Patagonia's Common Threads Garment Recycling Program: A Detailed Analysis

Executive Summary:

Patagonia has a long history of innovating to reduce environmental impact, from using recycled soda bottles in our Synchilla jackets beginning in 1993 to switching to 100% organic cotton in 1996. The Common Threads Garment Recycling Program, launching in Fall 2005, marks the latest milestone in our history of innovation.

Through the Common Threads Garment Recycling Program, Patagonia will collect worn-out, old Capilene base layer garments from customers in order to recycle the garments into new filament yarns that will be used to make new polyester (PET). Using the ECOCIRCLE™ recycling system from Teijin, a progressive fabric manufacturer in Japan, Patagonia's old Capilene garments will be broken down to make new polyester fibers.

Using old Capilene garments to make recycled polyester has several environmental benefits. As traditional polyester is made from petroleum, using recycled fibers greatly reduces the fossil fuel-based inputs needed to manufacture polyester. In addition, the program will enable us to take responsibility for Patagonia's Capilene garments at the end of their useful life. This take-back program will give us the ability to limit the waste that we are responsible for by diverting old garments from landfills – in perpetuity!

While the use of recycled PET significantly reduces the direct use of petroleum and natural gas (the raw material source for the production of DMT (dimethyl terephthalate) the primary precursor chemical used in the production of PET for Capilene garments), recycling US based Capilene involves increased transportation related energy requirements due to transcontinental shipments of used garments between the U.S. and Japan. Thus, we wanted to compare the environmental impacts of Teijin's three PET manufacturing options. We evaluated the energy use and greenhouse gas emissions that result from the following three scenarios:

> A.) Virgin Process: Teijin's production of polyester from virgin materials

> B.) Locally Recycled Process: Teijin's production of polyester using recycled garments that were collected locally. Garments collected at Patagonia Japan locations fit into this scenario.

> C.) Recycled Capilene Process: Teijin's production of polyester using Patagonia's recycled Capilene garments that were collected in the US.

We completed a detailed environmental analysis on these three options, explained in the following paragraphs and were able to compare the environmental impacts of manufacturing virgin and recycled polyester as well as quantify the impact that result from transporting used Capilene from our US customers to Japan.

Environmental Analysis:

Introduction
Patagonia's Capilene garments are made from polyester (Polyethylene Terephthalate (PET))-based fabrics and designed for use primarily as base layer insulation layers. This polyester fabric can be recycled in Teijin's ECOCIRCLE™ recycling system and used to make new PET. Teijin currently manufactures PET from both virgin materials and recycled polyester. At this point in time the polyester used in Teijin's ECOCIRCLE recycling system is collected from local sources in Japan.

Teijin uses DMT (dimethyl terephthalate) as the intermediate chemical in the manufacture of PET. Teijin provided us with energy use and CO_2 emissions information for both production of DMT from virgin materials and recycled polyester. Because we assume that Teijin uses the same process of polymerization from DMT to PET for both the virgin and recycled DMT we have not included it in the comparison. The unit of comparison from which all calculations contained in this analysis are normalized is 1 ton of DMT fiber. This analysis focuses on the energy used and CO_2 emitted up to the production of DMT and does not include steps beyond this point in the life cycle of polyester.

What follows is an explanation of how we calculated the energy use and CO_2 emissions from the three different production scenarios. Please refer to the Addendum/Appendix at the end of this document for conversion details and explanations for transport calculations.

A.) Virgin Process: Production of DMT from virgin materials

Production Energy – *DMT manufacturing*
Teijin provided the DMT manufacturing energy use data for the Virgin Process. The energy use data includes the following steps:

- Extraction and transport of raw materials (oil and natural gas)
- Manufacturing of DMT from raw materials (oil and natural gas)

Teijin	Energy Use (MJ/metric ton DMT)
Production of 1 metric ton DMT by Teijin	72,422

Production CO_2 – *DMT manufacturing*
Teijin provided the DMT manufacturing CO_2 emissions data for the Virgin Process. The CO_2 emissions data includes the following steps:

- Extraction and transport of raw materials (oil and natural gas)
- Manufacturing of DMT from raw materials (oil and natural gas)

	CO_2 (metric tons/1 metric ton of DMT
$CO_{2 \text{equivalents}}$	4.183

B.) Locally Recycled Process: Teijin's production of DMT using recycled garments that were collected locally

Production Energy – *DMT manufacturing*
Teijin provided the DMT manufacturing energy use data for the Locally Recycled Process. The energy use data includes the following steps:

- Collection of polyester from local sources (Japan)
- Manufacturing of DMT from recycled polyester (Japan)

Teijin	Energy Use (MJ/metric ton DMT)
Production of 1 metric ton DMT by Teijin	11,962

Production CO_2 – *DMT manufacturing*
Teijin provided the DMT manufacturing CO_2 emissions data for the Locally Recycled Process. The CO_2 emissions data includes the following steps:

- Collection of polyester from local sources (Japan)
- Manufacturing of DMT from recycled polyester (Japan)

	CO_2 (metric tons/1 metric ton of DMT)
$CO_{2equivalents}$	0.98

C.) Recycled Capilene Process: Teijin's production of DMT using Patagonia's recycled Capilene garments

Teijin provided energy data for the production of DMT from recycled polyester fiber. All other data was derived based on a combination of estimates and assumptions of critical factors.

The Recycled Capilene Process includes five steps:

- ***Step 1:*** Used garment collection (customers mail garments via bulk shipments 1200[1] miles from their homes to Reno refer to Transport section)
- ***Step 2:*** Collection and storage of garments (Reno, NV)
- ***Step 3:*** Transport from Reno NV via truck 200 miles to Oakland Port
- ***Step 4:*** Transport from Oakland Port to Matsuyama, Japan via container ship 5,600 miles
- ***Step 5:*** Manufacturing of DMT from recycled polyester (Japan)

Garment Collection Explanation
Although Patagonia produces a number of Capilene styles, and all Capilene styles will be included in the take back program, this analysis is based on a single fabric/garment

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[1] The distance of 1200 miles from customer to Reno, NV was selected because it is the average distance from all of our retail stores to Reno.

combination–Midweight Crew Neck Capilene (MW Capilene). We chose to focus on just one specific style of Capilene in order to maintain consistency in our analysis. Although our various Capilene styles appear similar, each is quite different; some styles include zippers, while others differ in sleeve length. These style differences along with the different fabric weights, causes differences in the overall weight of the garments. In order to calculate how many garments we need to produce one ton of DMT, we have to know the weight of the polyester contribution of each garment. We wanted to use a consistent weight so we chose to analyze only MW Capilene because it offers a good representation of the entire product line in regards to materials and weight. Our MW Capilene is one of 7 different Capilene categories and made up 22% of the total Capilene sold by Patagonia in FY 2004.

Garment Conversion
To estimate the number of used garments necessary for the production of 1 metric ton of PET fiber we used efficiency information provided by Teijin. Because Capilene garments are 100% polyester, the Japanese manufacturer estimated that the conversion during the recycling of the garments to DMT could be greater than 90%. Absent valid efficiency data, we have assumed that the conversion efficiency will be 90%. Therefore, to produce one metric ton of DMT will require 1.11 metric tons (4,900) of garments.

Recycled Garment to DMT Conversion

Unit	Conversion used
1 metric ton =	35,274 ounces
1 MW Capilene Crew Neck =	8 ounces
4,406 MW Capilene Crew Neck garments =	1 metric ton
Need 1.11 metric tons (factoring in 90% efficiency) to manufacture 1 ton of DMT =	4,900 garments
4900 garments =	1 metric ton DMT

Step 1: Transport from Customer to Patagonia's service center in Reno, NV
Please refer to the Transportation Appendix at the end of this document for conversion details and explanations for transport calculations.

Because we are encouraging our customers to mail their recycled garments to Patagonia, for this analysis we are assuming that all 4,900 garments (1.11 metric tons) will be mailed from our customers directly to our Reno Service Center. We also assume that the average distance the garments are mailed will be the average distance from Patagonia retail stores to the Service Center in Reno, NV. These assumptions, should they be inaccurate, have the potential to have a large impact on the results of our analysis.
Garments mailed: 4,900
1,200 miles by truck
Gallons of fuel: 22
Weight of transport: 1.11 tons of garments transported
Energy used: 3,504 MJ
CO_2 emissions: 0.124 metric tons CO_2

Step 2: Garment Collection and Storage/Reno Service Center Activity

<u>Production Energy</u>
Assumptions
The 1.11 metric tons of garments will be shipped 1,200 miles from a Patagonia retail store to the Reno Service Center. At the Reno Service Center each box will be unpacked, the used Capilene garments will be cut into pieces using a band saw, and the fabric scraps will be repacked into boxes. Once the scraps are packaged they will be transshipped to the Japanese manufacturer. We then assumed that it would take approximately 2 hrs total to unload, store, cut up garments, retrieve, and load each box for shipment to Japan. 45 boxes will be needed to transport all the garments (110 garments per box) We estimated that the 45 boxes will require 90 person hours (approx 2 hrs per box) at the Service Center and approximately 30 square feet of space.

Calculations
Energy use associated with Service Center activities is estimated to be negligible (0.261 MJ) as shown by the conversion and calculation details in the table below.

Reno Service Center - Energy Calculations

Calculation Components	Conversion Factor	Result
FY'04 Total Energy Use at Reno Service Center		3,985,294 MJ
Service Center size		211,000 sq. ft.
Estimated sq ft for garment recycling activities		30 sq. ft.
Sq. footage used as a percent of total sq. ft.	30 sq.ft./211,000 sq.ft.=	0.01%
Allocation of estimated annual energy use for 30 sq ft	3,985,294 MJ*0.010% of total sq.ft.=	566 MJ
Number of garments per garment box	110 (info provided per field trial)	110 garments per box
Number of boxes needed	45	45
Estimated handling and cutting time per garment box	2 hour	2 hour
Estimated staff hours for 1.11 tons (4,900) garments	(4,900 total garments/110 garments per box) * 2 hrs per box =	90 hrs
Staff time as a percentage of total annual staff hours	90 hrs /(10 hrs a day*5 days a week*52 weeks a year *75 employees) =	0.046%
Estimated Service Center energy use for garment recycling	566 MJ * 0.046% =	0.261 MJ

<u>Production CO_2</u>

Garment Collection and Recycling/Service Center Activity:

Based on a regional CO_2 emission factor of 0.22 lbs CO_2/MJ, we calculated a negligible amount of CO_2 emissions (0 metric tons) for the estimated 0.277 MJ energy use.

Step 3: Transport from Service Center in Reno, NV to Port in Oakland, CA
200 miles by truck
Gallons of fuel (diesel): 4
Weight of transport: 1.11 metric tons of garments
Energy used: 544 MJ
CO_2 emissions: 0.021 metric tons CO_2

Step 4: Transport from Oakland, CA to Matsuyama, Japan
This transport will likely include an initial stop at the port in Kobe, Japan and then be shipped via boat to Matsuyama. The initial distance from SF to Kobe is approximately 5374 miles via boat. It is then approximately 210 miles from Kobe to the Japanese manufacturer in Matsuyama.
5600 miles by boat
Gallons of fuel (residual fuel oil): 12
Weight of transport: 1.11 metric tons of garments
Energy Used: 1,723 MJ
CO_2 Emissions: 0.081 metric tons CO_2

Step 5: DMT manufacturing

Production Energy

Teijin provided the DMT manufacturing energy use data for the Recycled Capilene Process. The energy use data includes the following steps:

- Collection of polyester from local sources
- Manufacturing of DMT from recycled polyester

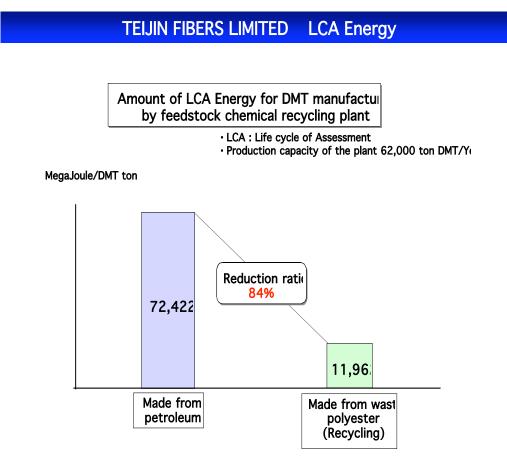| Teijin	Energy Use (MJ/metric ton DMT)
Production of 1 metric ton DMT by Teijin	11,962

Production CO_2
Teijin provided the DMT manufacturing CO_2 emissions data for the Recycled Capilene Process. The CO_2 emissions data includes the following steps:

- Collection of polyester from local sources
- Manufacturing of DMT from recycled polyester

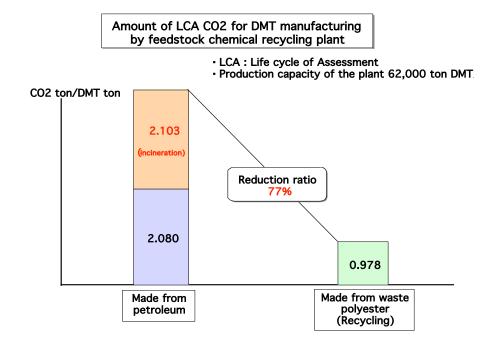|	CO_2 (metric tons/1 metric ton of DMT)
$CO_{2equivalents}$	0.98

Results:

After researching and collecting data from Teijin we were able to complete our analysis. We found that the process required to manufacturing DMT from raw materials (extraction and transport of oil and manufacturing DMT) uses 84% more energy than the process of manufacturing DMT from recycle polyester (local collection of polyester and manufacturing DMT). The chart below illustrates this information.

TEIJIN FIBERS LIMITED   LCA Energy

**Amount of LCA Energy for DMT manufactur
by feedstock chemical recycling plant**

· LCA : Life cycle of Assessment
· Production capacity of the plant 62,000 ton DMT/Y

MegaJoule/DMT ton

Reduction rati
84%

72,422

11,96

Made from
petroleum

Made from wast
polyester
(Recycling)

There are 77% fewer CO_2 emissions when DMT is manufactured using recycled polyester instead of using raw materials. As you can see in the illustration below, that more than half of the CO_2 produced during the Virgin Process is the result of incinerating old, used garments instead of recycling them.

Amount of LCA CO2 for DMT manufacturing
by feedstock chemical recycling plant

・LCA : Life cycle of Assessment
・Production capacity of the plant 62,000 ton DMT

CO2 ton/DMT ton

2.103
(incineration)

Reduction ratio
77%

2.080

0.978

Made from
petroleum

Made from waste
polyester
(Recycling)

The two charts above compare the energy use and CO_2 emissions from options A and B explained above. These charts reveal that using recycled polyester to manufacture DMT uses significantly less energy and produces significantly fewer CO_2 emissions.

When the transportation from Patagonia Customer in the US to Japan is factored into the ECOCIRCLE recycling system, manufacturing polyester fiber from recycled materials results in 76% less energy usage and 71% less CO_2 emissions than producing polyester from virgin materials. These statistics are encouraging, and they give us great hope that this program can help us reduce our environmental footprint.

The following chart provides a quantitative comparison of the three possible DMT manufacturing scenarios that were evaluated in this analysis.

Category	Option A Teijin w/ out Recycling	Option B Teijin w/ Local Recycling	Option C Teijin with Capilene Recycling	Units
Distance	0	0	7,000	Miles
Fuel for transport	0	0	38	Gallons
Energy (production)	72,422	11,962	11,962	MJ
Energy (transport)	0	0	5,771	MJ
Total Energy	**72,422**	**11,962**	**17,733**	**MJ**
CO2 emissions (production)	4.18	0.98	0.98	Metric tons
CO2 emissions (transport)	0.000	0.000	0.226	Metric tons
Total CO2 Emissions	**4.18**	**0.98**	**1.20**	**Metric tons**

Conclusion:

We provide this information for the benefit of our customers, the public at large, the media, and students conducting research on these topics. We hope that this information will help our customers understand why we have embarked upon such a program and how they can help reduce our collective ecological footprint. We wanted this analysis to reveal realistic environmental impacts that could result from transporting garments to Japan. We had to make assumptions, as we don't know how our customers will participate. We tried to think of our own habits and what would be best for the planet. We chose one scenario that would be best from an environmental perspective with the hope that this will encourage people to participate in the lowest impact way. For example, mailing in old Capilene garments rather than making a special trip to drive them to a Patagonia store results in significant energy and emissions savings.

We realize our analysis indicates that in terms of energy use and CO_2 emissions, the process of recycling old Capilene garments and shipping them from the US to Japan, is not the option with the least impacts. It also revealed that surprisingly, the international shipping from the US to Japan is not the area that produces the greatest impact. The transportation required to move old Capilene garments from customers' closets to collection centers domestically (either Retail stores or the Reno Distribution Center) has the greatest potential to produce environmental impacts. This is an encouraging finding because it's an area over which we have some control. By making wise choices, we have the opportunity to significantly reduce the impact of the overall process!

Fortunately recycling is the right thing to do with garments that have worn out. There are other factors that come into play that increase the environmental benefits of this program. The benefits of reducing oil extraction for polyester manufacturing and reducing the amount waste that enters our solid waste stream are important and are not factored into our analysis.

It's critical that we recognize that recycling clothing is not a cure-all for our environmental challenges. Room for improvement abounds. We plan to continue to hold ourselves to a rigorous standard for reducing our environmental footprint, with the support and cooperation of our suppliers and our customers alike. On the transportation front, greater use of alternative energy and high-volume shipping methods (such as railway and ship) will help to reduce the impact. Greater use of alternative energy in domestic and international transportation will also be a boon. This program can serve to inspire more companies to develop recycling technologies and participate in such programs. It is our hope that as demand grows for clothing made using recycled garments, facilities such as Teijin's ECOCIRCLE™ recycling plant will open in more locations, reducing the mileage collected garments need to travel on their journey. We feel that all of these factors work together to make Common Threads a very worthwhile program.

Transportation Appendix:

Units/Conversions
All energy values are reported in mega joules (MJ) and all CO_2 emissions are measured in metric tons-CO_2e. All additional weight measurements are also measured in metric tons. All weight and energy unit conversions (for example converting kWh to MJ) were made using conversion factors and calculators at www.onlineconversion.com.

Geographic Distances
The distances between geographic locations as materials flow through the Capilene life cycle stages were found using www.indo.com/distance/index.html. The website calculates distances in miles between two specific locations. In cases where a specific geographic location was not available in the online distance tool, the closest location was used and an estimate was made for the distance to the target city. For example, in calculating the distance between San Francisco and Kobe, Japan, because Kobe is not in the distance calculator, we used the distance between San Francisco and Osaka, plus an estimate of the distance from Osaka and Kobe.

Transportation Energy
Transportation energy was calculated through a combination of identifying transport distances and modes (truck, train or ship). Originating and destination locations were identified with any intervening waypoints (e.g., trucking from origin to a port, shipping to another port, trucking to destination). The method of transport was identified through research on the supply chain or provided by Patagonia staff and consultants or the Japanese manufacturer.

Fuel use was determined using miles per gallon estimates available at:
www.gicaonline.com/media/tools/gica040312.pdf and
http://www.irpt.net/irpt.nsf/LinksView/EnvironmentalAdvantages?Opendocument. These websites estimated that one metric ton of freight using one gallon of fuel can be shipped the following distances for each mode:

Mode	Distance in ton-miles per gallon of fuel
Automobile*	19
Truck	59
Train	386
Boat	522

* The mpg values for the automobile are not in ton-miles per gallon
  they are miles per gallon for an average sized sedan.

The ton-miles per gallon values for truck, train and boat in the chart above are high because they are based on shipping one ton one mile. These numbers reveal that shipping a lot of weight in one shipment can be very efficient. Using these estimates, we calculated the gallons of fuel needed for each mode segment by multiplying the segment

distance by the tonnage of material and then dividing by the appropriate mpg estimate. Fuel usage in gallons was then converted to MJ using the following factors:

Mode of Transport	Fuel	Energy Content per Gallon in MJ
19 mpg Car	Gasoline	132
Truck, Train, Boat*	Diesel	146

*Note that boats use both Diesel Fuel Oil and Residual Fuel Oil. For the purposes of this report we have assumed that the all shipments via boat will use Diesel Fuel Oil
Source: Diesel Fuel: http://www.vigyanprasar.com/comcom/definition.htm
Residual Fuel Oil: http://www.digal.pt/Digal_I/s13.html
Distillate Fuel Oil: http://www.vigyanprasar.com/comcom/definition.htm

Energy values were multiplied by gallons of fuel needed for each mode segment, which were then summed to find the total energy needed for transport between the origin location and destination.

Transport CO_2 Calculations

All CO_2 emissions were calculated using the "Emissions Based on Distance" worksheet in the GHG calculation tool, "Calculating CO_2 Emissions from Mobile Combustion" found at http://www.ghgprotocol.org/standard/tools.htm. Emission factors used at that site by transport mode are:

Transport CO_2 Conversions

Mode	Kg CO_2/Metric Ton-Mile
19 mpg Automobile	0.4305
Truck	0.0937
Train	0.0260
Boat	0.0132