Metadata

Screening LCAs for Single-use plastics (SUPs) and their substitutes in the thirteen SMEP countries

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Selection of plastic products and their substitutes

All substitute products were selected from the list published by SMEP/UNCTAD: Harmonized System (HS) subheadings for plastic substitutes. Concerning the mineral substitutes, the choice was made considering the significance of production, based on INDSTAT 4 2022 (UNIDO, 2022b), supplemented by exports data based on Trade Map (ITC, n.d.). Regarding the substitutes based on dedicated crops and agriculture by-products, the choice was made considering the significance of production according to the FAOSTAT (FAO, n.d.). Once the substitutes were chosen, the products to be substituted were defined as products made with plastic raw materials that perform the same function as the substitutes and are commonly found in the market. Table 1 presents a list of the substitute and plastic products encompassed in the study.

Table 1: Substitute and plastic products chosen for each of the SMEP countries

Country	Substitute product	Rationale	Plastic product
Bangladesh	Jute bag	Single yarn of jute or other textile bast fibres (HS Rev.8 code 530710) is the second product in terms of exported quantity in Bangladesh (Trade Map, 2021) and jute is the twelfth primary product from crops in terms of produced quantity (FAOSTAT, 2020).	HDPE* Bag
Nepal	Areca leaves plate	Areca is the 44th primary product from crops in terms of produced quantity, being the second SMEP country that most produces this agriculture product (FAOSTAT, 2020).	EPS** Plate
Pakistan	Cotton bag	Preparation and spinning of textile fibres (ISIC Rev.4 four-digit code 1311) is the main productive activity in factor values in Pakistan (INDSTAT 4, 2016). Single yarn of cotton, of uncombed fibres, containing >= 85% by weight of cotton and having a linear length (HS Rev.8 code 520512) is the 7th product in terms of exported value (Trade Map, 2021).	HDPE Bag
Democratic Republic of Congo	Glass cup	Glass and glass products (ISIC Rev.4 four-digit code 2610) are the fourth main productive activity in factor values in the Democratic Republic of Congo (INDSTAT 4, 2008).	EPS cup
Ethiopia	Wheat stem straw	Grain mill products (ISIC Rev.4 four-digit code 1531) constitute the second productive activity in factor values in Ethiopia (INDSTAT 4, 2013) and wheat is the third primary product from crops in terms of produced quantity (FAOSTAT, 2020).	PP*** straw
Ghana	Aluminium cup	Basic precious and other non-ferrous metals (ISIC Rev.4 four-digit code 2420) are Ghana's second main productive activity in factor values (INDSTAT 4, 2013).	EPS cup
Kenya	Banana leaves plate	Bananas are the fourth primary product of crops in terms of produced quantity in Kenya (FAOSTAT, 2020).	PS**** plate
Nigeria	Coconut fibre container	Coconuts are the 36º primary product from crops in terms of produced quantity, and Nigeria is the fourth SMEP country that produces the most of this agricultural product (FAOSTAT, 2020).	PP container
Rwanda	Glass bottle	Glass and glass products (ISIC Rev.4 four-digit code 2310) are Rwanda's ninth main productive activity in factor values (INDSTAT 4, 2014).	PET***** bottle
Senegal	Paper straw	Paper and paper products (ISIC Rev.4 three-digit code 170) are Senegal's 8th main productive activity in factor values (INDSTAT 4, 2019).	PP straw
Tanzania	Sisal bag	Sisal is the 43rd primary product from crops in terms of produced quantity, and Tanzania is the SMEP country that produces the most of this agriculture product (FAOSTAT, 2020).	HDPE Bag
Uganda	Plantain leaves plate	Plantains and others are the first primary product from crops in terms of produced quantity in Uganda (FAOSTAT, 2020).	PS plate
Zambia	Paper bag	Paper and paper products (ISIC Rev.4 three-digit code 170) are the third productive activity in factor values in Zambia (INDSTAT 4, 2015).	HDPE bag

Notes: * HDPE: High-density polyethylene.
** EPS: expanded polystyrene.
*** PP: polypropylene.
**** PS: polystyrene
***** PET: polyethylene terephthalate

Description of the products

Table 2 presents a detailed description of each encompassed substitute and plastic product by country.

Table 2: Description of substitute and plastic products selected for each of the SMEP countries

Country	Substitute product	Description	Plastic product	Description
Bangladesh	Jute bag	30 x 40 cm jute fabric body with two cotton webbing handles (50 cm each). Grammage of jute fabric: 360g/m^2. Grammage of cotton webbing: 15g/m.	HDPE Bag	30 x 40 cm HDPE body with two handles. Weight: 4.40 g.
Nepal	Areca leaves plate	23 cm round plate. Weight: 36.7 g.	EPS Plate	23 cm round plate. Weight of 5.6 g.
Pakistan	Cotton bag	30 x 40 cm cotton fabric body with two cotton webbing handles (50 cm each). Grammage of cotton fabric: 220g/m^2. Grammage of cotton webbing: 15g/m.	HDPE Bag	30 x 40 cm HDPE body with two handles. Weight: 4.40 g.
Democratic Republic of Congo	Glass cup	300 ml cup. Weight: 170 g.	EPS cup	300 ml cup. Weight: 2.4 g.
Ethiopia	Wheat stem straw	4mm straw with 20 cm length. Weight: 0.6 g.	PP straw	5 mm straw with 21 cm length. Weight: 0.41 g.
Ghana	Aluminium cup	300 ml cup. Weight: 30 g.	EPS cup	300 ml cup. Weight: 2.4 g.
Kenya	Banana leaves plate	19 cm round plate. Weight: 15 g.	PS plate	19 cm round plate. Weight: 4.1 g.
Nigeria	Coconut fibre container	Rectangular pot with a lid. Capacity: 250 ml. Weight: 18.2 g.	PP container	Rectangular pot with a lid. Capacity: 250 ml. Weight: 8.8 g.
Rwanda	Glass bottle	1 l bottle. Weight: 461 g. Cap is not included.	PET bottles	1 l bottle. Weight: 32 g. Cap is not included.
Senegal	Paper straw	6 mm straw with 20 cm length. Weight: 1.26 g.	PP straw	5 mm straw with 21 cm length. Weight: 0.41 g
Tanzania	Sisal bag	30 x 40 cm sisal fabric body with two cotton webbing handles (50 cm each). Grammage of sisal fabric: 950g/m^2. Grammage of cotton webbing: 15g/m.	HDPE Bag	30 x 40 HDPE body with two handles. Weight: 4.40 g.
Uganda	Plantain leaves plate	19 cm round plate. Weight: 15 g.	PS plate	19 cm round plate. Weight: 4.1 g.
Zambia	Paper bag	30 x 40 cm kraft paper body with two kraft paper handles (32 cm each). Grammage of kraft paper: 220g/m^2.	HDPE bag	30 x 40 HDPE body with two handles. Weight: 4.40 g.

Functional units and reference flows

The functional units and reference flow considered are listed in Table 3.

Table 3: Functional unit and reference flows for the SUPs and substitutes analysed for the SMEP countries

Country	Functional unit	Substitute product	Reference flow	Plastic product	Reference flow
Bangladesh	"Carrying 5 kg of items in three year's shopping (156 purchases) from the supermarket to the home"	Jute bag	1 bag	HDPE Bag	156 bags
Nepal	"Serving an average meal"	Areca leaves plate	1 plate	EPS Plate	1 plate
Pakistan	"Carrying 5 kg of items in three year's shopping (156 purchases) from the supermarket to the home"	Cotton bag	1 bag	HDPE Bag	156 bags
Democratic Republic of Congo	"Serving 300 ml of liquid in working days in one year's use (252 uses)"	Glass cup	1 cup	EPS cup	252 cups
Ethiopia	"Drinking 300 ml of a generic liquid from a regular glass"	Wheat stem straw	1 straw	PP straw	1 straw
Ghana	"Serving 300 ml of liquid in working days in one year's use (252 uses)"	Aluminium cup	1 cup	EPS cup	252 cups
Kenya	"Serving an average meal"	Banana leaves plate	1 plate	PS plate	1 plate
Nigeria	"Carrying 250 ml of food from the takeaway to the home"	Coconut fibre container	1 container	PP container	1 container
Rwanda	"Holding 1 l of liquid consumed in one year's shopping (52 purchases) from the factory to the supermarket and then to the home"	Glass bottles	2,6 bottles	PET bottles	52 bottles
Senegal	"Drinking 300 ml of a generic liquid from a regular glass"	Paper straw	1 straw	PP straw	1 straw
Tanzania	"Carrying 5 kg of items in three year's shopping (156 purchases) from the supermarket to the home"	Sisal bag	1 bag	HDPE Bag	156 bags
Uganda	"Serving an average meal"	Plantain leaves plate	1 plate	PS plate	1 plate
Zambia	"Carrying 5 kg of items in three year's shopping (156 purchases) from the supermarket to the home"	Paper bag	156 bags	HDPE bag	156 bags

Additional scenarios were created for some of the single-use substitutes (areca leaves plate, wheat stem straw, banana leaves plate, coconut fibre container, and plantain leaves plate) to consider as many uses as necessary for their environmental performance to reach better status than the one from the plastic products being substituted.

System boundaries

The study is designed as a 'cradle-to-grave' LCA. Therefore, it includes the extraction and production of raw materials, converting processes, all transports, use, and the final disposal or recycling of the products.

Generally, the study covers the following steps:

− production and converting of the primary raw materials used in the production of the plastic and substitute products;

− use[1], recycling, and final disposal of the plastic and substitute products;

− material transports, final distribution from manufacturers to the point of sale, and transport to the disposal/recycling site.

[1] For bags made of natural fibers, one washing was considered every four months of use. For cups made of mineral products, one washing was considered for each use. For the glass bottle, 20 uses were considered before disposal and one washing was considered for each use. Reverse logistics (transport from the point of sale to the industry) was not included considering that it happens in the same trucks that carry out the product distribution on their way back. For the additional scenarios of the plates and straws made from dedicated crops or agricultural by-products, one washing was considered for each use.

Not included:

− production, recycling, and final disposal of transport packaging materials (e.g., pallets, cardboard trays);

− production and disposal of the infrastructure and their maintenance;

− environmental effects related to storage phases.

Figures 1-18 show the considered processes and stages for all the SUPs and substitutes assessed.

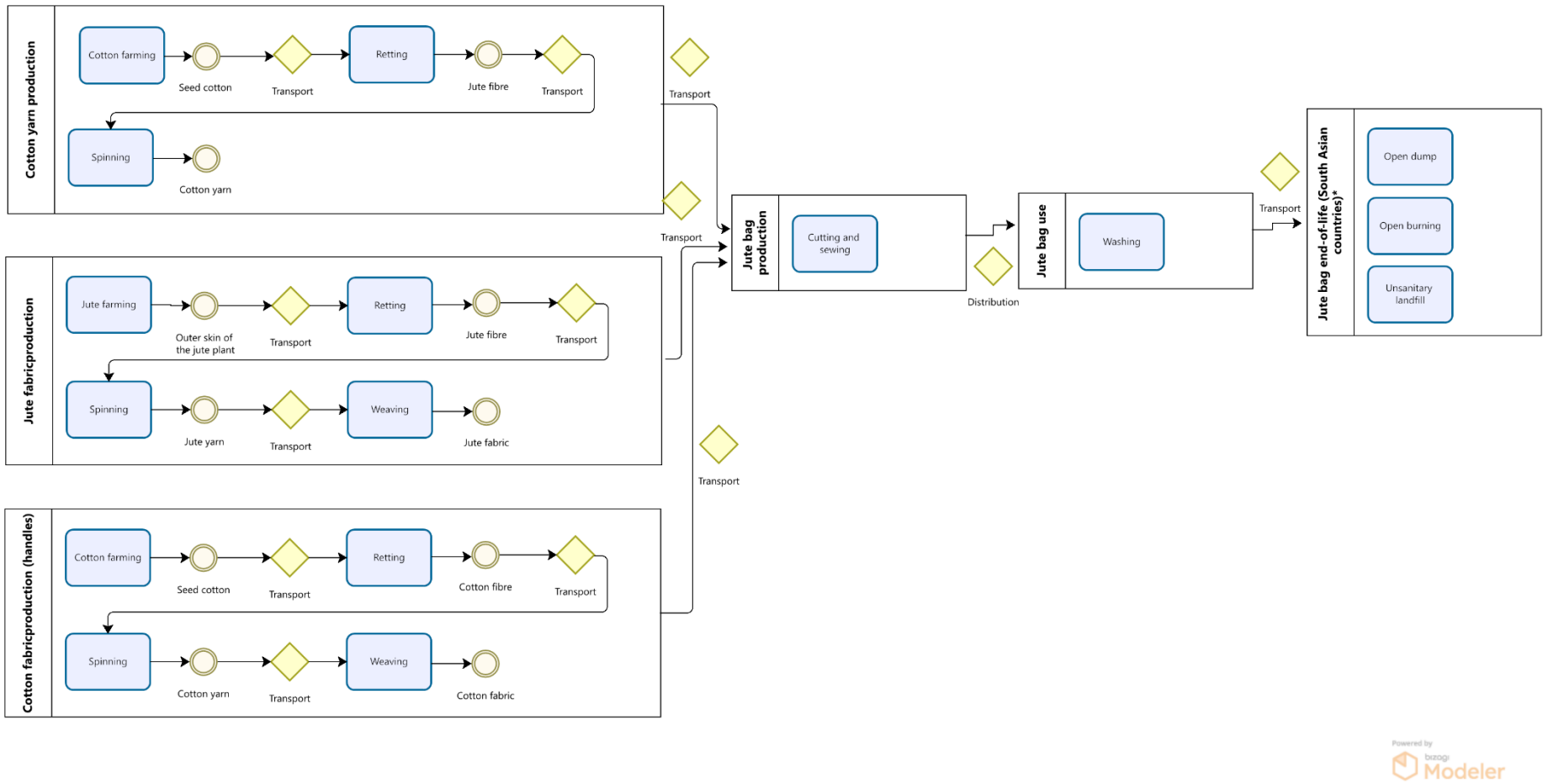

Figure 1: System boundaries: jute bag

*(Doka Life Cycle Assessments, 2018)

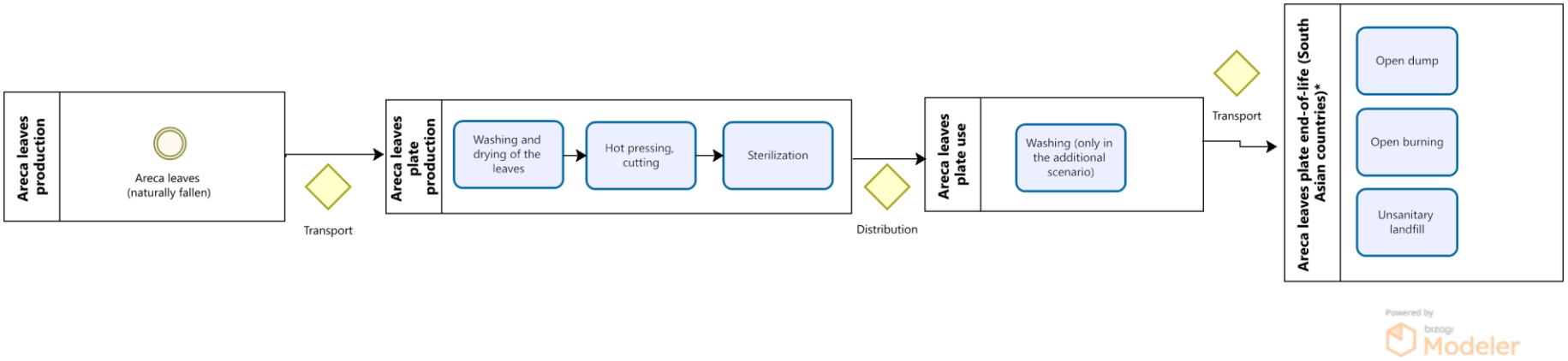

Figure 2: System boundaries: areca leaves plate

*(Doka Life Cycle Assessments, 2018)

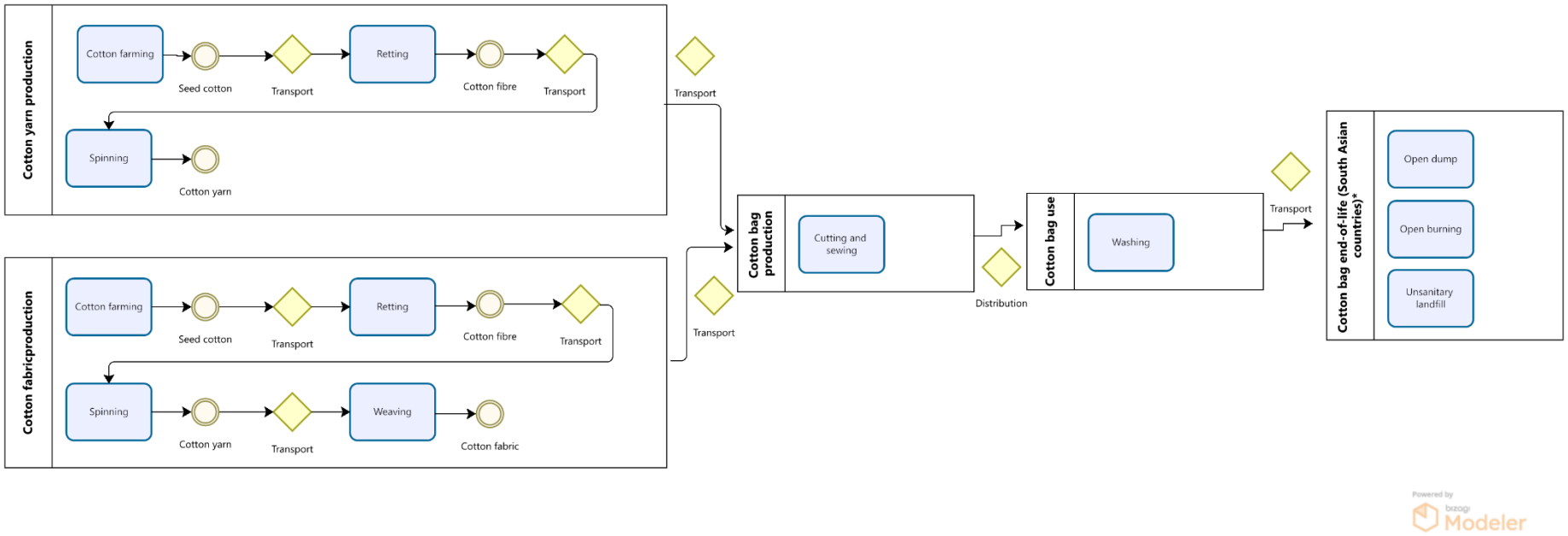

Figure 3: System boundaries: cotton bag

*(Doka Life Cycle Assessments, 2018)

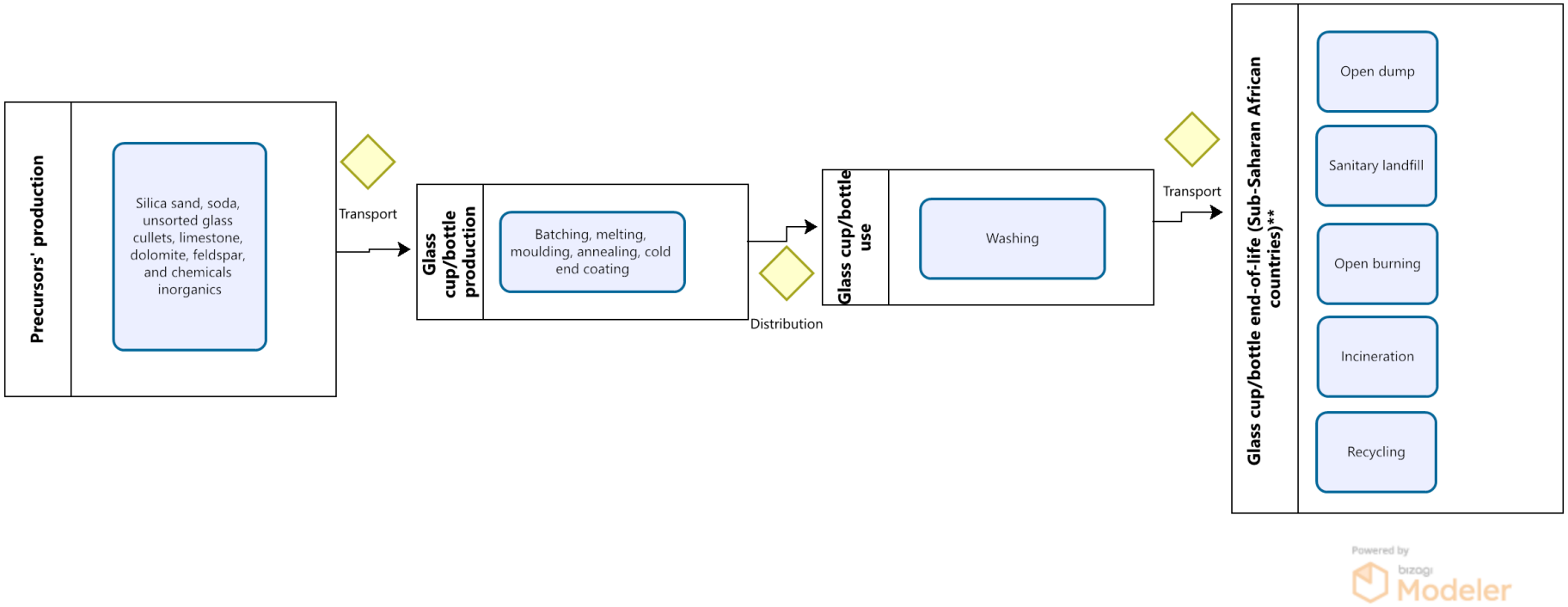

Figure 4: System boundaries: glass cup/bottle

***(The World Bank, n.d.; UNEP, 2018)

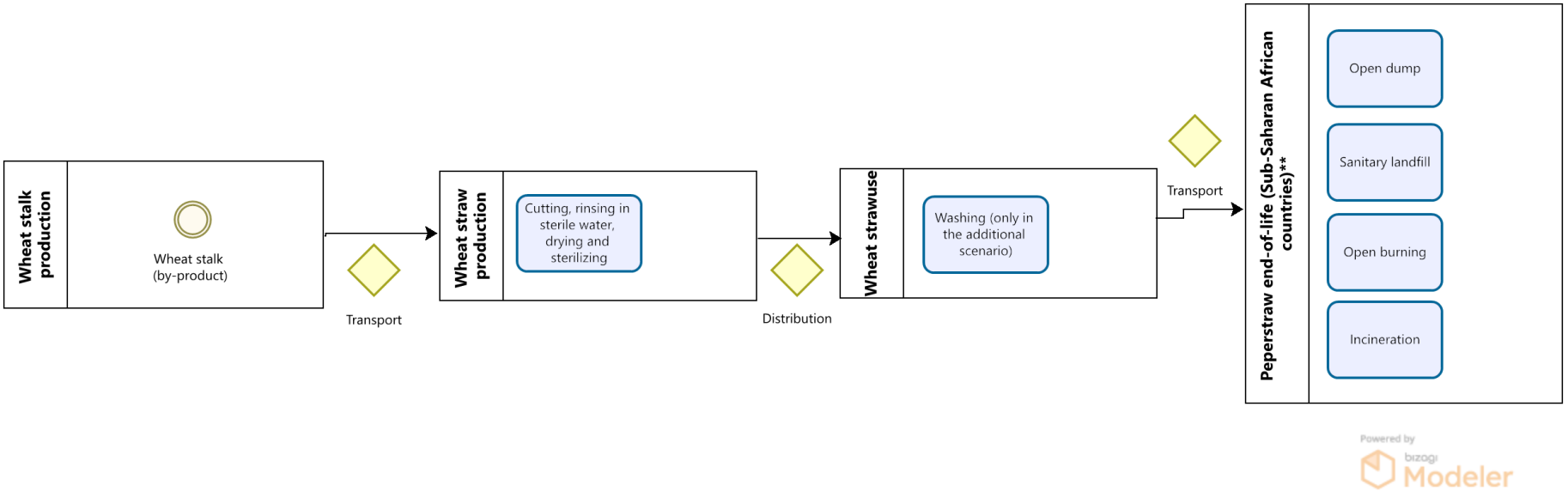

Figure 5: System boundaries: wheat stem straw

***(UNEP, 2018)

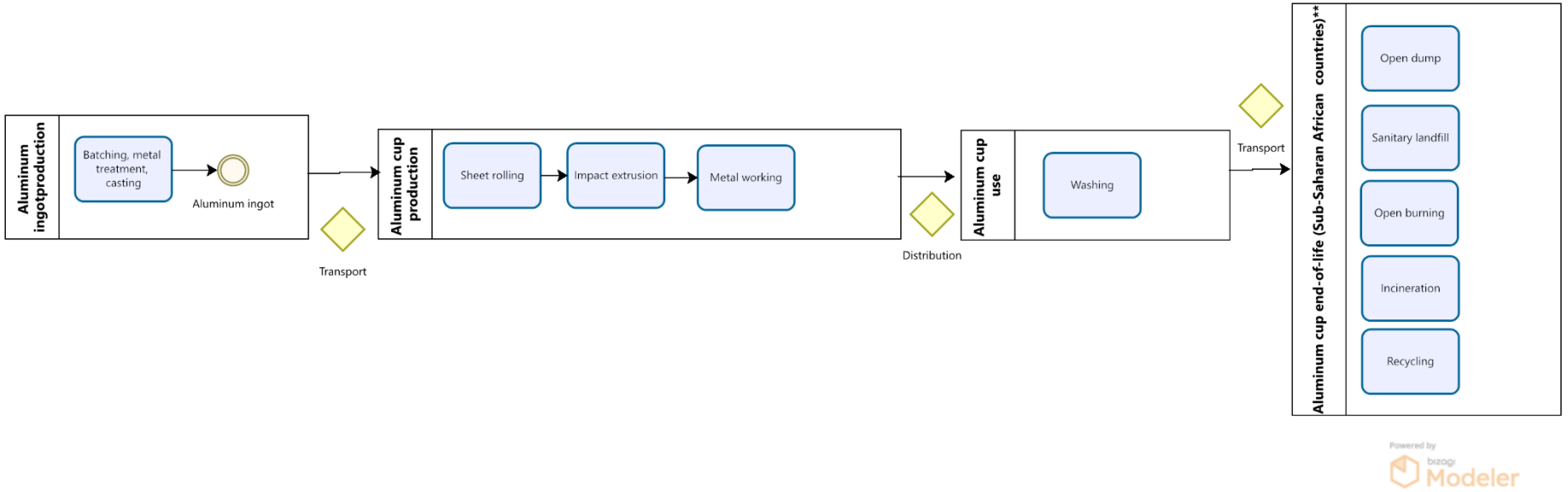

Figure 6: System boundaries: aluminum cup

**(UNEP, 2018)

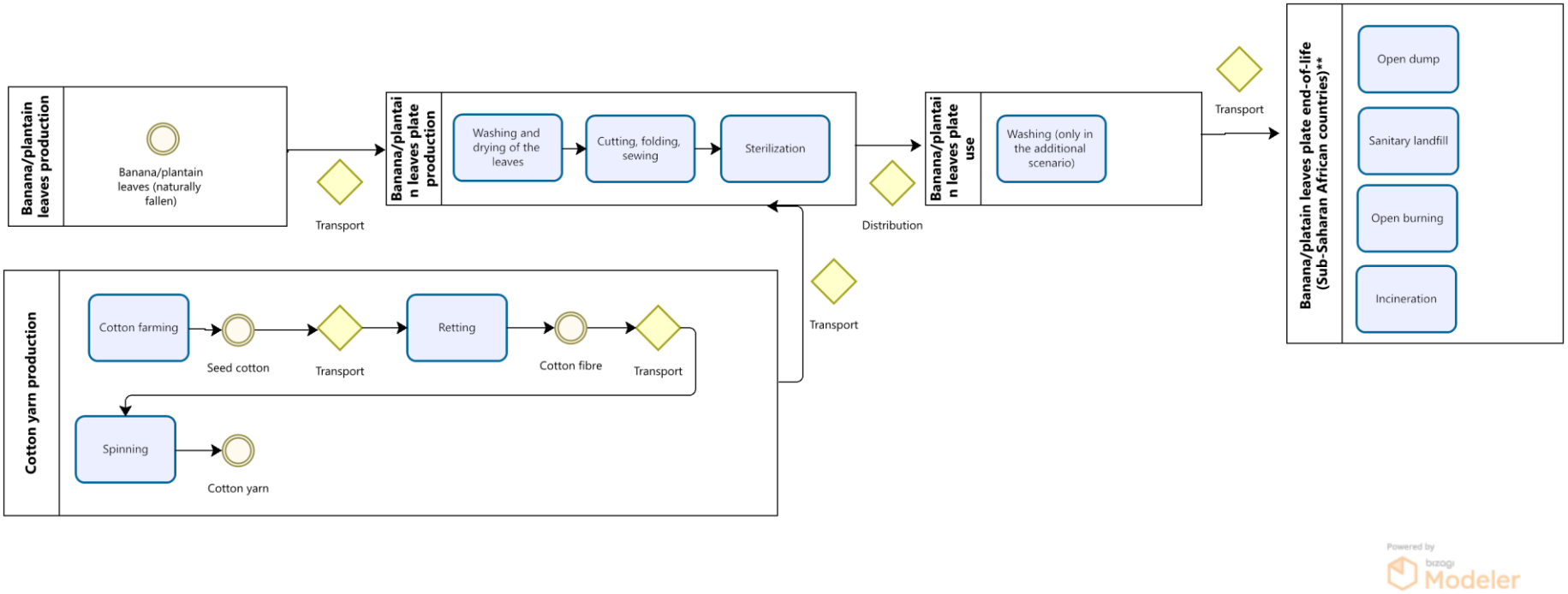

Figure 7: System boundaries: banana/plantain leaves plate

**(UNEP, 2018)

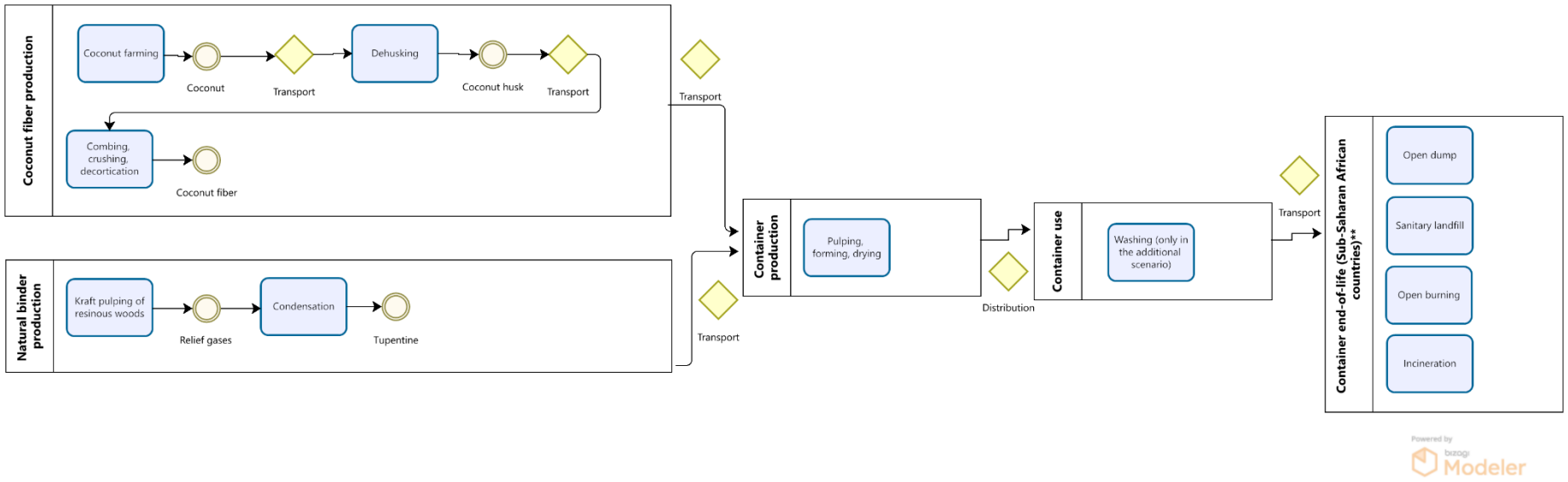

Figure 8: System boundaries: coconut fiber container

**(UNEP, 2018)

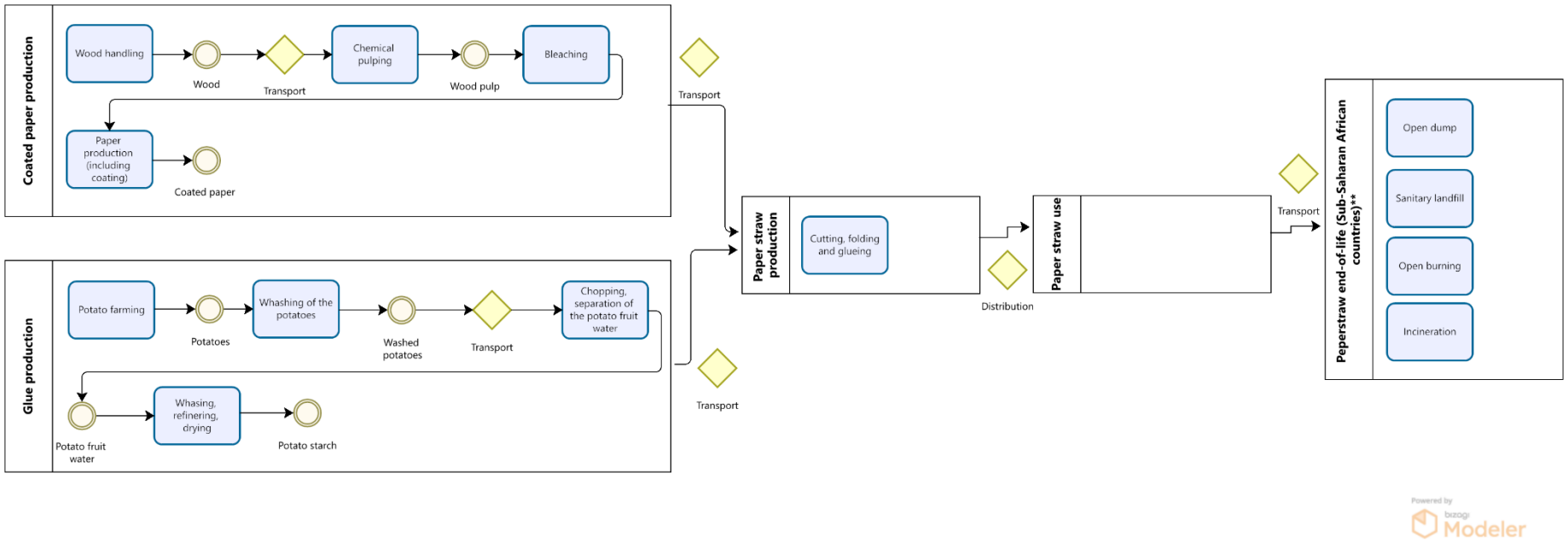

Figure 9: system boundaries: paper straw

***(UNEP, 2018)

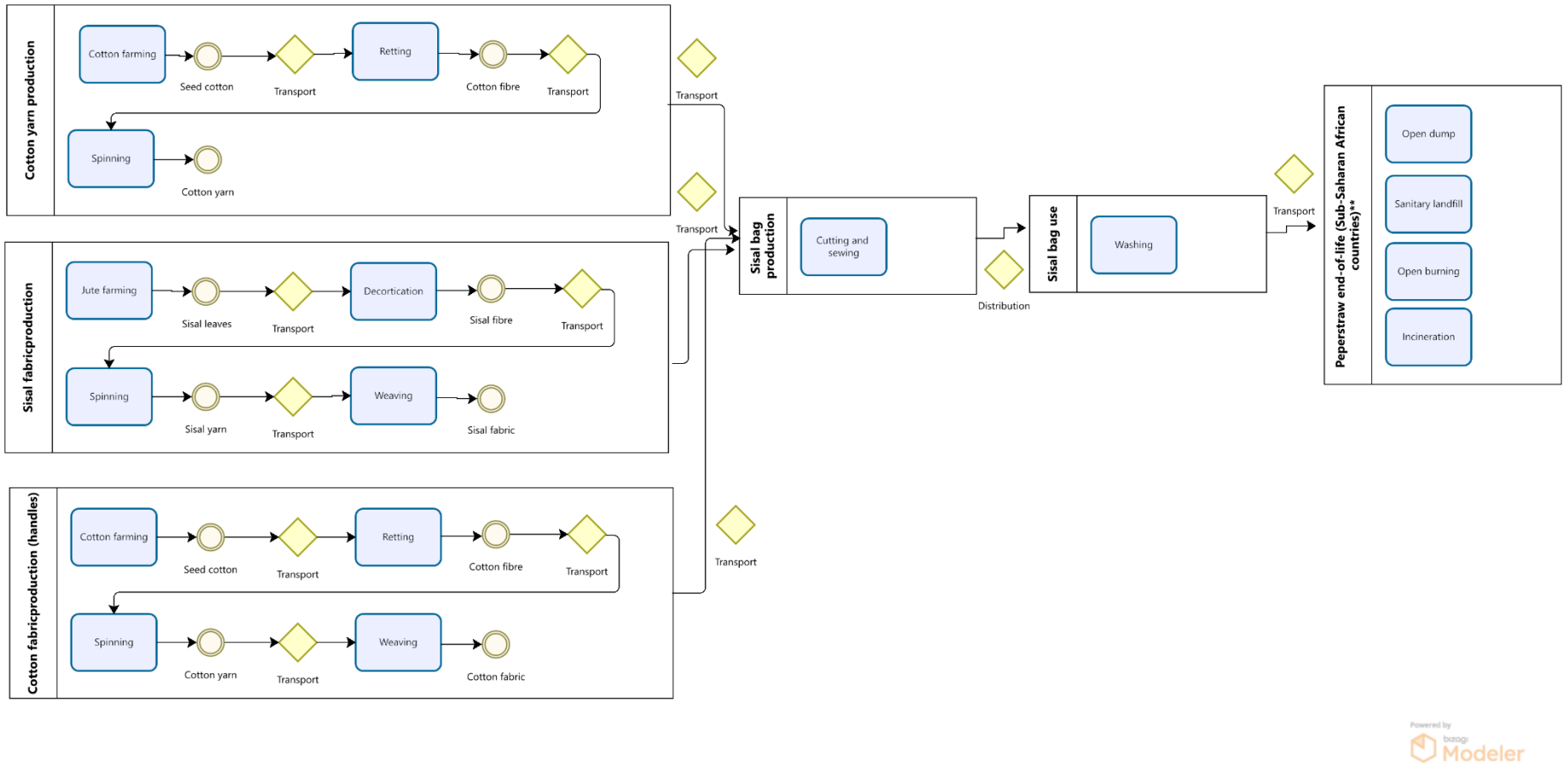

Figure 10: System boundaries: sisal bag

**(UNEP, 2018)

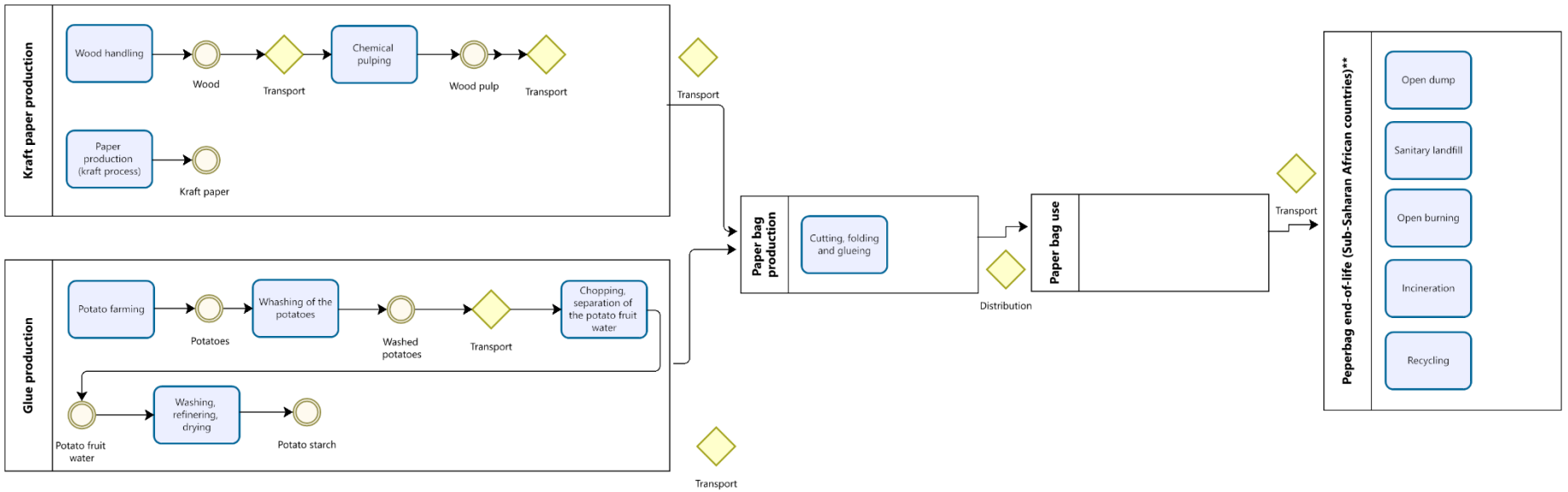

Figure 11: System boundaries: paper bag

***(UNEP, 2018; University of Leeds, n.d.)

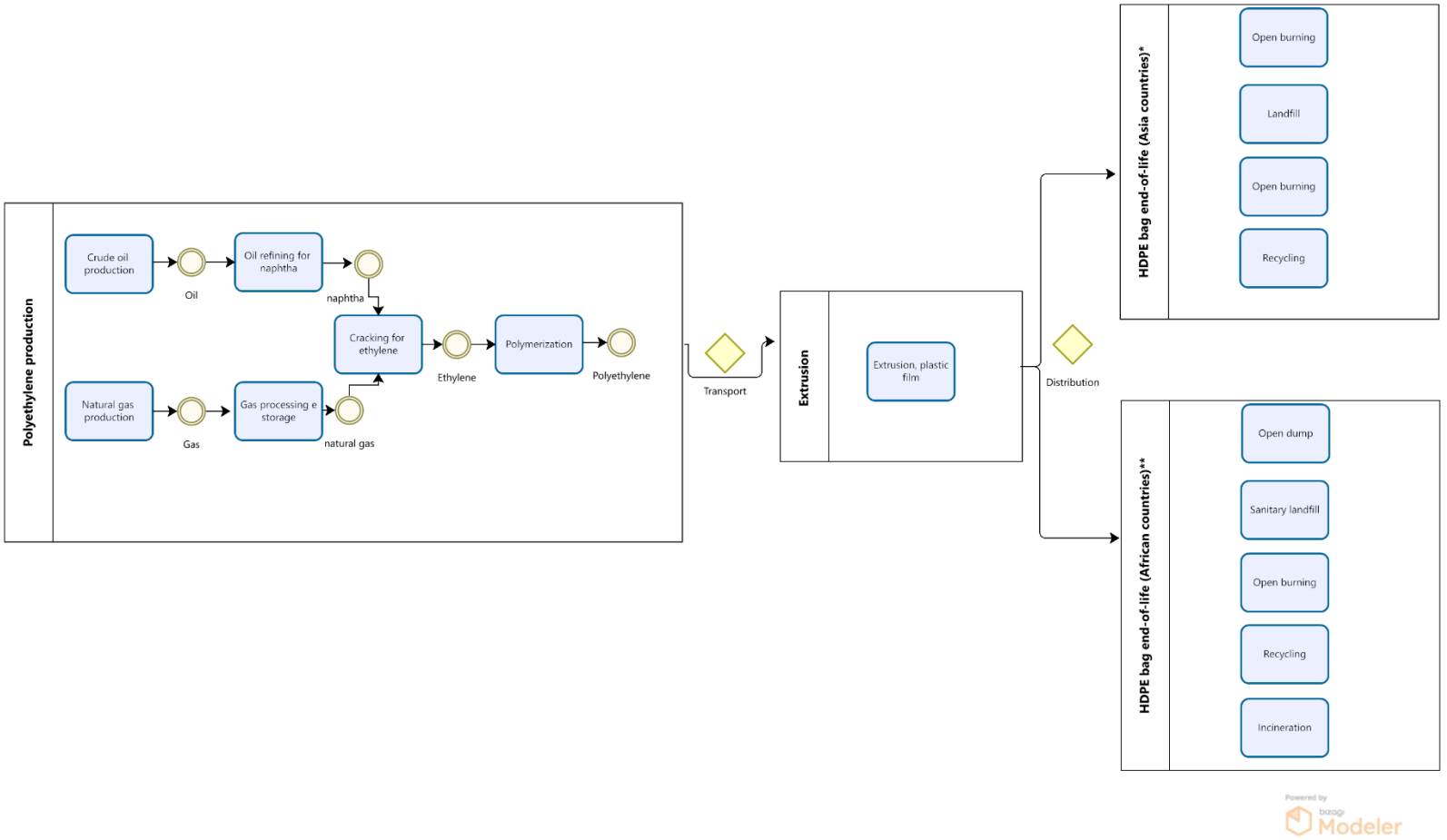

Figure 12: System boundaries: HDPE bag

*(Doka Life Cycle Assessments, 2018; The World Bank, n.d.; UNEP, 2017). **(UNEP, 2018; University of Leeds, n.d.)

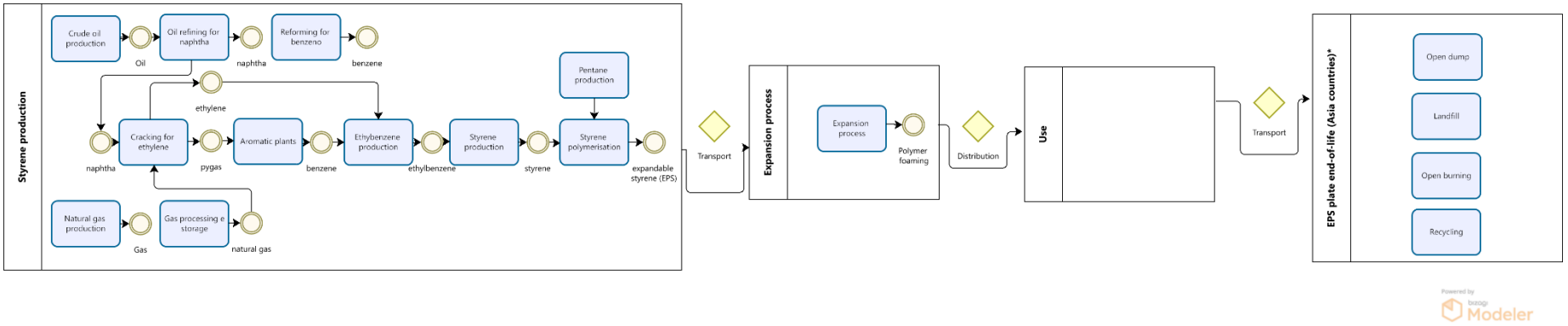

Figure 13: System boundaries: EPS plate

* (Central Bureau of Statistics Government of Nepal, 2021; Doka Life Cycle Assessments, 2018)

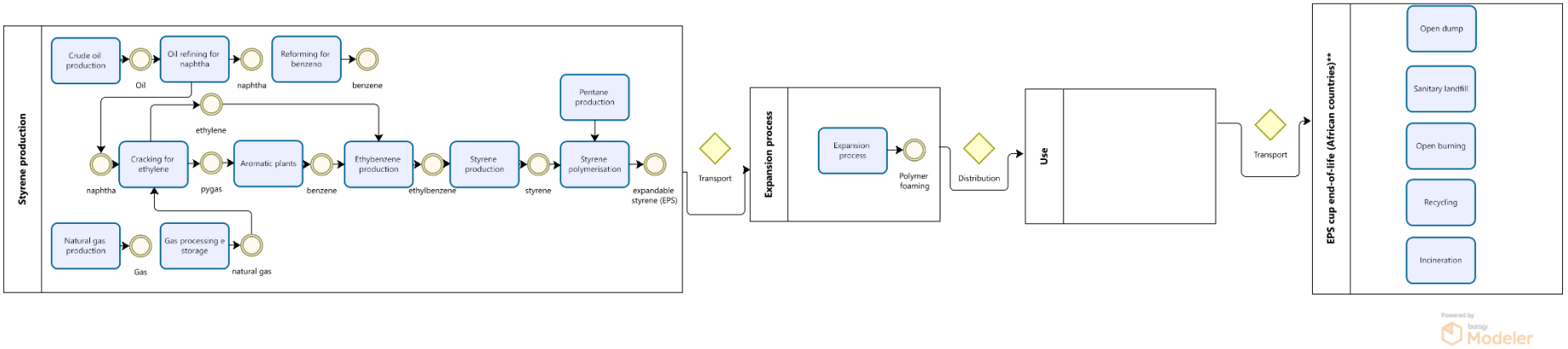

Figure 14: System boundaries: EPS cup

***(Global Plastic Action Partnership, 2021; The World Bank, n.d.; UNEP, 2018)

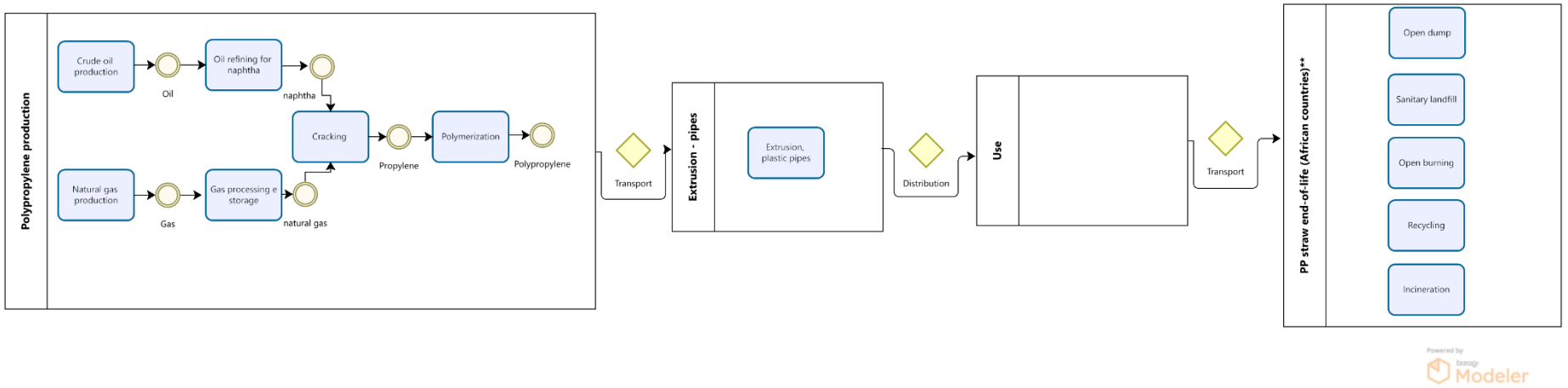

Figure 15: System boundaries: PP straw

***(OpenWASH, n.d.; UNEP, 2018)

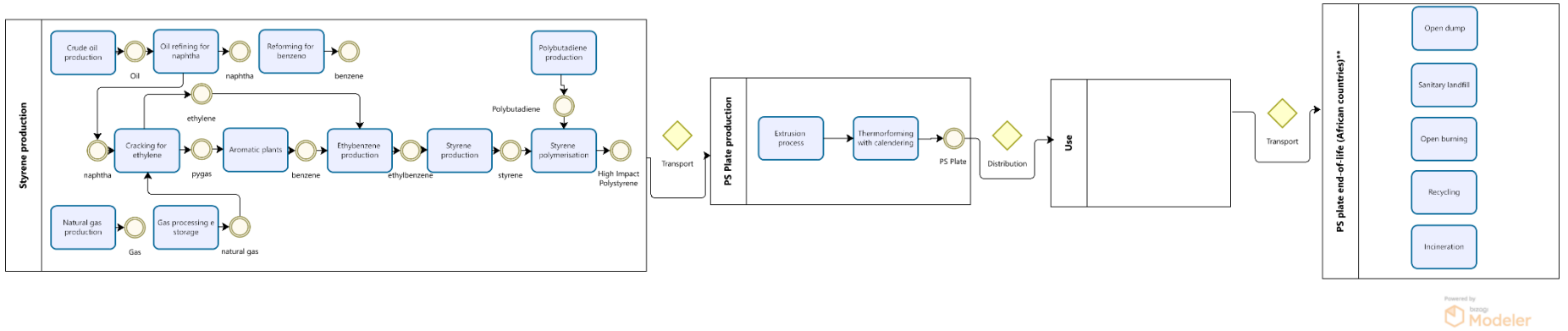

Figure 16: System boundaries: PS Plate

**(The World Bank, n.d.; UNEP, 2018)

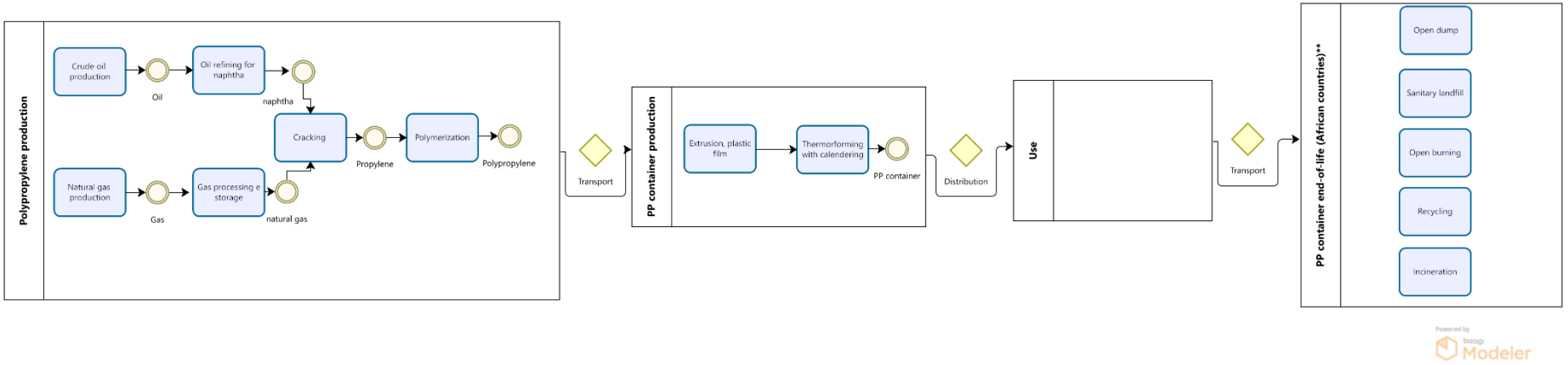

Figure 17: System boundaries: PP container

***(Ogwueleka & B P, 2021; UNEP, 2018)*

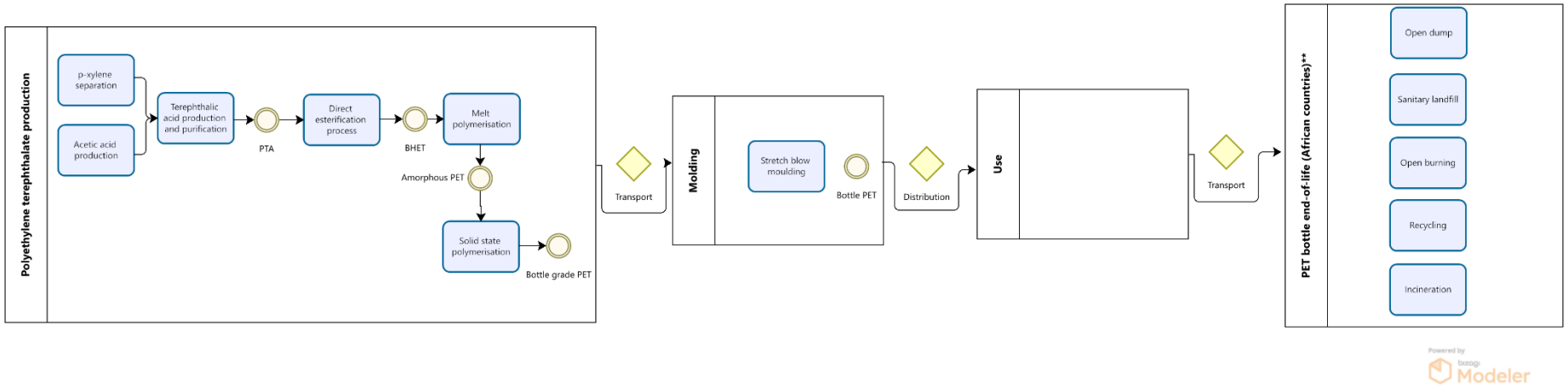

Figure 18: System boundaries: PET bottle

***(UNEP, 2018)

For substitute materials based on natural fibres originating from dedicated crops (coconut husks, cotton, jute, paper, sisal), the agricultural phase was considered, as far as this fibres are products/co-products with economic value.

For substitute materials based on natural fibres originating from agriculture by-products (areca and banana leaves and wheat stem), which can be defined as wastes, the agricultural phase was not considered, adopting a zero-burden approach[2].

Data gathering and data quality

The datasets used in this study are taken mainly from ecoinvent, supplemented by Agribalyse and secondary data based on literature, public information from industries/producers, and expert judgments. The general requirements and characteristics regarding data gathering and data quality are summarized in the subsequent paragraphs.

Geographic scope

The LCA study focuses on the production, distribution, and disposal of SUPs and substitutes consumed in the thirteen SMEP countries (Bangladesh, Nepal, Pakistan, Democratic Republic of Congo, Ethiopia, Ghana, Kenya, Nigeria, Rwanda, Senegal, Tanzania, Uganda, and Zambia).
Regarding the SUPs, production, import, and export data were used to define the amount of resin or final product being imported or produced locally/nationally (Table 4 and Table 6). Substitutes are assumed to be locally/nationally produced.

Table 4: Plastic resins - Production, exports, and imports data for the SMEP countries and rate of consumed resins assumed to be locally produced and imported

SMEP country	Production	Exports	Imports	Rate of consumed resins assumed to be locally produced	Rate of consumed resins assumed to be imported
Bangladesh*	117		463,821	0.00025	0.99975
Nepal*	0	0	0	0	1
Pakistan*	344,315	961,101	104,508	0.26376	0.73624
Congo (Kinshasa) *	0	0	0	0	0
Ethiopia*	0	0	87,116	0	1
Ghana**		4,301	205694	0	1
Kenya*		11,871	247,738	0	1
Nigeria*	0	0	1,325,083	0	1
Rwanda*	0	16	5,016	0	1
Senegal*	0	9,992	67,290	0	1
Tanzania*	0	0	0	0	0
Uganda**	0	0	1,443,505	0	1
Zambia**	0	0	896,827	0	1

Notes: * Thousand Dollars (2006) (UNIDO, 2022a)
** Tonnes (Babayemi et al., 2019)

[2] In a zero-burden assumption the activities that occurred prior to the generation or collection of the waste material, and consequently their environmental impacts, are left outside the system boundaries (Clift et al., 2000; Ekvall et al., 2007).

Table 5: Plastic products - Production, exports, and imports data for the SMEP countries and rate of consumed SUPs assumed to be locally produced and imported

SMEP country	Production	Imports	Exports	Rate of consumed SUPs assumed to be locally produced (national resin)	Rate of consumed SUPs assumed to be locally produced (imported resin)	Rate of consumed SUPs assumed to be imported
Bangladesh*	141,956	86,436	32,968	0.00014	0.55756	0.44230
Nepal*	117,786				1	
Pakistan*	440,421	197,325	106,509	0.16579	0.46277	0.37144
Congo (Kinshasa)*		13,958				1
Ethiopia*	86,607	43,784	107		0.66421	0.33579
Ghana*		73,013	47,377			1
Kenya*	120,526	69,765	84,256		0.63338	0.36662
Nigeria*		223,434	14,768			1
Rwanda*		9,094	258			1
Senegal*	105,156	44,007	23,241		0.70497	0.29503
Tanzania*	14,648	35,191	38,055			
Uganda**	1,443,505	505,236			0.74074	0.25926
Zambia**	896,827	609,749			0.59527	0.40473

Notes: * Thousand Dollars (2006) (UNIDO, 2022a)
** Tonnes (Babayemi et al., 2019)

Time scope

The reference time for the comparison of packaging systems is 2021. Where no figures are available for these years, the used data shall be as up-to-date as possible. Most of the applied data refer to the period between 2000 and 2021.

Technical reference

The process technology underlying the datasets used in the study reflects process configurations as well as technical and environmental levels which are typical for process operation in the reference period.

End-of-life assumptions

Waste disposal mixes for the Sub-Saharan African SMEP countries were taken from (UNEP, 2018), and for South Asian SMEP countries were taken from (Doka Life Cycle Assessments, 2018) (Table 6). Recycling rates were taken from (Central Bureau of Statistics Government of Nepal, 2021; Global Plastic Action Partnership, 2021; Ogwueleka & B P, 2021; OpenWASH, n.d.; The World Bank, n.d.; UNEP, 2017, 2018; University of Leeds, n.d.) (

Table 7).

Table 6: Waste disposal mixes considered for the SMEP countries (Doka Life Cycle Assessments, 2018)

SMEP country or region	Open dump	Open burning	Unsanitary landfill	Sanitary landfill	Incineration
Bangladesh	0,030295	0,080803	0,888902	0	0
Nepal	0,478285	0,517731	0,003984	0	0
Pakistan	0,226036	0,164173	0,609791	0	0
Sub-Saharan African countries	0,54	0,11	0	0,33	0,02

Table 7: Recycling rates considered for the SMEP countries (Central Bureau of Statistics Government of Nepal, 2021; Global Plastic Action Partnership, 2021; Ogwueleka & B P, 2021; OpenWASH, n.d.; The World Bank, n.d.; UNEP, 2017, 2018; University of Leeds, n.d.)

SMEP country	Recycling rate
Bangladesh	0,15
Nepal	0,041
Pakistan	0,08
Congo (Kinshasa)	0,049
Ethiopia	0,05
Ghana	0,095 (plastics)
	0,04 (aluminium)
Kenya	0,08
Nigeria	0,1
Rwanda	0,04
Senegal	0,04
Tanzania	0,04
Uganda	0,06
Zambia	0,14

Impact assessment

Life Cycle Impact assessment was performed based on the ReCiPe method (Huijbregts et al., 2016), for the impact categories: fossil resource scarcity; freshwater eutrophication; global warming; human carcinogenic toxicity; human non-carcinogenic toxicity; land use; marine ecotoxicity; marine eutrophication; ozone formation (human health); terrestrial acidification; terrestrial ecotoxicity; and water consumption. Unfortunately, the main impacts related to SUPs, i.e., pollution that occurs as a result of poor waste management, littering, and plastic waste entering rivers, seas, and oceans, are not assessed through the available impact categories.

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