

SUPPLEMENTARY MATERIAL

Table S1. Description of the six product stages involved in the fresh pasta life cycle network according to the Simapro software used in this work.

Product stage	Name	Main output	Unit	Reference Table
Process	High-amylose soft wheat cultivation	HABW grain	kg	Table S3
Process	25-kg paper bag production	SAF	kg	Table S5
Process	High-amylose bread wheat milling	HABW flour	kg	Table S6
Process	High-amylose soft bread pasta production	Fresh pasta	kg	Table S7
Process	PE bag production	PE bags	kg	Table S9
Process	Adhesive paper label production	Paper labels	kg	Table S10
Process	Carton production	Cartons	kg	Table S11
Process	Scotch tape production	Scotch tape	kg	Table S12
Process	EPAL wood pallet production	Wood pallet	kg	Table S13
Process	Shrink & shrank PE film production	PE film	kg	Table S14
Assembly	Assembly of the primary packaging for fresh pasta	Ass 1pack	p	Table S15
Assembly	Assembly of the secondary packaging for fresh pasta	Ass 2pack	p	Table S16
Assembly	Assembly of the tertiary packaging for fresh pasta	Ass 3pack	p	Table S17
Assembly	Assembly of the primary and secondary packages for fresh pasta	Ass 1-2pack	p	Table S18
Assembly	Assembly of the primary, secondary and tertiary packages for fresh pasta	Ass 1-3pack	p	Table S19
Assembly	Assembly of fresh pasta	Ass pasta	p	Table S20
Processes	Use phase	Cooked fresh pasta	kg	Table S21
Waste scenario	Waste scenario of plastic packaging wastes	PW	kg	Table S22
Waste scenario	Waste scenario of paper and cardboard packaging wastes	PCW	kg	Table S23
Waste scenario	Waste scenario of wooden pallet wastes	PALW	kg	Table S24
End of life scenario	End of life scenario of the primary packaging material wastes	EoL-1pack	-	Table S25
End of life scenario	End of life scenario of the secondary packaging material wastes	EoL-2pack	-	Table S26
End of life scenario	End of life of the tertiary packaging wastes	EoL-3pack	-	Table S27
End of life scenario	End of life scenario of the I, II, and III packaging material wastes	EoL-1-3pack	-	Table S28
Reuse	Reuse of the wooden pallet	Pallet reuse	p	Table S29
Life cycle	Life cycle of fresh pasta	LC-FP	p	Table S30
Life cycle	Life cycle of the primary, secondary and tertiary packaging materials	LC1-3pack	p	Table S31
Life cycle	Life cycle of the wooden pallet	LC-3pack	p	Table S32

Table S2 Input/output data for the conventional production of high-amylose bread wheat at the Massimo Filzi farm (Anguillara Sabazia, Italy), as referred to a nominal land area of 1 ha. All emission factors were extracted from the recently updated IPCC Guidelines [39].

Input/Output Parameter	Unit	Amount
Nominal non-irrigated land used (A_C)	ha	1.0
Land used to cultivate HASW	%	100
Set-aside land	%	0
HASW seed density	$\text{kg} \cdot \text{ha}^{-1}$	250
Distance travelled by seeds (Viterbo-Anguillara Sabazia, Italy)	km	62
<i>Input</i>		
Overall synthetic nitrogen supplied (F_S)	kg N a^{-1}	144
<i>Output</i>		
Crop yield	$\text{Mg} \cdot \text{ha}^{-1} \cdot \text{a}^{-1}$	1.5
Average grain moisture	$\text{g} \cdot \text{kg}^{-1}$	110
Dry grain yield	$\text{kg}_{\text{DM}} \cdot \text{ha}^{-1} \cdot \text{a}^{-1}$	1335
Above ground residues (AG_{DM})	$\text{Mg}_{\text{DM}} \cdot \text{ha}^{-1} \cdot \text{a}^{-1}$	2.55
N content of above-ground residues	$\text{kg N} \cdot (\text{kg}_{\text{DM}})^{-1}$	0.006
- Percentage of straw left in the field	%	0
- Percentage of straw incinerated	%	0
- Percentage of straw baling	%	100
Above ground biomass (AGR)	$(\text{kg}_{\text{DM}}) \text{ha}^{-1} \text{a}^{-1}$	2549
Below ground-to-above ground biomass ratio ($R_{\text{BG-BIO}}$)	$\text{kg} \cdot \text{kg}^{-1}$	0.23
Below ground residues (BG_{DM})	$\text{kg}_{\text{DM}} \cdot \text{ha}^{-1} \cdot \text{a}^{-1}$	893
N content of below-ground residues	$\text{kg N} \cdot (\text{kg}_{\text{DM}})^{-1}$	0.009
Nitrogen in crop residues (F_{CR})	$\text{kg N} \cdot \text{ha}^{-1} \cdot \text{a}^{-1}$	8.04
N emissions as NH_3 -ed NO_x ($\text{Frac}_{\text{GASF}}$)	$\text{kg NH}_3\text{-N} + \text{NO}_x\text{-N} \cdot (\text{kg N})^{-1}$	0.11 (0.02-0.33)
N leaching off ($\text{Frac}_{\text{LEACH}}$)	$\text{kg N} \cdot (\text{kg N})^{-1}$	0.24 (0.01-0.73)
N_2O -N emissions per unit mass of N fertilizer (EF_1)	$\text{kg N}_2\text{O-N} \cdot (\text{kg N})^{-1}$	0.01 (0.001-0.018)
N_2O -N emissions per unit mass of NH_3 and NO_x emitted (EF_4)	$\text{kg N}_2\text{O-N} \cdot (\text{kg NH}_3\text{-N} + \text{kg NO}_x\text{-N emitted})^{-1}$	0.01 (0.002-0.018)
N_2O -N emissions per unit mass of N leached off (EF_5)	$\text{kg N}_2\text{O-N} \cdot (\text{kg N leached off})^{-1}$	0.011 (0.0-0.020)
Direct N_2O emissions [$=(F_S + F_{\text{CR}}) \cdot \text{EF}_1 \cdot 44/28$]	$\text{kg N}_2\text{O ha}^{-1} \text{yr}^{-1}$	2.389
Indirect N_2O emissions from NH_3 e NO_x [$=F_S \text{ Frac}_{\text{GASF}} \cdot \text{EF}_4 \cdot 44/28$]	$\text{kg N}_2\text{O ha}^{-1} \text{yr}^{-1}$	0.249
Indirect N_2O emissions from N leaching off [$=(F_S + F_{\text{CR}}) \text{ Frac}_{\text{LEACH}} \cdot \text{EF}_5 \cdot 44/28$]	$\text{kg N}_2\text{O} \cdot \text{ha}^{-1} \cdot \text{yr}^{-1}$	0.631
Direct and indirect N_2O emissions	$\text{kg N}_2\text{O} \cdot \text{ha}^{-1} \cdot \text{yr}^{-1}$	3.269
Urea emission factor (EF_{UREA})	kg C/kg Urea	0.2
Reduction (η)	kg C/kg Urea	0.5
CO_2 emissions from urea ($F_{\text{CO}_2} = \text{Urea } A_C \text{ EF}_{\text{Urea}} \eta$)	$\text{kg CO}_{2\text{e}} \text{ha}^{-1} \text{yr}^{-1}$	55.00
NO emissions [40]	$\text{kg N ha}^{-1} \text{yr}^{-1}$	2.142
Nitrate emissions in water	$\text{kg NO}_3\text{-N ha}^{-1} \text{yr}^{-1}$	36.49
P emissions in water [0.05 kg P/ kg P applied]	$\text{kg P ha}^{-1} \text{yr}^{-1}$	2.01

Table S3. Inventory associated with the high-amylose bread wheat cultivation phase.

Inventory associated with the high amylose straw wheat cultivation phase:

Products										
Outputs to technosphere: Products and co-products		Amount	Unit	Quantity	Allocation	Waste type	Category	Comment		
FP-1 High Amylose Wheat Grain		CropYield = 1.5E3	kg	Mass	92.5 %	Biopolymer	A...Transformation			
STRAW		STRAW/SSSTRAW = 2.92	ton	Mass	7.5 %	Biopolymer	A...Transformation			
Add										
Outputs to technosphere: Avoided products		Amount	Unit	Distribution	SD2 or 2SD	Min	Max	Comment		
Add										
Inputs										
Inputs from nature		Sub-compartment	Amount	Unit	Distribution	SD2 or 2SD	Min	Max	Comment	
Occupation, annual crop, IT			AREA = 1	ha a						
Add										
Inputs from technosphere: materials/fuels				Amount	Unit	Distribution	SD2 or 2SD	Min	Max	Comment
Urea (RER) urea production Cut-off, S				UREA*AREA = 150	kg					See Table 1
Diammonium phosphate (RER) diammonium phosphate production Cut-off, S				FOSFBIAM*AREA = 200	kg					"
Ammonium nitrate (RER) ammonium nitrate production Cut-off, S				NITRAMM*AREA = 150	kg					"
Pesticide, unspecified (RER) production Cut-off, U				1.8*AREA = 1.8	kg					Fungicide (1 L/ha) + Herbicide (0.8 L/ha)
Diesel (Europe without Switzerland) market for Cut-off, S				70*AREA = 70	kg					See Table 1
Lubricating oil (RER) market for lubricating oil Cut-off, S				0.2*AREA = 0.2	kg					"
Wheat seed, for sowing (GLO) production Cut-off, S				Seed*AREA = 250	kg					"
Add										
Inputs from technosphere: electricity/heat				Amount	Unit	Distribution	SD2 or 2SD	Min	Max	Comment
Transport, freight, lorry 3.5-7.5 metric ton, EURO5 (RoW) transport, freight, lorry 3.5-7.5 metric ton				Seed*AREA*55 = 1.38E4	kgkm					Transport seeds VT-Anguillara Sabazia: 55 km
Transport, freight, lorry 7.5-16 metric ton, EURO5 (RER) transport, freight, lorry 7.5-16 metric ton				(UREA+FOSFBIAM+NITRAMM)*4	kgkm					TR fertilizers Varie-Anguillara Sabazia: 100 km
Transport, freight, light commercial vehicle (Europe without Switzerland) market for transport, 1				(1.8+70+0.2)*AREA*25 = 1.8E3	kgkm					TR pest+diesel fuel+Lubr oil Varie-Angu. Sab.: 25 km
Transport, freight, lorry 7.5-16 metric ton, EURO5 (RER) transport, freight, lorry 7.5-16 metric ton				STRAW/SSSTRAW*50 = 146	tkm					TR Paglia Ang Sab-Varie: 50 km
Add										
Outputs										
Emissions to air		Sub-compartment	Amount	Unit	Distribution	SD2 or 2SD	Min	Max	Comment	
Dinitrogen monoxide		low. pop., long-ter	FN2OTOT = 3.27	kg						
Nitrogen monoxide, IT		low. pop., long-ter	NOA = 4.59	kg						
Carbon dioxide, fossil		low. pop., long-ter	CO2U = 55	kg						
Add										
Emissions to water		Sub-compartment	Amount	Unit	Distribution	SD2 or 2SD	Min	Max	Comment	
Nitrate, IT		groundwater, long	NITRL = 36.5	kg						
Phosphorus, IT		groundwater, long	PLEACH = 2.01	kg						

Table S4 Total and partial material balances of the high-amylose bread wheat milling step in the pilot-scale mill with the pre-cleaning, cleaning, and grinding yields.

Step			Pre-cleaning			Cleaning		Tempering			Grinding					Pelletizing		
Stream	HASWG		ISS	TPP	GPP	TP	GP	TW	GPU		CR1	CR2	FGT	WE	HAWF		WFP	
	kg	% p/p	kg	kg	kg	kg	kg	kg	kg	% p/p	kg	kg	kg	kg	kg	% p/p	kg	% p/p
Water	824.6	11	0.41	7.83	816.3	41.7	774.6	375.0	1149.6	15.5	68.0	216.5	126.2	223.0	515.9	12.88	460.29	12.6
Dry matter	6671.4	89	3.34	63.38	6604.7	337.4	6267.4	0.0	6267.4	84.5	460.0	1464.5	853.8	0.0	3489.1	87.12	3178.97	87.4
Total	7496.0	100	3.75	71.21	7421.0	379.1	7042.0	375.0	7417.0	100.0	528.0	1681.0	980.0	223.0	4005.0	100.0	3639.27	100.0
Yield (%)			0.05	0.95	99.00	5.11	94.89	5	105		7	23	13	3	54		49	

Table S5. Total and partial material balances of the milling step of the HABW grains harvested from a nominal fertilized soil area of 1 ha. All symbols were listed in the Nomenclature section.

Step			Pre-cleaning			Cleaning		Tempering			Grinding					Pelletizing		Packaging				
Stream	HABWG		ISS	TPP	GPP	TP	GP	TW	GPU		CR1	CR2	FGT	WE	HABWF	WFP			SAF	SSAF	HABWFS	
	kg	% p/p	kg	kg	kg	kg	kg	kg	kg	% p/p	kg	kg	kg	kg	kg	% p/p	kg	% p/p	no.	kg	kg	kg
Water	165	11	0.08	1.57	163.4	8.3	155.0	75	230.0	15.5	13.6	43.3	25.3	44.6	103.2	12.88	92.11	12.6				
Dry matter	1335	89	0.67	12.68	1321.7	67.5	1254.1	0	1254.1	84.5	92.0	293.1	170.8	0	698.2	87.12	636.13	87.4				
Total	1500	100	0.75	14.25	1485.0	75.9	1409.1	75	1484.19	100.0	105.7	336.4	196.1	44.6	801.4	100.00	728.24	100.0	32.1	3.72	0.04	805.11

Table S6. Inventory associated with the production of 25-kg paper bags.

Table 15.6: Inventory associated with the production of 25 kg paper bag.

Products									
Outputs to technosphere: Products and co-products	Amount	Unit	Quantity	Allocatio	Waste type	Category	Comment		
FP-1 bis paper bags x flour	1	kg	Mass	100 %	Paper	P...\Transformation			
Add									
Outputs to technosphere: Avoided products	Amount	Unit	Distribution	SD2 or 2SD	Min	Max	Comment		
Add									
Inputs									
Inputs from nature	Sub-compartment	Amount	Unit	Distribution	SD2 or 2SD	Min	Max	Comment	
Add									
Inputs from technosphere: materials/fuels			Amount	Unit	Distrib	SD2 <	Min	Max	Comment
Paper sack (RER) market for paper sack Cut-off, S			1	kg	Unde				
Add									
Inputs from technosphere: electricity/heat			Amount	Unit	Distrib	SD2 <	Min	Max	Comment
Transport, freight, lorry 16-32 metric ton, EURO5 (RER) transport, freight, lorry 16-32 metric ton,			1*250 = 250	kgkm					TR Kraft paper raw material from forest area : 250 km

Table S7. Inventory associated with the high-amylose bread wheat flour production step.

Products									
Outputs to technosphere: Products and co-products	Amount	Unit	Quantity	Allocatio	Waste type	Category	Comment		
FP- 2 High Amylose Wheat Flour, at industrial mill	HAWG*YHAWF = 801	kg	Mass	84 %	Biopolymer	Food\Cereal produ	Economic allocation factors (UNAFTA, 2018)		
FP-Pelletized Middlings	HAWG*YWFP = 728	kg	Mass	16 %	Biopolymer	Food\Cereal produ			
FP-ISS	HAWG*YISS = 0.75	kg	Mass	0 %	Others	Food\Cereal produ	Impurities		
Add									
Outputs to technosphere: Avoided products	Amount	Unit	Distribution	SD2 or 2SD	Min	Max	Comment		
Add									
Inputs									
Inputs from nature	Sub-compartment	Amount	Unit	Distribution	SD2 or 2SD	Min	Max	Comment	
Add									
Inputs from technosphere: materials/fuels		Amount	Unit	Distrit	SD2 or 2SD	Min	Max	Comment	
FP-1 High Amylose Wheat Grain		HAWG = 1.5E3	kg						MP
Tap water [Europe without Switzerland] tap water production, underground water without treatment		HAWG*YMO = 75	kg						
FP-1 bis paper bags x flour		NSF*MSF*(1+SPSAF) = 3.72	kg						
Chlorine, liquid (RER) chlorine production, liquid Cut-off, S		DETER = 0.00255	kg						
Lubricating oil (RER) market for lubricating oil Cut-off, S		OLUBR = 0.00315	kg						
Inputs from technosphere: electricity/heat		Amount	Unit	Dis	SD2 or 2SD	Min	Max	Comment	
Electricity, medium voltage (IT) electricity voltage transformation from high to medium voltage Cut-off, S		147*HAWG/1000 = 221	kWh						147 kWh/Mg
Transport, freight, lorry 7.5-16 metric ton, EURO5 (RER) transport, freight, lorry 7.5-16 metric ton, EURO5 Cut-off, S		HAWG*20 = 3E4	kgkm						TR HAWF grains Anguillara Sabazia-Bracciano: 20
Transport, freight, lorry 16-32 metric ton, EURO5 (RER) transport, freight, lorry 16-32 metric ton, EURO5 Cut-off, S		NSF*MSF*(1+SSAF)*527 = 2.01E3	kgkm						TR paper bags Rho (MI)-Spoleto (PG): 527 km
Transport, freight, lorry 3.5-7.5 metric ton, EURO5 (RER) transport, freight, lorry 3.5-7.5 metric ton, EURO5 Cut-off, S		(HAWG*YISS+SSAF)*50 = 39.3	kgkm						TR ISS+paper bag waste: 50 km
Transport, freight, lorry 3.5-7.5 metric ton, EURO5 (RER) transport, freight, lorry 3.5-7.5 metric ton, EURO5 Cut-off, S		DETER/1000*112 = 0.000286	kgkm						TR Detergent- Nera Montoro (TR) -Bracciano: 112
Transport, freight, lorry 3.5-7.5 metric ton, EURO5 (RER) transport, freight, lorry 3.5-7.5 metric ton, EURO5 Cut-off, S		OLUBR/1000*133 = 0.000419	kgkm						TR Lubricating oil -Terni-Bracciano: 133 km
Transport, freight, lorry 7.5-16 metric ton, EURO5 (RER) transport, freight, lorry 7.5-16 metric ton, EURO5 Cut-off, S		HAWG*YWFP/1000*50 = 36.4	tkm						TR Milling by-products: MFG-CF: 50 km
Emissions to air	Sub-compartment	Amount	Unit	Distrib	SD2 or 2SD	Min	Max	Comment	
Water	low. pop.	44.6	kg	Under					see Table 3
Add									
Emissions to water	Sub-compartment	Amount	Unit	Distributio	SD2 or 2SD	Min	Max	Comment	
Add									
Emissions to soil	Sub-compartment	Amount	Unit	Distribution	SD2 or 2SD	Min	Max	Comment	
Add									
Final waste flows	Sub-compartment	Amount	Unit	Distribution	SD2 or 2SD	Min	Max	Comment	
Add									
Non material emissions	Sub-compartment	Amount	Unit	Distribution	SD2 or 2SD	Min	Max	Comment	
Add									
Social issues	Sub-compartment	Amount	Unit	Distribution	SD2 or 2SD	Min	Max	Comment	
Add									
Economic issues	Sub-compartment	Amount	Unit	Distribution	SD2 or 2SD	Min	Max	Comment	
Add									
Outputs to technosphere: Waste and emissions to treatment		Amount	Unit	Distribut	SD2 or 2SD	Min	Max	Comment	
Inert waste, for final disposal (RoW) treatment of inert waste, inert material landfill Cut-off, S		HAWG*YISS = 0.75	kg						
Paper (waste treatment) (GLO) recycling of paper Cut-off, S		SSAF*.808 = 0.0298	kg						
Waste paperboard (RoW) treatment of, sanitary landfill Cut-off, S		SSAF*.116 = 0.00428	kg						
Waste paperboard (Europe without Switzerland) treatment of waste paperboard, municipal incineration Cut-off, S		SSAF*.076 = 0.0028	kg						

Table S8. Total and partial material balances of the fresh pasta making, pasteurization, and pre-drying processes process using the HABW flour obtained by milling the HABW grains harvested from a nominal fertilized soil area of 1 ha (cf. Table S4). All symbols were listed in the Nomenclature section.

Step	Kneading								Extrusion				Pasteurization				Pre-drying/Cooling			
Stream	HABWF		WI		SI		I		VT		PTU		VP		PPU		VAT		PP	
	kg	%	kg	%	kg	%	kg	%	kg	%	kg	%	kg	%	kg	%	kg	%	kg	%
Water	103.2	12.88	296.5	100.0	1.6	36.41	398.2	36.4	85.7	100	312.4	31.0	50.4	100.0	362.8	34.29	143.2	100.00	219.6	24.0
Dry matter	698.2	87.12	0.0	0.0	2.8	63.59	695.4	63.6	0.0	0	695.4	69.0	0.0	0.0	695.4	65.71	0.0	0.00	695.4	76.0
Total	801.4	100.0	296.5	100.0	4.4	100.0	1093.6	100.0	85.7	100	1007.9	100.0	50.4	100.0	1058.2	100.0	143.2	100.00	915.0	100.0

Table S9. Inventory associated with the high-amylose bread wheat fresh pasta production step.

Products									
Outputs to technosphere: Products and co-products		Amount	Unit	Quantity	Allocatio	Waste type	Category	Comment	
FP- 3 Fresh Pasta from HAWF, at packaging		PFPACK = 901	kg	Mass	100 %	Compost	Food\Cereal produ		
FP-SI-SPP		ORGW = 18.1	kg	Mass	0 %	Biopolymer	Food\Cereal produ	Dough (SI) & pasteurized fresh pasta (SPP) wastes (Tables 4&6)	
Add									
Outputs to technosphere: Avoided products		Amount	Unit	Distribution	SD2 or 2SD	Min	Max	Comment	
Add									
Inputs									
Inputs from nature		Sub-compartment	Amount	Unit	Distribution	SD2 or 2SD	Min	Max	Comment
Add									
Inputs from technosphere: materials/fuels			Amount	Unit	Distrib	SD2 or 2SD	Min	Max	Comment
FP- 2 High Amylose Wheat Flour, at industrial mill			HAWF = 801	kg					
Tap water (Europe without Switzerland) market for Cut-off, S			HAWF*WFR = 297	kg					Water for dough preparation
Water, deionised (Europe without Switzerland) water production, deionised Cut-off, S			50.4	kg	Unde				To obtain steam x fresh pasta pasteurization
Chlorine, liquid (GLO) production Cut-off, S			DETER = 0.0141	kg					
Lubricating oil (RER) market for lubricating oil Cut-off, S			OLUBR = 0.0266	kg					
Add									
Inputs from technosphere: electricity/heat			Amount	Unit	Distrib	SD2 or 2SD	Min	Max	Comment
Heat, central or small-scale, natural gas (Europe without Switzerland) heat production, natu			PFPACK/1000*20 = 18	kWh					Thermal energy 20 kWh/Mg fresh pasta
Electricity, medium voltage (IT) electricity voltage transformation from high to medium vol			PFPACK/1000*200 = 180	kWh					Electric energy 200 kWh/Mg fresh pasta
Transport, freight, lorry 7.5-16 metric ton, EURO5 (RER) transport, freight, lorry 7.5-16 metri			HAWF*60 = 4.81E4	kgkm					TR HAWF - Bracciano (RM)- Roma: 60 km
Transport, freight, lorry 3.5-7.5 metric ton, EURO5 (RER) transport, freight, lorry 3.5-7.5 metri			DETER*83 = 1.17	kgkm					TR Detergent - Nera Montoro (TR)-RM: 83 km
Transport, freight, lorry 3.5-7.5 metric ton, EURO5 (RER) transport, freight, lorry 3.5-7.5 metri			OLUBR*103 = 2.74	kgkm					TR Lubricating oil -Terni -RM: 103 km
Emissions to air		Sub-compartment	Amount	Unit	Distrib	SD2 or 2SD	Min	Max	Comment
Water		low. pop., long-term	85.7	kg	Unde				Water evaporated at the extruder
Water		low. pop., long-term	143.2	kg	Unde				Water evaporated to reduce the moisture of fresh pasta to 24% w/w (see Table 4).
Ethane, 1,1,1,2-tetrafluoro-, HFC-134a		low. pop., long-term	PFPACK*FGY*.04 = 23.4	mg					Fugitive gas leakage (R404)
Ethane, 1,1,1-trifluoro-, HFC-143a		low. pop., long-term	PFPACK*FGY*.52 = 305	mg					
Ethane, pentafluoro-, HFC-125		low. pop., long-term	PFPACK*FGY*.44 = 258	mg					
Outputs to technosphere: Waste and emissions to treatment			Amount	Unit	Distrib	SD2 or 2SD	Min	Max	Comment
Wastewater, from residence (RoW) treatment of, capacity 1.1E10l/year Cut-off, S			PFPACK/1000*72 = 64.9	l					72 L/Mg of fresh pasta
Biowaste (RoW) treatment of biowaste by anaerobic digestion Cut-off, S			ORGW*.255 = 4.62	kg					Organic Waste disposal (Table 8)
Sludge from pulp and paper production (Europe without Switzerland) treatment of sludge from pulp and paper pro			ORGW*.31 = 5.62	kg					"
Raw sewage sludge (RoW) treatment of, municipal incineration Cut-off, S			ORGW*.18 = 3.26	kg					"S
Biowaste (RoW) treatment of biowaste, industrial composting Cut-off, S			ORGW*.255 = 4.62	kg					"

Table S10. Percentage fraction of the processing and packaging materials discarded, as collected in the fresh pasta factory examined in this work.

Processing and Packaging Materials discarded	Discarded Fraction (%)
Paper bags for wheat flour	1.0
Dough waste	0.4
Fresh pasta waste	1.5
<i>Primary packaging</i>	
PE bags	3.0
PE bag label	0.5
<i>Secondary packaging</i>	
Cartons (CAW)	1.0
Carton label	0.3
Scotch tape	0.3
<i>Tertiary packaging</i>	
Damaged wooden pallet	0.2
Wooden pallet label waste	0.2
Wooden pallet stretch & shrink film waste	0.2

Table S11. Total material balance of the packaging process of the HABW fresh pasta. All symbols were listed in the Nomenclature section.

Step	Primary packaging									
Stream	PP	SPP	N ₂ L	CO ₂ L		PE	SPE	ES	SES	PFS
	(kg)	(kg)	(kg)	(kg)	no.	(kg)	(kg)	(kg)	(kg)	(kg)
Total	915.0	13.7	9.0	4.5	1803	29.2	0.9	1.8	0.01	945.0
Step	Secondary packaging									
Stream	CA	SCA	EC	SEC		SC	SCW	PFC		
	no.	(kg)	(kg)	(kg)	(kg)	(kg)	(kg)	(kg)		
Total	150	85.0	0.8	0.3	0.001	1.1	0.003	1030.4		
Step	Tertiary packaging									
Stream	PAL	SPAL		EP		SEP	FP	SFP	PFP	
	n°	(kg)	(kg)	n°	(kg)	(kg)	(kg)	(kg)	(kg)	
Total	3.8	82.8	0.2	7.5	0.023	0.00005	2.574	0.005	1115.6	

Table S12. Inventory associated with the PE bag production step.

Products									
Outputs to technosphere: Products and co-products	Amount	Unit	Quantity	Allocatio	Waste type	Category	Comment		
FP-4 PE bag	1	kg	Mass	100 %	PE	Food\Cereal produ	This process allowed the manufacture of the primary packages for fresh pasta.		
Add									
Outputs to technosphere: Avoided products	Amount	Unit	Distribution	SD2 or 2SD	Min	Max	Comment		
Add									
Inputs									
Inputs from nature	Sub-compartment	Amount	Unit	Distribution	SD2 or 2SD	Min	Max	Comment	
Add									
Inputs from technosphere: materials/fuels	Amount			Unit	Distrit	SD2	Min	Max	Comment
Polyethylene, low density, granulate (RER) production Cut-off, S	1/0.976 = 1.02			kg					
Add									
Inputs from technosphere: electricity/heat	Amount			Unit	Distrib	SD2	Min	Max	Comment
Extrusion, plastic film (RER) extrusion, plastic film Cut-off, S	1/0.976 = 1.02			kg					
Transport, freight, lorry 7.5-16 metric ton, EURO5 (RER) transport, freight, lorry 7.5-16 metric	1/0.976*150 = 154			kgkm					TR PE granules PS -Avezzano (AQ): 150 km
Add									
Outputs to technosphere: Waste and emissions to treatment	Amount			Unit	Distrib	SD2 or	Min	Max	Comment
Waste polyethylene (GLO) treatment of waste polyethylene, open burning Cut-off, S	1/976-1 = 0.0246			kg					

Table S13. Inventory associated with the paper label production step.

Products										
Outputs to technosphere: Products and co-products		Amount	Unit	Quantity	Allocatio	Waste type	Category	Comment		
FP-5 paper label		1	kg	Mass	100 %	Paper	Paper+ B...\Market	Paper labels for I, II, & III packages		
Add										
Outputs to technosphere: Avoided products		Amount	Unit	Distribution	SD2 or 2SD	Min	Max	Comment		
Add										
Inputs										
Inputs from nature		Sub-compartment	Amount	Unit	Distribution	SD2 or 2SD	Min	Max	Comment	
Add										
Inputs from technosphere: materials/fuels				Amount	Unit	Distrit	SD2	Min	Max	Comment
Graphic paper, 100% recycled (RER) production Cut-off, S				1	kg	Unde				
Add										
Inputs from technosphere: electricity/heat				Amount	Unit	Distrib	SD2	Min	Max	Comment
Printed paper (Europe without Switzerland) operation, printer, laser, colour, per kg Cut-off				1	kg	Undefi				
Transport, freight, lorry 7.5-16 metric ton, EURO5 (RER) transport, freight, lorry 7.5-16 metric				1*250 = 250	kgkm					TR Paper for labels PS-FG: 250 km

Table S14. Inventory associated with the carton production step.

Products										
Outputs to technosphere: Products and co-products		Amount	Unit	Quantity	Allocatio	Waste type	Category	Comment		
FP-6 carton		1	kg	Mass	100 %	Cardboard	P...\Transformation	Production of cartons		
Add										
Outputs to technosphere: Avoided products		Amount	Unit	Distribution	SD2 or 2SD	Min	Max	Comment		
Add										
Inputs										
Inputs from nature		Sub-compartment	Amount	Unit	Distribution	SD2 or 2SD	Min	Max	Comment	
Add										
Inputs from technosphere: materials/fuels				Amount	Unit	Distrit	SD2 <	Min	Max	Comment
Corrugated board box (RER) production Cut-off, S				1	kg	Unde				
Add										
Inputs from technosphere: electricity/heat			Amount	Unit	Distrib	SD2	Min	Max	Comment	
Folding boxboard carton (RER) market for folding boxboard carton Cut-off, S			1	kg	Undefi					
Transport, freight, lorry 7.5-16 metric ton, EURO5 (RER) transport, freight, lorry 7.5-16 metric			1*250 = 250	kgkm					TS: Raw Material x Cartons PF-FG: 250 km	

Table S15. Inventory associated with the scotch tape production step.

Products											
Outputs to technosphere: Products and co-products		Amount	Unit	Quantity	Allocatio	Waste type	Category	Comment			
FP-7 scotch tape		1	kg	Mass	100 %	PP	Pl...\Transformation	Scotch tape x cartons			
Add											
Outputs to technosphere: Avoided products		Amount	Unit	Distribution	SD2 or 2SD	Min	Max	Comment			
Add											
Inputs											
Inputs from nature		Sub-compartment	Amount	Unit	Distribution	SD2 or 2SD	Min	Max	Comment		
Add											
Inputs from technosphere: materials/fuels				Amount	Unit	Distrib	SD2 or 2SD	Min	Max	Comment	
Polypropylene, granulate (RER) production Cut-off, S				1/976 = 1.02	kg						
Add											
Inputs from technosphere: electricity/heat				Amount	Unit	Distrib	SD2 or 2SD	Min	Max	Comment	
Extrusion, plastic film (RER) extrusion, plastic film Cut-off, S				1/976 = 1.02	kg						
Transport, freight, lorry 7.5-16 metric ton, EURO5 (RER) transport, freight, lorry 7.5-16 metric				1/0.976*150 = 154	kgkm					TS: PE granules PS-FG: 150 km	
Acrylic binder, without water, in 34% solution state (RER) acrylic binder production, product				1/30 = 0.0333	kg					tape thickness 300 micron, acrylic one 10 micron	
Outputs to technosphere: Waste and emissions to treatment											
Outputs to technosphere: Waste and emissions to treatment					Amount	Unit	Distrib	SD2 or 2SD	Min	Max	Comment
Waste polypropylene (GLO) treatment of waste polypropylene, open burning Cut-off, S					1/0.976-1 = 0.0246	kg					

Table S16. Inventory associated with the EPAL wooden pallet production step.

Products											
Outputs to technosphere: Products and co-products		Amount	Unit	Quantity	Allocatio	Waste type	Category	Comment			
FP-8 EPAL Pallet		22	kg	Mass	100 %	Wood	Pl...\Transformation				
Add											
Outputs to technosphere: Avoided products		Amount	Unit	Distribution	SD2 or 2SD	Min	Max	Comment			
Add											
Inputs											
Inputs from nature		Sub-compartment	Amount	Unit	Distribution	SD2 or 2SD	Min	Max	Comment		
Add											
Inputs from technosphere: materials/fuels				Amount		Unit	Distrib	SD2 <	Min	Max	Comment
EUR-flat pallet (RER) market for EUR-flat pallet Cut-off, S				1		p	Unde				
Add											
Inputs from technosphere: electricity/heat			Amount		Unit	Dis	SE	Mi	Ma	Comment	
Transport, freight, lorry 16-32 metric ton, EURO5 (RER) transport, freight, lorry 16-32 metric			22*100 = 2.2E3		kgkm					TR Wood x Pallet PS-wood pallet managing center: 100 km	

Table S17. Inventory associated with the shrink & shrank PE film production step.

Products										
Outputs to technosphere: Products and co-products	Amount	Unit	Quantity	Allocatio	Waste type	Category	Comment			
FP- 9 PE film x pallet	1	kg	Mass	100 %	PE	Pl...\Transformation				
Add										
Outputs to technosphere: Avoided products	Amount	Unit	Distribution	SD2 or 2SD	Min	Max	Comment			
Add										
Inputs										
Inputs from nature	Sub-compartment	Amount	Unit	Distribution	SD2 or 2SD	Min	Max	Comment		
Add										
Inputs from technosphere: materials/fuels			Amount	Unit	Distrib	SD2 or 2SD	Min	Max	Comment	
Polyethylene, low density, granulate (RER) production Cut-off, S			1/976 = 1.02	kg						
Add										
Inputs from technosphere: electricity/heat			Amount	Unit	Distrib	SD2 or 2SD	Min	Max	Comment	
Extrusion, plastic film (RER) extrusion, plastic film Cut-off, S			1/0.976 = 1.02	kg						
Transport, freight, lorry 7.5-16 metric ton, EURO5 (RoW) transport, freight, lorry 7.5-16 metric ton, EURO5 (RoW)			1/0.976*150 = 154	kgkm					TR PE granules PS-FG: 150 km	
Outputs to technosphere: Waste and emissions to treatment				Amount	Unit	Distrib	SD2 or 2SD	Min	Max	Comment
Waste polyethylene (GLO) treatment of waste polyethylene, open burning Cut-off, S				1/976-1 = 0.0246	kg					
Add										

Table S18. Assembly of the primary packaging for fresh pasta.

Name	Status	Comment					
FP- 13 Assembly of Primary Packaging	Finished	Assemblaggio del Pack I in MAP					
Materials/Assemblies	Amount	Unit	Distribution	SD2 or 2SD	Min	Max	Comment
FP-4 PE bag	15.7	g	Triangle		15.4	16	
FP-5 paper label	1	g	Undefined				
Add							
Processes	Amount	Unit	Distribution	SD2 or 2SD	Min	Max	Comment
Transport, freight, lorry 7.5-16 metric ton, EURO5 (RER) transport, freight, lorry 7.5-16 metric ton	15.7/1000*106 = 1.66	kgkm					TR PE bags- Avezzano (AQ) - Roma: 106 km
Transport, freight, lorry 7.5-16 metric ton, EURO5 (RER) transport, freight, lorry 7.5-16 metric ton	1/1000*65 = 0.065	kgkm					TR Labels- Nettuno (RM) - Roma: 65 km

Table S19. Assembly of the secondary packaging for fresh pasta.

Name	Status	Comment							
FP- 14 Assembly of Secondary Packaging	Finished	Assembly of Secondary Packages for fresh pasta							
Materials/Assemblies	Amount	Unit	Distribution	SD2 or 2SD	Min	Max	Comment		
FP-6 carton	560	g	Triangle		555	565			
FP-5 paper label	2	g	Undefined						
FP-7 scotch tape	7	g	Undefined						
Add									
Processes	Amount			Unit	Distrib	SD2 or 2S	Min	Max	Comment
Transport, freight, lorry 7.5-16 metric ton, EURO5 (RER) transport, freight, lorry 7.5-16 metric ton	560/1000*65 = 36.4			kgkm					TR Cartons - Nettuno (RM)-Roma: 65 km
Transport, freight, lorry 7.5-16 metric ton, EURO5 (RER) transport, freight, lorry 7.5-16 metric ton	7/1000*100 = 0.7			kgkm					TR Scotch tape: Avezzano (AQ)-Roma: 100 km
Transport, freight, lorry 7.5-16 metric ton, EURO5 (RER) transport, freight, lorry 7.5-16 metric ton	2/1000*65 = 0.13			kgkm					TR Paper labels- Nettuno (RM) - Roma: 65 km

Table S20. Assembly of the tertiary packaging for fresh pasta.

Name	Status	Comment							
FP- 15 Assembly of Tertiary Packaging	Finished	Assembly of III Packaging in EPAL wood pallet							
Materials/Assemblies	Amount	Unit	Distribution	SD2 or 2SD	Min	Max	Comment		
FP-8 EPAL Pallet	22	kg	Triangle		21	23			
Add									
Processes	Amount			Unit	Distribution	SD2 or 2SD	Min	Max	Comment
Transport, freight, lorry 7.5-16 metric ton, EURO5 (RER) transport, freight, lorry 7.5-16 metric ton	22*30 = 660			kgkm					TR Pallet: EPMC Pomezia (RM)-Roma: 30 km

Table S21. Assembly of primary and secondary packages for fresh pasta.

Name	Status	Comment					
FP - 16 Assembly of I & II packages	Finished	Assembly of I & II packaging (12 PE bags da 500 g in a carton)					
Materials/Assemblies	Amount	Unit	Distribution	SD2 or 2SD	Min	Max	Comment
FP- 13 Assembly of Primary Packaging	12	p	Undefined				
FP- 14 Assembly of Secondary Packaging	1	p	Undefined				

Table S22. Assembly of primary, secondary, and tertiary packages for fresh pasta.

Name	Status	Comment					
FP - 17 Assembly of I, II & III packages	Finished	Assembly of I, II & III Packs (40 carton x pallet + PE film+Labels)					
Materials/Assemblies	Amount	Unit	Distribution	SD2 or 2SD	Min	Max	Comment
FP - 16 Assembly of I & II packages	40	p	Undefined				
FP- 9 PE film x pallet	684	g	Undefined				
FP-5 paper label	2*3.11 = 6.22	g					
Add							
Processes	Amount	Unit	Distribution	SD2 or 2SD	Min	Max	Comment
Transport, freight, lorry 7.5-16 metric ton, EURO5 (RoW) transport, freight, lorry 7.5-16 metric ton	684/1000*100 = 68.4	kgkm					TR Film x pallet - Avezzano (AQ)-Roma: 100 km
Transport, freight, lorry 7.5-16 metric ton, EURO5 (RoW) transport, freight, lorry 7.5-16 metric ton	2*3.11/1000*65 = 0.404	kgkm					TR Labels x pallet - Nettuno (RM)-Roma: 65 km

Table S23. Assembly of fresh pasta (1 Functional Unit).

Name	Status	Comment					
FP - 18 Assembly of Fresh Pasta	Finished	Assembly of 1 Functional Unit: 500-g fresh pasta in modified atmosphere					
Materials/Assemblies	Amount	Unit	Distribution	SD2 or 2SD	Min	Max	Comment
FP- 3 Fresh Pasta from HAWF, at packaging	0.5	kg	Undefined				
Nitrogen, liquid (RER) market for Cut-off, S	5	g	Undefined				
Carbon dioxide, liquid (RER) market for Cut-off, S	2.5	g	Undefined				
Add							
Processes	Amount	Unit	Distribution	SD2 or 2SD	Min	Max	Comment
Transport, freight, lorry 7.5-16 metric ton, EURO5 (RER) transport, freight, lorry 7.5-16 metric ton	(5+2.5)/1000*95 = 0.713	kgkm					TR Liquid N2 + CO2-Nera Montoro (TR)-Roma: 95 km

Table S24. Inventory associated with the use phase.

Products										
Outputs to technosphere: Products and co-products		Amount	Unit	Quantity	Allocation	Category	Comment			
FP- 19 Use Phase		RFP = 1	kg	Mass	100 %	Ot...\Consumer Use	Pasta fresca pastorizzata cruda			
FP - Cooked Pasta waste		Pcotta*PW = 0.034	kg	Mass	0 %	Ot...\Consumer Use				
Add										
Outputs to technosphere: Avoided products		Amount	Unit	Distribution	SD2 or 2SD	Min	Max	Comment		
Add										
Inputs										
Inputs from nature		Sub-compartment	Amount	Unit	Distribution	SD2 or 2SD	Min	Max	Comment	
Add										
Inputs from technosphere: materials/fuels				Amount	Unit	Distribution	SD2 or 2SD	Min	Max	Comment
FP- 3 Fresh Pasta from HAWF, at packaging				0	kg	Under				
Tap water (Europe without Switzerland) market for Cut-off, S				RFP*WFPR = 10	kg					
Salt, white, for human consumption (sea, igneous or rock), no enrichment, processed in FR Ambient (local)				Salt*RFP = 100	g					
Add										
Inputs from technosphere: electricity/heat				Amount	Unit	Distribution	SD2 or 2SD	Min	Max	Comment
Electricity, low voltage (IT) market for Cut-off, S				EC*0.17 = 0.336	kWh					It referred to the energy consumed (17 % by electric hob) to cook 1 kg of dry pasta (UNAFPA, 2018).
Heat, central or small-scale, natural gas (Europe without Switzerland) market for heat, central or small-scale				EC*0.83 = 1.64	kWh					
Electricity, low voltage (IT) market for Cut-off, S				EFRIAGE = 2.46	kWh					Electricity consumed for preserving fresh pasta in fridge
Outputs										
Emissions to air		Sub-compartment	Amount	Unit	Distribution	SD2 or 2SD	Min	Max	Comment	
Water		low. pop., long-term	WE = 0.85	kg					Acqua evaporata durante la cottura	
Nitrogen, atmospheric		low. pop., long-term	10	g	Under				N2 freed as 1-kg fresh pasta bags (2 packages) are opened	
Carbon dioxide, fossil		low. pop., long-term	5	g	Under					
Outputs to technosphere: Waste and emissions to treatment				Amount	Unit	Distribution	SD2 or 2SD	Min	Max	Comment
Biowaste (CH) treatment of biowaste by anaerobic digestion Conseq, S				Pcotta*PW*0.255 = 0.00867	kg					Pasta waste disposed as organic waste
Biowaste (CH) treatment of biowaste, industrial composting Cut-off, S				Pcotta*PW*0.255 = 0.00867	kg					see Table 8
Sludge from pulp and paper production (Europe without Switzerland) treatment of sludge from pulp and paper production				Pcotta*PW*.31 = 0.0105	kg					Idem
Raw sewage sludge (RoW) treatment of, municipal incineration Cut-off, S				Pcotta*PW*.18 = 0.00612	kg					Idem
Wastewater, from residence (RoW) treatment of, capacity 1.1E10l/year Cut-off, S				PWATER = 8.5	l					Pasta water disposal in the kitchen sink

Table S25. Waste scenario for plastic packaging wastes (PLW).

Products										
Waste specification	Amount	Unit	Category	Comment						
FP - 10 Plastic Waste Scenarios	1	kg	Others							
Inputs										
Inputs from technosphere: materials/fuels				Amount	Unit	District SD2 c		Min	Max	Comment
Add										
Inputs from technosphere: electricity/heat				Amount	Unit	Dis SI		M	M	Comment
Add										
Outputs										
Materials and/or waste types separated from waste stream				Material / Waste type		Percentage		Comment		
Add										
Waste streams remaining after separation					Percentage	Comment				
Waste polyethylene (RoW) treatment of waste polyethylene, municipal incineration Cut-off, S					47 %	see Table 8				
PE (waste treatment) (GLO) recycling of PE Cut-off, S					45.6 %	Idem				
Waste polyethylene (RoW) treatment of waste polyethylene, sanitary landfill Cut-off, S					7.4 %	Idem				

Table S26. Waste scenario for cardboard and paper packaging wastes (PCW).

Waste specification	Amount	Unit	Category	Comment	
FP - 11 Paper&Cardboard Waste Scenarios	1	kg	Others		
Inputs					
Inputs from technosphere: materials/fuels	Amount	Unit	Distrit SD2 c Min	Max	Comment
Add					
Inputs from technosphere: electricity/heat	Amount	Unit	Dis SI M Mi		Comment
Add					
Outputs					
Materials and/or waste types separated from waste stream	Material / Waste type	Percentage	Comment		
Add					
Waste streams remaining after separation		Percentage	Comment		
Waste paperboard (RoW) treatment of, municipal incineration Cut-off, S		7.6 %	see Table 8		
Paper (waste treatment) (GLO) recycling of paper Cut-off, S		80.8 %	Idem		
Waste paperboard (RoW) treatment of, sanitary landfill Cut-off, S		11.6 %	Idem		

Table S27. Waste scenario of wooden pallet wastes (PALW).

Products											
Waste specification	Amount	Unit	Category	Comment							
FP - 12 Pallet Waste Scenarios	1	kg	Others								
Inputs											
Inputs from technosphere: materials/fuels				Amount	Unit	Distrit	SD2	ε	Min	Max	Comment
Add											
Inputs from technosphere: electricity/heat				Amount	Unit	Dis	SI	M	Mi	Comment	
Add											
Outputs											
Materials and/or waste types separated from waste stream				Material / Waste type		Percentage		Comment			
Add											
Waste streams remaining after separation						Percentage		Comment			
Waste wood, untreated {RoW} treatment of waste wood, untreated, municipal incineration Cut-off, S						2.1 %		see Table 8			
Waste wood, untreated {IT} market for waste wood, untreated Cut-off, S						63.1 %		Idem			
Waste wood, untreated {RoW} treatment of, sanitary landfill Cut-off, S						34.8 %		Idem			

Table S28. End-of-life of primary packaging material wastes (EoL-1pack).

Name	Status	Comment
FP - 20 EoL Primary Packaging	Finished	

Referring to assembly	Amount	Unit	Comment
FP- 13 Assembly of Primary Packaging	1	p	

Processes	Amount	Unit	Distrib	SD2 or 2S	Min	Max	Comment
Transport, freight, lorry 7.5-16 metric ton, EURO5 (RoW) transport, freight, lorry 7.5-16 metric t	16.7/1000*50 = 0.835	kgkm					TR Plastic and Paper wastes from FPFG, CH to - Waste Collection Centre: 50 km

Add	
Waste scenarios	Percentage
FP - 10 Plastic Waste Scenarios	94.03 %
FP- Paperboard Waste Disposal Scenario	5.97 %

Comment

Table S29. End-of-life of secondary packaging material wastes (EoL-2pack).

Name	Status	Comment
FP - 21 EoL Secondary Packaging	None	

Referring to assembly	Amount	Unit	Comment
FP- 14 Assembly of Secondary Packaging	1	p	

Processes	Amount	Unit	Distrib	SD2 or 2S	Min	Max	Comment
Transport, freight, lorry 7.5-16 metric ton, EURO5 (RoW) transport, freight, lorry 7.5-16 metric t	569/1000*50 = 28.4	kgkm					TR Paper&Cardboard and plastic waste from DC to waste collection center WCC: 50 km

Add	
Waste scenarios	Percentage
FP - 10 Plastic Waste Scenarios	1.23 %
FP - 11 Paper&Cardboard Waste Scenarios	98.77 %

Comment

Table S30. End-of-life of tertiary packaging material wastes (EoL-3pack).

Name			Status		Comment				
FP - 22 EoL Tertiary Packaging			Finished						
Referring to assembly		Amount	Unit	Comment					
FP- 15 Assembly of Tertiary Packaging		1	p						

Processes		Amount	Unit	Distrib	SD2 or 25	Min	Max	Comment
Transport, freight, lorry 7.5-16 metric ton, EURO5 (RoW) transport, freight, lorry 7.5-16 metric t		22*.998*100 = 2.2E3	kgkm					TR Reusable Pallets from DCs to EPAL Pallet managing Center (EPCM) Pomezia (RM): 100 km
Transport, freight, lorry 7.5-16 metric ton, EURO5 (RoW) transport, freight, lorry 7.5-16 metric t		22*.002*50 = 2.2	tkm					TR Broken Palles from DCs to EPCM: 50 km
Add								

Waste scenarios		Percentage	Comment	
FP - 12 Pallet Waste Scenarios		0.2 %	D	
Add				
Disassemblies		Percentage	Comment	
Add				
Reuses		Percentage	Comment	
FP - 24 Pallet reuse		99.8 %		

Table S31. End-of-life scenario for the primary, secondary and tertiary packaging material wastes, excluding wooden pallets (EoL-1-3pack).

Name			Status		Comment				
FP - 23 EoL I, II & III Packaging			Finished		Not including wood pallets				
Referring to assembly		Amount	Unit	Comment					
FP - 17 Assembly of I, II & III packages		1	p						

Processes		Amount	Unit	Distr	SD2 or 25	Min	Max	Comment
Transport, freight, lorry 7.5-16 metric ton, EURO5 (RoW) transport, freight, lorry 7.5-16 metric t		31.485*50 = 1.57E3	kgkm					TR Paper and plastic wastes from DCs to WCC: 50 km
Add								

Waste scenarios		Percentage	Comment	
FP - 10 Plastic Waste Scenarios		27.06 %		
FP - 11 Paper&Cardboard Waste Scenarios		72.94 %		

Table S32. Reuse phase of the wooden pallet (Pallet reuse).

Name		Status		Comment	
FP - 24 Pallet reuse		Finished			
Referring to assembly		Amount	Unit	Comment	
FP- 15 Assembly of Tertiary Packaging		1	p		

Table S33. Life cycle of HABWF fresh pasta (LC-FP).

Name		Status		Comment				
FP-Life Cycle of Fresh Pasta		Finished						
Assembly		Amount	Unit	Distribution	SD2 or 2SD	Min	Max	Comment
FP - 18 Assembly of Fresh Pasta		2	p	Undefined				Two 500-g bags

Processes		Amount	Unit	Distr	SD2 or 2SD	Min	Max	Comment
Transport, freight, lorry with refrigeration machine, 7.5-16 ton, EURO5, R134a refrigerant, freez		293.48/240*.5*2*100 = 122	kgkm					TR Palletized fresh pasta from Rome to DCs: 100 km
FP- 19 Use Phase		1	kg	Und				
Add								

Waste/Disposal scenario		Comment	

Additional life cycles		Number	Distribution	SD2 or 2SD	Min	Max	Comment
FP - Life Cycle of I, II & III packaging		1/240 = 0.00417					

Table S34. Life cycle of the primary, secondary, and tertiary packaging materials (LC-1-3pack).

Name		Status		Comment			
FP - Life Cycle of I, II & III packaging		Finished					

Assembly	Amount	Unit	Distribution	SD2 or 2SD	Min	Max	Comment
FP - 17 Assembly of I, II & III packages	1	p	Undefined				

Processes	Amount	Unit	Distr	SD2 or 2SD	Min	Max	Comment
Add							

Waste/Disposal scenario	Comment
FP - 23 EoL I, II & III Packaging	

Additional life cycles	Number	Distribution	SD2 or 2SD	Min	Max	Comment
FP-Life Cycle of Wooden Pallet	1	Undefined				

Table S35. Life cycle of the wooden pallet (LC-3pack).

Name		Status		Comment			
FP-Life Cycle of Wooden Pallet		None					

Assembly	Amount	Unit	Distribution	SD2 or 2SD	Min	Max	Comment
FP- 15 Assembly of Tertiary Packaging	1	p	Undefined				

Processes	Amount	Unit	Distribution	SD2 or 2SD	Min	Max
Add						

Waste/Disposal scenario	Comment
FP - 22 EoL Tertiary Packaging	

Table S36. Inventory associated with the cultivation phase of a typical bread wheat in Central Italy.

Products									
Outputs to technosphere: Products and co-products	Amount	Unit	Quantity	Allocation %	Waste type	Category	Comment		
FP GT -1 Soft Wheat Grain	CropYield = 7.26E3	kg	Mass	92.5 %	Biopolymer	A...\Transformation			
STRAW SW	STRAW/SSSTRAW = 12.4	ton	Mass	7.5 %	Biopolymer	A...\Transformation			
Add									
Outputs to technosphere: Avoided products	Amount	Unit	Distribution	SD2 or 2SD	Min	Max	Comment		
Add									
Inputs									
Inputs from nature	Sub-compartment	Amount	Unit	Distribution	SD2 or 2SD	Min	Max	Comment	
Occupation, annual crop, IT		AREA = 1	ha a						
Add									
Inputs from technosphere: materials/fuels		Amount	Unit	Distrib	SD2 or 2SD	Min	Max	Comment	
Urea (RER) urea production Cut-off, S		UREA*AREA = 150	kg					See Table 1	
Diammonium phosphate (RER) diammonium phosphate production Cut-off, S		FOSFBIAM*AREA = 200	kg					"	
Ammonium nitrate (RER) ammonium nitrate production Cut-off, S		NITRAMM*AREA = 150	kg					"	
Pesticide, unspecified (RER) production Cut-off, U		1.8*AREA = 1.8	kg					Fungicide (1 L/ha) + Herbicide (0.8 L/ha)	
Diesel (Europe without Switzerland) market for Cut-off, S		70*AREA = 70	kg					See Table 1	
Lubricating oil (RER) market for lubricating oil Cut-off, S		0.2*AREA = 0.2	kg					"	
Wheat seed, for sowing (GLO) production Cut-off, S		Seed*AREA = 250	kg					"	
Inputs from technosphere: electricity/heat		Amount	Unit	Dis	SI	M	Me	Comment	
Transport, freight, lorry 3.5-7.5 metric ton, EUROS (RoW) transport, freight, lorry 3.5-7.5 metric ton, EUROS		Seed*AREA*55 = 1.38E4	kgkm					Transport seeds VT-Anguillara Sabazia: 55 km	
Transport, freight, lorry 7.5-16 metric ton, EUROS (RER) transport, freight, lorry 7.5-16 metric ton, EUROS C		(UREA+FOSFBIAM+NITRAMM)*AREA	kgkm					TR fertilizers Varie-Anguillara Sabazia: 100 km	
Transport, freight, light commercial vehicle (Europe without Switzerland) market for transport, freight, light		(1.8+70+0.2)*AREA*25 = 1.8E3	kgkm					TR pest+diesel fuel+Lubr oil Varie-Angu. Sab.: 25 km	
Transport, freight, lorry 7.5-16 metric ton, EUROS (RER) transport, freight, lorry 7.5-16 metric ton, EUROS C		STRAW/SSSTRAW*50 = 619	tkm					TR Paglia Ang Sab-Varie: 50 km	
Add									
Outputs									
Emissions to air	Sub-compartment	Amount	Unit	Distrib	SD2 or 2SD	Min	Max	Comment	
Dinitrogen monoxide	low. pop., long-term	FN2OTOT = 3.82	kg						
Nitrogen monoxide, IT	low. pop., long-term	NOA = 4.59	kg						
Carbon dioxide, fossil	low. pop., long-term	CO2U = 55	kg						
Add									
Emissions to water	Sub-compartment	Amount	Unit	Distributio	SD2 or 2SD	Min	Max	Comment	
Nitrate, IT	groundwater, long	NITRL = 43.1	kg						
Phosphorus, IT	groundwater, long	PLEACH = 2.01	kg						

Table S37. Inventory associated with the milling phase of common wheat grains cultivated in Central Italy.

Products									
Outputs to technosphere: Products and co-products	Amount	Unit	Quantity	Allocation %	Waste type	Category	Comment		
FP GT - 2 Bread Wheat Flour, at industrial mill	HAWG*YHAWF = 5.3E3	kg	Mass	84 %	Biopolymer	Food\Cereal produ	Economic allocation factors (UNAFTA, 2		
FP GT -Pelletized Middlings	HAWG*YWFP = 2.21E3	kg	Mass	16 %	Biopolymer	Food\Cereal produ			
FP GT -ISS	HAWG*YISS = 3.63	kg	Mass	0 %	Others	Food\Cereal produ	Impurities		
Add									
Outputs to technosphere: Avoided products	Amount	Unit	Distribution	SD2 or 2SD	Min	Max	Comment		
Add									
Inputs									
Inputs from nature	Sub-compartment	Amount	Unit	Distribution	SD2 or 2SD	Min	Max	Comment	
Add									
Inputs from technosphere: materials/fuels		Amount	Unit	Distrit	SD2	Min	Max	Comment	
FP GT -1 Soft Wheat Grain		HAWG = 7.26E3	kg					MP	
Tap water (Europe without Switzerland) tap water production, underground water without treatment		HAWG*YMO = 238	kg						
FP-1 bis paper bags x flour		NSF*MSF*(1+SPSAF) = 24.6	kg						
Chlorine, liquid (RER) chlorine production, liquid Cut-off, S		DETER = 0.0123	kg						
Lubricating oil (RER) market for lubricating oil Cut-off, S		OLUBR = 0.0152	kg						
Add									
Inputs from technosphere: electricity/heat		Amount	Unit	Dis	SI	M	Mi	Comment	
Electricity, medium voltage (IT) electricity voltage transformation from high to medium voltage Cut-off, S		147*HAWG/1000 = 1.07E3	kWh					147 kWh/Mg	
Transport, freight, lorry 7.5-16 metric ton, EURO5 (RER) transport, freight, lorry 7.5-16 metric ton, EURO5 C		HAWG*20 = 1.45E5	kgkm					TR HAWF grains Anguillara Sabazia-Bracciano: 20 km	
Transport, freight, lorry 16-32 metric ton, EURO5 (RER) transport, freight, lorry 16-32 metric ton, EURO5 Cu		NSF*MSF*(1+SSAF)*527 = 1.6E4	kgkm					TR paper bags Rho (MI)-Spoleto (PG): 527 km	
Transport, freight, lorry 3.5-7.5 metric ton, EURO5 (RER) transport, freight, lorry 3.5-7.5 metric ton, EURO5 C		(HAWG*YISS+SSAF)*50 = 194	kgkm					TR ISS+paper bag waste: 50 km	
Transport, freight, lorry 3.5-7.5 metric ton, EURO5 (RER) transport, freight, lorry 3.5-7.5 metric ton, EURO5 C		DETER/1000*112 = 0.00138	kgkm					TR Detergent- Nera Montoro (TR) -Bracciano: 112 km	
Transport, freight, lorry 3.5-7.5 metric ton, EURO5 (RER) transport, freight, lorry 3.5-7.5 metric ton, EURO5 C		OLUBR/1000*133 = 0.00203	kgkm					TR Lubricating oil -Terni-Bracciano: 133 km	
Transport, freight, lorry 7.5-16 metric ton, EURO5 (RER) transport, freight, lorry 7.5-16 metric ton, EURO5 C		HAWG*YWFP/1000*50 = 111	tkm					TR Milling by-products: MFG-CF: 50 km	
Add									
Outputs									
Emissions to air	Sub-compartment	Amount	Unit	Distrit	SD2 or	Min	Max	Comment	
Water	low. pop.	44.6	kg	Unde				see Table 3	
Outputs to technosphere: Waste and emissions to treatment		Amount	Unit	Dis	SD	Min	Mi	Comment	
Inert waste, for final disposal (RoW) treatment of inert waste, inert material landfill Cut-off, S		HAWG*YISS = 3.63	kg						
Paper (waste treatment) (GLO) recycling of paper Cut-off, S		SSAF*.808 = 0.197	kg						
Waste paperboard (RoW) treatment of, sanitary landfill Cut-off, S		SSAF*.116 = 0.0283	kg						
Waste paperboard (Europe without Switzerland) treatment of waste paperboard, municipal incineration Cut-off, S		SSAF*.076 = 0.0185	kg						

Table S38. Inventory associated with the fresh pasta production step using type 00 bread wheat flour.

Products									
Outputs to technosphere: Products and co-products	Amount	Unit	Quantity	Allocation %	Waste type	Category	Comment		
FPGT- 3 Fresh Pasta from BWF, at packaging	PFPACK = 5.98E3	kg	Mass	100 %	Compost	Food\Cereal produ			
FPGT-SI-SPP	ORGW = 117	kg	Mass	0 %	Biopolymer	Food\Cereal produ	scarti impasto+pasta fresca pastorizzata		
Add									
Outputs to technosphere: Avoided products	Amount	Unit	Distribution	SD2 or 2SD	Min	Max	Comment		
Add									
Inputs									
Inputs from nature	Sub-compartment	Amount	Unit	Distribution	SD2 or 2SD	Min	Max	Comment	
Add									
Inputs from technosphere: materials/fuels		Amount	Unit	Distrit	SD2 c	Min	Max	Comment	
FP GT - 2 Bread Wheat Flour, at industrial mill		HAWF = 5.3E3	kg						
Tap water {Europe without Switzerland} market for Cut-off, S		HAWF*WFR = 1.32E3	kg					Acqua per Impasto	
Water, deionised {Europe without Switzerland} water production, deionised Cut-off, S		HAWF*YVPAST = 334	kg					Per produrre vapore per pastorizzare la pasta fresca	
Chlorine, liquid {GLO} production Cut-off, S		DETER = 0.0933	kg						
Lubricating oil {RER} market for lubricating oil Cut-off, S		OLUBR = 0.176	kg						
Add									
Inputs from technosphere: electricity/heat		Amount	Unit	Dis	SI	M	Mi	Comment	
Heat, central or small-scale, natural gas {Europe without Switzerland} heat production, natural gas, at boiler		HAWF*YPP/1000*78.8 = 479	kWh						
Electricity, medium voltage {IT} electricity voltage transformation from high to medium voltage Cut-off, S		HAWF*YPP/1000*147.8 = 898	kWh						
Transport, freight, lorry 7.5-16 metric ton, EURO5 {RER} transport, freight, lorry 7.5-16 metric ton, EURO5 C		HAWF*150 = 7.95E5	kgkm					TR HAWF - Spoleto- Roma: 150 km	
Transport, freight, lorry 3.5-7.5 metric ton, EURO5 {RER} transport, freight, lorry 3.5-7.5 metric ton, EURO5 C		DETER*83 = 7.75	kgkm					TR Detergente - Nera Montoro (TR)-RM: 83 km	
Transport, freight, lorry 3.5-7.5 metric ton, EURO5 {RER} transport, freight, lorry 3.5-7.5 metric ton, EURO5 C		OLUBR*103 = 18.2	kgkm					TR Olio lubrificante -Terni -RM: 103 km	
Outputs									
Emissions to air	Sub-compartment	Amount	Unit	Distil	SD2 or	Min	Max	Comment	
Water	low. pop., long-term	HAWF*YVTRAF = 98.6	kg					Water evaporated alle trafile	
Water	low. pop., long-term	HAWF*YVASC = 753	kg					Water evaporated per ridurre al 24% p/p l'umidità della pasta Fresca	
Ethane, pentafluoro-, HFC-125	low. pop., long-term	PFPACK*YFG*.44 = 1.71E3	mg						
Ethane, 1,1,1,2-tetrafluoro-, HFC-134a	low. pop., long-term	PFPACK*YFG*.04 = 156	mg						
Ethane, 1,1,1-trifluoro-, HFC-143a	low. pop., long-term	PFPACK*YFG*.52 = 2.02E3	mg						
Outputs to technosphere: Waste and emissions to treatment		Amount	Unit	Dis	SD:	Min	M:	Comment	
Wastewater, from residence {RoW} treatment of, capacity 1.1E10l/year Cut-off, S		PFPACK/1000*72 = 431	l					72 L/Mg of fresh pasta	
Biowaste {RoW} treatment of biowaste by anaerobic digestion Cut-off, S		ORGW*.255 = 30	kg						
Sludge from pulp and paper production {Europe without Switzerland} treatment of sludge from pulp and paper pro		ORGW*.31 = 36.4	kg						
Raw sewage sludge {RoW} treatment of, municipal incineration Cut-off, S		ORGW*.18 = 21.1	kg						
Biowaste {RoW} treatment of biowaste, industrial composting Cut-off, S		ORGW*.255 = 30	kg						