchips in-house, so we were obliged to use background data from past literature[5] in regards to sorting and woodchip making processes. Based on the energy consumption values for lumber sorting and crushing (typically using magnetic separators, air graders and/or metal detectors), we arrived at the consumption figures of 0.0233 kWh/kg (for electricity) and 0.00185 l/kg (for diesel). We then multiplied these by the respective emission coefficients set out in the Environment Ministry publication *Calculation methodology and emission coefficients for calculation, reporting and publication purposes*[3] The resulting figure for CO_2 emissions associated with sorting and woodchip manufacturing was 0.0179 kg-CO_2/kg. Around 70% of woodchip output is considered suitable for GEOLAM material recycling, with the remaining about 30% used as fuel[5].

Next, we calculated power consumption associated with production of wood flour at 0.9084 kWh per kilogram. This is an average figure based on the foreground data obtained from GEOLAM licensee who produce their own wood flour. Once again, we multiplied this figure by the corresponding CO_2 emission coefficient in *Calculation methodology and emission coefficients for calculation, reporting and publication purpose*[3] to calculate the CO_2 emissions for wood flour production. The result was 0.5096 kg-CO_2/kg. Product yield was 94.3%.

For CO_2 emissions associated with transportation, we used the scenario of a 10-t truck[6] loaded at 62% capacity[2] traveling a distance of 54.4 km[6], based on past literature. The unit emissions value was 0.1300 kg-CO_2/t-km[2,3] while emissions per kilogram carried were 0.0071 kg-CO_2/kg. These figures were applied to transportation of both woodchips and wood flour.

1-2-3. Production

Power consumption associated with production was found to be 1.8220 kWh per kg GEOLAM, based on the average of foreground data obtained from GEOLAM licensee. Multiplied by the CO_2 emissions coefficient for electric power[6], this leads to an emissions figure of 1.0221 kg-CO_2/kg. Product yield was 94.3%. The ratio of wood to plastic materials was 52:48.

1-2-4. Product transportation

It was difficult to define the CO_2 emissions for the product transportation process because of the variety of different sales channels employed by GEOLAM licensee from whom we were able to obtain foreground data. For this reason, we used the transportation criteria given in past literature and assumed a scenario of a 10-t truck[2] loaded at 62% capacity[2] traveling a distance of 500 km[2]. On this basis, unit emissions were 0.1300 kg-CO_2/t-km[2,3] and emissions per kilogram carried were 0.0650 kg-CO_2/kg.

1-2-5. Usage

We assumed that GEOLAM was used in the standard form of panels in an outdoor decking. Since GEOLAM does not require ongoing maintenance such as repainting, we assumed zero CO_2 emissions during the period of use.

1-3. Results and discussion

The $LCCO_2$ value for GEOLAM was 1.54 kg-CO_2 per kilogram of GEOLAM.

Table 1 $LCCO_2$ for WPRC per kilogram of product— calculation results

Process			Average	Proportion of CO_2 emissions
Procurement of raw plastic material	Input material (plastics)		0.515 kg	
	Transportation of used plastics	CO_2 emissions	0.033 kg-CO_2	2.1%
	Sorting, reprocessing, flake shredding	CO_2 emissions	0.044 kg-CO_2	2.9%
	Manufacturing recycled pellets	CO_2 emissions	0.042 kg-CO_2	2.7%
	Transportation of recycled pellets	CO_2 emissions	0.033 kg-CO_2	2.1%
Procurement of raw wood material	Input material（woods）		0.833 kg	
	Transportation of timber scrap	CO_2 emissions	0.002 kg-CO_2	0.1%
	Sorting, making woodchips	CO_2 emissions	0.010 kg-CO_2	0.6%
	Transportation of woodchips	CO_2 emissions	0.004 kg-CO_2	0.3%
	Making wood flour	CO_2 emissions	0.283 kg-CO_2	18.4%
	Transportation of wood flour	CO_2 emissions	0.004 kg-CO_2	0.3%
Product manufacturing	Input material (plastics)		0.506 kg	
	Input material (woods)		0.555 kg	
	Finished products		1.000 kg	
	Yield		94%	
		CO_2 emissions	1.022 kg-CO_2	66.3%
Product transportation	Transportation	CO_2 emissions	0.065 kg-CO_2	4.2%
Product usage	Product usage (20 years)	CO_2 emissions	0.000 kg-CO_2	0.0%
	Total		1.54 kg-CO_2 / kg	100%

2. Impact on $LCCO_2$ of using virgin plastic material in WPC production

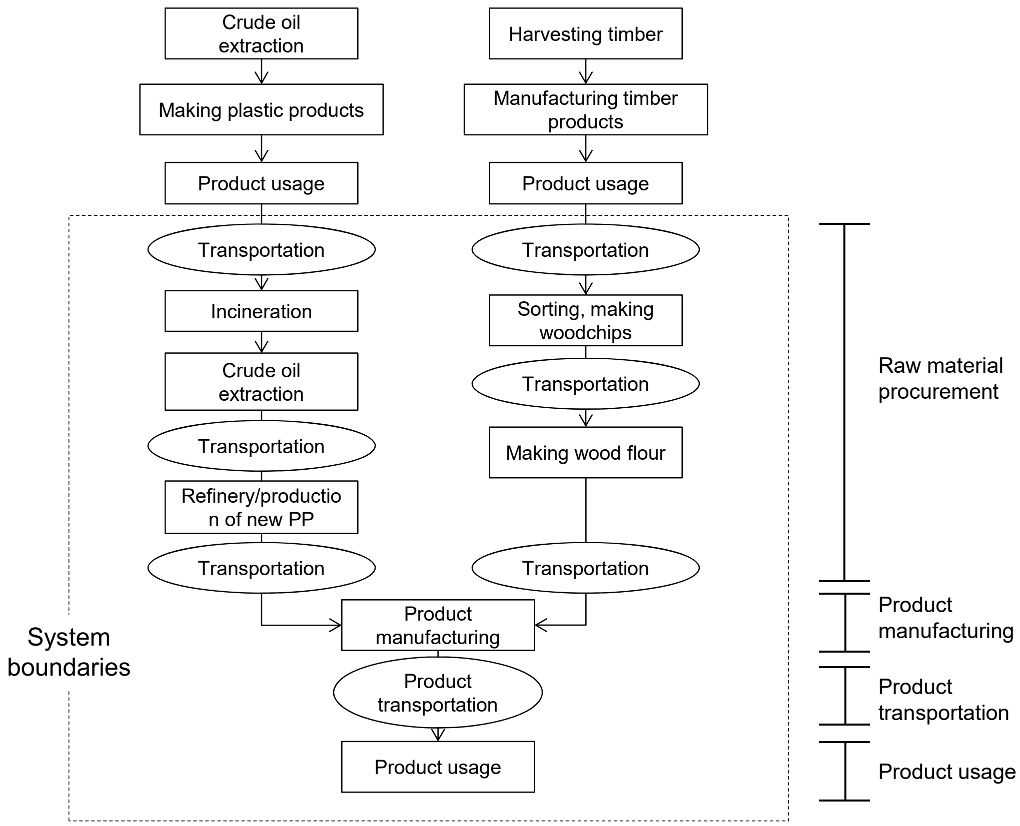
One of the key features of GEOLAM is that it is produced from recycled plastic materials. In order to evaluate the benefits of recycled plastics in terms of the $LCCO_2$, we considered the case of WPC produced from virgin rather than recycled plastics (known as "virgin WPC").

2-1. $LCCO_2$ assessment of virgin WPC

2-1-1. System boundaries and scenarios

Our calculation of the $LCCO_2$ for virgin WPC was based on the scenario depicted in Figure 3. In order to compare the recycled plastic and virgin plastic scenarios using the method proposed by Wada et al,[1] we standardized the evaluation scope by incorporating into the virgin material system a waste treatment/disposal process for products equivalent to the recycled materials used in the original products (see Figure 1). In our scenario, the main type of plastic material was virgin plastic, in the form of new polypropylene resin (PP). Thus, the raw material procurement process incorporates incineration of products equivalent to the recycled materials used in the original product.

Fig3



2-1-2. Process calculation conditions

For processes that are the same as the GEOLAM scenario in Figure 2, we used the calculation results from Section 1 *Calculating LCCO₂ of GEOLAM.*
The following sections describe the revised calculation conditions for new polypropylene resin (PP) as the plastic material.

2-1-2-1. Raw material procurement—plastic

As Figure 3 shows, procurement of plastic production material in the form of new polypropylene resin (PP) comprises a number of processes: transportation of used plastics, incineration, extraction of crude oil, transportation of crude oil, refinery/production of new PP, and transportation of new PP.

CO_2 emissions arising from transportation of used plastic products were calculated from past literature, based on the scenario of a 4-t truck[4] loaded at 62% capacity[2] traveling a distance of 30 km[4]. Unit CO_2 emissions were 0.2178 kg-CO_2/t-km[2,3], while emissions per kilogram carried were 0.0065 kg-CO_2/kg.

CO_2 emissions associated with extraction of crude oil, transportation of crude oil and refinery/production of new PP respectively were quoted from past literature[7]. The combined total for these processes was 1.379187 kg-CO_2/kg.

Finally, emissions arising from transportation of new PP were calculated from past literature, based on the scenario of a 10-t truck[5] loaded at 62% capacity[5] and traveling a distance of 500 km[5]. On this basis, unit CO_2 emissions were 0.1300 kg-CO_2/t-km[5,6] while emissions per kilogram carried were 0.0650 kg-CO_2/kg.

2-1-3. Results

Table 2 summarizes the calculation of $LCCO_2$ for virgin WPC. The calculation result was 3.271 kg-CO_2 per kilogram.

Table2: $LCCO_2$ for WPRC (Virgin plastics) per kilogram of product— calculation results

Process			**Average for all companies**	**Proportion of CO_2 emissions**
Procurement of raw plastic material	Input material (plastics)		0.506 kg	
	Transportation of used plastics	CO_2 emissions	0.001 kg-CO_2	0.0%
	Plastic waste incineration	CO_2 emissions	1.149 kg-CO_2	35.1%
	Crude oil extraction	CO_2 emissions	0.698 kg-CO_2	21.3%
	Importing crude oil	CO_2 emissions		
	New plastic manufacturing	CO_2 emissions		
	Transportation of New PP	CO_2 emissions	0.033 kg-CO_2	1.0%
Procurement of raw wood material	Input material（woods）		0.833 kg	
	Transportation of timber scrap	CO_2 emissions	0.002 kg-CO_2	0.1%
	Sorting, making woodchips	CO_2 emissions	0.010 kg-CO_2	0.3%
	Transportation of woodchips	CO_2 emissions	0.004 kg-CO_2	0.1%
	Making wood flour	CO_2 emissions	0.283 kg-CO_2	8.7%
	Transportation of wood flour	CO_2 emissions	0.004 kg-CO_2	0.1%
Product manufacturing	Input material (plastics)		0.477 kg	
	Input material (woods)		0.523 kg	
	Finished products		1.000 kg	
	Yield		94%	
		CO_2 emissions	1.02 kg-CO_2	31.2%
Product transportation	Transportation	CO_2 emissions	0.065 kg-CO_2	2.0%
Product usage	Product usage (20 years)	CO_2 emissions	0.000 kg-CO_2	0.0%
	Total		3.27 kg-CO_2	100%

3-1. $LCCO_2$ assessment of Hardwood

3-1-1. System boundaries and scenarios

Our calculation of the $LCCO_2$ for Hardwood was based on the scenario depicted as follows using the method proposed by Wood miles forum Kyoto ,Japn[8],
CO_2 emissions associated with wood processing + CO_2 emissions arising from transportation of hardwood (From South America)

3-1-2. Process calculation conditions

CO_2 emissions associated with wood processing of hardwood were 363.43 kg-CO_2/m3[8] and since all of the Hardwood used for Deck in Japan is mainly supplied from South America (Ipe wood) we calculated CO_2 emissions for transportation of hard wood were 286 kg-CO_2/m3[8].

3-1-3. Results

The wood consumption of 10m2 of solid decking board were calculated as follows
10m2×0.022m(22mm thickness board)=0.22 ㎥
We assume product yield was 40%, thus real wood consumption was calculated by wood consumption multiplied by product yield, 0.55m2 (0.22m3÷40%)
Based on the above scenario, CO_2 emissions for Hardwood were calculated 357.2 kg-CO_2/10m2 using following method
(CO_2 emissions associated with wood processing + CO_2 emissions arising from transportation of hardwood)× wood consumption of 10m2 of solid decking board
(363.43 kg-CO_2/m3+286 kg-CO_2/m3)×0.55=357.2 kg-CO_2/10m2

4. Conclusions

The following conclusions were drawn from our analysis.

(1) The $LCCO_2$ for GEOLAM was 1.54 kg-CO_2/kg.

(2) The $LCCO_2$ for virgin WPCwas 3.27 kg-CO_2/kg. Thus, the use of recycled plastics as the production input material reduces total CO_2 emissions across all processes by 53.6%.

(3) The $LCCO_2$ value for 10 m^2 of GEOLAM solid decking material was 430.6kg-CO_2. And he $LCCO_2$ value for 10 m^2 of GEOLAM Micropore decking material was 288.2kg-CO_2. For virgin WPC solid decking, the value was 913.9 kg-CO_2 . The $LCCO_2$ for Hardwood was 357.2 kg-CO_2/10m2.Thus, GEOLAM had the lowest $LCCO_2$ value as shown below

	GEOLAM	GEOLAM	Virgin WPC	Hardwood
	Micropore	Solid	Solid	Solid
Weight/per 10m2	187	279	279	-
Kg-CO_2	288.2	430.6	913.9	357.2

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