Environmental Product Declaration
ISO 14025 EN15804+A2 2019 Compliant for
LumaWool™ Panels and Tiles

Autex Industries Pty Ltd
702 to 718 Rosebank Road,
Avondale, Auckland, New Zealand

EcoPlatform EPD Reference	AX01 2025EP
EPD Registration No.	AX01 2025EP
Issue Date	03 Mar 2025
Valid Until	03 Mar 2030
EPD Type	Cradle to grave
Geographical Scope	New Zealand to global market

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Mandatory Disclosures

EPD Verification and LCA detail			
Range Name	**Autex Acoustics® Panels**	**Product Name**	LumaWool™ Felt

Demonstration of Verification	
Objectives	To show improved, net-zero, net-positive and regenerative results and timely imperatives to secure viable climate and biodiversity on earth against a background of increasing disasters attributable to anthropogenic climate change.
Communication	This EPD discloses potential environmental outcomes compliant with ISO14025:2010. Independent external verification of this declaration and data ensures fitness for business-to-consumer communication [1].
Comparability	Different program EPDs may not be comparable. Comparability is further dependent on the product category rules and data source used.
Reliability	Life Cycle Impact Assessment (LCIA) results are relative expressions that do not predict impacts on category endpoints, exceeded thresholds, safety margins or risks.

EPD Program Operator	**LCA and EPD Producer**	**Declaration Owner**
Global GreenTag International Pty Ltd L38, 71 Eagle St., Brisbane QLD 4000 Australia Phone: +61 (0)7 33 999 686 http://www.globalgreentag.com	The Evah Institute 21 Roslyn Crt, Tamborine QLD 4217 Australia Phone: +61 (0)7 5545 0998 https://www.evah.institute	Autex Industries Ltd 702-718 Rosebank Rd. Avondale Auckland 1026 New Zealand Phone: +64 (9) 828 9179 http://www.autexacoustics.co.nz
Global GreenTag International green product certification trust brands	The Evah Institute Becoming Ecopositive	Autex Acoustics®

Product Category Rules (PCR)	Global GreenTag International Platform EPD compliant with ISO14025 standard [1] impact assessment methodology in reference EN15804 [2] & Sub-PCR WCL:2023.
EPD Owner	This EPD is the property of the declared manufacturer tabled above.
☑ Internal	Delwyn Jones 18Aug2026 — LCA & EPD Developed by Delwyn Jones, The Evah Institute 01Mar2025 — LCA & EPD Peer Review by Dr Sharmina Begum, The Evah Institute 18 Aug 2026 — EPD Platform Operator Review by David Baggs, Global GreenTag Pty Ltd
☑ External	I, the undersigned, 3rd party verifier, hereby confirm my examination did not find any relevant deviations by the EDP owner, LCA report or PCRs based on EN 15804 2012+A2:2019 and ECO Platform agreed interpretations by CEN TR 16970. Company-specific, upstream and downstream data in the LCA & environmental features report files held at The Evah Institute were plausible and consistent. This verification applied Global GreenTag International adopted ECO Platform checklists and this EPD states where to find PCRs and programme rules. 01 03 2025 — Third Party Verifier, Murray Jones, Ecquate Pty Ltd PO Box 123 Thirroul NSW 2515 Australia.
Explanations	Further explanatory information is available at info@globalgreentag.com or by contacting certification1@globalgreentag.com.

Program Description

EPD Scope	The scope is cradle to grave A1 to C4 + D as defined by ISO14025. [1]
System boundary	The system boundary with nature includes material & energy acquisition, processing, manufacture, transport, installation, use plus waste out to end of life.
Stages included	All known operations and stages in modules A1 to D3 are included.
Information	Figure 1 depicts A1 to C4 modules inside this cradle to grave system boundary.

Model	**Building Life Cycle Assessment**																**Beyond system**		
Information	**Actual**			**Scenarios**															
Stages	Product			Construct		Use							End-of-Life				Benefit & load		
						Fabric					Operate								
Modules	A1	A2	A3	A4	A5	B1	B2	B3	B4	B5	B6	B7	C1	C2	C3	C4	D1	D2	D3
Operations Cradle to Grave Fate C_2F & beyond system to Cradle (C_2C)	Resources	Transport	Manufacture	Transport	Construct	Use	Maintain	Repair	Replace	Refurbish	Energy use	Water use	Demolish	Transport	Process Waste	Disposal	Reuse	Recovery	Recycling
C_2Grave	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	O	O	O

Figure 1 Modules A to C Within the Cradle to Grave System Boundary and D Beyond

Primary Data Sources and Quality

Primary Data	Data was collected in accordance with EN ISO 14044:2006, 4.3.2, from primary sources including manufacturers, suppliers and their publications on standards locations, logistics, technology, market share, management system and commitment to improved environmental performance.
Cut-off & Data quality	Criteria complies with EN 15804:2012+A2:2019.
Allocation	Physical by mass and/or energy flow share and not by economic share.
Range and variability	Significant differences of mean LCIA results are declared.

Data Sources

Primary Data	Primary data is from primary sources 2023 to 2025 including manufacturer and supplier standards, logistics, technology, market share and management system in accordance with EN ISO 14044:2006, 4.3.2. All are physically allocated and none economically.
A1-A3 Stage inclusions	Operations include all • known raw material acquisition, refining and processing plus • scrap or material reuse from prior systems; • electricity generated from all sources with extraction, refining & transport plus • secondary fuel energy and recovery processes. Also • transport to factory gate; • manufacture of inputs, ancillaries, products, packaging, maintenance, replacement • plus flows leaving at end-of-waste boundary and • fate of all flows at end of life.
Variability	Significant differences of average LCIA results are declared.
Chemicals of Concern	Contains no substances in the European Chemicals Agency “Authorised or Candidate Lists of Substances of Very High Concern (SVHCs)”.

Product Information

This section provides data required to calculate assessment results factoring different mass and periods.

Manufacturing Site	702-718 Rosebank Road, Avondale, Auckland, New Zealand
Range Names	Autex Acoustics® Panels
Brand Name & Code	LumaWool™ Felt
Time	Made and sold in 2025 for first use
Factory warranty	10 years
Site Representation and Geography	New Zealand, Australasia, Pacific Rim and the World
Functional Performance in Building	Reduce and control reverberated noise and echo in building interiors. create high-performance acoustic features for interior space.
Reference Service Life	RSL 20 years with 97% reuse. Higher churn must factor results B4 & B5.
Declared Unit	Wool Felt of given kg/m^2 coverage and noise reduction coefficient NRC[1]
Functional Unit	20 year use per kg declared >0.2NRC product of given kg/m^{2}coverage.

Product Components Base Material Origin and Detail

This section summarises factory components, functions, source nation and % mass share. Key components by function, type, sources and % mass share are tabled below.

Function	Component	Source	Amount
Substrate	Knitted felted sheep wool	New Zealand	>99<100
Process additives	Dyes & conditioners	Global	<0.1%

Product Functional & Technical Performance Information

This section provides manufacturer specifications and additional information.

Applicable standards	Sound absorption performance complies as determined using ISO 354 methodology. Reaction to fire performance complies with ISO 9705:1993, AS 5637.1:2015, BS EN 13501-1 and ASTM E84.
Length*Width	(25,000*1,600) mm
Acoustic Properties	0.45-0.70 NRC
Coverage	1000 gsm

[1] NRC = Noise reduction coefficient conforming to ISO11654 standard methods

System Scope and Boundaries

Figure 2 shows included processes in a cradle to grave system boundary to end of life fates reuse, recycling, or landfill grave.

Stages A1 to 3 model actual operations to acquire, refine, transport, fabricate, coat, use, clean, repair, reuse and dispose of metal, masonry, ceramic, timber, glass, plastic and composites.

Stage A4 to C4 are modelled on typical scenarios to forecast operations including those of:

- Mining, extracting and refining resources to make commodities and packaging;
- Acquiring, cultivating, harvesting, extracting, refining produce and biomass;
- Fuel production to supply power and process energy and freight;
- Chemicals use in processing resources, intermediates and ancillaries;
- Process energy, fuel and freight of resources, intermediates and ancillaries;
- Use, cleaning, recoating, repair, recycling, re-use and landfill, as well as
- Infrastructure process energy transformed and material wear loss e.g. tyres.

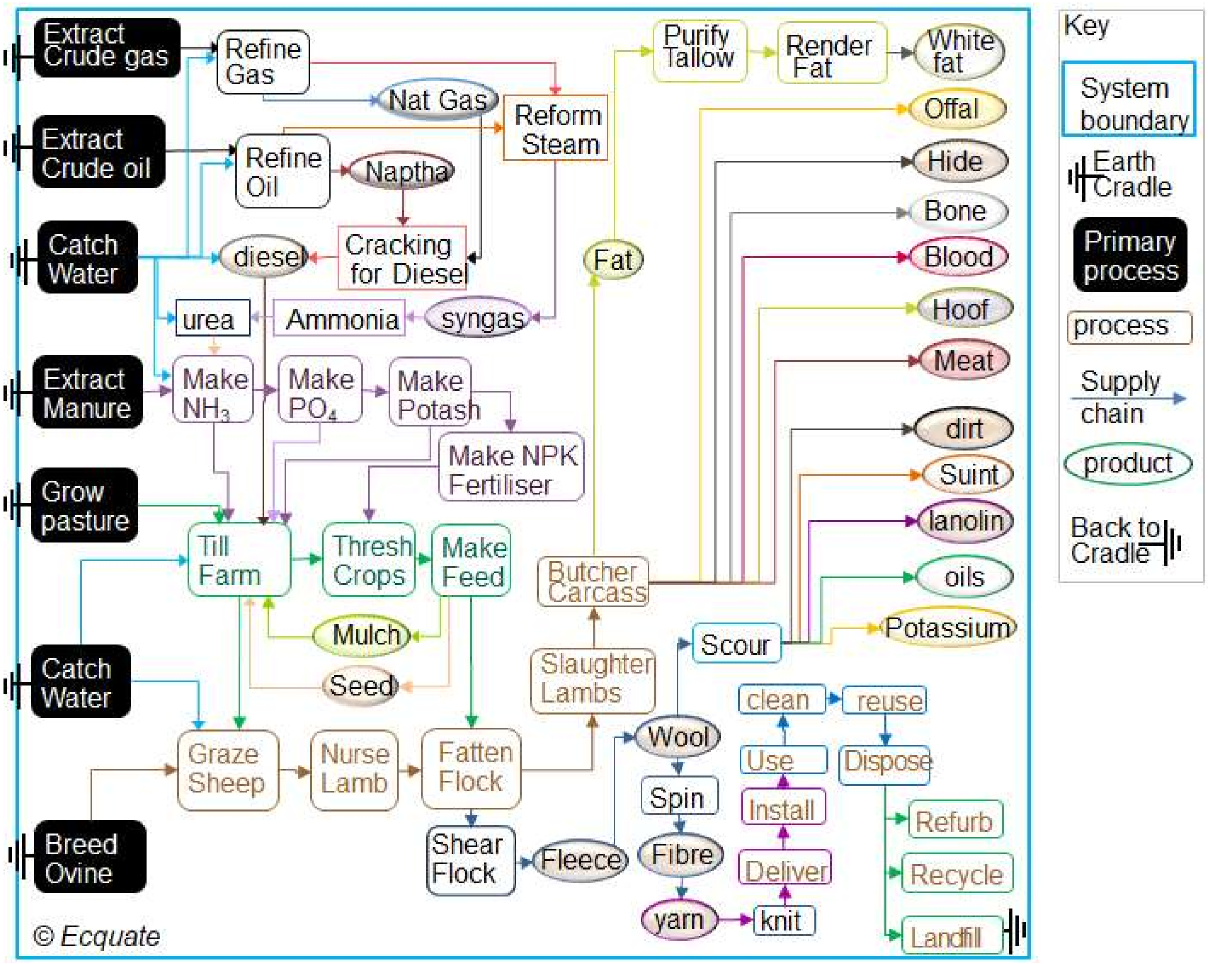

Figure 2. Product Process Flow Chart

Scenario Descriptions

This section defines modelling stages scenarios A4 to D3 beyond actual operations in module A1 to A3.

Module	Type specified	Amount	Type specified	Amount
Construction Modules				
A4 Transport factory to depot then to site	Sea Shipping	13,000	85% Capacity	Full back load
	Interstate Rail	1300 km	85% Capacity	Full back load
	25t semi-trailer	200 km	85% Capacity	No back load
A5 Install	VOCs indoors	0%	Packaging & Waste	0%
Building Modules				
B1 Use	VOCs	0%	No other flows	0%
B2 Maintain	fit for purpose	0%	fit for purpose	100%
B3 Repair	fit for purpose	95%	Repair damaged	5%
B4 Replace	fit for purpose	0%	No other flows	0%
B5 Refurbish	fit for purpose	0%	fit for purpose	100%
B6 Energy use	off grid	0%	Solar and wind energy	100%
B7 Water use	off grid	0%	Rain and dew	100%
End of Life Modules				
C1 Demolish	Fit for purpose	0%	No other flows	0%
C2 Transport	Fit for purpose	0%	No other flows	0%
C3 Waste Processing	Fit for disposal	0%	No other flows	0%
C4 Disposal	Fit for purpose	0%	No other flows	0%
Beyond System Boundary Modules				
D1 Reuse	Fit for purpose	95%	No other flows	0%
D2 Recover	Fit for purpose	2%	No other flows	0%
D3 Recycle	Fit for purpose	3%	No other flows	0%

Whole of life Performance

Waste	Cradle to grave waste to landfill from operations was non-hazardous.
Disposal	No production waste is sent to river, land or ocean outfalls or council landfills.
Effluent	LCI results and ESCAP raised no red-light concerns in emissions to water[2].
Wildlife safety	Low VOC, no plastics, glues or formaldehydes.
No Chemicals of Very High Concern	Contains no substances in the "Authorised or Candidate Lists of Substances of Very High Concern (SVHCs)" with the European Chemicals Agency.
Health Protection	The product does not contain levels of carcinogenic, toxic or hazardous substances that warrant ecological or human health concern cradle to grave. No issues or red-light concerns existed for product human or ecological toxicity.
Environmental Protection	Continuous improvement under the maker's uncertified management system avoids toxics, waste and pollution plus reduce their material and energy use.
Environmental Health Effects	No potential in-use impacts on environment or health are known.
Health Safety & Environment	Apart from compliance to occupational and workplace health safety and environmental laws no additional personal protection is considered essential for manufacture, use or reuse.

LCA Primary Data Quality

Data was <10 years and quality parameters are tabled below. Cut-off & quality is ISO14025 compliant[1].

Table a LCA Primary Data Quality Parameters and Uncertainty

Background	Data Quality	Parameters and Uncertainty (U)			
Correlation	Metric σg	U ±0.01	U ±0.05	U ±0.10	U ±0.20
Reliability	Reporting	Site Audit	Expert verify	Region	Sector
	Sample	>66% trend	>25% trend	>10% batch	>5% batch
Completion	Including	>50%	>25%	>10%	>5%
	Cut-off	0.01%w/w	0.05%w/w	0.1%w/w	0.5%w/w
Temporal	Data Age	<3 years	≤5 years	<7.5 years	<10 years
	Duration	>3 years	<3 years	<2 years	1 year
Technology	Typology	Actual	Comparable	In Class	Convention
Geography	Focus	Process	Line	Plant	Corporate
	Range	Continent	Nation	Plant	Line
	Jurisdiction	Representation is Global, Australasia and Pacific Rim			

2 According with national standards in ANZECC Guideline For Fresh & Marine Water Quality (2000)

Background Data Type and Sensitivity

Sheep Wool Composition

Apart from Keratin protein, greasy wool fleece contains 26% soil, 28% suint 12% fat, 1% water and <1% trace minerals[3].

Removing soil, suint and fat leaves clean dry wool comprising 97% protein mass [4].

Table 1 lists strong wool chemical analysis results from literature reviews and industry research.

Table 1 Chemical Analysis Results ex Woolworks NZ[5] & CSIRO

Sample No.	Source	Hydrogen	Carbon	Oxygen	Nitrogen	Sulphur	Total
>30	Literature	45	30	14	10	2	101
>8	ICP MS[6]	45	30	13	10	3	101
>8	SEM XD[7]	44	22	21	9	3	99
>16	Methionine[8] [9]	45	27	14	7	7	100
>50	Polyamide	44	24	16	13	3	100
>16	Wool Protein [10]	51	27	13	7	2	100
>128	Mean	46	27	15	9	3	100

Where analysis could not detect hydrogen, its content was calculated stoichiometrically. Overall averages are 46% hydrogen 27% carbon, 15% oxygen, 9% nitrogen and 3% sulphur.

Hydrogen content is highest followed by carbon then less oxygen, much less nitrogen and least sulphur. The high hydrogen and carbon reflect abundant input sources and low oxygen reflects limited availability in rumen[11] compared to that in fodder.

Sheep Coproducts

Table 2 lists NZ upland Merino Perrindale sheep coproduct average allocated wet mass data from site and industry [12].

Table 2 NZ Upland Herd Strong Greasy Wool Fleece Coproduct Mass %Share

Coproduct	Carcass	Meal: organs, blood,	Hide	Fleece	Tallow	Wet Gut	Sum
Mass %	50	22	13	7.7	6.7	0.6	100

While wool has a 7.7% mass share of total coproduct, this ignores its insulation value reducing energy demand of flocks grazing in the open across exposed uplands in cold wet weather.

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[3] Parlato M. Valenti F. Midolo G. & Porto S. (2022) Livestock Wastes Sustainable Use & Management, JO Energies DOI 10.3390/en15093008.

[4] International Wool Textile Organisation https://iwto.org/sustainability/life-cycle-assessment/

5 Woolworks Pty Ltd Hawks Bay New Zealand Confidential Report 2023

6 Inductively Coupled Plasma Mass Spectrometry https://pmc.ncbi.nlm.nih.gov/articles/PMC6719745/#

7 Scanning Electron Microscopy Xray Diffraction https://wiki.aapg.org/SEM,_XRD,_CL,_and_XF_methods

8 Reis, P.J. (1988). The Influence of Absorbed Nutrients on Wool Growth. In: Rogers, G.E., Reis, P.J., Ward, K.A., Marshall, R.C. (eds) The Biology of Wool and Hair. Springer, Dordrecht. https://doi.org/10.1007/978-94-011-9702-1_13

[9] Liu S. M and Masters D.G (2000) Animal Science, Volume 71, Issue 1, https://doi.org/10.1017/S1357729800055004

[10] Rogers et al. 1988, The Biology of Wool and Hair. Springer, Dordrecht. https://doi.org/10.1007/978-94-011-9702-1_13

[11] Hackman J. F. & Firkins J.L. (2015) Maximizing efficiency of rumen microbial protein production, Front Microbiol., Sec. Systems Microbiology V6 https://doi.org/10.3389/fmicb.2015.00465

[12] Australasian Livestock coproduct mass share data reported in 2024 by https://www.mla.com.au/

Durable Sheep Wool Coproducts

Since 2009, the Evah Institute has developed LCIA for cattle tallow, sheep wool and goat cashmere products.

Table 3 lists many sheep coproducts.

Other ruminant products include emollients, fats, foods, feeds, fibres, fertiliser, hides, nutrients, leathers, oils, and waxes.

This table lists durable applications including insulation, upholstery, carpets, and plasticisers Within the sheep industry supply chain scope of work.

Table 3 Sheep Industry Coproducts

Hide	Wool	Lanolin	Fats	Carcass	Intestines
Leathers	Yarns	Pharmaceuticals	Tallow	Meats	Sausage Casings
Upholstery	Fabric & Felt	Lotions	Polymers	Bone	Instrument Strings
Luggage	Carpet	Motor Oils	Plasticisers	Offal	Surgical Sutures
Footwear	Upholstery	Lubricants	Surfactants	Protein	Racquet Strings
Nursery Rugs	Doona Fill	Printing Ink	Industry Soap	Manures	Organs
Drum head	Matress Fill	Adhesive Tape	Chemicals	Potash	Meat & bone meal
Chamois	Clothing	Shampoo	Fatty Acids	Phosphorus	Blood meal
Sports gear	Knitwear	Conditioner	Solvents	N Fertiiser	Pet food
Baseballs	Coats & Hats	Cosmetics	Paints	Minerals	Blood
Tennis Balls	Socks & Mits	Lipstick	Chewing Gum	Nutrients	Cultures
Oil Spill Pad	Art Brushes	Mascara	Explosives	Ash	Bacteria

Sheep Fleece Greenhouse Gas (GHG) Emissions to 100-year Horizons

This section describes Greenhouse Gas (GHG) estimates cited in recent literature [4 to 9]. Figure 3 shows GHG ranging (8 to 58) kg CO_{2e} /kg with a red line depicting the average 22kg CO_{2e} /kg fleece.

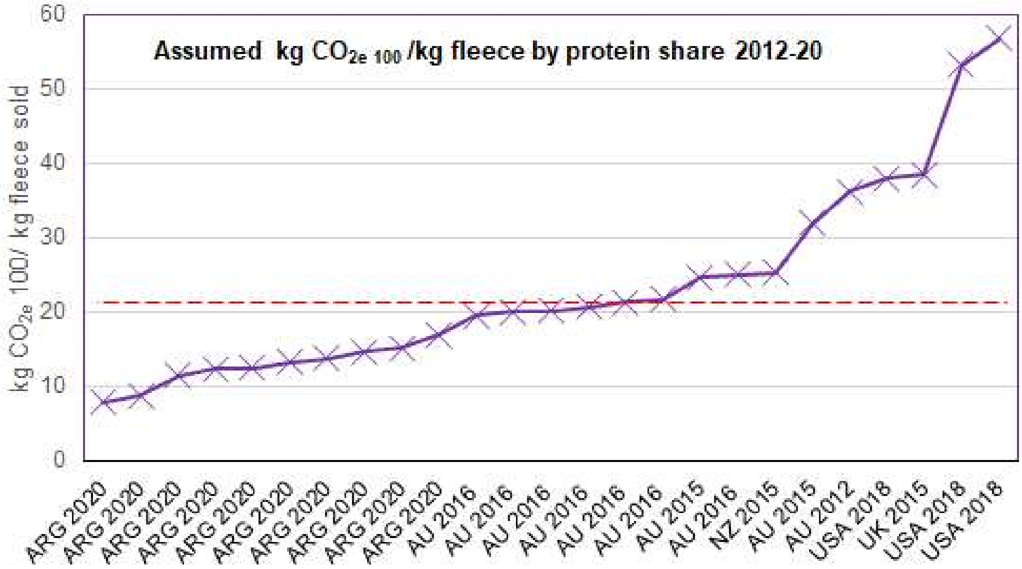


Figure 3 Recently Cited Assumed Wool Fleece GWP

Table 4 cites such results from a wide range of nations and climate. All were allocated on 22% to 50% share of the total. Being >3 to 6 times higher than 7.7% mass share means they do not reflect mass shares in Table 2.

Table 4 Recently Cited Wool Fleece Allocations by Protein.

Country	First Author	Year	Code	Share %	kg CO_{2e}/kg
New Zealand		2015	NZ 2015	43	25.3
Australia	Wiedemann	2015	AU 2015	45 and 50	32.0 and 24.7 respectively
				35 and 38	25.0 and 21.7 respectively
		2016	AU 2016	40 and 42	19.5 and 21.3 respectively
				47	20.1 and 20.0
Australia	Cottle	2016	AU 2016	36	20.7
USA	Wiedemann	2018	USA 2018	22	38.4
Argentina	Peri	2020	ARG 2020	33	7.8, 8.8, 11.5, 12.4, 12.4, 13.3, 13.7, 14.7, 15.1, 16.9
New Zealand	Mazzetti	2023	Uncharted	31	22.2

Such LCA excluding major coproduct shares does not comply with EN15804 standard for building product EPDs. The Mazzetto et al LCA report in 2023 for Wool Impact New Zealand (NZ) also finds 22kg CO_{2e} 100kg fleece [13]. It did so after allocating 31% burdens to sheep wool and 69% to the hot carcass on protein content.

Clean dry wool contains 97% protein whereas hot carcass meat contains only 25% protein and 75% water by mass. It is assumed, that the authors factored in such differences.

[13] Mazzetto A. Falconer S. & Ledgard S. (2023) Carbon footprint of strong wool from an average New Zealand sheep farm system, Confidential Report for Wool Impact RE450/2023/038

NZ Average Herd Total GWP versus Wool Shares

Table 5 reports GHG emissions allocated to the whole animal versus across the 2 same products. It compares these to Evah biophysically allocated LCA to all coproducts including embodied carbon from comparable herds grazing on marginal upland in New Zealand.

Note that Evah reduced the 7.7% mass fleece share to 5.7% based on its insulation reducing energy demand and heat loss 25% annually in cold wet weather.

Table 5 NZ Upland Herd Strong Greasy Wool Fleece GWP Mazzetto Vs Evah

Allocated kg CO_{2e}/kg % share	100% Live Animal	31% Mazzetto[14]	5.7%Evah
Enteric	59.55	18.46	3.407
Excreta	5.839	1.810	0.334
Fertiliser	3.548	1.100	0.203
Crops	0.839	0.260	0.048
Fuel	0.935	0.290	0.054
Lime	0.645	0.200	0.037
Pasture renewal	0.258	0.080	0.015
Pesticide	0.065	0.020	0.004
Shearing	0.069	0.022	0.004
Electricity	0.032	0.010	0.002
Herbicide	0.032	0.010	0.002
Rumen drawdown	0	0	-9.90
Pasture sequestration	0	0	-2.03
Soil drawdown	0	0	-0.018
Sub-total	72	22	-7.8

All such cited studies also exclude all sequestration and embodied chemical drawdown [4 to 9]. On short-term single-use food, medicine, and packaging products LCA practice often ignores embodied input.

History has shown, however, it is better to consider than ignore embodied content that can have cumulative effects over the full life cycle or over the longer term.

[14] Mazzetto et al op cit

EN15804 Compliance Sheep Product LCA

Again, all such cradle to farm gate LCA excluding significant embodied GHG fails to comply with the EN15804 standard for building product EPDs.

No durable wood, wool, polymer, ceramic, metal, or mineral merits its embodied content being ignored.

Their quantification can reveal short term risks and enduring opportunities arising for mitigating human, environmental and climate health and resource depletion via:

- landfill emissions retrieval for climate security and to reform feedstock for economic return.
- material reuse, recovery, recycling and upcycling for economic returns on investment
- feedstock energy recovery and reuse for fuel value and to reduce fire loads
- feedstock energy recovery to avoid contaminating waterways, air and land

Moreover, their quantification can reveal longer term risks and enduring opportunities arising for resource recovery via sewer mining sources of

- biomethane sources to fuel industry and greener-urban techologies
- hydrogen sources to fuel industry and urban climate-safe techology
- energy to pump distilled water for urban reuse to avoid more sea level rise
- energy to pump distilled water to industry and agriculture for economic security
- biomass for making polymers, fertilisers and soil-carbon-enriching bio char.
- biosolids via composting to avoid human disease and marine pollution
- prescription drugs via biodigesors to avoid contaminating marine food chains
- hormones via bio digestors to avoid polluting marine food chains as well as
- scarce materials and tramp elements for making electronic components.

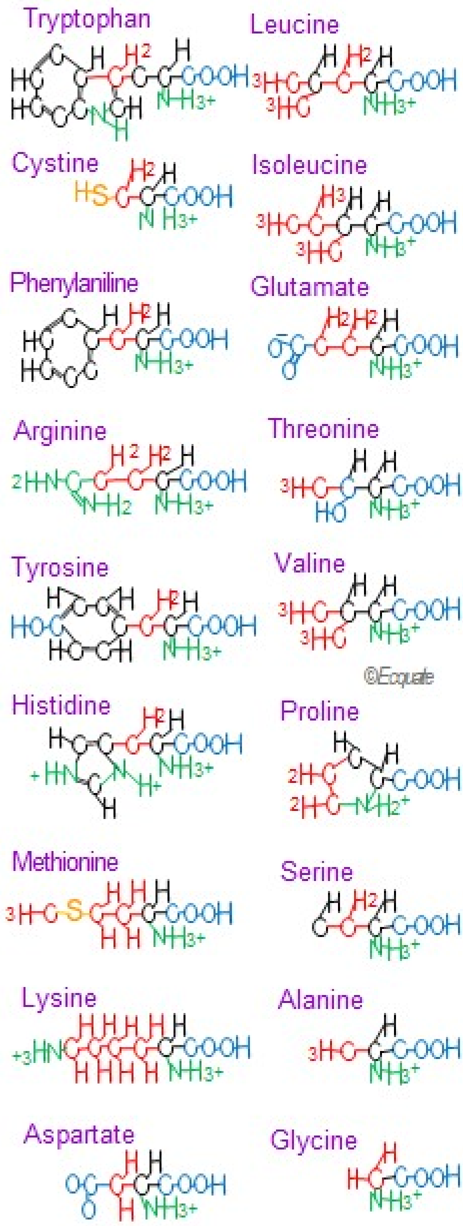
Wool Protein Chemical Compositions

Merino cross breed wool protein comprises amino acids with molecular formulae and mass share as in Table 6. In the last column each amino acid's microstructure depicted has the same basic structure of attached α-carbon, hydrogen, α-carboxyl, α-amine and multivariate R-groups.

Hydrocarbon **C-C-H**, methyl **CH_3** and methylene **CH_2** groups are shown in red, carboxyl **C=O** in blue, amines **N-H** and ammonias **N-H_3** in green and sulphides **S** in yellow. Unknown Carbon or **R** groups are shown in black.

Table 6 Chemical Microstructure Low GWP Wool protein CO_2, CH and CH_3 mass share

Protein	1 Mole	Chemical	Molecules		
Amino Acids	fraction	Formula	CO_2	CH	CH_3
Tryptophan	0.08675	$C_{11}H_{12}N_2O_3$	7	4	1
Cystine	0.08202	$C_6H_{12}N_2O_4S_2$	1	0	1
Phenylaniline	0.07137	$C_9H_{11}NO_2$	2	6	1
Arginine	0.06861	$C_6H_{14}N_4O_2$	2	2	2
Tyrosine	0.06506	$C_9H_{11}NO_3$	4	6	1
Histidine	0.06112	$C_6H_9N_3O_2$	1	2	1
Methionine	0.05875	$C_5H_{11}NO_2S$	1	1	3
Lysine	0.05757	$C_6H_{14}N_2O_2$	1	1	4
Aspartate	0.05244	$C_4H_7NO_4$	3	0	1
Leucine	0.05166	$C_6H_{14}N_2O_2$	1	2	4
Isoleucine	0.05166	$C_6H_{13}NO_2$	1	1	4
Glutamate	0.04850	$C_3H_9N0_4$	2	0	2
Threonine	0.04692	$C_4H_9NO_3$	2	0	2
Valine	0.04614	$C_5H_{11}NO_2$	1	2	3
Proline	0.04535	$C_5H_9NO_2$	1	1	3
Serine	0.04140	$C_3H_7NO_3$	2	0	1
Alanine	0.03509	$C_3H_7NO_2$	1	1	1
Glycine	0.02957	$C_2H_5NO_2$	1	0	1
Sum			34	29	36



All 18 contain methyl and methylene groups but only methionine and cystine contain sulphur.

Chemical Microstructures of Wool Polyamide, Methionine versus Protein

This section compares typical clean sheep wool depictions of atomic and compound types from generic polyamide to specifically known amino acids. Apart from methyl and methylene groups methionine is one of only two amino acid sources of sulphur depicted in yellow in each case[15]. Figure 4 depicts wool polyamide $n(C_2H_4O_2NxS_2Ry)$ with some known methyl content but any unknown side chains.

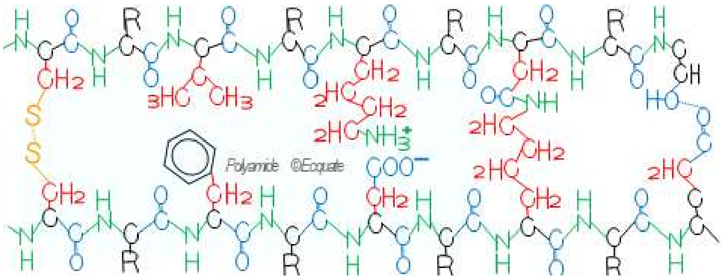


Figure 4 Wool Microstructure as a Generic Polyamide

Figure 5 depicts the methyl-richest amino acid methionine $n(C_5H_{11}O_2NS)$. It maximises merino wool growth.

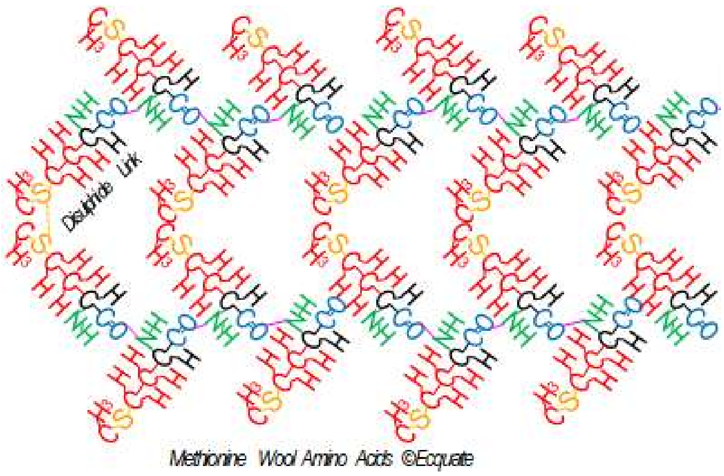


Figure 5 Wool Depicting all Methionine Amino Acids

Lastly Figure 6 depicts the methyl rich wool polymer $(C_2H_4O_2NxS_2)$ with all side chains known and depicted.

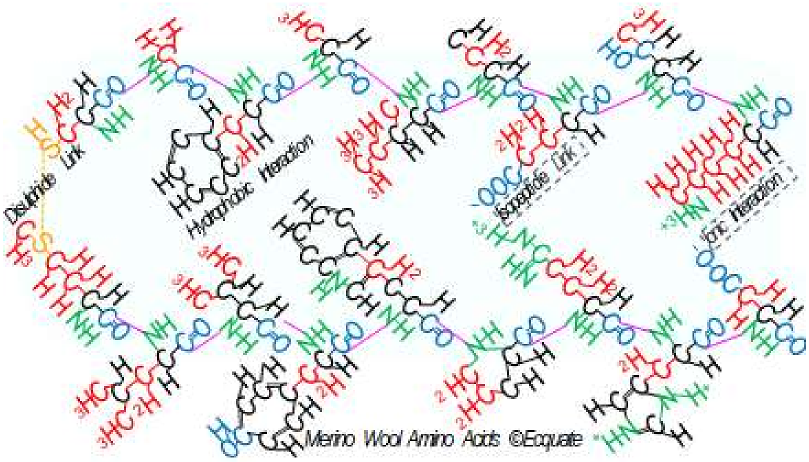


Figure 6 Wool Protein with all Typical Amino Acids

[15] Reis, P.J. (1988) op cit

Greenhouse Gas in Wool Polyamide, Methionine versus Protein

Table 7 lists theoretical polymer chemistry versus embodied GHG to 100 years. The range of such wool results include 3 low and 3 median result sets with means ±10%. Another higher value is also listed in Table 8.

Table 7 Modelling Assumptions for GWP embodied Clean Wool Fibre

Wool Molecular / GHG Modelling Assumptions	Molar mass Shares			GHG CO_{2eq} 100/kg			
	CO_2	CH_4	S +N	1*CO_2	27.2*CH_4	Sum	Means
Polyamide	0.733	0.267	0.000	0.733	7.267	8.00	
Methionine	0.666	0.306	0.028	0.666	8.334	9.00	8.8
Protein O_2 limited	0.652	0.320	0.028	0.652	8.708	9.36	
Protein H_2 limited	0.380	0.592	0.028	0.380	16.112	16.5	
67% Rumen Protein	0.337	0.635	0.028	0.337	17.275	17.6	18.1
67% Rumen Methanotroph	0.244	0.729	0.027	0.244	19.818	20.1	

Table 8 lists wool polymer chemistry modelling assumptions against Global Warming Potential (GWP) results to 100-year horizons of biogenic, land use change, fossil fuel use and the total GHG [16].

These cradle to grave results also show close lower and median result set means ±10% plus a higher value including minimum N_2O emissions. Biogenic GWP results are most sensitive to inclusion of embodied N_2O in the protein modelling. At this stage no other lower or median results declared include embodied N_2O.

Table 8 Modelling Assumptions for GWP embodied Clean Wool Fibre

Wool / GWP Model Assumed	Biogenic	LULUC	Fossil Fuels	Total	Mean
Polyamide	-8.3	-1.7	2.8	-7.2	
Methionine	-9.3	-1.7	2.8	-8.2	8.0
Protein O_2 limited	-9.7	-1.7	2.8	-8.6	
Protein H_2 limited	-16	-1.7	2.8	-16	
67% Rumen Protein	-18	-1.7	2.8	-17	17.3
67% Rumen Methanotroph	-20	-1.7	2.8	-19	
67%Rumen Methanotroph +N_2O	-28	-1.7	2.8	-27	NA

In summary this background data shows fleece GHG most sensitive to polymer and rumen microbial chemistry. More evidence, however, is vital to reveal which best fits a particular herd, rumen, soil or forage type.

More importantly, site-specific data is vital to show if upper result inclusion of embodied N_2O fits upland station wool production in marginal land grazing across New Zealand, Australia, South Africa, PR China and USA.

Background and Primary LCA Data Included and Excluded in this EPD

This EPD declares the lowest embodied GWP wool protein estimate considering no significant land use change since 1925. Pasture drawdown was modelled on CSIRO fodder intake of 33% foraging. It also includes lowest soil drawdown from on-site testing.

The 7.7% mass fleece share was reduced for flocks grazing on marginal upland in New Zealand to 5.7% as wool insulation reduces winter heat loss 25% of the year.

[16] Characterisation factors from 2021 Intergovernmental Panel on Climate Change (IPCC), AR 6 Climate Change, https://www.ipcc.ch/

Environmental Impact Terminology

Environmental impacts contributing to risks of social and ecological issues and collapse are tabled below with common names and remedies given for each indicator.

Global warming forcing climate change	Greenhouse gases absorb infra-red radiation. This heat reduces thermal energy differentials, from equator to poles, forcing ocean current and wind circulation to blend and regulate climate. Weakly blended "lumpier" weather has more frequent, extreme heat wave, fire-storm, cyclone, rain-storm, flood and blizzard events. Accumulation of carbon dioxide, natural gas methane, nitrous oxides and volatile organic compounds from burning fossil fuels causes global warming. Forest and wilderness growth absorbing air-borne carbon in biomass can drawdown such accumulation. Urgent renewable energy reliance is vital in time to avoid imminent tipping points and the worsening "***climate emergency***".
Ozone layer depletion	Stratospheric ozone loss weakens the planet's solar shield so more shorter wavelength ultraviolet (UVB) light reaching earth damages plants and increases malignant melanoma and skin cancer in humans and animals. Chlorofluorocarbons, hydrochlorofluorocarbons (HCFC), chlorobromomethane, hydrobromofluorocarbons, carbon tetrachloride, methyl chloroform, methyl bromide and halon gas cause ozone layer loss. To repair the "***ozone hole***" reliance on ozone-safe refrigerants, aerosols and solvents is essential to avoid further its depletion and enable accumulation of naturally-formed ozone.
Acidification	Acidification reduces soil and waterway pH, impedes nitrogen fixation vital for plant growth and inhibits natural decomposition. It increases rates and incidence of fish kills, forest loss and deterioration of buildings and materials. Chief synthetic causes of "***acid rain***" are emissions of sulphur and nitrogen oxides, hydrochloric and hydrofluoric acids and ammonia from burning fossil fuels polluting precipitation of rain and snow world-wide.
Eutrophication of terrestrial, freshwater and marine life	Eutrophication from excessively high macronutrient levels added to natural waters promotes excessive plant growth that severely reduces oxygen, water and habitat security for aquatic and terrestrial organisms across related ecosystems. Chief synthetic cause of "***algal blooms***" is nitrogen (N, NOx, NH_4) and phosphorus (P, PO_4^{3-}) in rain run-off over-fertilised land catchments.
Photochemical ozone creation	Tropospheric photochemical ozone, called "***summer smog***" near ground level, is created from natural and synthetic compounds in UV sunlight. Low concentration smog damages vegetation and crops. High concentration smog is hazardous to human health. Chief synthetic causes are nitrogen oxides, carbon monoxide and volatile organic compounds (VOC) pollutants. Avoiding reliance on dirtiest coal fuel and volatile chemicals has reduced smog incidence in many areas globally.
Depletion of minerals, metals & water	Abiotic depletion of finite mineral resources increases time, effort and money required to obtain more resources to the point of extinction of naturally viable reserves. This can limit access to available, valuable and scarce elements vital for human-life. The youth movement "***extinction rebellion***" calls on adults to secure climate, reserves and biodiversity for current and future generations.
Depletion of fossil fuel reserves	Abiotic depletion of resources by consuming finite oil, natural gas, coal and yellowcake fossil fuel reserves leaves current and future generations suffering limited available, accessible, plentiful, essential valuable as well as scarce raw material, medicinal, chemical, feedstock and fuel stock. Approaching "***peak oil***" acknowledged fossil fuel reserves are finite and the need for decision-makers to act to avoid market instability, insecurity and or oil and gas wars.

Environmental Parameters and Methods

Table 9 lists methods and parameters for environmental impact, resource use and waste output. Table 10 lists results for environmental impact, resource use and waste output per functional unit. As there were no flows for module B1, B4, B5, B6, B7 and C3 all their LCA results are zero.

Table 9 Environmental Parameters, Units and Methods Description

Parameter	Acronym	Unit	Method Description
Environmental Impact			
Climate Change biogenic	GWPb	kg CO_{2eq}	GWP sequestered from air [10]
Climate Change luluc	GWPl	kg CO_{2eq}	GWP land use & change [10]
Climate Change fossil	GWPf	kg CO_{2eq}	GWP fossil fuels [10]
Climate Change total	GWPT	kg CO_{2eq}	Global Warming Potential [10]
Stratospheric Ozone Depletion	ODP	kg CFC_{11e}	Stratospheric Ozone Loss [11]
Photochemical Ozone Creation	POCP	kg $NVOC_{e}$	Summer Smog [12]
Acidification Potential	AP	mol H^{+}_{eq}	Accumulated Exceedance [13]
Eutrophication Freshwater	EPF	kg P_{eq}	Excess freshwater nutrients [14]
Eutrophication Marine	EPM	kg N_{eq}	Excess marine nutrients [15]
Eutrophication Terrestrial	EPT	mol N_{eq}	Excess nutrients to land [16]
Fossil Depletion	ADPF	MJ_{ncv}	Abiotic Depletion fossil fuel [17]
Mineral and Metal Depletion	ADPE	kg Sb_{eq}	Abiotic Depletion minerals [18]
Water Scarcity Depletion	WDP	$m^3_{WDP\ eq}$	Water Deprivation Scarcity [19,20]
Resource Use			
Net Fresh Water	FW	m^3	Lake, river, well & town water
Secondary Material	SM	kg	Post-consumer recycled Material
Renewable Secondary Fuel	RSF	MJ_{ncv}	PCR biomass burnt
Non-renewable Secondary Fuel	NRSF	MJ_{ncv}	PCR fossil feedstock & fuel use
Primary Renewable Material Energy	PERM	MJ_{ncv}	Biomass feedstock material retained
Primary Renewable Energy	PERE	MJ_{ncv}	Renewable energy and biomass fuel
Total Primary Renewable Energy	PERT	MJ_{ncv}	Total renewable energy & biomass fuel
Primary Non-renewable Material	PENRM	MJ_{ncv}	Fossil feedstock material retained
Primary Non-renewable Energy	PENRE	MJ_{ncv}	Fossil fuel burnt
Total Primary Non-renewable Energy	PENRT	MJ_{ncv}	Total fossil energy and feedstock use
Waste Output			
Hazardous Waste Disposed	HWD	kg	Reprocessed to contain risks
Non-hazardous Waste Disposed	NHWD	kg	Municipal landfill facility waste
Radioactive Waste Disposed	RWD	kg	Most ex nuclear power stations
Components For Reuse	CRU	kg	Product scrap for reuse as is
Material For Recycling	MFR	kg	Factory scrap to remanufacture
Material For Energy Recovery	MER	kg	Factory scrap used as fuel
Exported Energy Electrical	EEE	MJ_{ncv}	Uncommon for building products
Exported Energy Thermal	EET	MJ_{ncv}	Uncommon for building products

Results Module A and B

Table 10 lists Module A and B environmental impact, resource use and waste results per functional unit.

Table 10 Results Modules A and B / functional unit

Parameter	Produce	Deliver	Construct	Maintain	Repair
/Module	A1-3	A4	A5	B2	B3
Environmental Impact					
Climate Change biogenic	-9.7	-1.0E-06	-0.24	-2.4E-05	-1.1E-04
Climate Change luluc	-1.7	1.1E-04	0	-7.3E-04	7.1E-04
Climate Change fossil	2.8	1.1E-02	7.1E-02	7.4E-04	7.1E-06
Climate Change total	-8.6	1.1E-02	-0.21	-2.1E-05	6.1E-04
Stratospheric Ozone Depletion	3.4E-09	1.7E-13	8.4E-11	3.3E-12	8.4E-15
Photochemical Ozone	0	8.1E-05	0	3.0E-06	0
Acidification Potential	0	8.3E-06	0	1.2E-06	0
Eutrophication Freshwater	4.8E-05	4.9E-10	1.2E-06	7.1E-10	1.2E-10
Eutrophication Marine	0	1.5E-06	0	2.1E-07	0
Eutrophication Terrestrial	0	5.3E-06	0	1.5E-06	0
Fossil Depletion	4.7E-04	7.2E-06	1.2E-05	3.4E-07	1.2E-09
Mineral and Metal Depletion	1.6	1.3E-02	4.2E-02	4.9E-04	4.2E-06
Water Scarcity Depletion	9.3E-03	2.3E-06	2.3E-04	1.1E-05	2.3E-08
Resource Use					
Net Fresh Water	5.7E-02	1.4E-05	1.4E-03	6.6E-05	1.4E-07
Secondary Material	0	9.0E-07	0	0	0
Renewable Secondary Fuel	2.4E-02	6.8E-06	5.0E-03	8.1E-05	5.9E-08
Non-renewable Secondary Fuel	7.1E-02	7.4E-04	1.8E-03	1.4E-03	1.8E-07
Primary Renewable Material Energy	42	2.4E-03	1.1	7.4E-03	1.1E-04
Primary Renewable Energy	7.3	3.0E-04	0.18	7.7E-02	1.8E-05
Total Primary Renewable Energy	50	2.7E-03	1.2	8.5E-02	1.2E-04
Primary Non-renewable Material Energy	6.3	0.19	0.16	6.5E-02	1.6E-05
Primary Non-renewable Energy	21	0.11	0.54	5.3E-02	5.4E-05
Total Primary Non-renewable Energy	27	0.30	0.70	0.12	7.0E-05
Waste Output					
Hazardous Waste	1.5E-03	2.1E-05	3.9E-05	1.1E-06	3.9E-09
Non-hazardous Waste	4.3E-02	1.7E-04	1.1E-03	1.1E-04	1.1E-07
Radioactive Waste	2.5E-17	8.9E-32	6.3E-19	2.5E-20	6.3E-23
Components For Reuse	1.6	1.0E-05	4.0E-02	4.1E-11	4.0E-06
Material For Recycling	2.2E-05	2.3E-07	5.7E-07	3.7E-08	1.0E-04
Material For Energy Recovery	2.2E-02	5.5E-06	5.4E-04	8.3E-05	5.4E-08
Exported Energy Electrical	0	0	0	0	0
Exported Energy Thermal	0	0	0	0	0

Results Module C and D

Table 11 lists Module C and D environmental impact, resource use and waste results per functional unit.

Table 11 Results Modules C and D / functional unit

Parameter	Demolish	Transport	Dispose	Reuse	Recover	Recycle
/Module	C1	C2	C4	D1	D2	D3
Environmental Impact						
Climate Change biogenic	-1.2E-05	-1.0E-06	3.5	7.3	-1.8E-05	0.24
Climate Change luluc	-5.3E-05	5.9E-05	-3.0E-05	1.3	0	4.3E-02
Climate Change fossil	1.8E-03	6.1E-03	5.9E-05	-2.1	2.4E-04	-7.0E-02
Climate Change total	1.8E-03	6.2E-03	3.5	6.4	2.2E-04	0.21
Stratospheric Ozone Depletion	7.7E-17	1.1E-13	4.6E-13	-2.5E-09	5.4E-13	-8.4E-11
Photochemical Ozone	7.1E-06	6.0E-05	1.1E-06	0	9.3E-07	0
Acidification Potential	3.2E-06	5.1E-06	2.4E-04	0	4.0E-07	0
Eutrophication Freshwater	3.5E-13	3.1E-10	4.4E-10	-3.6E-05	1.2E-10	-1.2E-06
Eutrophication Marine	5.8E-07	9.4E-07	1.7E-08	0	7.0E-08	0
Eutrophication Terrestrial	3.8E-06	3.2E-06	1.3E-07	0	4.8E-07	0
Fossil Depletion	9.2E-12	4.0E-06	2.2E-08	-3.5E-04	5.7E-08	-1.2E-05
Mineral and Metal Depletion	7.9E-04	7.5E-03	3.8E-05	-1.2	1.3E-04	-4.0E-02
Water Scarcity Depletion	8.3E-08	1.4E-06	6.2E-07	-7.0E-03	1.8E-05	-2.3E-04
Resource Use						
Net Fresh Water	5.1E-07	8.7E-06	3.8E-06	-4.3E-02	1.1E-04	-1.4E-03
Secondary Material	8.1E-07	6.0E-07	9.4E-08	0	0	0
Renewable Secondary Fuel	4.3E-05	9.2E-05	6.7E-08	-1.8E-02	3.8E-05	-5.9E-04
Non-renewable Secondary Fuel	4.3E-10	4.8E-04	8.1E-07	-5.3E-02	7.7E-06	-1.8E-03
Primary Renewable Material Energy	2.2E-03	2.0E-04	-2.2E-02	-32	2.0E-04	-1.1
Primary Renewable Energy	1.4E-09	1.6E-03	2.5E-02	-5.5	2.9E-04	-0.18
Total Primary Renewable Energy	2.3E-03	1.9E-03	3.0E-03	-37	5.2E-04	-1.2
Primary Non-renewable Material	1.6E-02	6.3E-02	1.8E-04	-4.7	3.2E-04	-0.16
Primary Non-renewable Energy	2.5E-04	3.7E-02	4.3E-04	-16	2.1E-03	-0.53
Total Primary Non-renewable Energy	1.7E-02	0.10	6.1E-04	-21	2.4E-03	-0.69
Waste Output						
Hazardous Waste	6.5E-08	1.2E-05	1.2E-07	-1.1E-03	1.9E-07	-3.8E-05
Non-hazardous Waste	1.7E-06	9.6E-05	1.8E-05	-3.2E-02	1.8E-05	-1.1E-03
Radioactive Waste	9.7E-38	7.0E-32	8.7E-21	-1.9E-17	4.1E-21	-6.3E-19
Components For Reuse	1.0E-05	1.0E-05	1.4E-15	-1.2	1.0E-05	-4.0E-02
Material For Recycling	2.6E-13	1.5E-07	2.5E-02	-1.7E-05	6.1E-09	-5.5E-07
Material For Energy Recovery	2.0E-05	3.9E-06	6.8E-08	-1.6E-02	1.5E-05	-5.4E-04
Exported Energy Electrical	0	0	0	0	0	0
Exported Energy Thermal	0	0	0	0	0	0

Interpretationof Life Cycle Inventory and Impact Results

Cradle to Gate A1 to A3

LumaWool™ acoustic insulation panel Greenhouse gas (GHG) Global Warming Potential (GWP) kgCO_{2e} /kg functional unit results cradle to gate for various assumed wool chemical components. Figure 7 charts component type versus GWP. Here GWP varied directly with assumed and embodied molecules, particularly methyl, methylene and carboxyl groups. The polyamide had least GWP, then methionine and Protein ($O_{2\ ltd}$) all in close agreement. Better negative GWP was found from group of the

- Hydrogen limited protein,
- 67% methane-rich rumen protein with 33% grass sequestered CO_{2e}-rich sugars and
- 67% methane-rich Methanophile rumen protein 33% grass sequestered CO_{2e}-rich sugars,

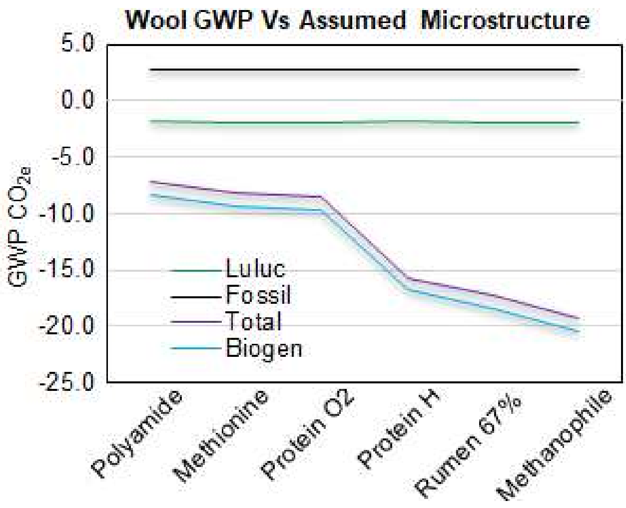


Figure 7 Feedstock type versus GWP (CO_{2e}kg)/kg product.

Cradle to Grave A4 to D3

This EPD declares low range results from modelling Oxygen limited protein flows embodied in LumaWool™ results cradle A1 to D3 fates/functional unit beyond the system boundary. Figure 8 shows that overall total GWP results are best A1 to A3. They are worse in C2 trucking to landfill and C4 disposal via combustion but worst in reuse avoiding new wool product. Biogenic GWP is best A1 to A3, worse in C2 and C4 but worst in D1. Luluc GWP is best A1 to A3 and worst in D1 reuse. Fossil fuel GWP use is highest from A1 to A3, then lowest in D1 reuse.

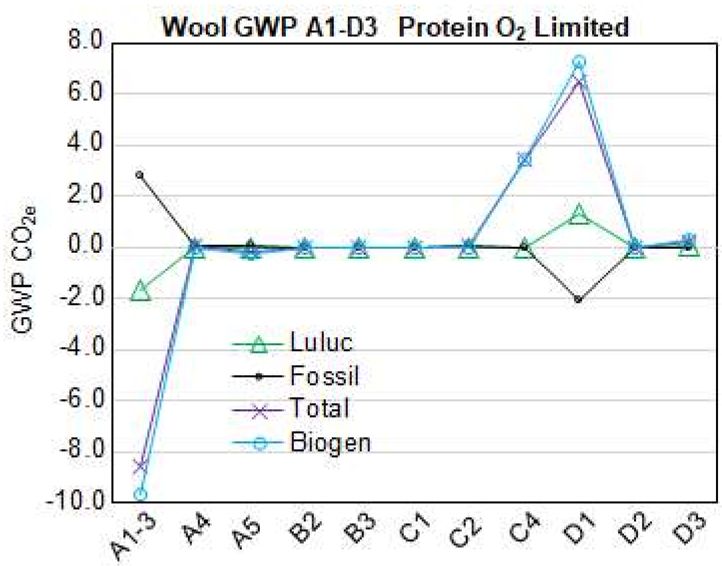


Figure 8 Feedstock type versus GWP (CO_{2e}kg)/kg product.

Life Cycle Assessment Methods and Data

LCA Author	The Evah Institute https://evah.institute/
Study Period	Factory data was collected from 2023 to 2025
LCA Method	ISO 14040 & ISO 14044 Standard Compliant
LCIA method	ReCiPe 2016 Life Cycle Impact Assessment
Scope	Cradle to fate including all supply chain phases and stages depicted in Figure a.
Phases	The LCA covered all known flows in all known stages cradle to end of life fate.
Assumptions	Use is to typical Australian Facility Mangement Association professional practice.
Scenarios	Use, cleaning, maintenance plus disposal and re-use were scenario-based using Facility Management Association denoted and published typical operations.
Processes	All known processes are included from resource acquisition, water, fuel & energy use, power generation & distribution, freight, refining, intermediates, manufacture, scrap re-use, packing and dispatch, installation, use, maintenance and landfill. All significant waste and emission flows from all supply chain operations used to make, pack and install the product are included.

Evah industry databases cover all known domestic and global scope 1 and 2 operations.

They exclude scope 3 burdens from capital facilities, equipment churn, noise and dehydration as well as incidental activities and employee commuting.

Electricity supply models in active databases are updated annually. As each project is modelled and new data is available the databases are updated.

They are then audited by external Type 1 ecolabel certifiers.

The databases exist in top zones of commercial global modelling and calculating engines.

Quality control methods are applied to ensure:

- Coverage of place in time with all information for each dataset noted, checked and updated;[17]
- Consistency to Evah guidelines for all process technology, transport and energy demand; [18]
- Completeness of modeling based on in-house reports, literature and industry reviews;
- Plausibility in 2 way checks of LCI input and output flows of data checked for validity, plus
- Mathematical correctness of all calculations in mass and energy balance cross checks.

[17] Jones D G (2004) LCI Database for Commercial Building Report 2001-006-B-15 Icon.net, Australia
[18] Evah Tools, Databases and Methodology Queensland, Australia at http://www.evah.com.au/tools.html

Data Sources Representativeness and Quality

Primary Data

Primary data used for modelling the state of art of each operation includes all known process for:

- Technology sequences
- Energy and water use
- Landfill and effluent, plus
- Reliance on raw and recycled material
- High and reduced process emissions
- Freight and distribution systems.

Electricity mix is site location-based throughout as per the PCR. All applied background databases and software versions are declared. Cut-off criteria complies with EN 15804:2012+A2:2019. Table 9 defines all characterisation factor versions. No primary data set with >±30% uncertainty is used. No data from EcoInvent was used. Primary data is sourced from client annual reports and publications on corporate locations, logistics, technology use, market share, management systems, standards and commitment to improved environmental performance. Information on operations is also sourced from client:

- Supply chain mills
- Factory site development license applications
- Supplier technical manuals
- Manufacturing specifications
- Manufacturer websites
- Corporate annual reports and
- Industry sector experts

Background supply chain data

Background data is sourced from

- The International Energy Agency
- IBISWorld
- USGS Minerals
- Franklin Associates
- Boustead 6
- Plastics Europe,
- CML2
- Simapro 9.5
- EcoInvent 3.9 and
- NREL USLCI model databases

Information on operations is also sourced from:

- Library documents
- NPI and web searches
- Review papers
- Building manuals
- Global industry association and
- Government reports on best available technology (BAT).

For benchmarking, comparison and integrity checks inventory data is developed to represent best available technology (BAT) and business as usual (BAU) operations covering industry sector supply and infrastructure in Australia and overseas. Such technology, performance and license conditions were modelled and evaluated across mining, farming, forestry, freight, infrastructure and manufacturing and building industry sectors since 1995.

As most sources do not provide estimates of accuracy, a pedigree matrix of uncertainty estimates to 95% confidence levels of Geometric Standard Deviation squared (σ_g) is used to define previously stated data quality on Page 7 in Table a.[19]

[19] Evah Institute data quality control system accords with UNEP SETAC Global LCI Database Quality 2010 Guidelines

Supply Chain Modelling Assumptions

Australian building sector rules and Evah assumptions applied are tabled below

Scope Boundaries Assumptions and Metadata

Quality/Domain	National including Import and Export
Process Model	It is typical currently most common industrial or best (BAT) technology practice.
Resource flows	LCI uses regional data for resource mapping, fuels, energy, electricity & logistics.
Temporal	Project data collated over prior 4 years but represents the last year averages.
Geography	Jurisdiction is for declared client, site, regional, national, Pacific Rim then Europe.
Representation	Representing the declared client', suppliers and energy providers to each cradle.
Consistency	All known operations are modelled according to operations with closest proximity.
Technology	Industry supply chains modelled are typical recent Pacific Rim practice.
Functional Unit	Applies 20 or 60 year typical service life period, use, cleaning & disposal/kg or m^2.
System Control	
Primary Sources	Client' supplier mills, publications, websites, specifications and manuals are used.
Other Sources	Recent IEA, GGT, Simapro, IBIS, EcoInvent sources used and cited in LCA reports.
Data mix	Power grid and renewable shares are updated according to latest IEA reports.
Operational	Company data is used for process performance, product share, waste & emissions.
Logistics	Local data is used for power, fuel mix, water supply, logistics share & capacity.
New Data Entry	New data is entered by current researchers at Malaika LCT, Evah and GGTI.
Data Generator	All current cited manufacturers, Evah, GGTI, IBIS & others & in LCA reports.
Data Publisher	Publishers include the Evah Institute, GGTI and designated clients only.
Contributors	All professional and personal contributors cited in Evah & GGTI records.
Data Flow & Mix	
System Boundary	All known resources & emissions modelled from Earth cradle to end of life fate.
System flows	All known flows modelled from/to air, land, water & community sources & sinks.
Capital inclusions	Natural stocksΔ, industry stockpilesΔ, capital wear Δ, system losses & use.
Arid Practice	Dry technology adopted; Water use is factored by 0.1 as for e.g. mining.
Transportation	Distance >20% than EU; >20% fuel efficient larger vehicles, load & distance.
Industrial	Company or industry sector data for manufacturing & minerals involved.
Mining	All resource extraction is based on Australian or Pacific Rim technology.
Imported fuel	Fuel mix is from nearest UAE, SE Asian, Canadian or New Zealand sources.
Finishes	Processing inputs with finishing burdens are factored in or that is denoted.
Validation	
Accuracy	10^{th} generation study is ± 5 to 15% uncertain due to some background data.
Completeness	All significant operations are tracked and documented from cradle to grave.
Precision	Tracking of >90% flows apply a 90:10 rule sequentially to 99.9% & beyond.
Allocation	All allocated to co products on reaction stoichiometry by energy or mass fraction.
Burdens	Includes all known resource use from & emissions to community air, land & water.
Plausibility	Results are checked and benchmarked against BAT, BAU & worst practice.
Sensitivity	Calculated U is reported & compared to Bath U RICE & EcoInvent libraries.
Validity Checks	Checked versus Plastics Europe, Bath U RICE & or Industry LCA Literature.

Normative References

[1] ISO 14025:2010 Environmental labels and declarations – Type III – environmental declarations - Principles and procedures

[2] EN 15804:2012+A2:2019 Sustainability of construction works - Environmental product declarations - Core rules for the product category of construction products

[3] GreenTag™ 2024 EPD Program, Product Category Rules https://www.globalgreentag.com/epd-program.html Sub-PCR WCL:2023

[4] Cottle DJ, Cowie AL 2016. Allocation of greenhouse gas production between wool and meat in the life cycle assessment of Australian sheep production. I J LCA 21(6):820-830.

[5] Dougherty HC, Oltjen JW, Mitloehner FM, DePeters EJ, Pettey LA, Macon D, Finzel J, Rodrigues K, Kebreab E 2018. Carbon and blue water footprints of California sheep production. Journal of Animal Science 97(2):945-961.

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EPD:BA™

Environmental Product Declaration:Benefit Addendum

Nature Positive+ EPD :BA Declaration
Compliance beyond EN 15804+A2, ISO 14025 ISO 21930

Global
GreenTag
International

Nature Positive Assessment

The United Nations (UN) Nature Positive (N+) Program provides global impetus for EPDs to consider gain versus loss in climate and biodiversity security [27, 28, 29]. But the reach of most LCIA methods such as the leading ReCiPe is modelling damage and depletion from maxima to zero as depicted on the left-hand side of in Figure 7 [29, 30, 31, 32].

Conventional LCIA models environmental damages to e.g. climate and loss of human health, ecosystem quality and resource supply [32, 33}.

The reach of N+, however extends scientific sightlines beyond zero damage to quantify benefits, gains and regeneration [33, 34], 35. Other information in N+ EPDs sight beyond damage to define additional information on net-positive benefit outcomes including many gains depicted on the right-hand side of Figure a [30 to 32].

Figure 4 depicts the ReCiPe LCIA method modelling damage, depletion and loss versus the Evah Life Cycle Benefit indicators (LCBA) method modelling benefit, repletion and gain to assess net-loss and net-gain of

- climate security,
- human wellness and
- resource supply viability [33 to 36].

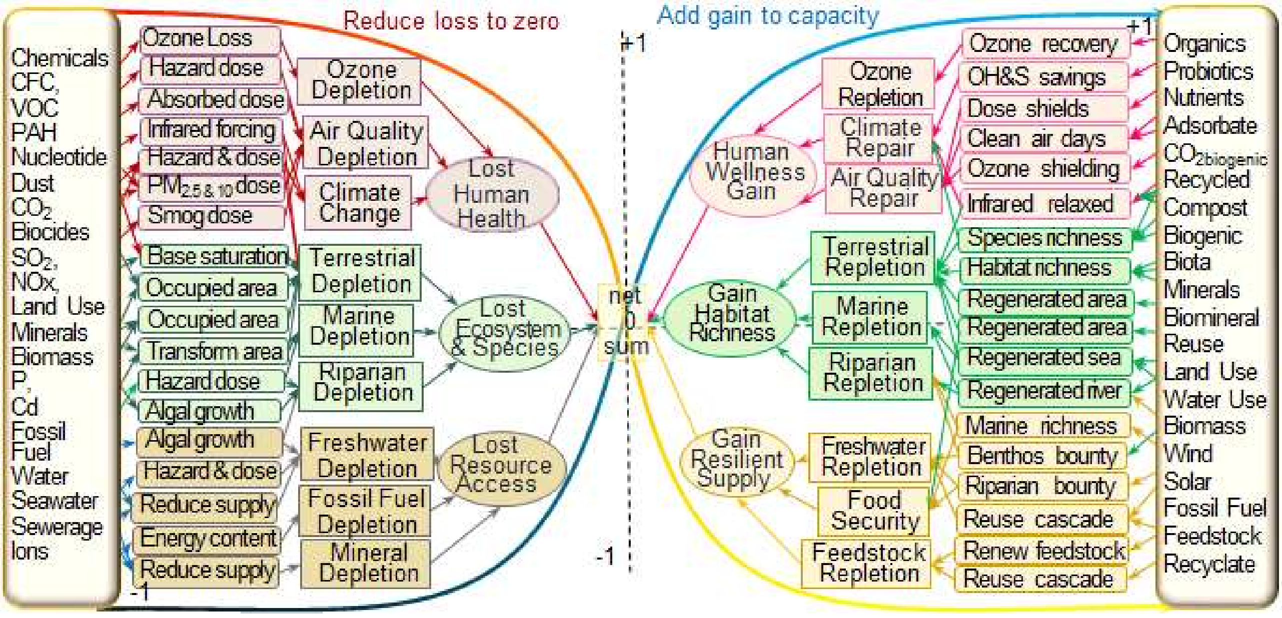

Figure 4 ReCiPe LCIA of damaging loss versus Evah LCBA of beneficial gain

Such extended assessment is applicable to empower communication and reduce barriers for regenerative and nature-positive initiatives. LCA of benefits offers community, government and business a new environmental science tool with examples of methods to measure gains in accelerating climate security and restoration.

Using LCBA in conjunction with conventional LCIA modelling of damages allows LCA modelling of damages to and beyond zero climate, health, ecosystems and supply losses to beneficial gains in e.g. climate, wellness, biodiversity and supply security.

Reaching to quantify and show positive gains well beyond the negative and zero loss outcomes, LCBA enables a truer market assessment. The capacity to report positive metrics can also reduce prevalent greenwashing and reliance on bad news that has disempowered scientifically valid communications and efforts to engage community action.

Environmental Benefit Terminology

Key environmental benefits contributing to ecological regeneration of climate and biodiversity security are tabled below with common names and responses for each indicator.

Climate Security	Reliance on renewable energy is vital to restore thermal energy differentials, from equator to poles. Differential forcing of ocean current and wind circulation blends and regulates climate to reduce extreme weather events. Forest, wilderness and algal growth can drawdown such gasses. Carbon banked in standing forests, detritus, roots and soils brakes climate change. Greenhouse gas *d*rawdown and sequestration in product biomass is vital for "***Climate security***".
Water Security	***"Water security*** arises from conservation and recycling as well as reliance on renewable and reclaimed biomass to avoid climate-change-induced drought. Hectares of intensive forest and plantings stabilise rain catchment and ground water table levels. Ground mulches retain soil hydration and reduce water stress.
Ozone Repletion	Repairing the planet's stratospheric ozone solar shield protects plants, humans and animals allowing them to be ***sun-safe***" for longer in the outdoors. Ground level oxygenation via growing plants and algae is a vital way to enable accumulation at higher levels of naturally-formed Ozone***.*** Restoring the ozone layer also depends on use of ozone-safe refrigerants, aerosols and solvents
Buffered air, land and waters	Acid rain-free air-sheds are safer for natural terrestrial, aquatic and urban communities. Buffered air-pH supports healthy soil and waterways, nitrogen fixation vital for plant growth and natural decomposition. Safe pH supports health of fisheries, forests, buildings and materials. The chief way to enhance "***natural-rain***" is reliance on renewable fuels and power supply.
Oxygenated terrestrial and aquatic life	In natural waterways balanced nutrient and oxygen availability for aquatic and terrestrial organisms promotes healthy growth as well as water and habitat security across related ecosystems. A vital way to enhance healthy waterways is tight control of slow-release fertilisers avoiding synthetic nutrients in run-off over land catchments.
Sweet-air	Smog-free air in summer near ground level when most people live and breathe outside is generated by plants and avoiding or filtering pollutants. **Sweet-air** enables healthy vegetation, crops and humans to thrive. Chief ways to enhance sweet-air are reliance on low-emission renewable energy and non-volatile chemicals.
Resource Repletion	The extinction rebellion youth movement calls on governance to secure climate, material reserves and biodiversity for current and future generations. Chief ways to ensure resource repletion include investing in sustainably managed **"circularity",** recycling, renewables and reclaimed biomass. This retains accessible, plentiful, essential valuable raw material, medicinal, chemical, feedstock and fuel stock.
Biodiversity Security	Extensive bushland, biodynamic and organic agriculture plus standing forests offer natural land use ranges and corridors for wildlife, herds and flora **"biodiversity"**: • habitat bird, bee, pollinator, avian, worm biome, shelter, forage and grazing • leaf & litter forage enhance soil condition, mulch, nutrition and retention, • soil microbiota, detritus-feeders and biotic refuges reduce temperature stress • sequestered CO_{2e} in natural habitat, biomass & soil braking climate change.
Ecological Wellness	Human ecological health benefits flow from reliance on renewable and reclaimed biomass instead of fossil fuel. Chief ways to enhance **"wellness"** include avoiding particulates and pollution, smog, volatile organics and carcinogens. Climate and ozone security and safer air-sheds ensue for natural, terrestrial, aquatic and urban communities.

Life Cycle Benefit Assessment Reference Framework

This section summarises the LCBA framework of indicators measures and metrics. Local and global human wellness, habitat regeneration and supply resilience are framed across United Nations Sustainable development goals (UN SDG) s [16 to 32]. LCBA reaches beyond zero loss to show gains in climate, wellness, biodiversity and supply security. Most apply comparable LCIA measures and metrics for example as in common use for avoided impacts. All are also shown versus % circularity outcomes.

LCA framework of LCBA indicators

Benefit Layer	**Exposure & Jurisdiction**	**Unit pa**	**Local**	**Global**	**UN**	**Circularity**
Healthy Able Life Years		**HALY/capita**		**metric**	**SDG**	**% Capacity**
Local Shelter	Household shelter	m^2 GFA	Housed	UN $_{eq}$		Housing
Fresh Food	Affordably nourished	kJ UN $_{eq}$	Nourished	UN $_{eq}$		Nutrition
Fresh Air	Oxygen indoors	kg O_2	Oxygenate	O_2 $_{C1750}$		Oxygenation
Clean Air	$PM_{2.5}$ dust-free	µg PM2.5	Clean Air	PM $_{C1750}$		Decongestion
Sweet Air	VOC free indoors	µg VOC	Safe Air	VOC $_{C1750}$		Inhalation
Sun Safety	Ozone layer repair	kg O_2 $_{outdoors}$	Sun Safe	O_3 $_{C1750}$		Ozonating
Time in Nature	100 days recreation pppa	R&R Ha	Relaxed	Ha $_{C1750}$		Free-time
Medical Access	Paramedic Care	hours $_{aid}$	Paramedic	hours $_{to\ aid}$		Medic-access
Work Dignity	>30hrs paid work/week	$\$_{eq}$/hour	Employed	km UN $_{eq}$		Secure-work
Fresh Water	Potable rain hydrated	m^3	Catchment	rain $_{C1750}$		Potability
Supply Energy & Resource Viability		**SERV/capita**				
Viable Water	Refill local reservoirs	m^3 $_{freshwater}$	Watered	Rain $_{C1750}$		Freshwater
Viable Air	Photosynthetic Cities	kg O_{2e100}	Breathable	O_2 $_{C1750}$		Oxygenation
Viable C-bank	Resink Carbon in product	kg CO_{2e100}	Embody C	CO_{2e100}		Bank-carbon
Viable Energy	Reliance on renewable	kg $_{renewed}$	Renewal	oil $_{eq}$		Renewability
Viable Food	Reliance on local food	kJ $_{km}$	Autonomy	UN $_{eq}$		Food autonomy
Viable Supply	Refuel local reserves	kg $_{feedstock}$	Fuelstock	oil $_{eq}$		Autonomy
Viable Mineral	Recycle scarce material	MJ $_{elemental}$	Security	oil $_{eq}$		Mineral security
Viable Feedstock	Recycle material & scrap	MJ $_{recycle}$	Feedstock	oil $_{eq}$		Recyclability
Viable Disaster	Reserved sustenance	t $_{back-up}$	Sustenance	UN $_{eq}$		Recoverability
Viable Shelter	Refuges in disasters	bed $_{pc}$	Refugia	GFA		Safe havens
Positive Ecosystem ReFormation		**PERF/Ha**				
Natural Access	Nature parks & tracks	m^2 R&R	Innature	Reach $_{C1750}$		Natural Access
Urban Bounty	Pre-urban carrying capacity	t flora/GFA	Urbundant	Bounty $_{C1750}$		Greenspace
Soil Carbon	Carbon banking	kg CO_{2e20}	C Soilbank	Soil C $_{C1750}$		Soil-Carbon
Climate Brakes	Carbon drawdown	t CO_{2e20}	C Biomass	Worms $_{C1750}$		Climate safety
Plants & Algae	Carbon drawdown	t CO_{2e100}	Drawdown	Algae $_{C1750}$		Climate security
Aquatic Stock	Species rich range	t Frog-rich	Species	Frogs $_{C1750}$		Aquatic bounty
Marine Stock	Species richness & range	t Fish-rich	Species	Whales $_{C1750}$		Marine bounty
Wildlife Habitat	Corridor & refuge range	Ha Biomes	Apex $_{species}$	Range $_{C1750}$		Linked Ranges
Terrestrial Stock	Rich flora & fauna range	t Wildlife	Species	Bears $_{C1750}$		Wildlife rich
Avian Stock	Species rich refugia	t Bird-rich	Richness	Birds $_{C1750}$		Abundance
Pollinator stock	Species richness & range	t Pollinated	Species	Bees $_{C1750}$		Biodiversity
Nature Reserve	Scarce reserves restocked	t Abundant	Reserves	Stock $_{C1750}$		Reserves

Otari Station

LumaWool™ sheep fleece is from Otari Station's 10,000 acres of land ranging from fertile and productive river flats rolling to steep hill country peaking at 700m. It hosts sheep, cattle, forests, original vegetation reserves and bee hives producing manuka honey. Yearly it hosts a mountain bike and trail run to raise funds for Hunterville School[20]. Otairi Station also hosted the main events at the Otairi-Pukeroa dog trials in 2025.

Otairi follows the Managapapa River to its confluence with the Turakina River, offering majestic views of Mount Ruapehu and Wanganui River depicted inset [21] Much flora in the river basin is broadleaf and podocarp forest with understories of crown and other ferns and a variety of shrubs. The river and its tributaries are home to invertebrates such as mayflies, stoneflies and caddis flies. Blue duck populations are found at the junction of the Whanganui River and Mangatepopo and Okupata streams. The Nankeen night heron roosts along the Whanganui River and breeds in New Zealand only here.

Native fish species in the river include Cran's bully, upland bully, climbing galaxias, longfin and short-finned eels, pouched lamprey, shortjaw kokopu, torrent fish, New Zealand smelt and black flounder. Other native aquatic species include koura and declining numbers of New Zealand freshwater mussels.

Values of the Ngati Manawa,

Otairi Station has 2324 hectares subject to Māori ahikaroa hearth-land rights under the Ngati Manawa: Tawhiuau Mountain and Rangitāiki river guardians. Their principles to avoid harm or lost value include:

- protection of wahi tapu (lands), indigenous flora and fauna and its wider environment;
- recognition of its mana (life-force), kaitiakitanga (guardianship) and tikanga (customs);
- respect for tikanga historical, social, cultural and maunga (mountain's) spiritual significance;
- encouraging respect for their association with their sacred maunga,
- accurate portrayal of their association with Mount Tawhiuau and recognising their
- relationship with wahi tapu (spiritual places) and their wahi whakahirahira (vital significance)

Figure 5 depicts the Ngati Manawa world view, foundation and interaction of people and environment. Te Po the source of creation balances positive and negative elements of interdependent realms to maintain dependant ecology.

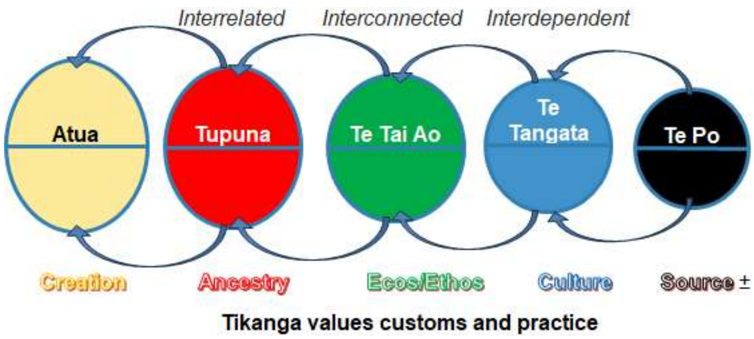

Figure 5 Ngati Manawa World View

Te Tangata, their organisation, has an iwi, of interdependent kinship groups with separate responsibility.

Te Tai Ao, the environment created by separating sky and earth links spiritual and physical realms. Interdependent ethos, ecosystems and practises include place to belong, hearth-land rights and self-determination. Survival depends living and working in harmony with Te Tai Ao.

Tupuna or ancestors imparted knowledge of and environmental responsibilities to Atua. Their guardians' knowledge of how and what we do was passed down through song, story-telling and conversation.

Atua are Māori gods and spirits controlling and creating environments. Ngāti Manawa are guardians of the Tawhiuau Mountain and Rangitāiki river. From Atua, they are responsible to maintain and care for all inhabitants and components. Their methods and protocols are embodied in their being, thinking and doing, an inherent part of their self-determination and ancestry. All this is monitored and protected by their elders' advice and guidance.

[20]https://store.pggwrightson.co.nz/knowledge-hub/an-enduring-connection-to-the-land-sees-otairi-station-thrive
[21] https://en.wikipedia.org/wiki/Whanganui_River

Contemptorary Natural and Social Disasters

In the data period that this LCA covers, many worst-ever-recorded and widespread natural and social disasters also disrupted supply chains locally nationally and globally.

After recent widespread worst-ever recorded environmental and social disasters, few benefits were expected for the geographical area where most product components were sourced.

In the last decade many reports describe historic social and natural disasters and their impacts on natural land, bush, urban, air and aquatic and marine environments [32].

Regenerative Imperatives

Despite compelling positive results shown in the following section they also illustrate that nature positive outcomes are imperatives for regeneration to combat recent natural disasters attributable to anthropogenic climate change [15].

So after a decade of increasingly widespread worst-ever recorded local, national and global, environmental and social disasters disrupted security no benefits were expected from:

- urban stock of flora in parks, walls and greenspace for urban life.
- aquatic stock of frogs in rivers, lakes and dams, aquatic life and
- marine and fish stock in nearby estuaries, bays and oceans for marine life.

Life Cycle Benefit Assessment

Some materials and practices inherently promote wellness and like medicine others inherently destroy illness. Positive and net-positive gains and benefits can offset damages and loss.

Benefits from less and avoided impacts and gains arising from properties inherent within a component or utility can also be additive.

The ultimate source of metabolic energy for all biological systems, photosynthesis in plant and algal biomass generates oxygen while drawing down carbon dioxide and water from air that enacts:

- supply of feedstock and food to grow living communities of biomes, wildlife, livestock and people
- energy delivery for ecosystem growth of viable genetic, habitat and species biodiversity ranges
- braking of greenhouse gas force accelerating anthropogenic climate change as well as
- oxygen release that is a buffer against anthropogenic depletion of stratospheric ozone layer.

Together these all increase wellness. Positive benefit, gain and circularity results for each damage outcome range from levels being:

- improved where it avoids 1 to 99% loss.
- net-zero gain when it avoids 100% loss.
- net-benefit when it regains ≥100% loss.
- regenerative where it regains ≥200% loss.

In this declaration the

- product supply chain and reports confirm a range of inherently positive outcomes /kg.
- functional unit is a kilogram of the product used over 20 years and reuse beyond cradle to grave.

The results in the next sections illustrate if, how and why nature positive wellness, ecosystem and supply benefits arise from reliance on renewable energy and circularity of all types of fossil and biomass feedstock resources. It describes cradle to cradle outcome results under sub-headings

- Unsustainable losses showing no effect
- Net-zero avoiding loss or slightly improved gain
- Improved avoiding all loss.
- Nature Positive net-benefit compensating for more than the loss.
- Regenerative Outcomes compensating for all loss plus replacing it.

Unsustainable Losses Cradle to Cradle

Table 6a lists unsustainable supply parameters depletion, damage and loss results that reflect no inherent gain or benefit.

Table 6a Unchanged Sheep wool 20year Outcomes/Functional Unit

Damage measure	Result	Unit
Induced Climate Change		
Fossil fuel emissions	3.03	Greenhouse force equivalence (kg $CO_{2e\ 100\ yr}$
Human Health Depletion		
Photochemical Smog	1.6E-02	kg Non methane Volatile Organics (NMVOC)
Ecotoxicity Human Health	2.0E-07	Death & DisAbility Lost Years (DALY)
Stratospheric Ozone Loss	3.6E-09	kg $\text{ChloroFlouroCarbon}_{11EQ}$ (CFC_{-11e})
Carcinogens	5.0E-09	Comparative Toxic Units (CTU_e)
Radioactive Waste	2.7E-17	Uranium_{235} e. q. Radiation (kBq U_{235e})
Ionizing Radiation	2.7E-17	kBq U_{235e}
Ecosystem Depletion		
Ecotoxins	7.9E-03	Potential Disappeared Fraction ($PDFm^2yr$)
Eutrophication (EP) Freshwater	5.2E-05	kg Phosphorus P_{eq}
Eutrophication (EP) Marine	9.2E-87	kg Nitrogen N_{eq}
Eutrophication (EP) Terrestrial	9.2E-87	mol Nitrogen N_{eq}
Resource Depletion		
Primary[22] Total Fossil Energy	30	MJ_{ncv}[23]
Primary Fossil Energy	23	MJ_{ncv}
Primary Fossil Feedstock	6.8	MJ_{ncv}
Primary Renewable Energy	7.9	MJ_{ncv}
Fossil Fuel Depletion	1.76	$MJ_{surplus}$[24]
Secondary[25] Renewable Fuel	2.6E-02	MJ_{ncv}
Secondary Fossil Fuel	7.6E-02	MJ_{ncv}
Freshwater use	6.1E-02	m^3
Total Resource Accessibility Loss	3.0E-04	$MJ_{surplus}$

[22] Primary means Virgin (1ry)
[23] MJncv means Megajoule net calorific value
[24] $MJ_{surplus\ means}$ excess energy required versus former access
[25] Secondary means Post Consumer Recycled (2ry)

Near Net Zero Gain Outcomes Cradle to Cradle

This section describes slightly improved wellness, ecosystem and supply near net zero outcomes from including flows that form embodied protein versus ignoring them in the durable renewable product.

Table 6b lists slightly better wellness with 7% less ecotoxicity from cleaner air outdoors avoiding inhalation of 8% less ethylene equivalent photochemical summer smog. It also lists near slightly better supply with 2% more energy reuse and avoiding loss of 4% mineral and metal overall.

Table 6b Near Net Zero Wellness Outcomes/Functional Unit

Damage	Unit	Result	∆	Damage	Unit	Result	∆
Wellness Outcomes							
Ecotox H Health	HALY	1.8E-07	7%	Summer Smog	kg C_2H_2	2.5E-03	8%
Supply Outcomes							
Energy for Reuse	MJ	35	2%	Mineral & Metal	kg S_{eq}	5.2E-04	4%

Improved Outcomes Cradle to Cradle

This section describes reducing then replacing significantly more than 100% of loss to show improved wellness, ecosystem and supply outcomes. All arise when flows that form embodied protein are included.

Table 6c lists improved wellness security from less early death and disability from

- 13% fewer parts per million (ppm) of ultra fine (2.5 µm to <10 µm) particulates in air
- 42% less cancer toxicity inhaling cleaner air with fewer respirable synthetic organic chemicals.
- 90% less non-cancer toxicity mostly from lower synthetic inorganic chemicals

It also lists contributions to improved supply security from

- 12% more total energy embodied potentially available for reuse and recycling at end of life
- 21% more total primary renewable energy & 25% total primary renewable feedstock counted
- 96% more reuse and recycling at end of life from avoiding general waste to landfill.

Furthermore, it shows net-gains in ecosystem security and 79% more natural and marginal land use avoiding arable land used for crops, natural land use changed for mining or hazardous landfill operations.

Table 6c Benefit Outcomes/Functional Unit

Measures	Unit	Result	∆	Measures	Unit	Result	∆
Wellness Improvements							
Particulates 2.5_{ppm}	DALY	1.4E-10	13%	Cancer toxicity ex respirable organics	CTUh	5.6E-09	42%
Non-cancer toxicity	CTUh	9.2E-08	90%				
Supply Improvements							
Total Embodied Energy	MJ_{ncv}	82	12%	Feedstock Renewal	MJ	45	25%
Total 1ry Energy Renewal	MJ_{ncv}	53	21%	General Waste	kg	0.05	96%
Ecosystem Improvements							
GWP Land use & change	kg CO_{2e}	-1.51	12%	Natural land use	points	0.19	79%

Nature Positive Outcomes Cradle to Cradle

Beyond replacing all loss achieves zero net gain while avoiding over 100% loss beyond net zero gain achieves nature positive outcomes as described in this section. Table 6d shows EcoIndicator 99 wellness security net-gains including from avoided human death and disability from 100% fewer ultra fine (2.5 µm to <10 µm) particulates and 100% less lost human health life years. It also lists ecosystem net-gains from 100% less disappeared ecosystem and 100% less damage and loss overall in EcoIndicator 99 Points.

Table 6d. Net Gains/kg Functional Unit

Measures	Unit	Result	∆%	Measures	Unit	Result	∆%
Wellness Benefits							
Human Health	DALY	0	100	Respirable Inorganics	DALY	0	100
Ecosystem Benefit							
Ecosystem Quality	PDFm^2*yr	0	100	EcoIndicator 99	points	0	100

Regenerative Outcomes Cradle to Cradle

This section describes gains that account for all loss replacement, and more than doubling that amount to redeem ecosystem and climate pre-industrial capacity and regenerate wellness and supply security. Table 6e lists amounts regenerative climate outcomes /functional unit. Regenerative climate outcomes arise from avoiding 225% more global warming via:

- biogenic drawdown via photosynthesis by leaf, algae, roots and soil into durable biomass
- drawdown via chemosythesis by rumen microbes into protein to grow wool fibre (97% protein)
- as well as carbon banks in soil and product biomass over the longer 100 year term.
- Regenerative wellness benefits arise from net-gains in 136% more photosynthetically produced oxygen for all humans as well as livestock and wildlife and indeed all living things to breathe.

Factoring in embodied protein accounts for growing ecosystem regeneration benefits from:

- upland marginal land security from retained biota, seed, fibre and soil biomass with grazing,
- leaf, algae photosynthetic sequestration in biomass for drawdown into fodder for herds and
- rumen and soil aerobic and anaerobic microbiota chemosynthetic drawdown into wool biomass

LumaWool™ insulation product accrues regenerative ecosystem benefits including:

- greater biodiversity this decade from 313% more biogenic $CO_{2\ eq\ 20\ yrs}$ drawdown from the air
- pH balance from 849% less acidification of air land and waters in the longer term.

Ecosystem Quality gains arise from 849% less acidification to air land and water. Supply regeneration includes 270% more matter & energy circularity from reliance on total primary renewable energy, primary biomass and material for energy recovery.

Table 6e Regeneration/kg Functional Unit

Measures	Unit	Result	∆	PEF%
Climate Regeneration				
Far Term Climate Braking	kg $CO_{2\ eq\ 100\ yrs}$	-5.88	225%	8.1
Wellness Regeneration				
Oxygenated Global Airshed	kg $O_{2\ eq\ 100\ yrs}$	-4.28	136%	8.1
Ecosystem Regeneration				
Biodiversity Biogenic Drawdown	kg $CO_{2\ eq\ 20\ yrs}$	-7.20	313%	10.3
Acidification pH Balance	mol H^+ eq.	6.8E-02	849%	23.5
Supply Regeneration				
Circularity of matter & energy	MJ share	63	270%	9.2

Product Environment Footprint/ Global Citizen Annually

Ths section reports on the Life Cycle Impact Assessment (LCIA) results using the product environment footprint (PEF) method. The average PEF/ global citizen annually is in Table 7a below. As is fairly typical of European LCIA normalisation methods since 1995 the consumption tootprint was normalised to

- 40% Ecosystem quality loss outcomes
- 30% Resource access loss outcomes and
- 30% Human health loss outcomes.

The contributing product consumption footprint of average EU-27 citizens in 2021 was dominated by food consumption at 48% of the single weighted score of 100%. Ths was followed by housing and mobility impacts. The consumption of household goods and appliances contribute to 17% overall.

PEF benefit results were also normalised to a single weighted 100% score with maximum shares from

- 40% Ecosystem quality gain outcomes
- 30% Resource access gain outcomes
- 30% Human health gain outcomes

Table 7a Average Global Annual Product Environment Footprint/ Citizen

Tier	Outcome Category	PEF Unit	Icon	Impact	% Score
Eco system Quality Loss	Climate Change	kg $CO_{2\ eq\ 100\ yrs}$		1.07E+14	20
	Ecotoxicity Freshwater	CTUe		8.15E+13	4
	Acidification	mol $H^{+}_{eq.}$		3.83E+11	4
	Stratospheric Ozone Deletion	kg $CFC\text{-}11_{eq.}$		1.61E+08	4
	Eutrophication Terrestrial	mol $N_{eq.}$		1.22E+12	3
	Eutrophication Marine	kg $N_{eq.}$		1.95E+11	3
	Eutrophication Freshwater	kg $P_{eq.}$		5.06E+09	3
Resource Access Loss	Freshwater Use	m^3 water $_{eq.}$		7.91E+13	8
	Land Use	points		9.90E+15	4
	Biodiversity Drawdown	kg $CO_{2\ eq\ 20\ yrs}$		9.90E+15	4
	Resource Use Renewable Feedstock	MJ		1.13E+14	2
	Resource Circularity Matter & Energy	MJ share		2.25E+14	4
	Resource Use Fossil Energy Reuse	MJ		1.13E+14	2
	Resource Use Minerals and Metals	kg $Sb_{eq.}$		3.99E+08	6
Human Health Loss	Particulate Matter	PPM10		2.14E+06	5
	Human Ecotoxicity	HALY		2.14E+06	5
	Ionizing Radiation	kBq $U_{235\ eq.}$		1.02E+12	5
	Volatile Organic Chemicals	kg $NMVOC_{eq.}$		2.80E+11	2
	Photochemical Ozone	kg C_2H_2		2.80E+11	2
	Human Cancer toxicity	CTUh		2.66E+05	5
	Human Non-Cancer toxicity	CTUh		3.27E+06	5
Sum	**Gross sum**	**multidimension**		**normalised**	**100%**

The LumaWool™ product global PEF benefit/kg functional unit over 20 years is in Table 7b below. The Ecosystem quality 18% gain is from outcomes including:

- 3.8% braking greenhouse force embodied in the wool and
- 14% balance in pH without emissions causing acidification.

Resource security 13% gain contributions include better accessibility :

- 6.0% biogenic drawdown reflecting retained biodiversity
- 3.4% natural marginal land use and 3.0% circularity of feedstock in matter & energy and
- 0.48% feedstock renewal, 0.06% reused energy and 0.8% reused mineral and metals.

Human health 9% gain is from outcomes yielding more hale and able life years

- 5.1% avoided non-cancer toxicity, 2.4% avoided cancer toxicity and 0.73% better wellness
- 0.45% avoided photochemical smog from fewer synthetic volatile organic chemicals and
- 0.39% avoided ecotoxicity from polluting polyaromatic hydrocarbons and metal ions.

Table 7b LumaWool™ Global Product Environmetnal Footprint/kg Functional Unit

Tier	Outcome Category	PEF Unit	Icon	% Benefit	%Score
	Climate Braking Far Term	kg CO_2 eq. 100 yr.		225	
	Potable Freshwater	CTUe		0.0	
Eco system Security	pH Balance	mol H^+ eq..		849	
	Stratospheric Ozone Refill	kg CFC-11 eq.		0	18
	Terrestrial Oxygen-Nutrient Balance	mol N eq.		0	
	Marine Oxygen-Nutrient Balance	kg N eq..		0	
	Freshwater Oxygen-Nutrient Balance	kg P eq.		0	
	Freshwater Cascades	m^3 water eq.		0	
	Natural Land Use and Change	points		179	
	Biogenic Drawdown & Biodiversity	kg CO_2 eq. 20 yr.		313	
Resource Security	Feedstock Renewal	MJ		25	13
	Circularity of Matter & Energy	MJ share		156	
	Reused Energy	MJ		3	
	Reused Mineral and Metal	kg Sb eq.		4	
	Wellness	PPM10		13	
	Avoided Ecotoxicity	HALY		7	
	Avoided Ionizing Radiation	kBq U_{235} eq.		0	
Human Health Security	Avoided Volatile Organic Chemical Free	kg NMVOC eq.		0	9
	Avoided Photochemical Smog Free	kg C_2H_2		8	
	Avoided Cancer Toxicity	CTUh		42	
	Avoided Non-cancer Toxicity	CTUh		90	
Sum	**Gross sum**	**multidimension**		**normalised**	**40%**

Nature Positive LCBA, UNSDG and Circularity Results

The LCBA, land use and % circularity results are tabled below across the Nature Positive framework that covers all 17 UN SDGs. Land use area results beyond the system boundary have asterisks. Overall, 11 are improved, 1 net-zero gain, 3 net-benefits and 10 regenerative. Some14 exceed a full circularity result.

Table 8 Summary of LCBA results /kg Functional Unit

Benefit Layer	Exposure & Jurisdiction	Unit	Circularity	SDG
Healthy Able Life Years (HALY)		**HALY/kg**	**% Capacity**	**Icon**
Local Shelter	Household shelter	m^2 GFA	100% Ruminant housing	
Fresh Food	Affordably nourished	kJ	313% Nutrition	
Clean Air	$PM_{2.5}$ dust-free	μg $PM_{10+2.5}$	13% Decongestion	
Sweet Air	VOC free outdoors	μg VOC	42% Less cancer	
Fresh Air	Oxygen indoors	kg O_2	136% Oxygenation	
Time in Nature	100 days recreation pppa	R&R Ha	0.3% days R&R space*	
Fresh Water	Potable rain hydrated	l rain	97% Potability*	
Sun Safety	Ozone layer repair	kg O_2 outdoors	236% Ozonating	
Supply Energy & Resource Viability (SERV)		**SERV/kg**	**% Capacity**	
Viable Water	Refill local reservoirs	m^3 freshwater	100% Watered	
Viable Air	Photosynthetic cities	kg O_{2e100}	236% Oxygenation	
Viable C-bank	Resinkc carbon in product	kg CO_{2e100}	225% Bank-carbon	
Viable Energy	Reliance on renewable	MJ ncv	25% Renewability	
Viable Food	Reliance on local food	kJ ncv	313% Food autonomy	
Viable Supply	Refuel local reserves	MJ ncv	65% Autonomy	
Viable Feedstock	Recycle material & scrap	MJ ncv	270% Recyclability	
Viable Mineral	Recycle scarce material	MJ ncv	0.4% Mineral security	
Viable Disaster	Reserved sustenance	MJ ncv	270% Recoverability	
Viable Shelter	Refuges in disasters	MJ ncv	67% Safe havens*	
Positive Ecosystem ReFormation (PERF)		**PERF/kg**	**% Capacity**	
Wildlife Habitat	Corridor & refuge range	MJ biomes	20% Linked ranges*	
Viable Water	Refill local reservoirs	l water	6% Freshwater*	
Climate Brakes	Carbon drawdown	kg CO_{2e20}	313% Climate safety	
Plants & Algae	Carbon drawdown	kg CO_{2e100}	313% Rubisco security	
Aquatic Stock	Species rich range	kg frog stock	0.2% Aquatic bounty*	
Terrestrial Stock	Species rich refugia	kg Terrastock	20% Wildlife rich*[26]	
Carbon banking	Soil carbon	kg CO_{2e100}	0.02% Soil-carbon	
Arial Stock	Species rich refugia	kg Avistock	50% Abundance*	
Pollinator stock	Species rich range	kg Beestock	50% Biodiversity*	

[26] Relic ancient biodiversity refuge on farm site

The following section explains benefits from Table 8 Nature Positive LCBA, circularity and UN SDG results.

Healthy Able Life Years (HALY) % capacity includes:

- 0.3% R&R recreation time in nature at hill climb bike races and dog trials
- 13% clean air decongested being $PM_{2.5}$ dust-free
- 42% sweet air with less cancer risk being VOC-free outdoors
- 97% fresh potable rainwater hydrated and potability reliant on town and rain water
- 100% local shelter for shepherds, sheep and sheep dogs on marginal highlands
- 136% fresh air via photosythetic oxygenation available via island winds to indoors
- 236% sun safety from photosythetic oxygen for biosphere refill and ozone layer repair and
- 313% fresh affordable nutrition for sheep and dogs not displacing arable cropping land.

Supply energy & resource viability (SERV) capacity includes:

- 0.4% mineral security from washery reclaimed potassium
- 25% reliance on renewable energy
- 65% autonomy in viable supply refuelling local reserves
- 67% shelter refuges in natural disasters
- 225% carbon bank via resinking carbon in product
- 236% renewable oxygen generation to air for cities
- 270% feedstock recyclability of material and scrap
- 270% disaster recoverability via sustenance from fodder reserves plus
- 313% local food autonomy reliance for sheep grazing marginal hill country.

Positive ecosystem reformation (PERF) capacity includes:

- 0.02% carbon banking in marginal land soil across hill country
- 0.2% aquatic stock with freshwater species-rich range
- 6% freshwater refill of local reservoirs
- 20% linked corridors, refuges and ranges of wildlife habitat
- 20% wildlife stock and species rich terrestrial refugia
- 50% arial stock abundance with species-rich refugia
- 50% pollinator stock-biodiversity with species-rich range and
- 313% climate safety-braking climate force and carbon drawdown via rubisco in plants and algae.

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Qualitative Summary Across LCBA Indicator Framework

Many results not quantified for this study can instead be quantified under different carbon offset, forestry, biodiversity or water or soil conservation schemas. This section lists additional outcomes beyond the LCA system boundary to cover gaps or factors that could be counted for completeness in future EPDs.

Healthy Able Life Years (HALY) Inset and Set Apart Qualities

Local Shelter	Forests, trees and scrub offer shelter across Otairi station as previously noted Avian, insect and sub grade soil biota shelter across Otairi station
Fresh Food	67% of agricultural land can grow ruminant milk and meat but not plant crops Floral feedstock for birds and bees is most evident across Otairi grazing fields Sheep manure building stronger wetter, deeper soils and bugs.
Fresh Air	Plants & algae ensure clean air across the hill country
Time in Nature	Local town, farm and school community recreation events
Work Dignity	Agricultural produce industry employs a third of all workers worldwide Forested land is inset but set apart for timber industry workings not in this LCA Bee hives set apart employ apiarists as well and health industry workers
Medical Access	Bee hives in separate Manuka fields and foraging in pasture making honey Wool grease coproducts are used in pharmaceuticals and healthcare
Fresh Water	Potable water rain catchment across pasture and forest not counted in LCI

Supply Energy & Resource Viability (SERV) Inset and Set Apart Qualities

Viable Water	Refill local reservoirs from pastural rain catchment not counted in LCI
Viable Air	Photosynthetic oxygen buffers clean air supply blown to cities near and far
Viable C-bank	Wool fleece weather-calming force is 8 to 25 times bigger than its weight.
Viable Energy	Wool growth is on renewable photosythetic and chemosynthesic energy
Viable Food	Sheep food is reliant on forage and rumen feedstock across marginal land
Viable Supply	Sheep flock supplier is from across marginal land unfit for plant crops
Viable Mineral	HawkesBay WoolWorks Washery extracting fleece potassium for fertiliser
Viable Feedstock	HawkesBay WoolWorks Washery extracting fleece Suint for fertiliser HawkesBay WoolWorks Washery extracting grease for health care products
Viable Disaster	HawkesBay WoolWorks rebuilt with kit moved above forecast flood levels
Viable Shelter	Otairi Station offers disaster-refuge for many avairian and freshwater species

Positive Ecosystem ReFormation (PERF) Inset and Set Apart Qualities

Natural Access	Forested valleys and ridged corridors connecting natural habitats.
Urban Bounty	Wool insulation in buildings can lock-up bad weather forces for 100 years
Soil Carbon	Carbon is banked across Otairi soil bar in few rock, road, track and roof areas.
Climate Brakes	Wool blankets, doonas and carpet brakes bad weather force for 20 years
Plants & Algae	Carbon drawdown across Otairi station scrub, grass & woodland as previously noted
Aquatic Stock	Otairi Station rivers are stocked with freshwater species as previously noted
Wildlife Habitat	Forested valleys and ridges connect natural habitat, refugia and extended range
Terrestrial & Avian Stock	Original rich flora & fauna range wildlife habitat is set apart for heritage & study Species rich range refugia for many bird, insect species across Otairi station
Pollinator stock	Species richness & range pollinator stock is most evident across Otairi grazing fields
Nature Reserve	Scarce reserves have been retained and restocked for heritage & study

Interpretation of LCBA

This section interprets the Life Cycle benefit results ranging from improvement, net-gain to regenerative outcomes/kg functional unit cradle to cradle (F unit). Unlike linear primary fossil feedstock material and or fossil fuelled operations, inherent benefits arise from reliance on renewable, recycled, reused and or recyclable component circularity in supply.

Figures 5,6 and 7 chart net gain, nature positive and regenerative ecosystem, wellness and supply security.

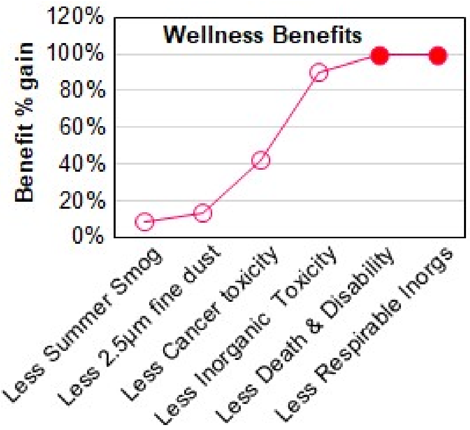

Figure 5 Wellness Security/kg F unit

Wellness offset 17 PEF points from:

- 7% less human ecotoxity
- 8% less photochemical smog
- 13% less 2.5μm particulates
- 42% less respirable organics
- 42% less cancer toxicity
- 90% less non-cancer toxicity
- 100% less respirable particulates and
- 100% better human wellness.

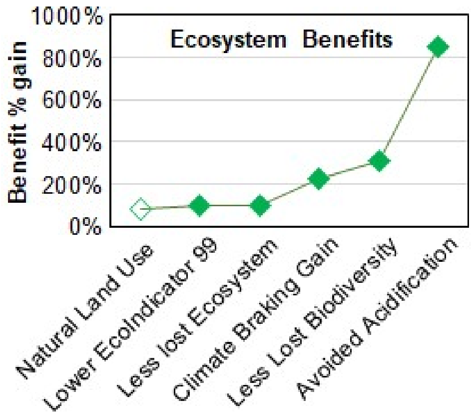

Figure 6 Ecosytem Security/kg F unit

Ecosystem offset 46 PEF points from:

- 79% avoided natural land use change
- 100% avoided Ecosystem Quality loss EI99
- 100% avoided EcoIndicator 99 loss
- 225% stronger climate brake force to 100 years
- 313% avoided biodiversity loss and
- 849% better pH balance from less acidification.

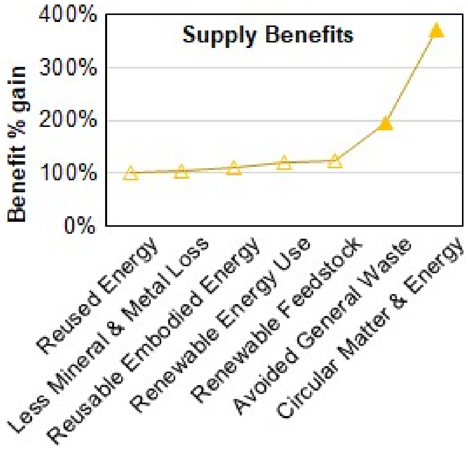

Figure 7 Supply Security/kg F unit

Supply offset 17 PEF points from:

- 2% more energy reuse
- 4% avoided mineral and metal depletion
- 12% more total embodied energy
- 21% more total primary renewable energy
- 25% more feedstock renewal
- 96% avoided general waste and
- 270% more matter and energy circularity.

Altogether these LumaWool™ product benefits offset 80% of the annual ecofootprint per capita global citizen/kg product use.

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Further and explanatory information is found at

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Environmental Product Declaration

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