CA 1

Calculating MIPS for a Woman's Polo-neck Sweater

1 The Product and the Method

The Company – Finn Karelia Virke Oy

Finn Karelia Virke Oy, is a Finnish company that produces women's and men's clothes of their own fabrics. The company, founded in 1945, has a turnover of 31.0 million Euros (2004) and a total personnel of 540. The company has two factories: one in Orimattila, Finland, and one in Konstantynow, Poland, and subsidiaries in Germany and in Poland. The production capacity is 6,000 pieces per day. About 90% of the production is exported to Europe, USA, Canada and Australia.

The Product – Woman's Polo-neck Sweater

The example product is a woman's polo-neck sweater (Figure 1.1). It is produced in several different colours and sold in large numbers in Poland, Germany, Finland, Sweden and several other countries. It is made of 50/50 polyester/cotton knit. It is not self-evident what the "service unit" should consist of for a sweater. In the end the chosen unit was to wear the sweater 50 times long enough to require washing, and thus washing it after each time. The lifecycle of the sweater thus consists of production, use and 50 washings and finally the wasting of it on a landfill.

The Method – MIPS

The MIPS method is a tool for measuring and managing the human-induced material flows. MIPS stands for Material Input Per Service unit. It is a value that can be calculated for all final products that provide a service. The MIPS value relates the natural resources consumed by a product during its entire life cycle to the overall benefit derived from it. It provides a rough – but nevertheless indicative – approximation of the product's potential environmental load. The smaller a product's MIPS value, the lower its environmental load is considered to be, because it will be consuming fewer natural resources in relation to the amount of service it produces.

Expressed as an equation, MIPS is expressed as:

MIPS = material input/service unit

The material input forming the MIPS numerator refers to the total amount of natural resources needed for the creation and use of the product in question and for its waste management. It includes not only the materials bound up within it and those required for its production, but also all the materials involved in its transportation, equipment and packaging

Figure 1.1 *Woman´s polo-neck sweater.*

throughout its life cycle. The material input also includes the resources extracted from nature and used for producing the energy needed by the product. It thus encompasses the natural resources consumed throughout the product's entire life cycle and expresses this as a unit of mass, for example kilograms [Schmidt-Bleek, 1994].

2 MIPS Calculation

Databases

The calculation of material inputs makes use of the MI factors (also called material intensities) already calculated for many widely used materials, such as steel, cement and glass, and for different means of electricity production and transportation. The MI factor expresses in kilograms, the amount of natural resources needed to create one kilogram of material or one kilowatt-hour or one ton-kilometer. In practice, material input is calculated by multiplying the material and energy consumption and transportations of the product by the corresponding MI factors.

The service unit forming the MIPS denominator refers to the benefit derived from the product. It cannot be measured like a material input but is instead determined separately for each product. The total amount of times or years of use during the life cycle are examples of what may be selected as the service unit of a product [Autio and Lettenmeier, 2002].

Table 1.1 *Materials of the sweater.*

Materials and components	Weight/ product (kg)	Waste/ product (kg)	Total weight (kg)	MI factor (kg/kg)	Material Input (kg)	Comments
Sewing thread (polyester)	0.1155	0.0305	0.146	3.6	0.526	Knitting room waste 1.6% Selvedge waste 3% Cutting waste 21.5%
Sewing thread (cotton)	0.1155	0.0305	0.146	22	3.212	Waste: see above
Colorant and chemicals	0	0.236	0.236	1.5	0.354	Salt 75% Others 25% (crude oil)
Card labels	0.0027	0.00002	0.0027	15	0.041	MI factor: paper
Neck label	0.0004		0.0004	3.6	0.001	
Product label	0.0003		0.0003	3.6	0.001	MI factor: polyester
Cutting plastic		0.0009	0.0009	5.4	0.005	
Cutting paper		0.0026	0.0026	15	0.039	
Lot label		0.0004	0.0004	15	0.007	
Water						50.28 l/sweater, from own wool
				Total:	**4.18**	

Table 1.2 *Packing materials of the sweater.*

Materials and components	Weight/ product (kg)	Waste/ product (kg)	Total weight (kg)	MI factor (kg/kg)	Material Input (kg)	Comments
Bobbin		0.005	0.005	3	0.014	Measured, divided per sweater by weight
Wooden platform		0.016	0.016	2.2	0.035	See above
Cardboard		0.014	0.014	3	0.041	See above
Plastic bag	0.003		0.003	5.4	0.016	See above
Hangers	0.038		0.038	7	0.266	Measured
				Total:	**0.37**	

Table 1.3 *Electricity consumption in the production of the sweater.*

Electricity (public network)	Electric Energy Input (kWh)	MI factor (kg/kWh)	Material Input (kg)	Comments
Knitting	0.2	0.41	0.082	Partial estimate
Dyeing and finishing	0.28	0.41	0.115	Partial estimate, partly based on the machine wattage
Cutting and sewing	0.01	0.41	0.004	Based on the wattage of the cutter
		Total:	**0.20**	

Table 1.4 *Other energy consumption in the production of the sweater.*

Source of energy (oil, natural gas etc.)	Weight (kg)	MI factor (kg/kg)	Material Input (kg)	Comments
Natural gas	0.354	1.3	0.46	Partial estimate
		Total:	**0.46**	

Production Phase

The MIPS calculation of the sweater is shown below step by step. The calculations concerning the production phase has been published in Finnish in Autio and Lettenmeier [2002].

Calculation of the material input of the production phase starts with listing all the materials of the sweater (Table 1.1). The weight of each material and the amount of waste that is produced in the production processes are expressed in kilograms and added up. Then, the total weight of each material is multiplied with a corresponding MI factor. The result is the material input in kilograms. Comments concerning the calculation are written in the comments column.

Also the packing materials of the sweater and all the packing material waste created in the production phase are listed and expressed in kilograms (Table 1.2). The total weight of each packing material is multiplied with a corresponding MI factor.

The electricity consumption of production is expressed in kilowatt-hours (Table 1.3) and other sources of energy in kilograms (Table 1.4). Again, the material inputs are calculated by using the MI factors.

Also the transportation distances from the suppliers to the company and from the company to the customers need to be determined. The distances (expressed in kilometres) are mul-

The Finnkarelia Company

Factories
Finnkarelia was founded in 1945 and has two factories.

The Orimattila factory in Finland was completed in 1970 and has since then been expanded eight times. The factory floor area is more than 5,2 acres (22,000 m²).

Production in the Konstantynow factory, Poland, started in autumn 1991.

Production
Production starts with the yarn, which is knitted in the knitting department at a capacity of 2,000 to 2,300 kg a day. The modern and environmentally friendly machinery guarantees a fast finishing of the cloth and also an efficient development of the product.

Computerised production planning coupled with a high level of garment manufacturing technology enables the factory to process the fabrics through the cutting department, where automatic computer driven cutters cut 10 km of cloth daily.

The cut pieces are transferred to the sewing departments in Orimattila and Poland. In the finishing department the garments get their final touch. An automatic transport system then transfers the garments to the warehouse with a capacity of 300,000 pieces. From the warehouse the garments are then delivered to the customers.

http://www.finnkarelia.com

Table 1.5 *Transports in the production of the sweater.*

Mode of transportation	Distance (km)	Weight of transported goods (t)	Distance x weight (tkm)	MI factor (kg/tkm)	Material Input (kg)	Comments
Truck, incoming	1523	0.000291	0.443	1	0.443	Sewing thread + colorant
Ship, incoming	1134	0.000291	0.330	0.006	0.002	
Truck, outbound	1523	0.000234	0.356	1	0.356	Sweater
Ship, outbound	1134	0.000234	0.265	0.006	0.002	
				Total:	**0.80**	

tiplied with the mass of transported goods (expressed in tons). The ton-kilometers are then multiplied with the MI factors. Different modes of transport are dealt with separately.

Use Phase

In this calculation, the use phase includes the washing of the sweater. Both the production of the washing machine and the electricity consumption during the use of the machine are included. In Table 1.6 the material input of the materials of the washing machine is calculated in the same way as above for the sweater. Also the material input caused by transportations (Table 1.7) and the electricity consumption in the production phase of the washing machine (Table 1.8) are calculated.

Since there are also other clothes to be washed in the washing machine, the material input of the machine must be allocated per one sweater. The total material input of the washing machine is 1588 kg + 35.42 kg + 22.55 kg = 1645.97 kg. It is presumed that the washing machine can wash 2,000 times during its life cycle. This means that one wash consumes 1645.97 kg / 2000 = 0.823 kg natural resources. Presumed that there are ten sweaters at the same time in the washing machine and that one sweater will be washed 50 times during its life cycle, the following amount of the material flows of the washing machine can be allocated for one sweater: (0.823 kg / 10) x 50 = 4.115 kg.

Also the electricity consumption during the use of the washing machine must be taken into account (Table 1.9). If a sweater is washed 50 times in +40ºC during its life cycle, 9.81 kWh of electricity is consumed. This corresponds to 4.02 kg of natural resources.

Table 1.6 *Materials of a washing machine.*

Material	Weight/ product (kg)	MI factor (kg/kg)	Material Input (kg)	Comments
Steel	24.5	7	171.5	
Copper	1.33	500	665	
Tin	0.07	6800	476	
Aluminium	1.4	85	119	
Iron	7	5.6	39.2	
Zinc	0.7	23	16.1	
Glas	1.4	3	4.2	
Cement	20.3	1.3	26.39	
Plasic	11.2	5.4	60.48	MI factor: polyethylene
Rubber	2.1	5	10.5	
		Total:	**1588**	

Table 1.7 *Transports of a washing machine.*

Mode of transportation	Distance (km)	Weight of transported goods (t)	Distance x weight (tkm)	MI factor (kg/tkm)	Material Input (kg)	Comments
Truck transport	500	0.070	35	1	35	
Sea transport	1000	0.070	70	0.006	0.42	
				Total:	**35.42**	

Electricity (public network)	Electric Energy Input (kWh)	MI factor (kg/kWh)	Material Input (kg)	Comments
Electricity	55	0.41	22.55	
		Total:	**22.55**	

Table 1.8 *Electricity consumption in the production of a washing machine.*

Electricity (public network)	Electric Energy Input (kWh)	MI factor (kg/kWh)	Material Input (kg)	Comments
Electricity	9.81	0.41	4.02	
		Total:	**4.02**	

Table 1.9 *Electricity consumption caused by the washing of the sweater (in +40ºC, 50 times).*

Waste disposal	Weight/ product (kg)	MI factor (kg/kg)	Material Input (kg)	Comments
Landfill deposit	0.231	1.1	0.25	
		Total:	**0.25**	

Table 1.10 *Waste disposal of the sweater.*

Table 1.11 *Life-cycle-wide material flows of the sweater.*

Production	Material Input (kg)/sweater	%
Materials	4.18	29.0
Packing materials	0.37	2.6
Electricity consumption	0.20	1.4
Other energy consumption	0.46	3.2
Transports	0.8	5.6
Subtotal	*6.01*	*41.7*
Usage	**Material Input (kg)/sweater**	**%**
Washing machine	4.12	28.6
Electricity consumption of the washing machine	4.02	27.9
Subtotal	*8.14*	*56.5*
Waste disposal	**Material Input (kg)/sweater**	**%**
Landfill deposit	0.25	1.8
Subtotal	*0.25*	*1.8*
Total	**14.40**	**100**

Waste Disposal Phase

It is assumed that the sweater will end up on a landfill in the end of its life cycle. The material input of the landfill treatment is calculated in Table 1.10.

3 Overall Results of the Calculation

Summation of the Material Inputs

The life-cycle-wide material inputs of the sweater are summed up in Table 1.11. About 57% of the natural resource consumption originates from the use of the sweater. About 42% of the natural resource consumption is caused by the production phase, in which the materials of the sweater are the most important factor. Waste disposal causes only 2% of the natural resource consumption of the sweater.

It must be emphasized that the MI factor used for electricity consumption in this calculation represents average power production in Finland. The MI factor for power production varies very much between different countries. For example, the MI factor for power production in Germany is about ten times bigger than the Finnish one. Thus, it has a significant impact on the results, which MI factors are being used.

Service Unit (S) and the MIPS Value

In order to calculate a MIPS value for the product, also the service unit must be defined. In the case of a sweater, the service unit could be defined for example as the amount of times the sweater is worn or the amount of times the sweater is washed during its life cycle. In this calculation, the latter is chosen. As mentioned it is assumed that the sweater will be washed 50 times during its life cycle. Therefore, the MIPS value of the sweater is:

MIPS = MI/S = 14.40 kg/50 washes = 0.288 kg/washing cycle ≈ 0.3 kg/washing cycle

4 Reducing MIPS, Increasing Material Efficiency

Ways to Reduce Material Intensity

In order to increase material efficiency of the product, the MIPS value needs to be reduced. This can be achieved either by diminishing the material input of the product or by increasing the amount of service the product produces during its life cycle. The material input of the product can be diminished, for example, by changing the materials of the product, by decreasing the amount of waste created in the production phase, by optimising packaging, by decreasing the use of energy and by minimizing the transportations. The service of the product can be increased, for example, by prolonging the service life of the product and by making the product versatile.

Figure 1.2 *Production starts with the yarn, which is knitted in the knitting department at a capacity of 2,000 to 2,300 kg a day.*

For example, if the cotton in the sweater was replaced with viscose, the life-cycle-wide material input of the sweater would decrease from 14.4 kg to 11.9 kg per sweater. If the sweater were made purely out of cotton, its material input would be ca. 16.8 kg per sweater. Thus, the strategy of using mixed textiles chosen by Finn Karelia Virke Oy can be considered resource efficient.

Also the consumer can affect the MIPS value of the sweater. Ten sweaters at the same time in the washing machine, as assumed in the calculation, is perhaps not that much. Washing laundry only in full washing machines is a way to decrease the MIPS value of clothes.

It is also important to take proper care of the sweater and to avoid unnecessary washing of the garment. This way it is possible to prolong the service life of the sweater and to reduce the electricity consumption during the use phase.

As Finnish electricity has a relatively small material intensity, the relevance of the washing as a part of the life cycle of the sweater may even radically increase outside Finland. Thus, the strategy chosen by Finn Karelia Virke Oy of producing textiles that can be washed at low temperatures can be considered resource efficient, too. Drying the sweater in a tumble dryer would also increase the material input over the life cycle.

As shown in this example, the MIPS-concept enables companies to make life cycle considerations based on relatively simple calculations. From a life cycle point of view, the production process within the company is not the only relevant phase. Thus, a company should also think about its options to reduce the material input on the consumer side. Finn Karelia

Student Exercise

A students' exercise would be to repeat the calculation of the MIPS for the sweater. Vary the study by letting different student groups examine the consequences of the following changes:

1. Calculate the MIPS including all five resource categories available today.
2. Vary the assumption on how many sweaters can be part of a single wash. Check several different washing machines. They use quite different amounts of electricity per kg of clothing and different washing programs.
3. Vary some other assumptions, for example a) that the wasted sweater is sent to solid waste incineration, which would be the most typical today b) that the electricity would be taken in Poland and Germany instead of Finland c) that the transport of the resources to the plant is different.

After the study estimate which factor is the most important for reducing the MIPS. Make an assessment specifically of the greenhouse gas emission for the various assumptions.

Virke, for instance, has spent some efforts on communicating the advantages of low washing temperatures to the consumers. Also the production of textiles less disposed to quick changes in fashion has been a way to ensure the resource efficiency of the products produced by the company.

Improving the Calculation

The MIPS calculation presented here was calculated already in 2001. The MI factors used in the calculation have since been improved. Thus in this calculation only the solid natural resources – the sum of abiotic and biotic resources – are included in the calculation. Since some time the natural resources are divided into five different categories in the MIPS calculation: abiotic natural resources, biotic natural resources, water, air and what is termed "earth movement in agriculture and forestry". Five different MIPS values can thus be calculated for any product. [Ritthoff et al., 2002] Updated MI factors for all five natural resource categories can be found at the Wuppertal Institute's web page.

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References

Autio, S. and Lettenmeier, M. (2002). Ekotehokkuus – Business As Future. Yrityksen ekoteho-opas *(Eco-efficiency – business as future. A corporate guide to eco-efficiency)*. Dipoli reports C, environmental training. Espoo: Helsinki University of Technology Lifelong Learning Institute Dipoli. 80 p. (In Finnish)

Ritthoff, M., Rohn, H. and Liedtke, C. (2002). Calculating MIPS. Material productivity of products and services. *Wuppertal Spezial 27e.* Wuppertal: Wuppertal Institute for Climate, Environment and Energy at the Science Centre North Rhine-Westphalia. 52 p. *http://www.wupperinst.org/Publikationen/Wuppertal_Spezial/ws27e.pdf* (Also in German, Russian and Finnish.)

Schmidt-Bleek, F. (1994). *Wieviel Umwelt braucht der Mensch? MIPS, das Maß für ökologisches Wirtschaften*. Birkhäuser: Berlin, Basel, Boston. (English ed, Schmidt-Bleek, F. 1996. *The Fossil Makers – Factor 10 and more*. Birkhäuser, Berlin.) *http://www.factor10-institute.org/seitenges/Pdf-Files.htm*

Internet Resources

Wuppertal Institute
– Material Intensity factors of materials and energy sources

http://www.wupperinst.org/Projekte/mipsonline/download/MIT_v2.pdf