MASTER OF SCIENCE IN CHEMICAL AND MATERIALS ENGINEERING

Do environmental balloons exist?

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1 Introduction

In the past years, the public opinion about environmental problems has become stronger. Strikes against global warming and student protests are examples of that. Another example are the calls to ban plastic use in general. Although this seems a bit unrealistic at first, new rules have already been implemented to ban plastic where it is unnecessary, like straws, plates and cotton swabs. But the limitation of plastics will not be limited to those applications. Especially in the domain of single-use plastics, the necessity of their use will be researched a lot stricter. Plastic balloons will also not escape this trend.

Balloons are mainly used for events to advertise companies or to decorate the space for festivity purposes. They have been around for centuries and were often crafted via animal intestines to honor the gods. It was only in 1824 that Michael Faraday made the first rubber balloon and filled it with hydrogen gas. In 1847 the first vulcanised toy balloons were produced which were able to withstand a range of temperatures. Balloons really came through to the public during the Chicago world's fair of 1933 [1].

In the following paper, the consequences of different kinds of balloons on the environment will be investigated. A life cycle analysis will also be executed and there will be recommendations on how to make the balloon process and use as eco-friendly as possible. Finally, a practical aspect will come into play: seeing as the project was handed to us through the *Wetenschapswinkel* of the VUBrussels, some alternatives to balloons with the sole purpose of advertisement are compared using a defined functional unit.

2 Manufacturing Process of Balloon from natural latex

2.1 Raw materials

Following raw materials are used for the manufacturing of Balloon from natural latex [2].

1. Natural latex white yellowish opaque liquid obtained from the trees. It contains isoprene and other minor organic compounds such as proteins, starch, sugar, etc as monomers dispersed in the aqueous medium.
2. Dispersant such as potassium laurate or any other surfactant is added to prevent the coagulation of the latex as the monomers in the latex coagulate upon exposure to the air.
3. Additives such as Potassium hydroxide, Sulphur, Zinc Dibutyl Dithiocarbamate (ZDC), ZnO and vegetable oils are added in the latex to have desired properties such as required thickness, high rate of drying, maximum elongation and easy inflation.
4. Styrenated Phenols are added as antioxidant and Wax is added as antiozonant.
5. Metalic oxide such as titanium dioxide or other organic dyes are added to the latex to give certain color to the balloon.

2.2 Manufacturing Process

- The latex obtained from the tree is centrifuged in order to increase its viscosity by increasing the contents of dry rubber up to 60%. Since the balloons can not be manufactured from the field latex due to its low viscosity. And then all the additives pigments, anti degrading agents and etc are added into the latex which is then poured into the tanks. The latex is kept at a certain temperature with continuous stirring to avoid it's settling and bring it to the equilibrium state. This is called the matured state, it is required to produce good quality balloons.[2]
- The molds of the balloons, which are shaped as deflated balloons, can be made from stainless steel, aluminum or porcelain. The molds are heated between 38 ℃to 93 ℃. Heated molds are immersed into the coagulant solution for few seconds. The coagulant does the gelation of the latex at the surface of the mold. The coagulant solution is the mixture of water, soap, talc powder and the calcium based salts such as Calcium chloride. Calcium chloride is the coagulant while soap helps evenly spread a thin film. The talc would help in the removal of the balloon from the mold [3].
- The molds are inserted into the latex tank for a few seconds to have the coating of the rubber on the molds. Not longer than few seconds though, since high residence time in the tank would increase the thickness of the coating which is unwanted. A ring is formed at the opening of the balloon by rolling the edges of the balloon by a brush. In order to remove excess coagulant, the molds are immersed into the plain water. This step is also crucial to remove impurities like certain proteins that lead to latex allergies. The water produced during this step is a waste produced of the balloon industries [2] .
- Then the rubber on the mold is cured. Different ways are available to achieve this. If the latex already contained a vulcanizing agent, then the rubber is cured at moderate temperature. If not, then the mold is kept at oven temperature for almost an hour to cure the rubber.
- After curing, the balloons are removed from the molds. The balloons are removed by spraying water or air. If water is used to remove them, then the additional steps of centrifugation and drying have to be carried out to remove the water from the balloons[3].
- Finally, the balloons are collected in the baskets or nets to be then packed into the bags.

2.2.1 Waste streams of manufacturing process of balloons from natural latex

The pollution of the production of natural latex can be divided in two sections. The Rubber plantation (production of fresh latex) and the Rubber mills (production of primary latex). The following aspects were incorporated when calculating the CO_2-eq/ton product in the study of W. Jawjit and his co-workers [4].

As mentioned before it is concentrated latex of around 60% that is being used to create natural latex balloons. Around 2 ton of fresh latex is needed to produce 1 ton of concentrated latex. The total emissions depend largely on what kind of soil the rubber trees were grown. In case emissions.jpg

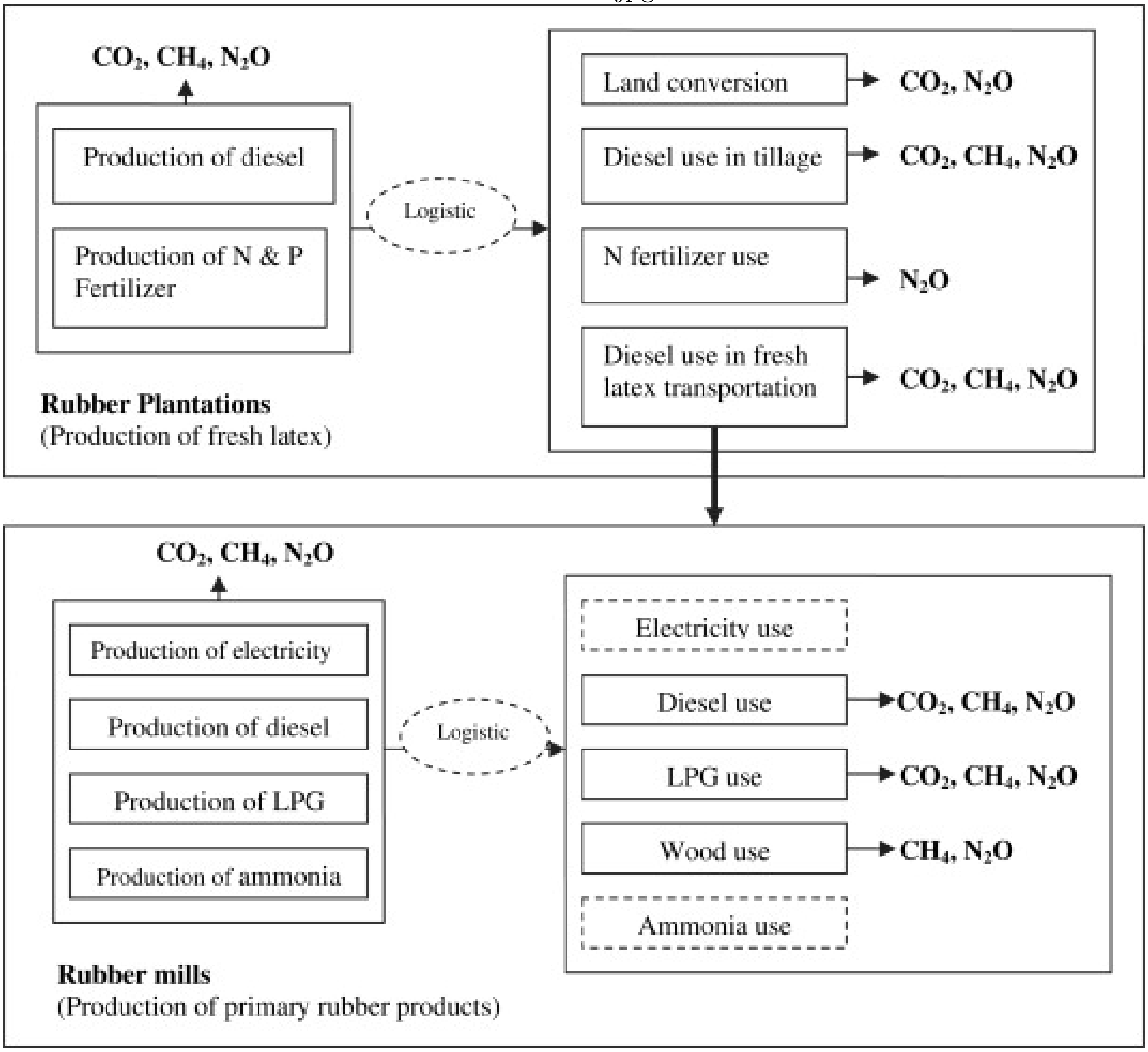

Figure 1: A Schematic overview of the production of fresh latex and primary rubber products (concentrated latex, STR 20 and RSS) and associated emissions of greenhouse gases. Solid lines indicated that the activities or processes are considered in the referenced study, while dotted lines indicate that the activities or processes are not considered.

of cultivated land, the emissions come out to be 0.54 ton CO_2-eq/ton product. On the other hand most rubber trees have been planted on tropical forest ground in the last 20 years. In this case th[illegible]ssions are around 13 ton CO_2-eq/ton product which is a big difference.

When observing 1 it is noticed that there are environmental unfriendly waste streams caused by the cultivation of the rubber trees. This shows that even products that are based on natural products are not always as "green" as they appear. For that reason it is necessary choose your final product by critically evaluating the data gathered, rather than picking the one that seem appealing.

2.3 Synthetic latex

2.3.1 Manufacturing process of balloons from synthetic latex

Synthetic latex tries to have the same properties as natural latex. Instead of using rubber trees to harvest the latex, synthetic latex is petrochemical based. The most used starting product for synthetic latex balloons is neoprene. Both neoprene and natural latex exhibit both good flexibility over a wide range of temperatures. However, natural rubber is still preferred since it has slightly better properties and, most importantly, it is biodegradable. As for the CO_2-eq/ton of the two rubbers, we based our results on the CES data which will be displayed in section 4.2.

The way the balloons are made almost completely identical as for the natural latex except for one crucial step. Synthetic latex has the advantage of not having the proteins that causes latex allergies. This means that the process of making the balloons contains less unit operations. So except for that sole unit operation we assume that the CO_2-eq/ton of balloon product is the same for both manufacturing processes.

2.4 Environmental consequences

2.4.1 Biodegradability

There are a lot of misconceptions regarding the biodegradability of latex balloons. Standard natural latex is biodegradable, but as mentioned above, additives are added to the balloon. This extends the lifetime of the balloon. There are several sources ([5] [6] [7]) talking about the time is takes for natural latex balloons to fully degrade, but there is no general consensus about the duration. In spite of this, it is still possible to conclude that full degradation of the natural latex balloon can take up to several years depending on the precise conditions, and takes even longer when exposed to water instead of earth.
Balloons made out of synthetic latex or mylar on the other hand are not biodegradable. Logically, releasing these kinds of balloons into nature would be more harmful than the latex balloons. As mentioned later in this paper, mylar balloons can be reused easier than latex balloons, which is an advantage in economical and ecological perspective.

2.4.2 Influence on animal life

Latex balloons are able to decompose spontaneously, but this process takes several years. The lack of speed of this decomposition proves that balloons are not as biodegradable as many people think. The main environmental problem with the balloon is the fact that animals can mistake it for food. Several studies have been conducted on this with mixed results. The kind of animal has a big influence on the effect of balloon poisoning.
According to Irwin's work[8], turtles are more sensitive to accumulate plastic in its inner organs than certain fish or land birds. on the other hand Roman, et al.[9] confirms severe consequences when seabirds consume pieces of plastics. Ingesting a single piece of plastic as

a mortality rate of 20.4% for seabirds. The latter paper especially shows why balloons are a danger for animal life: balloon pieces are 32 times more deadly than hard plastics when ingested. Balloons are thus way more dangerous than the more common plastic pollutants like plastic bottles. The consummated balloon fragment have a high risk of obstructing the intestine, which leads to the death of the seabird.

2.4.3 Legislation

Plastics have been a torn in the eye of a lot of environmental friendly organisations over the last few years, especially single-use plastics. Governmental institutions are therefore also making efforts to reduce the use of these. Balloons are a prime example of these single-use plastics
The European Commission [10] has done their research to check the feasibility of limiting the use of these plastics. Considering balloons, banning them completely was not a possibility. Also enforcing extra requirements on the production process is not considered since no potential litter reduction design features were found. The main limitations on balloons that the EC is considering is licensing mass balloon releases, executing information campaigns discouraging mass balloon releases and labelling balloon packages.
The EC is considering a ban on balloon sticks. But these balloon sticks are made of a hard polymer and are thus less dangerous for animal life than the balloon itself. It does not seem that efficient at first sight, but in the end reducing unnecessary plastic usage is still a good measure.

2.4.4 Helium problematic

2019 has been a rough year concerning the helium supply. But according to popular belief, this has not been a recent problem. Even in 1958, there were already events where the Helium was limited due to temporary shortages. [11] A big reason for the fluctuations of the supply of Helium is due to limiting Helium sources. Only a handful of countries have the adequate natural gas sources where Helium is extracted from. Whenever one of these reserves run out (Federal Helium Reserve USA) or close down due to other reasons (Political troubles in Qatar), short-term shortages are present. At the GAWDA (Gases and Welders Distributors Association) 2019 convention, helium expert Phil Kornbluth has a lecture about this topic. According to him [12], this shortage will ease at the start of 2020 due to in new projects starting up in Algeria, Gazproms Amur Project in Russia and another project in Qatar. The helium recycle of used helium in MRI-apparature also lowers the demand of helium, leading to the fact that the demand of helium is now at a lower point than in 2011.

3 Life cycle assessment - case studies

The literature regarding the LCAs of latex balloons is rather scarce, and no published studies could be found on this topic. Instead, the LCAs analyzed in this work were papers on latex production in Thailand and Sri Lanka, and disposable rubber gloves production in Malaysia.

The later choice is justified by the fact that both the balloons and the gloves are disposable, single-use latex products, and therefore, the LCA of the gloves helps understanding the case of the latex balloons.

3.1 Rubber production (Sri Lanka and Thailand)

Jawji et al. studied concentrated latex mills in Thailand in order to assess the potential environmental damage by LCA and investigate the effects of cleaner technology options[13].

The methodology is based on the ISO 14040 series, taking a "Gate-to-Gate" approach (Partial LCA). The system accounts for fresh latex transportation and concentrated latex production. Figure 2 shows the flowchart of latex production as well as the boundaries of the analysed system.

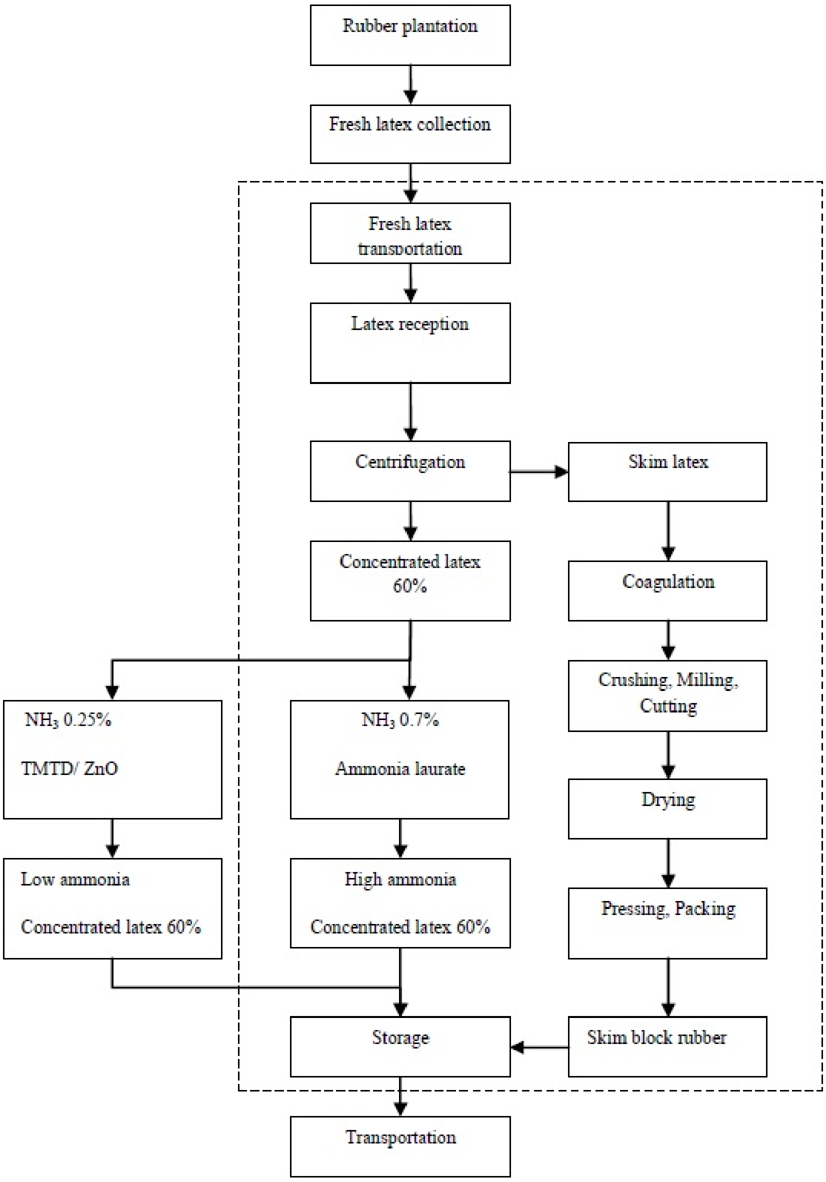

Figure 2: The flowchart of latex production. The dashed lines represent the system boundary.

The activities taken into account include electricity use, diesel use (for transportation and heating), chemicals use (ammonia, lauric acid, DAP, zinc oxide), and wastewater treatment. The functional unit is 1 ton of concentrated latex. Data was obtained from four concentrated latex mills in the south of Thailand. Emissions of pollutants from concentrated latex production were quantified as a function of activities and emission factors. If available, Thailand-specific emission factors were used. Otherwise, emission factors were taken from Eco-invent 2.0. Table 1 shows the average data obtained in the four factories in Thailand.

Table 1: The average data collected in four different rubber mills in Thailand.

Resource/ Energy use	Fresh latex	Water	Electricity	Ammonia	TMTD	ZnO	DAP	Lauric acid	Sulfuric acid	Diesel	LPG
Unit	Ton	m^3	m^3	kg	kg	kg	kg	kg	kg	Litre	kg
Average value used for emission calculation	2.5	7	105	17	0.6	0.6	2.3	0.5	13.4	6.5	3.4

Five environmental impacts were studied: global warming, acidification, eutrophication, human toxicity and photochemical oxidation. The potential impact assessment was quantified by using characterization factors developed by the Center of Environmental Science of Leiden University (CML). The influence of each activity in the environmental impact can be observed in Table 2.

Table 2: The emissions of each activity divided in the five studied environmental impact indicators.

Environmental impact / Pollutants	Unit	Total	Activities							
			DAP use	ZnO use	Lauric acid use	Ammonia use	Diesel transport	H_2SO_4 use	Electricity use	Diesel use for drying
Global warming										
CO_2	kg	148	3.6	1.8	0.4	34.1	17.3	1.8	74.5	14.5
CH_4	g	533	5.4	4.3	1.7	67.7	0.6	2.4	433.2	17.7
N_2O	g	3	0.1	0.0	0.9	0.5	0	0.03	1.5	0.4
Acidification										
SO_2	g	1105	80.3	1.2	1.4	75.2	14.4	173.2	736.9	21.9
NO_x	g	583	10.9	1.6	2.9	42.0	70.1	10.8	183.1	261.4
NH_3	g	2	0.1	0.0	1.2	0.3	0	0.1	0.1	0.0
Eutrophication										
Phosphate	g	122	121.4	0.0	0.2	0.4	0	0.1	0.1	0.0
Nitrate	g	23	4.8	0.6	0.7	16.2	0	5.0	5.7	0
COD	g	141	7.0	0.5	3.0	85.9	0	7.9	36.2	0.7
N	g	2	0.0	0.0	0.6	1.7	0	0.0	0.0	0
Human Toxicity										
SO_2	g	1105	80.3	1.2	1.4	75.2	14.4	173.2	736.9	21.9
NO_x	g	583	10.9	1.6	2.9	42.0	70.1	10.8	183.1	261.4
NH_3	g	2	0.1	0.0	1.2	0.3	0.0	0.1	0.1	0.0
Particulate matter	g	23	2.3	0.1	1.6	9.6	1.8	0.7	1.2	6.0
Smog										
CO	g	190	6.5	0.9	14.3	20.0	48.4	5.1	14.8	79.7
NOx	g	583	10.9	1.6	2.9	42.0	70.1	10.8	183.1	261.4
NMVOC	g	143	1.3	0.5	0.3	12.5	13.8	0.8	23.4	90.6

It can be seen that the electricity use for centrifugation has the largest share, compared with other activities, in global warming (53%), acidification (60%), and photochemical oxidation

(60%). Ammonia use for latex preservation accounts for 40% of human toxicity, whereas use of DAP accounts for 60% of eutrophication. Diesel use for heating was also found to be an important contributor to several environmental impacts.
Based on these results, the following cleaner technology (CT) options are therefore identified: 1) electricity efficiency improvement (by installation of inverters to centrifugal machines); 2) improvement of ammonia preparation and storage (by chilling systems); 3) minimizing the use of DAP (by extending coagulation time); and 4) substitution of diesel by LPG. These four CT options result in reductions of the total environmental impact by 12%, 8%, 3%, and 5%, respectively. Table 3 shows the cleaner technology suggestions in comparison with the reference (studied case).

Table 3: The emissions of each activity divided in the five studied environmental impact indicators.

Impact category	Unit	Reference (no option) case	CT Options			
			Electricity[a)]	Ammonia[b)]	DAP[c)]	LPG[d)]
Acidification	kg SO_2 eq	1.6	1.48	1.60	1.55	1.49
Eutrophication	kg PO_4^{3-} eq	0.21	0.20	0.20	0.18	0.17
Global warming	kg CO_2 eq	161	148.94	153.90	156.22	156.84
Human toxicity	kg 1,4-DB eq	36	34.55	33.66	35.47	34.10
Photochemical oxidation	kg C_2H_4-eq	0.07	0.067	0.072	0.070	0.070
Overall environmental impact	Pt	18.00	15.74	16.21	16.42	16.25

a) = Electricity efficiency improvement

b) = Improvement of ammonia storage and preparation

c) = Reduction in DAP use

d) = Substitution of diesel with LPG

In this study, results from the LCA were used to identify and prioritize the important activities (electricity use, and ammonia use in this study) associated with the environmental impact. All of the presented CT options presented were technically and practically feasible for concentrated latex production.

Dunuwila et al. studied a Sri Lankan crepe rubber mill. The study consisted in three steps: 1. quantification of factory's economic loss and environmental impacts, 2. proposal of reduction options; and 3. benefit validation. The approach was gate-to-gate and the functional unit was 1 ton of dry rubber. The results agree with the previous study in regards to the global warming potential (GWP): the energy consumption was the most contributing factor to GWP. It was found that the plant could reduce its GWP by up to 2% by the efficient use of fresh water (by fixing leakages, improving monitoring and install a water recirculation cooling system), chemicals (improving the monitoring) and electricity (replacing old lamps with LED ones, since replacing old machinery was not an option due to high capital costs)[14].
Vidanagama et al. studied rubber the emissions and climate impacts related to plantations, raw rubber processing, and rubber product manufacturing process in Sri Lanka. The approach was cradle-to-gate, and the functional unit was 1 ton of dry rubber. Once again, the main emitting factor was the energy use. In this study, it was found that the factories had already started improving the energy-efficiency of their processes, and the main suggestions

were the improvement of the supply chain around the factories, switching from diesel to biodiesel for transporting and switching to renewable energy sources (such as biomass)[15].

3.2 Rubber gloves production (Malaysia)

Poh et al. studied the inventory analysis and impact assessment of a nitrile-butadiene rubber glove manufacturing industry (NBR) in Selangor, Malaysia. The functional unit was defined as 1kg of produced NBR gloves, and the approach was cradle-to-gate[16].
Figure 3 shows the input - overall flow - output block diagram of the NBR glove manufacturing process. Former cleaning (reuse from the previous batch of gloves production) is carried out followed by coagulant dipping for adhesive improvement. Then, NBR rubber dipping and gelling to form a film of latex, followed by leaching and beading, drying and vulcanization to increase the mechanical properties of NBR gloves, cooling, chlorination, then post-leaching and drying, stripping and inspection for the production quality, and lastly packaging for distribution to the end consumers take place.

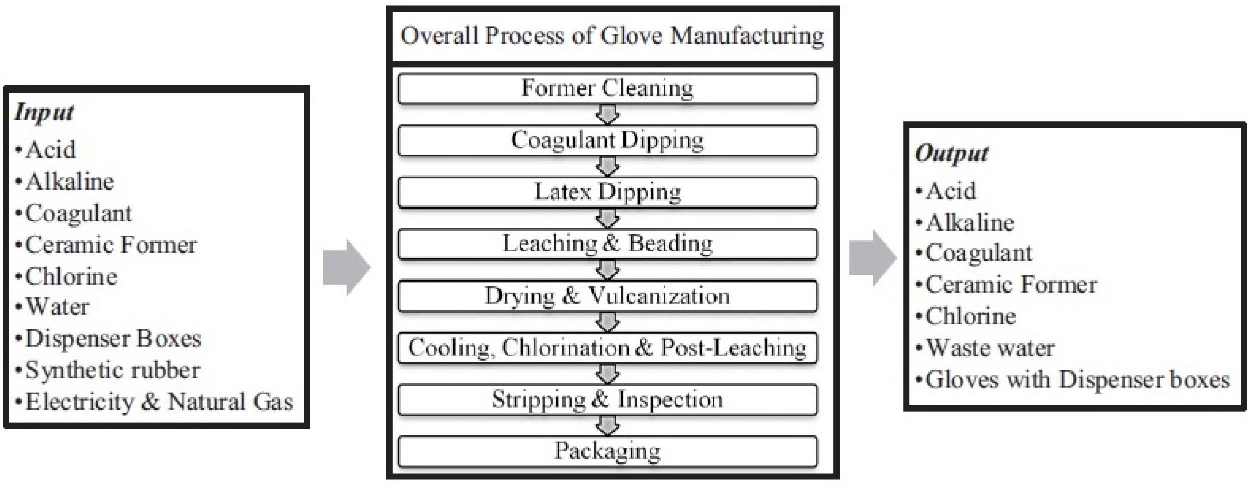

Figure 3: Simplified block diagram of rubber glove manufacturing, showing input, overall flow and output.

Table 4 presents the inventory vectors (matrix A and B) for the base case scenario. Note that negative flows in the table indicate the inputs of the resources. Throughout the base case study, utilities such as commercial electricity for heating purpose contributed as the largest impact towards the environment, and also required the highest cost.

Five alternatives (Alt) were proposed in order to reduce the energy consumption for heating:

- Alt. I – wastewater recycle use to produce steam with heavy fuel oil (HFO).
- Alt. II – wastewater recycle use to produce steam with diesel
- Alt. III – wastewater recycle use to produce steam with biodiesel
- Alt. IV – solar energy

Table 4: The inventory vectors for the studied case.

	Electricity generation	Natural gas generation	Acid presynthesis	Alkaline presynthesis	Coagulant presynthesis	Synthetic rubber presynthesis	Chlorine presynthesis	Ceramic former	Cleaning process	In process	Packag-ing
Matrix **A**											
Electricity [MJ]	1	−0.18886	−0.9501	−98.0916	−0.21327	−0.378	−11.15351	−4.39	−368.424	−403.308	−0.036
Natural gas [kg]	0	1	0	0	0	0	0	0	0	−10.57	0
Acid [kg]	0	0	1	0	0	0	0	0	−2.105	0	0
Alkaline [kg]	0	0	0	1	0	0	0	0	−2.62	0	0
Coagulant [kg]	0	0	0	0	1	0	0	0	0	−4.689	0
Synthetic rubber [kg]	0	0	0	0	0	1	0	0	0	−100	0
Chlorine [kg]	0	0	0	0	0	0	1	0	0	−3.407	0
Ceramic former [kg]	0	0	0	0	0	0	0	1	−22 000	0	22 000
Former [kg]	0	0	0	0	0	0	0	0	22 504	−22 504	0
Gloves with former [kg]	0	0	0	0	0	0	0	0	0	22 100	−22 100
Matrix **B**											
Gloves with boxes [kg]	0	0	0	0	0	0	0	0	0	0	110.5
Direct water [kg]	0	0	0	0	0	0	0	0	0	−986.405	0
Indirect water [kg]	0	−0.08828	−0.30568	−217.24	−0.47705	−6	−24.58861	−1.6284	0	0	0
CO [g]	0.041547	3.68272	0.47506	0.38168	0	0.19	0	0.06	0	0	0
NO_x [g]	0.241317	0.18886	0	5.34351	0	0.583	0.58703	0.1	0	0	0
PM10 [g]	0.015008	0.00000	0	0.38168	0	0.023	0	0.02	0	0	0
SO_2 [g]	0.191455	0.09443	0.47506	9.16031	0	0.0226	1.17405	0.03	0	0	0
VOC [g]	0.004794	0.18886	0	0	0	0.143	0	0.06	0	0	0
CO_2 [kg]	0.180763	0.12417	0.03135	3.84008	0.01621	0.148	0.43469	0.09256	0	0	0

- Alt. V – recover of wastewater thermal energy with heat exchanger

Table 5 shows the comparison of the potential effect on several environmental impacts resulting of the implementation of each alternative. The negative values indicate lower environmental impact than the base case scenario.

Table 5: The impact of each suggested alternative on the studied indicators.

	GWP/CF [%]	*AP* [%]	*POFP* [%]	*EP* [%]	*HTP* [%]	*WF* [%]
Base	0	0	0	0	0	0
Alt. I	37.14	6.35	138.7	−15.7	−6	2.86
Alt. II	2.48	−38.19	29.73	−38.34	−34.84	4.72
Alt. III	−12.25	−40.48	−28.92	−33.56	−20.78	2.26
Alt. IV	406970	27163	941296	25666	71307	20623
Alt. V	−8.69	−11.72	−8.74	−11.07	−10.98	0
Best Alt.	III	III	III	II	II	V

- Global warming (GWP)
- Carbon footprint (CF)
- Acidification (AP)
- Photochemical ozone formation (POFP)
- Eutrophication (EP)
- Human toxicity (HTP)
- Water footprint (WF)

It can be seen that despite having a small increase in water footprint, alternative 3 (biodiesel) is the best way to reduce most environmental impacts, as well as alternative 5 (reuse of heat exchanger water).

3.3 Discussion

The four LCAs in rubber and rubber gloves production have found that the highest environmental impact corresponds to the high use of electrical energy in wet processing and

transport. The presented solutions tackled exclusively the mentioned problem, and they all go towards the use of cleaner sources of energy (particularly biodiesel) as well as reducing waste in the plant.
Unfortunately, the literature for disposable latex objects (such as condoms, balloons and rubber gloves) is very limited. The performed LCAs are either cradle-to-gate or gate-to-gate, and no data could be found about end-of-life and adequate disposal of such goods.

4 Mylar Balloon

Mylar balloons, also known as foil balloons, are balloons made of a polyester called BoPET - or bi-axially oriented polyethylene terephthalate. This material is used because of its gas barrier properties: a Mylar balloon filled with gas deflates very slowly such that it is still usable after several weeks. The balloons are sometimes coated with aluminium to enhance the reflective property of the balloon, making them more appealing to the eye and to produce an impermeable layer.

4.1 Manufacturing process of Mylar balloons

BoPET is manufactured by drawing PET (figure 4) such that it obtains the desired biaxial orientation. Once drawn, the film is crystallized under tension under a temperature of roughly 220°C. This heat treatment prevents the material to regain its former shape as well as locks the desired orientation of the molecules. Surface rougheners are added in the production to prevent adhesion of the film to itself such as silicon dioxide[17].

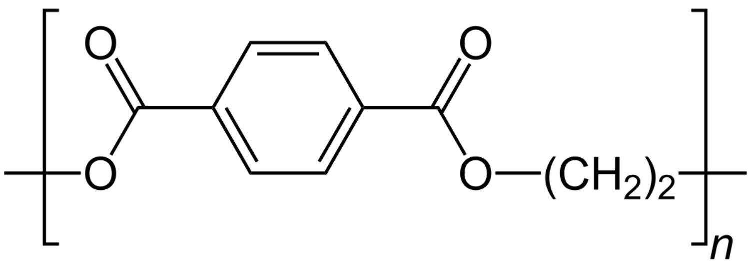

Figure 4: Chemical structure of the ethylene terephthalate monomer.

BoPET is initially highly transparent. This material can be metallized by vapor deposition of gold, aluminium, or other metals. The film becomes highly reflective as well as practically impermeable to gases.

5 The functional unit

A functional unit's purpose is to make it easier for the user to define statistics, or in this case materials, to be able to compare these more fairly. For example, when comparing a company's electricity consumption, one could compare different companies' electricity consumption per employee in the company. The functional unit becomes the employee. However, maybe the choice of this unit is unfair towards other companies; they would perhaps rather like to be compared with respect to the total value of the company, giving rise to a completely new functional unit. As an example, table 6 shows how different functional units show different properties.

	Company A	Company B
Electricity Consumption	10.000 Wh	10.000 Wh
Number of Employees	20	100
Consumption/Employee	500 Wh	100 Wh
Company Value	€1.000,00	€500,00
Consumption/Company Value	10 Wh	20 Wh

Table 6: Example of how a functional unit can skew results.

Table 6 shows how, when choosing a different functional unit, either company B is more ecological (when looking at employee count) or company A is more ecological (when looking at the company value). This shows that defining the correct functional unit depends on a multitude of factors, and every different functional unit highlights a different property of the compared entities.

5.1 Defining the functional unit for this problem

Depending on the function of the objects that will be used, the correct unit has to be chosen. The function for which the balloons are used in the OdeGand festival are for advertisement purposes, so the surface area of the balloons is of importance. Balloons also give an atmosphere of festivities but as this can hardly be put in a unit, a mental note of this will be taken when using the objects.

The main functional unit that will be used for comparison will be the surface area, as this is the main objective of the balloons that are used during the OdeGand festival.

5.2 Application

Different materials can be used for advertising purposes. Standard advertisement materials are, as discussed above, the balloons. These balloons can be made of synthetic rubber, natural rubber and Mylar. Other materials that are in high demand for advertisement are cardboard, high density polyethylene (HDPE) for billboards, and vinyl banners made of polyvinyl chloride (PVC).

If for 1 m^2, 1 kg is used as material, an equivalency can be made between surface area and mass (because it is the total amount of material produced that leaves a footprint, not the surface area). This mass per surface area can then be converted into ecological units, such as CO_2 per unit surface area emitted, or energy per unit surface area consumed.

Values have to be updated because of the shape of the material. As an example, a balloon, with a surface area of one square meter, will never use its full surface area for its purpose because the top and bottom parts of the surface do not function as well as the rest of the surface. As another example, a banner can be used on both sides, effectively halving the total cost related to surface area. Because of this, a factor is introduced called the surface factor *f*. This factor is used to change the mass per surface area to an effective surface area, see table 7.

Table 7: Mass per square meter of the materials compared, the surface factor *f*, and the final mass used in comparisons.

Materials used	**Mass [kg/m²]**	**Surface factor *f* [-]**	**Mass / *f* [kg/m²]**
Natural Rubber	0.04	0.7	0.057
Synthetic Rubber	0.04	0.7	0.057
Mylar	0.21	1	0.21
Cardboard	0.68	2	0.34
HDPE	2.2	2	1.1
PVC	0.51[18]	2	0.26

Table 8: Comparison between materials with respect to carbon dioxide emissions per square meter and energy consumption per square meter, as found through CES EduPack.

Materials used	**Mass [kg/m²]**	**CO_2 emission [kg CO_2/m²]**	**Energy [Wh/m²]**
Natural Rubber	0.057	0.11	1230
Synthetic Rubber	0.057	0.09	1021
Mylar	0.21	0.94	4833
Cardboard	0.34	0.34	4354
HDPE	1.1	3.08	24020
PVC	0.26[18]	0.74	4263

Comparing the results in table 8 in terms of carbon emitted and energy consumed per square meter, synthetic rubber seems to be the best option. The HDPE alternative is by far the worst one compared. This is also due to the fact that a high mass is needed to have a square meter worth of material.

However, cardboard is recyclable, and non-balloon materials could easily be reused for advertisement purposes over the years as opposed to balloon materials. The balloon material would degrade faster over time. Calculations were not made with an eye on recycled materials, nor on reuse of the advertisement banners. If banners could be reused for a couple years, it seems cardboard would surpass the emissions of carbon and energy consumption after 4 years of use. Using cardboard that was recycled could prove even more advantageous, surpassing the emissions and energy consumption in an even shorter period.

6 Code of conduct for Balloon release by NABAS

National association of balloon artists and suppliers (NABAS) has put some code of conducts that should be followed while releasing balloons in the environment[19].

- Only the Balloons made from natural latex rubber should be used for the release to the environment as the balloons made from the other materials are not degradable.
- Any material used in the balloons release should be biodegradable or recyclable, such as labels attached should be made of recyclable paper.
- Only helium gas should be used to inflate the balloons as the helium is lighter than air. As the balloons rise then the gas expands causing the balloons to burst into the pieces which will be helpful in its decomposition.
- Balloons should be released singly, because single balloons disperse quickly and easily. They should not be tied together during the release.
- If releasing more than 5 thousand balloons then approval must be obtained from the relevant air traffic and local authorities. They should be informed 28 days prior to the release.
- Balloon larger than 12 inch cannot be released.
- Weights should be attached to the balloons being sold in order to avoid their escape.

7 Conclusion

For the OdeGand festival, different materials were compared by using a functional unit. This functional unit was the surface area of the material in use, because the objects existed for advertisement purposes. The use of balloons made from either synthetic or natural rubber are decent choices for carbon emissions or energy consumption when comparing with this functional unit. Although the natural rubber when disposed correctly will prove to be more eco-friendly since it degrades at a faster rate. Reuse of the objects could make cardboard a better option after a mere 4 years. This comparison was made without holding recycling into account. If the cardboard were recycled, the cardboard could become environmentally better over an even shorter period.

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