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Review

Inaccurate polyester textile environmental product declarations

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Abstract: Development of Environmental Product Declarations (EPD)s used for green marketing, specification, procurement, certification and green building rating systems are important for documenting and understanding product environmental performance. Considering such applications any misleading of stakeholders has serious legal ramifications. Various studies have highlighted EPD veracity depends mainly on the data quality of underpinning life cycle assessment (LCA). This paper compares data quality across polyester product case studies, literature surveys and EPDs. Life Cycle Inventory (LCI) and Life Cycle Impact Assessment (LCIA) results are presented and interpreted. Surveys show recycled polyester fibre results are most sensitive to melt spinning energy data which varies over a wide range. The case studies compare results from median, lower and upper energy use in melt spinning. The work highlights that, accurate, clear definitions and vocabulary is as vital for specific foreground process data as it is for generic background supply chain data. This is to avoid misconceptions and mismatched assumptions in respect of EPD data quality and incorrect acceptance of inadequate charting of all essential processes. If product-specific accurate data is inaccessible, EPD options include presenting impact assessment results from LCI of best and worst-case scenarios. This is preferable to legal risks of using junk data that misleads stakeholders in marketing. General recommendations are presented for LCA practitioners to improve EPD data quality and accuracy. These include using multiple data sources to avoid reliance on any single database. Data also needs to be verified by a third-party with industry expertise independent of the specific manufacturer. It recommends using suitable, comprehensive and specific product-related scenarios for data development in any EPD.

Keywords: polyester; textiles; rPET fibre; melt spinning; LCA; EPD

1. Background

Environmental Product Declarations (EPD)s are a standardised LCA-based eco-label that conform to International Standard Organisation (ISO) Environmental Management System (EMS) methods. For companies, products and buildings, these may include

- ISO 14020:2000 Environmental Labels and Declarations—General principles [1];
- ISO 14025:2006 Environmental labels and declarations—Type III declarations [2];
- ISO 14040:2006 LCA: Principles & framework [3] ISO 14044:2006 EMS: LCA [4] or
- EN 15804:2012+A2:2019 Sustainability of construction works—EPDs [5].

A cradle to grave EPD declares lifetime damages from resource acquisition, refining, freight, manufacture, use and disposal. EPDs are a rich source of information on damages, renewability and pollution. Manufacturing efficiencies are derived from waste output and energy inputs.

Robust, transparent and reliable product declarations are useful for manufacturers to understand their supply chain and improve operations. EPDs should also enable consumers' confidence in product credentials, showcase a brand's green credentials and show supply chain transparency.

The literature reports EPDs becoming increasingly vital tools in assessing sustainability projects. Rosario, Palumbo et al. 2021, for example, report green building rating systems increased use of EPDs in the last few years [6]. Procurement organisations also use them to compare environmental performance and Jelse and Peerens (2018) show LCA-based selection criteria in EPDs applied to purchasing [7].

For green public procurement, they offer some of the most important evidence that attributes of goods and services meet key eco-preferred requirements in tender documents. The core LCA and EPD goal is, however, process improvement to reduce depleting resources, ecosystem and human health.

EPDs can also reflect United Nations Sustainable Development Goals (UNSDG)s [8] including:

- Responsible consumption and production; Avoid wasting water;
- Affordable clean energy; Climate action; Good health and well-being; and
- Decent work and economic growth.
- To address issues, UNSDGs employ guidelines and strategic planning [9] including:
- Proportion of renewable energy; Energy efficiency; Climate protection measures,
- Use of natural resources; Effects of chemicals, air, water and soil contamination;
- Global resource efficiency, and decoupling economic development.

Consequently, many studies considering EPD significance, emphasise the need for veracity and reliability in LCAs underpinning them which depends on their data quality in inventory databases.

2. Introduction

This work compares literature reviews with EPD and LCA case studies of polyester insulation and textile apparel. The focus is on blended post-consumer recycled and primary polyester fibre insulation. Studies show fibre LCA results are most sensitive to the highest-energy operation which is melt-spinning. The paper examines essential data reliability, integrity and accuracy for truthful declarations.

It argues that such EPDs need more clarity in expressing data quality. It recommends practitioners avoid relying on single data sources to ensure legally-defensible veracity in marketing declarations.

3. Aims

For product-specific polyester fibre LCA and EPDs, the paper aims to show:

- literature surveys comparing data ranges and quality;
- reported melt-spin process details including energy types and usage;
- case studies of manufacturer supply chains, LCAs, and EPDs;
- impact result sensitivity to variance in melt-spin energy use;
- correlations with product recycled content, gross energy use and other parameters;
- the importance of clarity in expressing and using acceptable data qualities;
- strategies to avoid uncertain data that undermines veracity of declarations as well as
- recommended actions to uphold confidence for green procurement and marketing.

4. Materials and scoping methods

In a 2019 world survey of all production of synthetic woven and bonded textiles, polyester fibres represented 75% followed by cellulosic, polyamide, polypropylene then acrylic [10]. Of that total China accounted for 67%, India 8%, USA 4%, EU 3% and Indonesia 3%. So Pacific Rim manufactured polyester fibre reflects the dominant synthetic textile supply chain to global markets.

Table 1 summarises polyester fibre LCA of applications in this supply chain and market, for example, by The Evah Institute authors, reported in Biaz, Rimando et al. [11]. Evah LCA case studies of twenty-two insulation products for EN 15804:2012+A2:2019 compliant EPDs are described in this paper. All were 3rd party certified by Global GreenTag$^{\text{certTM}}$ for business to consumer communication [12]. Products comprise primary polyethylene terephthalate (PET) fibre, and polyethylene terephthalate glycol (PETG) binding fibre blends with >80% post-consumer recycled (rPET) fibre [13].

Table 1. Polyester fibre applications.

Cradle to grave	20 years			60 years	
Application type	blinds	textiles	upholstery	membranes	insulation

5. Data quality literature review

This section reviews data quality. A crucial aspect of EPDs is developing inventory data for foreground and background operations. Foreground processes occur at the EPD commissioner and supplier sites one step up the value chain. Modahl, Askham et al. report background operations comprise all other processes in supply chains upstream to raw material cradles [14].

Sources vary with specific requirements and Ferranti, Berry et al. (2018) report that data may be collected for three years to identify brand-specific resource input and emission output [15]. Typical LCI uses brand-specific foreground data but regional, national or generic data on background operations. Manufacturers provide specific data for their brands but generic data is from sources such as literature and commercial LCI databases [15]. Such data is acquired from many sources, including manufacturers, website, specifications, interviews, literature, reports, and commercial databases.

For validity, the International Reference Life Cycle Data (ILCD) 2010 Handbook advises use of specific primary industry sector data and not generic data [16]. Rosario, Palumbo et al. (2021) also report that product specific LCA data for EPD is also advised by building sustainability assessment frameworks and Green Building Rating Systems such as the German Sustainable Building Council (DGNB) [6,9]. Table 2 describes findings of nine reviews of EPD data quality in four key journals.

Table 2. Summary of EPD data quality.

Journal	Literature review findings
Sustain-ability	In 2021 Rosario, Palumbo et al. considered the latest amended ISO 15804 guide for construction product EPDs [6]. They highlighted integrating comprehensive suitable scenarios and stages if using EPDs to source data.
Journal of Cleaner Production	Rosario, Palumbo et al. indicated studies identifying influences of generic and specific datasets on LCA results for EPD [6]. These include those by: Lasvaux, Habert et al. in 2015 [17]; Strazza, Del Borghi et al. in 2016 [18] and Palumbo in 2021 [19].
	In 2020 Scrucca, Baldassarri et al. identified sources of uncertainty in a wine bottle LCA. Initially 6 practitioners independently used the same LCI data, system boundary and functional unit. Despite different allocations, their results were comparable [20]. However significant variations in results arose after they applied different inventory data.
	In 2016 Strazza, Del Borghi et al. investigated use of EPD results and found that independent third-party verification can improve data quality [18].
Energies	A passive house LCA by Palumbo in 2021 found significant scenario differences, 40 to 50% primary renewable energy,10 to 20% acidification, eutrophication and global warming potential (GWP) using AH–LCA v.1.6 tool versus EPD data [19].
The International Journal of LCA	In 2015, a building material EPD case study by Lasvaux, Habert et al. found ≥25% higher impacts from product-specific data versus generic data [17].
	In 2013 Modahl, Askham et al. revealed clear data definitions were vital for accuracy [14]. They found significant differences in results from generic versus specific foreground data in 2 versions of one office chair EPD. They highlighted need for accurate data definitions to avoid mismatched assumptions in product comparisons.

5.1. rPET fibre melt-spin process

This section describes the rPET melt spinning (melt-spin) process. Recycling requires physically converting flake, pellet or chip made from bottle and other scrap into fibre or other products. Two key ways to produce recycled fibre are by:

- directly extruding flake into fibre; or less commonly

- pelletising flakes into pellets or chips before melt-extrusion and spinning into fibre.

The melt-spin-extrusion process feeds flakes, pellets, granulate or chips from hoppers into a screw extruder for melting and pressurising [21,22]. This involves:

- melting and discharging polymer downstream by gear pumps
- filament formation, cooling, drawing and heat setting, and
- cutting into staple fibres and winding.

Figure 1, a melt-spinning line schematic, depicts yellow polymer in a melt-spin screw extruder, spin pack and filament draw-down unit [23]. Behind them, side extruders feed in coloured masterbatches to make dope-dyed yarn. A melt pump sets correct production rates.

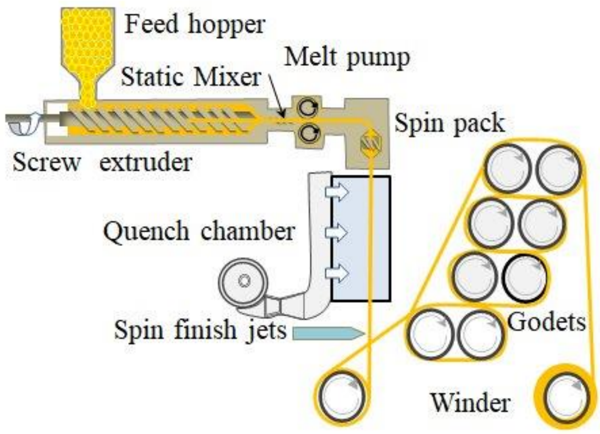

Figure 1. Melt-spinning line schematic (adapted from [23]).

Molten polymer is blended and filtered in the spin pack. A spinneret within forms different size strands which are then extruded and cooled in the quenching chamber and spun into filaments. Spin finishes are applied before filaments are drawn by godets. Heated godets and their guidance over hot plates improve filament drawability. A winder reels filaments onto bobbins. For insulation, filament bundles are crimped and cut into short-staple fibres a few centimetres long [23].

Recycled PET flakes are melt-spun into filaments, then drawn and textured or cut to a set length into staple fibres. Filament or staple fibre properties depend on melt-spin spinneret size, temperature and pressure. A separate large spinneret is used for cutting staple fibres from filaments.

5.2. PET fibre melt-spin process energy

This section cites polyester fibre melt-spin energy data including electricity and heat from various fuels [21–27]. Figure 2 charts the range from recent surveys of industry and EcoInvent V2 to 3.4 data by Hufenus and Yan et. al. in 2020 [27] and Sandin, Roos & Johansson in 2019 [24]. It also includes older data from van der Velden et al. in 2014 [23] Shen, Worrell et al. 2010 [25] and Laursen et al. 1997 [26].

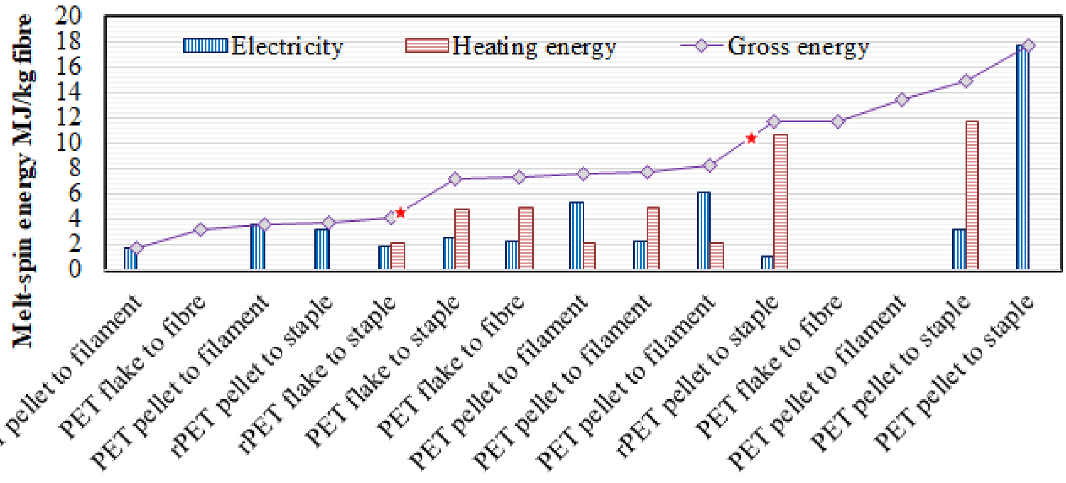

Figure 2. PET melt-spin gross energy & sources (extracts from [21–27]).

Gross melt-spin energy ranged from 3.2 to 11.7 MJ/kg PET staple fibre and 1.1 to 13.6 MJ/kg partially drawn untextured filament. Overall PET fibre melt-spin energy ranged from 1.8 MJ/kg to 17.64 MJ/kg with a mean of 8.3 ± 8 MJ/kg and standard deviation of very significant uncertainty. The first star on the gross energy chart in Figure 2 shows the 4.1 MJ median lower melt-spin energy/kg fibre and the second star on that line shows 10.4 MJ/kg median upper melt-spin energy.

Figure 3 details the more reliable <five-year-old low 3.7 and 4.1 MJ gross energy/kg rPET staple fibre about half, PET staple fibre ex pellet 7.2 MJ melt-spin energy, and filament made ex flake and pellet with 7.6 MJ and 7.8 MJ/kg melt-spin energy. Two high energy datasets lacked energy mix detail.

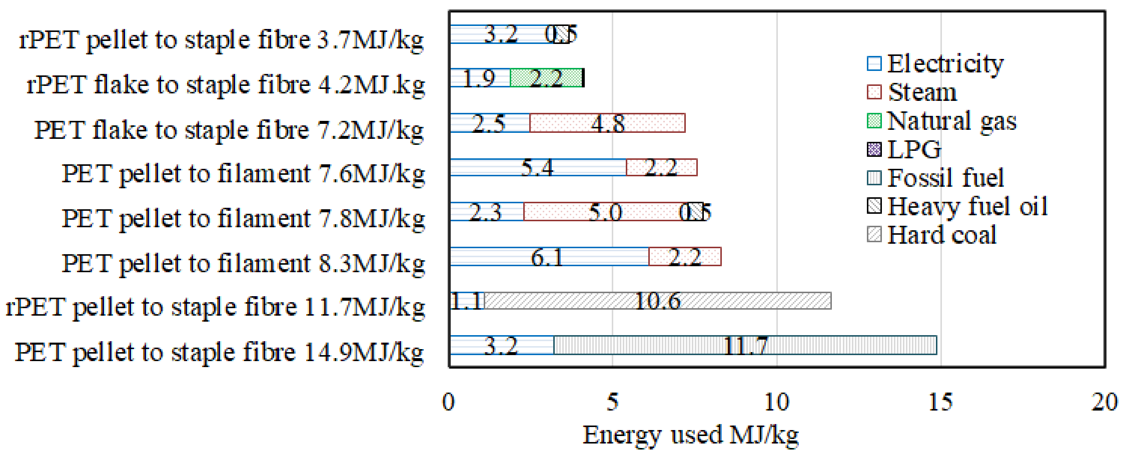

Figure 3. Melt-spin process energy data [23–27].

5.3. *Sensitivity analysis*

As Figure 4 depicts, Sandin, Roos & Johansson [24] in 2019 reported usage of 96 to 125 MJ gross energy/kg PET clothing fabric similar to case studies described later in this paper.

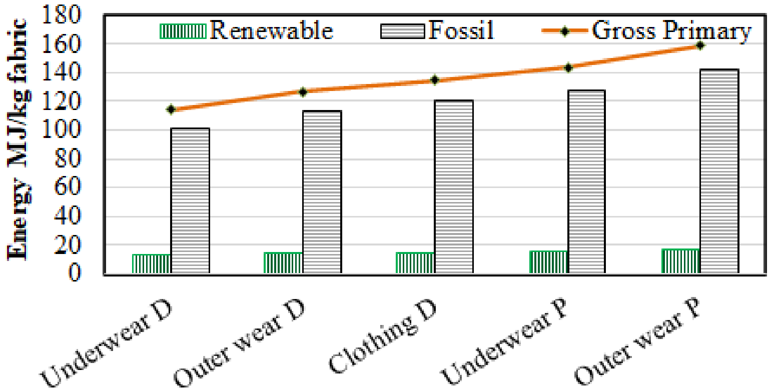

Figure 4. PET Fabric MJ/kg (adapted from [24]).

In 2017–18 Roos [21] also reported a 3rd party reviewed LCA of 6 dope-dyed and piece-dyed polyester fabrics using first-hand industry PET fibre spinning foreground data with EcoInvent V3.4 background data [21]. Figure 5 charts those extrusion spun versus knitted and wet treated results for GWP. While this small-scale fibre production efficiency may improve at larger-scale, both the gross amount and largest spinning process share is very significant.

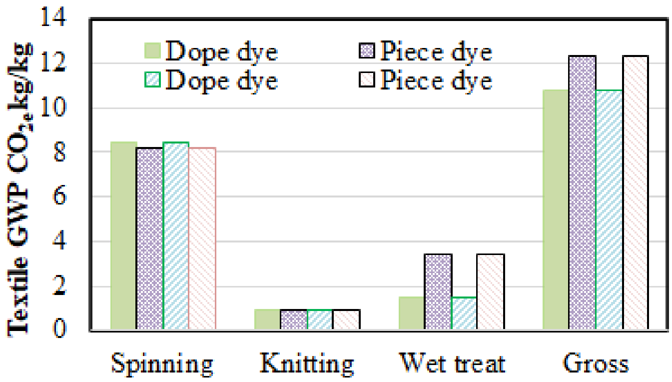

Figure 5. PET Fabric GWP kg CO_{2eq}/kg (adapted from [20]).

It too shows GWP comparable to a 10 MJ electric melt-spin energy LCA case study reported on next in this paper. Previous Evah LCA studies also cited reports of rPET fibre LCA being most sensitive to hot melt-spin energy.

6. LCA case study

This section details an rPET fibre insulation LCA case study. Figure 6 charts process flows inside the system boundary. The scope includes PET, rPET and PETG inputs to manufacture and transport to factory gate and all known domestic and global industry supply chains from cradles at the boundary.

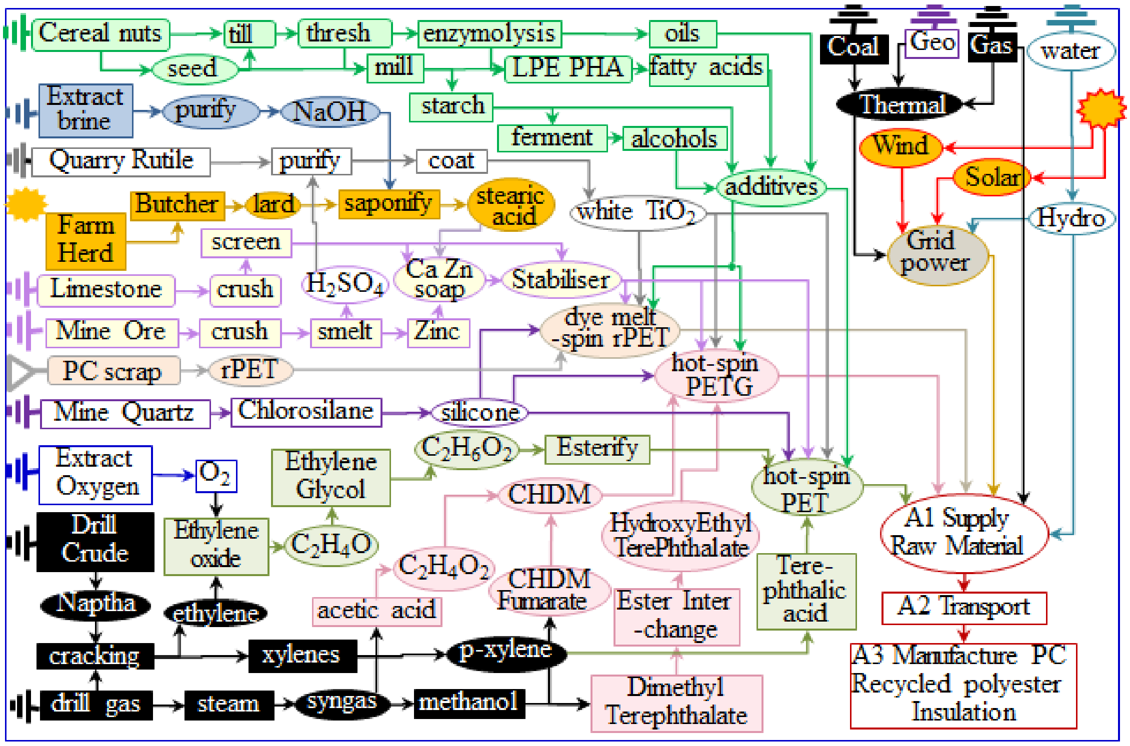

Figure 6. Process flow chart for non-woven product.

Figure 7 shows, this A1 to A3 study covered EPD modules from earth or scrap cradles to factory.

Model	Actual			Scenarios													Potential		
Stages	Production			Construct		Use							End-of-Life				Benefit & load beyond system		
						Fabric					Operation								
Modules	A1	A2	A3	A4	A5	B	B	B	B4	B	B6	B7	C1	C2	C3	C4	D1 -3		
Unit processes	Resources	Transport	Manufacture	Transport	Construct	Use	Maintain	Repair	Replace	Refurbish	Energy use	Water use	Demolish	Transport	Process Waste	Disposal	Reuse	Recovery	Recycling
Cradle to Gate+ Options	Mandatory			O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O
Grave				M	M	M	M	M	M	M	M	M	M	M	M	M	O	O	O

Figure 7. Building life cycle (mandatory (M), optional (O)).

6.1. Data collection

Data for this LCA case study was collected according to ISO 14044:2006 section 4.3.2 [4]. Specific primary data <5 years old was sourced from manufacturer submissions, suppliers' annual reports, technical reports, manuals, product specifications and websites. It also drew on 3rd party reports, publications on corporate locations, logistics and technology standards. Generic and background data was collected from the International Energy Agency, IBISWorld, USGS Minerals, Franklin Associates, Plastics Europe, NREL USLCI, EcoInvent as well as academic and industry literature [28–34].

As primary and background data sources rarely provide estimates of accuracy, Evah applies a data quality guide using a pedigree matrix approach of uncertainty estimation to 95% confidence levels of Geometric Standard Deviation[2] (σg). Table 3 lists uncertainty estimates and data quality control system compliant to the ILCD handbook [16] and UNEP Society for Environmental Toxicology and Chemistry (SETAC) LCI data quality guidelines [35]. All data used had U ≤0.2 uncertainty.

Table 3. Data quality uncertainty (U).

Metric σg	U ± 0.01	U ± 0.05	U ± 0.10	U ± 0.20	U ± 0.30
Age of data	≤1 year	≤3 years	≤7 years	≤10 years	>10 years
Duration	>3yr	3yr	2yr	1yr	<1yr
Data source	Process	Line	Plant	Corporate	Sector
Technology	Actual	Comparable	Within class	Conventional	Within sector
Reliability on	Site audit	Expert verify	Region report	Sector report	Academic
Precision to	Process	Line	Plant	Company	Industry
Geography	Process	Line	Plant	Nation	Continent
True of the	Process	Mill	Company	Group	Industry
Sites cover of	>50%	>25%	>10%	>5%	<5%
Sample size	>66% trend	>25% trend	>10% batch	>5% batch	Academic
Cut-off mass	0.01%	0.05%	0.1%	0.5%	1%
Consistent to	±0.01	<±0.05	<±0.10	<±0.20	<±0.30
Reproducible	>98%	>95%	>90%	>80%	<70%
Certainty	Very high	High	Typical	Poor	>±0.30

6.2. Data quality parameters

Considering wider variance of background data quality and sensitivity to melt-spin energy use, the melt-spin average of 8.3 ± 8 MJ/kg PET fibre was rejected for LCA modelling. Evah's cut-off is ±30% so the ±8 MJ/kg standard deviation from the mean 8.3 MJ/kg being ±100% was far too uncertain. Instead, median lower and upper melt-spin energy data was used. Lower melt-spin energy was modelled with 4.102 MJ/kg fibre comprising 1.87 MJ electricity, 2.21 MJ natural gas & 0.02 MJ propane.

The two LCA modes of upper melt-spin energy were developed using the 10.4 MJ electricity / kg median versus 8.1 MJ electricity, 2.21 MJ natural gas and 0.02 MJ propane/kg fibre. For simplicity, the EPDs declared results of one lower and one upper melt-spin energy 10.4 MJ electricity/kg only.

6.3. EPD LCI and LCIA results

Table 4 lists and Figure 8 charts total inventory and impact assessment results versus mass % rPET and PET + PETG insulation for lower and upper melt-spin values. The nine charted products include four from Table 4. Comparing upper and lower energy shows significant differences in impact results.

Various results indicate upper melt-spin energy contributes 2 to 4 times higher impact than lower melt-spin energy. Fresh water and primary non-renewable energy inputs are 3 to 4 times higher. GWP and general waste output is >3 times higher.

Table 4. Inventory results/kg product (A1–A3).

Results (Secondary = 2nd Primary = 1°)	Unit	Lower				Upper			
		A	B	C	D	A	B	C	D
Greenhouse gas biogenic	kg CO_{2eq}	−0.4	−0.5	−1.0	−1.1	−0.4	−0.5	−1.0	−1.2
Greenhouse gas fossil		2.5	2.4	2.9	3.0	8.1	8.3	8.1	8.0
Greenhouse gas total		2.1	1.9	1.9	1.9	6.4	6.5	6.2	6.1
Depletion fossil fuel	MJ	2.5	2.2	2.8	2.8	5.8	5.9	6.1	6.2
Secondary material	kg	0.68	0.76	0.69	0.69	0.69	0.76	0.69	0.69
2nd renewable fuel	MJ	1.4	1.7	5.1	5.1	2.2	2.6	5.3	5.9
2nd finite fuel	MJ	0.25	0.14	0.25	0.25	0.26	0.15	0.26	0.26
1° renew energy	MJ	4.1	5.0	7.8	8.4	6.9	8.0	11	11
1° renew feedstock	MJ	3.6	4.7	12	14	3.50	4.70	12	14
Total 1° renewable energy	MJ	7.6	9.7	20	22	10	13	23	25
1° finite energy	MJ	33	31	36	38	91	94	95	97
1° finite feedstock	MJ	9.7	7.9	11	11	13	11	13	14
Total 1° finite energy	MJ	42	39	47	48	100	110	110	110
General waste	kg	0.49	0.51	0.47	0.50	1.6	1.7	1.6	1.6
Material for recycling	kg	0.12	0.21	0.24	0.23	0.17	0.26	0.28	0.27

The chart also shows increasing GWP trends with decreasing % rPET and increasing % PET, despite fibre supply from seven companies in three nations.

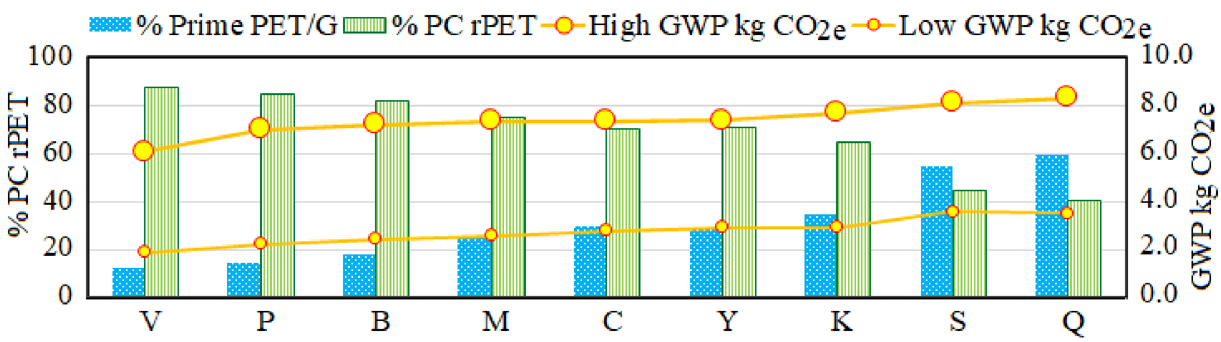

Figure 8. High and low GWP results Vs % rPET (A1–A3).

Such variation in energy use linked to ecosystem depletion and damages suggests that more accurate melt-spin energy definition is vital to have confidence in true rPET fibre LCA and EPDs. Unless based on recent post 2019 rPET spinning-industry datasets, LCA results based on any one pre 2019 melt-spin energy background data value are too uncertain to be representative of rPET fibre.

7. PET fibre product EPDs

This section reports public domain information collated from PET fibre insulation from 3 EPD programs. EPD programmes operating around the world, use product category rules (PCR) entailing their specific LCA guidelines, procedures and requirements. Table 5 details different rPET EPDs using PCRs comparable with the authors' case study as well declaring results for the same A1–A3 scope.

Table 5. PET fibre EPD details.

Code	EPD operator	Function	Stages	Depth	Cover	% Staple fibre		Bond fibre %
			A1-3+	mm	kg/m^2	rPET	PET	
US1	SCS global services	Ceiling panel	B1-7 C1-4	9	1.3	50	35	8 PA & 8 PUR
IT1	International EPD system	Insulation panel	C1-4 D	20	0.4	30	40	30 PETG
IT2				100	2	30	40	
AZ1	Australasian EPD	Acoustic insulation	-	26	3.84	60	40	-
AZ2			C2 C4	24	3	60	-	40
AU3			-	100	1	60	40	-

7.1. *EPD LCI and LCIA results*

Table 6 and Figure 9 compare results per kg product. They show GWP increasing with gross energy use. Lower Pacific Rim energy use results have least GWP and intermediate Australasian EPD GWP results are less than International and US EPDs. Pacific Rim upper energy use has highest GWP.

Table 6. Summary results/kg product cradle to gate (*author's estimate only for charting).

EPD No./Unit		GWP (kg CO_{2eq})	Feedstock (MJ)	Energy not material (MJ)	Gross energy (MJ)
Lower	b	1.9	13	36	49
	c	1.9	23	44	67
	d	1.9	25	46	70
	a	2.1	13	37	50
Az	3	3.0	6.0	51	57
	2	3.6	10	62	72
	1	3.8	13	69	82
IT	1	4.0	30	56	86
	2	4.0	30	56	86
US	1	4.7	30*	59*	89
Upper	D	6.1	28	108	135
	C	6.2	25	106	133
	A	6.4	17	98	110
	B	6.5	16	102	123

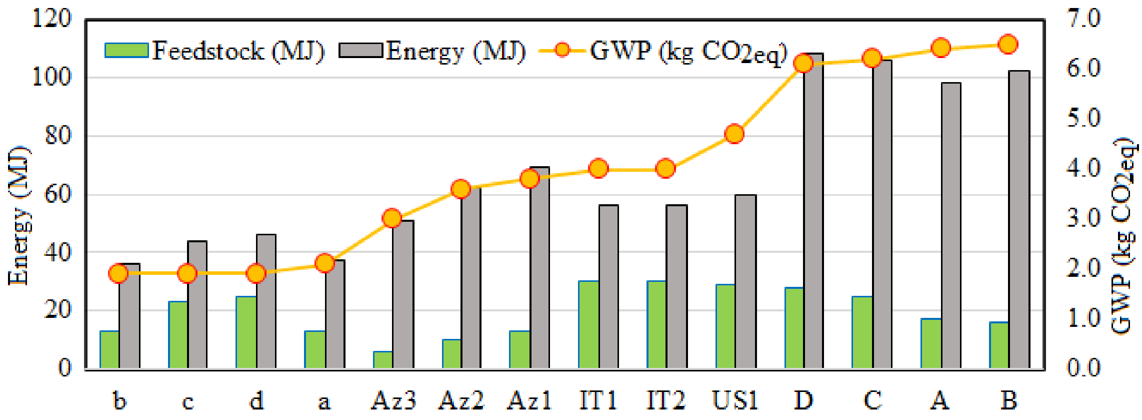

Figure 9. PET Fibre EPD Details.

Table 7 details LCA results of twenty-one comparable products in the Australasian EPD Az1 set. It shows GWP (kg CO_{2eq}) and Fossil Fuel Depletion (ABDFF) (MJ) impact versus rPET from zero to 83% mass share. Figure 10 charts all their primary PET fibre (%) versus GWP and ADPFF results.

Table 7. Australian Az1 insulation impacts/kg product A1–3.

Acoustic insulation	Code	Core colour	Density kg/m^3	rPET mass %	GWP kg CO_{2eq}	ADPFF MJ ncv
Fabric E	EF	Colour	350	83.2	2.95	46.0
Panel 50 mm	P5	Black	77	72.3	3.25	53.4
Panel 25 mm	P2	Black	77	72.0	3.21	53.1
Fabric Em	EM	Colour	350	72.8	3.19	52.3
Panel 12 m Deluxe	D1	White	200	62.4	3.37	57.5
Panel 7 mm Deluxe	D7	Black	200	62.4	3.40	65.7
Ceiling flat tile 13 mm H	C	White	203	48.5	3.73	66.3
Baffle R 26 mm	R2	Black	148	47.4	3.75	67.0
Baffle P 26 mm	P	White	148	13.3	3.76	87.0
Ceiling 3D tile 8 mm H	TH	White	305	31.9	4.29	78.2
Ceiling 3D tile 8 mm WW	T3	White	203	28.8	4.28	79.1
Ceiling flat tile 25 mm	T	White	203	27.9	4.20	78.9
Wall 3D tile 4 mm ET	W	White	305	25.5	4.16	77.0
Wall 3D tile 4 mm W	T4	White	305	23.8	4.42	82.5
Wall 3D tile 8 mm H	Tw	White	305	20.0	4.52	87.0
Baffle R 26 m	R	White	148	13.3	4.52	67.0
Panel quiet 25 mm	Q	White	117	10.4	4.57	88.8
Panel 24 mm deluxe	D2	B&W	125	63.4	2.43	57.5
Panel 48 mm deluxe	D4	B&W	125	0.0	2.84	43.9
Board 7 mm	B	White	148	52.0	3.74	87.0
Felt hanging screen 25 mm	H	White	137	74.4	4.74	91.4

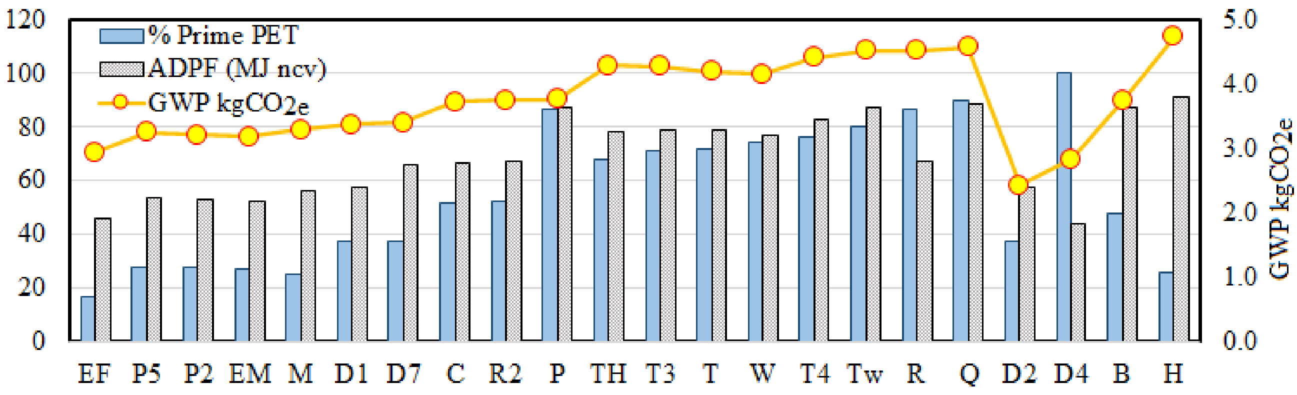

Figure 10. EPD % PET Vs ADPFF and GWP results A1–A3.

Most GWP and ADPFF results trend with Az1 EPD % PET (and rPET by difference) results except the four last products. Their GWP did increase somewhat with density but not evidently with ADPFF, % rPET, thickness or renewable energy used. As their fibre supply is not declared, they may have unique supply chains or manufacture processes. These four include GWP emissions of:

- 2.4 kg CO_{2eq}/kg 6% rPET 24 mm panel 125 kg/m^3 density using 57.5 MJ ADPFF;
- 2.8 kg CO_{2eq}/kg 73% rPET 48 mm panel 125 kg/m^3 density using 43.9 MJ ADFF;
- 3.74 kg CO_{2eq}/kg 52% rPET 7 mm board 134 kg/m^3 density using 87 MJ ADPFF;
- 4.7 kg CO_{22eq}/kg 74% rPET 25 mm felt 137 kg/m^3 density using 91.4 MJ ADPFF.

8. Discussion of results

Product manufactured from 60% rPET derived from post-consumer packaging is converted to flake and or pellet then fibre via melt spinning. LCA is most sensitive to this process energy. Considering its highest sensitivity overall, the high ±8 MJ/kg standard deviation of average 8.3 ± 8 MJ/kg rPET fibre melt-spin energy use meant its data quality was far too uncertain for LCA modelling.

Resultant variation in energy use and LCA and LCIA result suggests that better defined and more accurate melt-spin energy definition is vital for true rPET LCA to have confidence in affected EPDs. Unless based on recent post 2019 spinning-industry datasets, LCA results based on one melt-spin energy value are too uncertain to be representative of rPET fibre.

Most of the EPDs reported their primary data was from first-hand sources. Considering their reliance on primary non-renewable energy sources, all gross energy and most GWP results declared in EPDs from 3 EPD programmes appear too low to include gross melt-spin energy. All their interpretation ignored both the significance of background data quality and sensitivity to rPET melt-spinning energy demand. Some did not note melt spinning in their LCA process diagram.

9. Conclusions

This study presented results from rPET fibre EPD case studies. Literature reviews found variations in melt-spin fibre energy data too uncertain for use in any compliant rPET fibre EPD. New, accurate, consistent and reliable melt-spin energy data is vital for LCA of such EPDs. Reliable background data is essential for LCA of rPET fibre and EPDs, which at the moment is not the case. Analysis of rPET melt-spin processing and energy data provided in this study will be useful for LCA practitioners.

10. Recommendations

Recommended professional practice is to avoid gaps, misconceptions, mismatched assumptions and incorrect acceptance. This involves actions to declare:

- Multiple data sources to avoid reliance on single sources or single data points with gaps.
- Integrated suitable and comprehensively defined scenarios for product life cycle stages.
- Product-specific data sources not generic data e. G. Excluding recycling operations.
- Clear, accurate well-defined specific data in foreground processes.
- Clear, accurately defined generic data for all significant background processes.
- Most reliable best and worst-case lci if product-specific accurate data is inaccessible.
- Verification by an independent third-party of least reliable data.

Author contributions

Conceptualisation, Moazzem, S. and Jones, D.; methodology, Moazzem, S., Jones, D.; software, Jones, D.; validation, Jones, D. and Vlieg, M; formal analysis, Moazzem, S, Jones, D. and Vlieg, M; investigation, Vlieg, M., Moazzem, S., Naiker, D. and Jones, D.; resources, Vlieg, M., Moazzem, S., Jones, D, Naiker, D. and Jones, D.; data curation, Jones, D.; writing, original draft preparation, Moazzem, S. and Jones, D.; writing, review and editing, Moazzem, S., and Jones, D.; visualization, Jones, D. and Vlieg, M.; supervision, Jones, D., Vlieg, M.; project administration, Jones, D.

Conflict of interest

The authors declare no conflict of interest.

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