Eidgenössische Technische Hochschule Zürich
Swiss Federal Institute of Technology Zurich

ESD ecological systems design

LCA of Rivella and Michel soft drinks packaging

A Seed Sustainability project

Master Thesis Spring Semester

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16.07.2012

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ETH Zürich, July 16, 2012

Abstract

The Seed Sustainability platform, an initiative from ETH Sustainability, has set up a partnership between the soft drinks manufacturer Rivella AG and the Swiss Federal Institute of Technology Zürich. The Seed project is aimed at assessing the sustainability of Rivella AG's products. Rivella and Michel beverages have been assessed in the master thesis of (Eyman 2012) and in the bachelor thesis of (Knecht, Lanners et al. 2012), respectively. The focus of the present master thesis is on packaging. This thesis will perform a life cycle assessment (LCA) of refillable glass bottles and one-way PET bottles from their production to their disposal. Refillable glass bottles and one-way PET bottles are used in catering and retailing, respectively.

Rivella AG requested a comparison between Rivella 50 cl PET and Rivella 33 cl glass bottles, as well as a comparison between Michel 75 cl PET and Michel 100 cl glass bottles. Due to different packaging volume and the reuse of glass bottles, the functional unit is based upon delivering a certain amount of beverage to the final customer. The functional unit for the Rivella comparison is the delivery of 9.9 l of Rivella soft drink in 19.8 PET bottles or in one glass bottle refilled 30 times. The functional unit for the Michel comparison is defined as supplying 15 l of Michel juice in one glass bottle refilled 15 times or in 20 PET bottles.

Glass and PET bottles are produced with primary and secondary material, i.e. cullets or recycled PET-Flakes and are recycled at their end-of-life into secondary material. This study applies and discusses two modelling approaches dealing with the allocation of the secondary material, namely the recycled content and the avoided burden approaches. Both methods show that Rivella and Michel refillable glass bottles have lower environmental impacts with regard to the ecological scarcity 2006 and the IPCC 2007 100 years methods.

For glass bottles, the bottling process produces 50 % of the packaging's environmental impacts. Other important life cycle steps are the bottle's capping and the distribution to caterers, whose contributions are 20 % and 14 %, respectively. Because glass bottles are reused multiple times, the bottle's manufacture is credited with less than 12% of the product's impacts. For PET bottles, the manufacture of the PET bottle accounts for 60 % of the burden, while the second largest contribution is the bottling process with 20 %. Secondary and tertiary packaging amount to 5 % and the bottle incineration in MSWI accounts for 7 %.

From the results, it can be concluded that refillable glass bottles should not be replaced by one-way PET bottles in catering. Due to their weight, one-way glass bottles are also not an alternative to PET bottles in retailing. Within each packaging, the sensitivity analysis shows that optimisation of the packaging weight and the recycled content should be set as priorities for both packaging types. From a wider perspective, beverage dispensing machines should be considered as an alternative to glass bottles in the catering sector. Last but not least, the current trend to produce PET from renewable resources is not sustainable from an overarching LCA perspective.

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Abbreviations

CIP	clean-in-place
EP	eco-points indicators from the ecological scarcity 2006 method
EPD	environmental product declaration
ECCS	electrolytic chrome-coated steel
ETHZ	Swiss federal institute of technology Zürich
FOEN	federal office for the environment
FOS	Swiss federal office for statistics
GWP	global warming potential from the IPCC 2007 method
GTST	high temperature, short time pasteurisation
IGSU	interest group for a clean environment in Switzerland
IPCC	international panel on climate change
LCA	life cycle assessment
LCI	life cycle inventory
MEG	monoethylene glycol
MSWI	municipal solid waste incineration
OPS	oriented polystyrene
PET	polyethylene terephthalate
PLA	polylactic acid
PTA	purified terephthalic acid
PRS	PET-Recycling Switzerland
RC	recycled content approach

1 Introduction

Nowadays, companies are expected to include environmental and social improvement measures into their business models but they often lack the know-how. The Seed Sustainability platform, an initiative of ETH Sustainability, coordinates requests from industry with the expertise of ETHZ researchers and students. A Seed project has been set up in partnership with the soft drinks manufacturer Rivella AG. An assessment of its social, environmental and economic performance across its supply chain will enable identification areas with potential for improvement. Measures to reduce the carbon footprint will be defined, allowing the company to implement the recommendations.

Rivella AG is a soft drinks manufacturer located in Rothrist (CH). Its carbonated drinks are labelled under the name Rivella, and its juices carry the Michel label. These beverages are contained in refillable glass and one-way polyethylene terephthalate (PET) bottles. Refillable glass bottles and one-way PET bottles are used in catering and retailing, respectively.

Two theses focusing on the environmental impacts of producing Rivella and Michel beverages have been completed. Both investigations focus only on the beverage at the production site in its packaging, and do not measure the subsequent impacts of distribution, consumption and disposal. The bachelor thesis of (Knecht, Lanners et al. 2012) showed that 20 cl glass and 33 cl PET containers account for 28.6 % and 38.6 % of Michel juices' global warming potential. The master thesis of (Eyman 2012) revealed that a 50 cl PET bottle account for 55.2 % of the global warming potential of Rivella Blue and 21.5 % of the ecological scarcity impacts of Rivella Green. Packaging is a major factor in the environmental performance and has to be further investigated.

The present master thesis focuses on the whole life cycle of Rivella and Michel refillable glass and one-way PET bottles from the production of the packaging until its final, post-consumption disposal. This thesis does not include discussion of the beverage itself. The first goal is to compare environmental performance of refillable glass and one-way PET bottles. The second goal is to assess the impact share of each individual life cycle step, so as to identify areas with potential for improvement.

Section 2 starts with a short introduction of the life cycle assessment methodology and defines the goal and scope of the study. The system boundaries, the functional unit and the modelling approaches to deal with PET and glass bottles recycling will be explained. The inventory analysis is also presented in this section. Section 3 presents the impacts assessments results, which will be interpreted and discussed in section 4. Conclusions and recommendations are presented in the final section.

2 Methods

2.1 LCA methodology

The life cycle assessment (LCA) is a method to assess the environmental impacts of a product with a perspective encompassing its whole life cycle. The environmental impacts of a product are evaluated from cradle to grave, which means from the resource extraction up to the disposal of the product. The International Organization for Standardization (ISO) has standardised the general procedure of conducting an LCA in ISO 14040:2006 (ISO 2006a) and ISO 14044:2006 (ISO 2006b). A LCA consists of four phases as illustrated in Fig. 2.1.

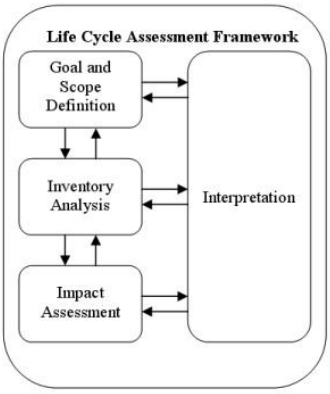

Fig. 2.1 : Phases of the life cycle assessment (ISO)

The *Goal and Scope Definition* (phase 1) introduces Rivella AG's requirements and covers the description of the object of investigation and its life cycle. The functional unit which determines the basis for the comparison is also defined here.

In the Inventory Analysis (phase 2), processes already inventoried in the ecoinvent database version 2.2 and new processes, which will be created based on data collection or literature research will allow the quantification of pollutant emissions and resource consumptions throughout the whole life cycle. The ecoinvent database is a product of the ecoinvent Centre, which is a Competence Centre of the Swiss Federal Institute of Technology Zürich and Lausanne, the Paul Scherrer Institute, the Swiss Federal Laboratories for Material Testing and Research and the Swiss Federal Research Station Agroscope Reckenholz-Tänikon.

In the *Impact Assessment* (phase 3), inventory results are converted into environmental impact indicators. The LCA software SimaPro version 7.3.3, which was developed by PRé Consultants and includes the ecoinvent database version 2.2, is used. The two impact assessment methods applied in this study are the ecological scarcity 2006 method updated by (Frischknecht, Steiner et al. 2009) and the IPPC 2007 method 100 years proposed by (Solomon, Qin et al. 2007). These methods have also been used by (Eyman 2012) and (Knecht, Lanners et al. 2012).
The IPCC 2007 method measures the global warming contribution of different gases and compares it with the reference gas carbon dioxide. The global warming potential (GWP) is expressed in kg CO2-equivalent (kg CO2-eq) with different life spans of 20, 50 and 100 years.
In the ecological scarcity method pollutant emissions and resource use are first characterised in a similar way as the global warming potential method, however, the reference is not only carbon dioxide but a reference substance within an impact category, i.e. emission into air, emission into surface water, emission into ground water, emission into top soil, energy resources, natural resources and deposited waste. The results are then normalised to the Swiss context by assessing the contribution of the specific substance to the Swiss overall environmental impacts. Finally, results are weighted with eco-factors that are based upon the comparison between the current situation and the critical situation defined in Swiss environmental laws or targeted by Swiss authorities. All impact categories

are expressed in terms of eco-points (EP). A total value is computed by simply adding the EP of each impact category.

The results of the inventory analysis and the impact assessment are analysed and commented in the *Interpretation* (phase 4) according to the initially defined goal and scope of the LCA. Final conclusions are drawn and recommendations stated.

2.2 Goal and scope definition

2.2.1 Outline of the study

As illustrated in Fig. 2.2, Michel juices are available in 20 cl and 100 cl glass, and 33 cl, 50 cl and 75 cl transparent PET bottles. Rivella is offered in 33 cl glass, and 33 cl, 50 cl, 100 and 150 cl brown PET bottles.

Fig. 2.2 : Rivella (left) and Michel (right) variety of packaging (source: www.rivella.com)

Rivella AG requested a comparison of Rivella 50 cl PET and Rivella 33 cl glass bottles, as well as a comparison of Michel 75 cl PET and Michel 100 cl glass bottles. The goal is to compare the environmental impacts of the glass and PET bottles by conducting an LCA on Rivella and Michel packaging. This will not include production of the beverage itself. The second aim is to decide whether or not glass bottles used in catering should be replaced by PET bottles. The influence of sensitive parameters such as transport distance, recycled content of PET bottles and recirculation rate of glass bottle will be discussed. The following questions will be answered:

- Which packaging has a higher environmental impact?
- Which life cycle steps contribute the most to the environmental impacts?
- What are the potential improvements?

2.2.2 Life cycles of glass and PET packaging

Glass packaging life cycle

Rivella and Michel's life cycle are illustrated in Fig. 2.3. Rivella 33 cl and Michel 100 cl refillable glass bottles are produced by Vetropack AG in Pöchlarn (AU). They are made of 76 % and 48 % post-consumer cullets, respectively. They are transported by truck to Rothrist (CH) where they are washed, filled, capped, labelled and stored in plastic crates. When the lorry delivers them to caterers, it takes back the empty glass bottles and brings them back to Rothrist for washing and refilling. 100 % of the bottles are returned to Rivella AG. Rivella bottles are recirculated 30 times whereas the Michel bottles are refilled 15 times. At their end of life they are transported back to Pöchlarn to be crushed down to cullets and melted with primary glass to produce new packaging glass.

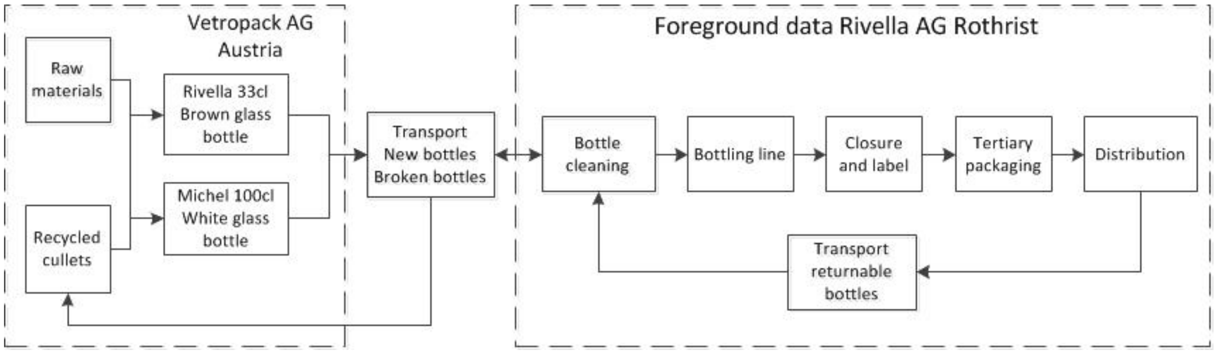

Fig. 2.3 : System boundaries of Rivella and Michel glass bottles

PET packaging life cycle

In order to describe the life cycles of brown and white PET bottles two consumption groups have been defined using the definition described by (Detzel, Giegrich et al. 2004):

1) Bottles for "home consumption" having a volume of > 0.5 l
2) Bottles for "away from home consumption" having a volume of ≤ 0.5 l

These two groups imply several consequences. A bottle consumed at home will not be disposed of in the same way as a bottle consumed on the way.

Rivella 50 cl brown PET bottle

The life cycle of Rivella 50 cl is depicted in Fig. 2.4. Rivella 50 cl brown PET bottles are made of 30 % recycled PET-Flakes food grade from post-consumer PET bottles. These PET-Flakes are produced in Switzerland by RecyPET AG (CH) and transported by lorry to Alpla AG in Fussach (AU) who mixes them with 70 % virgin PET to produce preforms. Preforms are transformed into bottles at Rothrist. After the rinsing process, bottles are filled, capped and labelled. They are distributed to distribution centres who then deliver them to the final retail store.

The Rivella 50 cl belongs to the "away from home consumption" group. This implies that not all the bottles will be properly collected because people throw them in the first garbage they see instead of keeping them until the next PET collection point. A recycling rate of 80 % was achieved in 2010 for PET bottles in Switzerland (FOEN 2010). Therefore, a basis scenario will assume that 20 % of the post-consumer PET bottles are incinerated rather than recycled[1].

It is assumed that the totality of the 80 % collected PET bottles is reprocessed in Switzerland. In reality, 5 % of the sorted amount is exported for reprocessing to Italy or Germany (PRS 2011). PET bottles are first sorted by colours at a sorting facility. At the recycling facility, they are converted into PET-Flakes food grade and PET-Flakes non-food grade. Recycled PET-Flakes non-food grade replace virgin PET in the production of fabric, film and strapping while PET-Flakes food grade are used to make new bottles. In the present LCA no distinction is made between PET-Flakes food grade and PET-Flakes non-food grade. The recycling process is the same for both outputs.

[1] In reality, this amount is around 15-17 % because a share of the non-collected bottles are either exported or littered or kept for other uses. PET represents only 5 % of the total littering amount. PRS. (2012). "Littering Pet Recycling." Retrieved 30.06.2012, from http://www.petrecycling.ch/fr/littering.html-0. Thus, to keep it simple, these paths have not been considered.

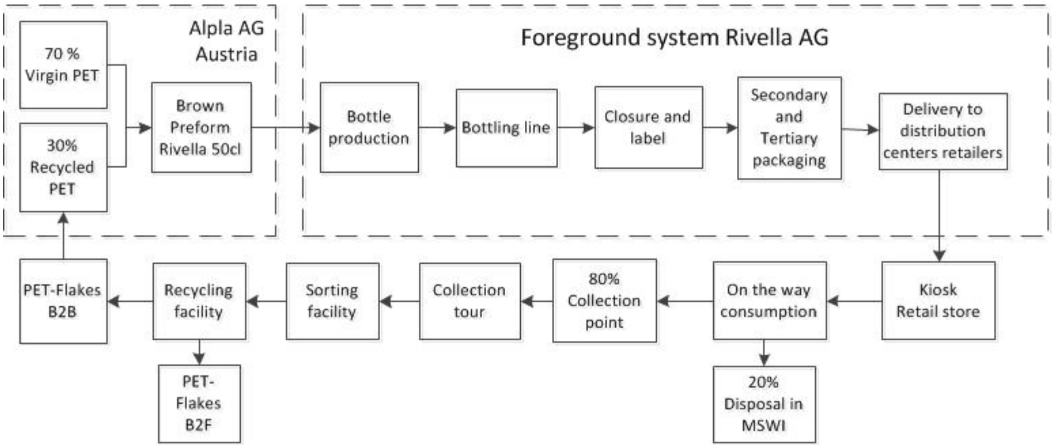

Fig. 2.4 : System boundaries of Rivella 50 cl PET bottle

Michel 75 cl transparent PET bottle

Michel 75 cl life cycle is shown in Fig. 2.5. Michel 75 cl transparent PET bottles are produced with 100 % virgin PET because it is challenging to store non-carbonated drinks up to a period of 6 months without any alteration of the vitamin content and the colour[2]. Therefore, no recycled content is added to avoid any risks. It is a three-layer bottle with an inner nylon layer, which acts as an oxygen barrier. The bottling line proceeds in the same as the one for Rivella 50 cl. Due to their size, 75 cl PET bottles belong to the consumption group "home consumption" defined above. Retailers selling beverages in PET bottles are required to take back all bottles made of this material. Consequently, shoppers can return their PET bottles to the retail stores while going shopping. Moreover, the introduction of a refuse bag charge in the 90's has prompted households to reduce their waste volume. These factors allow us to assume that nearly 100 % of the PET bottles consumed at home will be sorted from household waste and returned to the retail store. The sorting and recycling processes are similar to the Rivella 50 cl. The only difference is that the recycled PET-Flakes are recycled in another PET bottle.

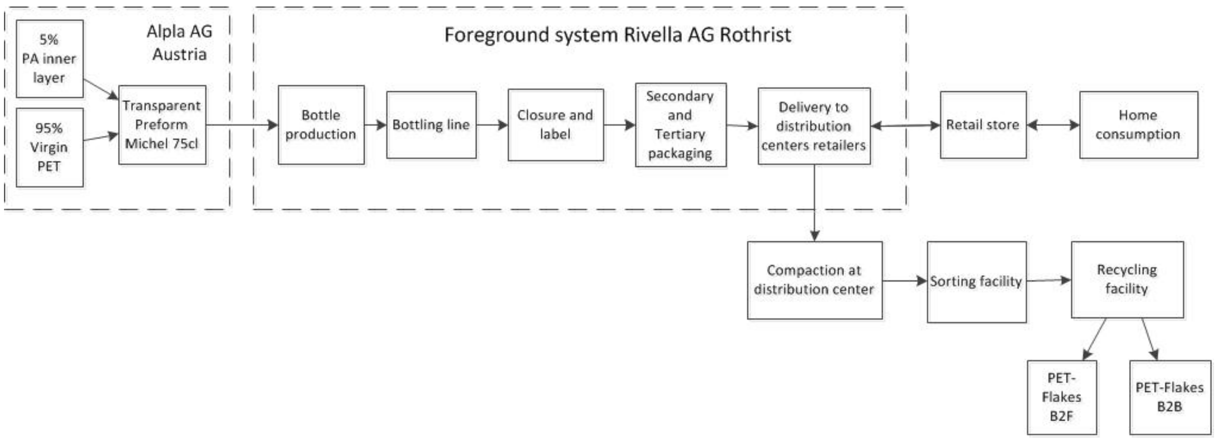

Fig. 2.5 : System boundaries of Michel 75 cl PET bottle

[2] Email communication with Stefan Höltschi from Rivella AG

2.2.3 Modelling approaches on recycling of materials

Given the system boundaries described in the previous section, a decision must be made on how to model the environmental impacts of the recycled material contained in the primary bottle and the environmental burden of the recycled material, which is produced from this primary bottle. The environmental impacts can either be given to the primary or the secondary product, i.e. the first bottle or the second bottle or the textile made of recycled PET-Flakes.

(Frischknecht 2010) describes two life cycle inventory (LCI) modelling approaches applied on recycling of materials. The first method is the end of life or avoided burden approach. The primary product does not bear the environmental impacts corresponding to the amount of primary material that will be recycled at the end of its life. The primary product only bears the impact of the recycling process, which takes place at the end of its life, as depicted on the right side of Fig. 2.6.
The second method is the recycled content approach and is illustrated on the left side of Fig. 2.6. The recycled content in the primary product is considered. Consequently, the last life cycle step is the disposal of the primary product at the recycling collection point. The burden of the recycling process is given to the secondary product.

2.2.4 Functional unit and reference year

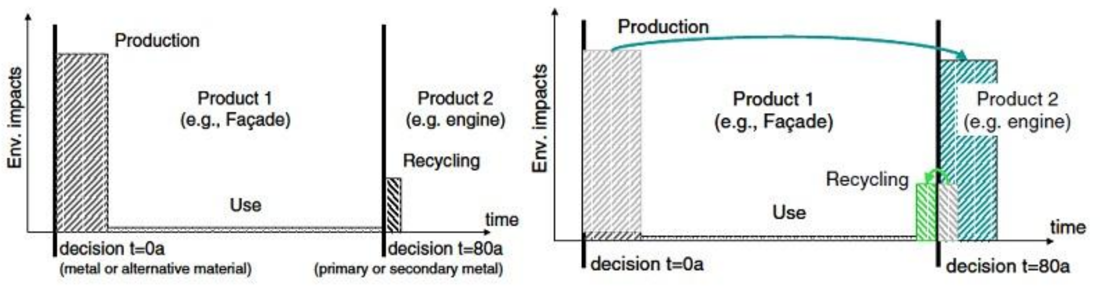

Fig. 2.6 : Recycled content approach (left) and avoided burden approach (right) showing the allocation of the primary material taken from (Frischknecht 2010)

Due to different packaging volumes, the functional unit is defined as the volume of beverage delivered by one refillable glass bottle and the corresponding amount of PET bottles necessary to supply the same volume. A Rivella 33 cl glass bottle is refilled 30 times. Consequently, at the end of its life, one glass bottle will have contained in total 9.9 l of carbonated soft drinks. A Michel 100 cl glass bottle is reused 15 times. Therefore, one Michel glass bottle offers 15 l of juices over its whole life. The functional units are the following:

- Delivering 9.9 l of Rivella drink in one refillable 33 cl glass bottle refilled 30 times or in 19.8 PET bottles of 50 cl
- Delivering 15 l of Michel juices in one refillable 100 cl glass bottle refilled 15 times or in 20 PET bottles of 75 cl

The chosen reference year is 2011 because the company Helbling Beratung + Bauplanung AG collected data about the production volume, the operation time as well as the energy and water consumptions of all processes between December 2010 and November 2011 at the production factory in Rothrist (Helbling 2012).

2.3 Life Cycle Inventory

In the following section, each life cycle step is described and inventoried. When necessary, assumptions are made. Data for the inventory either come from the ecoinvent database or from literature. Rivella AG provided most of the data for the packaging's characteristics and bottles' distribution to retailers and caterers. Data for the sorting and recycling processes of PET bottles were collected from literature.

2.3.1 Transport

An assumption has to be made on the transport of the different materials to or from Rothrist. Based on statistics on transport of goods from the Swiss Federal Office of Statistics (FOS), 64 % of the inland traffic is done by lorry while 78 % of the import and export goods are transported in a semi-trailer truck (FOS 2012). The average gross vehicle weight for lorries varies from 3.5 to 20 t while it is between 20 t and 28 t for semi-trailer trucks (Tuchschmid and Halder 2010). Table 2.1 summarizes the ecoinvent transport dataset that will be used for the goods.

Table 2.1 : Ecoinvent dataset selected for the transport of goods to and from Rothrist (Tuchschmid and Halder 2010)

Origin of goods	ecoinvent unit process	Average load [tons][1)]
Inland goods	Transport, lorry 3.5-20t, fleet average/CH	2.90
Exported goods	Transport, lorry 20-28t, fleet average/CH	5.80
Imported goods	Transport, lorry, >16t, fleet average/RER	9.51

[1)] From ecoinvent report No.14 Tab 5-117 and Tab 5-118 (Spielman, Bauer et al. 2007)

2.3.2 Bottle manufacturing

Glass bottles

Michel 100 cl and Rivella 33 cl are manufactured by Vetropack Austria GmbH at Pöchlarn (AU). Packaging glass belongs to the soda-lime glass group. It is produced from primary minerals such as sand, soda, feldspar, limestone, dolomite and post-consumer cullets, which come from glass bottles that have been collected The ecoinvent database makes a difference between the production of brown, white and green glass in Switzerland, Germany and Europe (Hishier 2007). These processes include glass cullets from public collection. Table 2.2 shows that the shares of white and brown cullets given by Vetropack are 10 point lower and 10 point higher than the shares of German cullets, respectively. Glass is transported in a truck >32 t to Rothrist (CH), using information given by Vetropack on its logistics.

Table 2.2 : Shares of post-consumer cullets in the production of white and brown German packaging glass and comparison with Vetropack AG's shares (Hishier 2007)

	Vetropack [%]	German [%]
White glass	48	58
Brown glass	76	65

PET bottles

PET is a thermoplastic polymer produced from the reaction of teraphthalic acid (PTA) and ethylene glycol (EG), which are produced from crude oil and natural gas.

Michel and Rivella preforms are manufactured by Alpla AG located in Fussach (AU). Rivella 50 cl is made of 70 % virgin PET and 30 % recycled PET-Flakes. The recycled PET-Flakes are produced by RecyPET AG in Frauenfeld (CH) and transported by truck to Fussach. More details about the PET-Flakes recycling process can be found in section 2.3.8. In reality, PET-Flakes are mixed with virgin PET and are directly converted into preforms during the injection moulding process. The ecoinvent dataset on virgin PET is available as “PET, granulate, bottle grade”. Even though Alpla AG produces preforms directly from flakes, the recycled PET-Flakes are converted into granulate to be consistent with the virgin PET material in the ecoinvent database. An electricity and heat consumption of 447 kWh and 252 MJ per t granulate are used for an input of 1031 t PET-Flakes (Shen, Nieuwlaar et al. 2011). A ecoinvent dataset for the injection moulding process is already available in the database (Hishier 2007).

Michel 75 cl contains 95 % virgin PET and 5 % of nylon, which is used as an inner layer and an oxygen barrier. (Klöpffer and Grahl 2009) state that nylon 66 is used and added during the injection moulding process of the preform. Thus, the ecoinvent processes “Nylon 66, at plant” and “virgin PET” are the input for the injection moulding process.

Preforms are delivered in a lorry > 16 t, using the transport assumption defined in section 2.3.1. The conversion of the preforms into bottles takes place at Rothrist. The stretch blow moulding process is available in the ecoinvent database. Electricity consumption are 0.017 kWh per 50 cl preform and 0.026 kWh per 75 cl preforms (Helbling 2012).

2.3.3 Bottling at Rothrist

There are four bottling lines at Rothrist. Line 1 and 5 are dedicated to PET bottles whereas line 2 and 4 are dedicated to glass bottles. Each bottling line includes rinsing, filling, capping, labelling and finally palletising of bottles (see Appendix A.6 for the process flow diagram). (Helbling 2012) has collected detailed hot water and fresh water consumptions for each process (see Appendix A.1.3).

Table 2.3 summarizes the aggregated energy consumptions of Rivella and Michel bottles analysed in this study. Rivella 33 cl glass bottle is produced on line 2, while Michel 100 cl glass bottle is processed on line 4. The first cycle of the glass bottle is differentiated from the other ones. For cycle 1, the energy consumption of the washing machines in line 2 and 4 are removed while the rinsing process in line 4, which is used to rinse new bottles, is kept. In 2011 no new Rivella 33 cl were bought so no rinsing process is included for line 2. However, no adjustment can be made to the electricity consumption of line 2 and 4 because the electricity consumption is not given per process and only per line. The osmosis water is used for the rinsing of caps and bottles in line 1 and 5. Michel 75 cl has a larger consumption of hot water due to the higher share of the Clean-In-Place (CIP) process. Most important is the hot water consumption for Michel 100 cl, caused by the washing of the bottles and the CIP process.

Table 2.3 : Hot water, electricity, steam and water consumption of Rivella and Michel PET and glass bottles (Helbling 2012)

	Hot water [kWh/unit]	Electricity [kWh/unit]	Steam [kWh/unit]	Water [m3/unit]	Osmosis water [m3/unit]
Rivella 33 cl Glass Cycle 1	0.009	0.026		0.0006	0.00003
Rivella 33 cl Glass Cycle 2-20	0.039	0.026		0.0013	0.00003
Rivella 50 cl PET	0.025	0.048	0.012	0.0007	0.00030
Michel 75 cl PET	0.062	0.042	0.016	0.0017	0.00020
Michel 100 cl Glass Cycle 1	0.052	0.091	0.008	0.0026	0.00009
Michel 100 cl Glass Cycle 2-20	0.142	0.091	0.008	0.0037	0.00009

The used water is sent to the wastewater treatment plant located in Aarburg (CH), whose average capacity is 45’000 population equivalent (Aarburg 2011). One population equivalent refers to a load of 60 grams of biological oxygen demand in raw sewage per day, which is the typical BOD load generated by one person (Doka 2009). In the ecoinvent database, a wastewater treatment plant of class 3 has an average between 10’000 and 50’000 population equivalent. Thus, this process is chosen to model the wastewater treatment.

2.3.4 Closure and label

The characteristics of closures and labels were identified with the collaboration of Rivella and suppliers listed in Table 2.4. The Rivella 33 cl glass bottle is closed with a crown cork made of primary electrolytic chrome-coated steel (ECCS) with a thickness of 0.235 mm and a polyethylene joint. A new ecoinvent dataset was created with the description of the production process given by (Habersatter and Fecker 1998) (see Appendix A.2).

Michel 100 cl glass bottles are closed with a Vacuvent cap made of aluminium-alloy following the norm DIN EN 541. Primary aluminium accounts from 96.25 % to 99.5 % of the total weight while the rest is a share of other metals. The dataset created for the crown cork was used but the input was changed to primary aluminium. Moreover, an adjustment was made to the output weight because Vacuvent caps and crown corks do not weight the same, as depicted in Table 2.5.

Rivella 50 cl and Michel 75 cl PET bottles are closed with caps made of virgin HDPE, which are made with an injection moulding process.

A label made of woodfree paper and printed on one side is used for Rivella 33 cl, Rivella 50 cl and Michel 100 cl. In order to include a printing process, the ecoinvent dataset “Production of carton board boxes, offset printing, at plant/CH U” was adapted (Hishier 2007).

The Michel 75 cl bottle has a plastic sleeve made of oriented polystyrene (OPS). OPS is produced from Styrene-Butadiene-Styrene granulate. Butadiene is included in the ecoinvent process “polystyrene, high impact, HIPS” (Hishier 2007). Thus, the ecoinvent process “packaging film, LDPE, at plant/RER” is adapted to the input “polystyrene, high impact, HIPS”. The sleeve is printed with an UV-offset printer. In order to include the printing process, the ecoinvent process “production of carton board boxes, offset printing, at plant/CH” was adapted in a similar way as for the paper label.

Labels of glass bottles will be removed when bottles are washed before refilling at Rothrist and sent to the Municipal Solid Waste Incinerator (MSWI). The crown corks are recovered at the MSWI with the magnetic iron scrap separator. Vacuvent aluminium caps will be incinerated. Labels and caps of PET bottles will be recovered at the sorting plant and recycled (PRS 2011).

2.3.5 Secondary and tertiary packaging

The characteristics of secondary and tertiary packaging were defined with the collaboration of Rivella AG and suppliers listed in Table 2.4.

The plastic foil for the tray and the one for the pallet are made of LDPE and LLDE respectively. The ecoinvent process “Packaging film, LDPE, at plant/RER” has been used for the LDPE foil and adjusted for the LLDPE foil (Hishier 2007).

The tray is made of recycled, single wall cardboard and is flexodruck printed. The input of the ecoinvent process “Packaging, corrugated board, mixed fibre” was changed to cardboard with recycling fibres. However, the offset printing included in this process was not changed to a flexodruck process (Hishier 2007). The intermediate layer is made of recycled paper. The paper label for the pallet has been neglected because its weight per bottle is negligible. Plastic foils will be disposed of during the distribution process. It is assumed that they are sent to the MSWI while the tray and the intermediate layer are recycled. Glass bottles are packaged in plastic crates. The plastic crates are not considered in the inventory because they are 100 % reused and there was no new purchase in the last ten years. The pallets are also 100 % reused and were not considered in the inventory.

Table 2.4 summarizes the origin of labels, caps, secondary and tertiary packaging as well as the distance estimated with (ViaMichelin 2007). The assumptions made for the transport in section 2.3.1 were used. Information given by the crown corks’ manufacturer was used to choose a more accurate transport type.

Table 2.4 : Origin, distance estimated and type of truck for the delivery of label, cap, secondary and tertiary packaging of Rivella and Michel glass and PET bottles to Rothrist

Material	**Company**	**Origin**	**Distance** [km]	**Truck**
Crown corks	Pelliconi	Atessa, IT	940	16-32 t
Vacuvent cap	Metallwaren-Fabrik	Hückeswagen, DE	513	3.5-16 t
Rivella PET cap	Alpla AG	Fussach, AU	173	>16 t
Michel PET cap	Bericap	Budenheim, DE	378	>16 t
Paper label	Goelz	Mengen, DE	189[1)]	3.5-20 t
Paper label	läser AG	Gontenschwil, CH	33[1)]	
Sleeves	NYCO	Kirchberg, CH	46	3.5-20 t
Tray	SCA Packaging	Oftring, CH	4	3.5-20 t
Plastic foil for tray	Permapack AG	Apeldoorn, Nl	718	3.5-20 t
Plastic foil for pallet	Orgapack AG	Chamboeuf, FR	300	3.5-20 t
Intermediate layer for pallet	Schelling	Rupperswil, CH	26	3.5-20 t

[1)]An allocation is applied to the amount delivered by both companies

Table 2.5 gives an overview of the weights of bottles, caps, labels as well as secondary and tertiary packaging per bottle. It can be seen that the Michel 75 cl PET bottle is heavier than the Rivella 50 cl PET bottle because of its multi-layered design and its larger size. In addition, its cap is heavier because the bottle's neck is wider.

Table 2.5 : Weight of primary and secondary packaging per Michel and Rivella PET and glass bottles

	Primary packaging			**Secondary packaging**		**Tertiary packaging**			**Total**
all [g]	**Bottle**	**Cap**	**label**	**Cardboard or Crate**	**Plastic foil**	**Plastic foil**	**Intermediate layer**	**Pallet**	
Rivella 50 cl PET 24 X 50 cl	19.4	2.85	0.9	3.542	1.313	0.162	0.231	17.7	46.1
Rivella 33 cl Glass 24 X 33 cl	278	2.15	0.6	64.6	none	0.1	none	20.0	365.5
Michel 75 cl PET 6 X 75 cl	34	3.7	1.65	none	2.08	0.231	3.189	25.6	70.5
Michel100cl Glass 12 X 100 cl	625	1.55	1.6	154	none	0.260	none	59.9	842.3

2.3.6 Distribution and selling

PET bottles

PET bottles are first transported to retailers' regional distribution centres. Migros and Coop retailers account for 56 % of the total weight retrieved at Rivella AG. The share is increased to 83 % with other retailers, namely Denner, Landi, Spar and Valora. Bevero AG takes care of the delivery of PET bottles to Coop, Denner and other small distributors. Migros, Landi and Spar come directly to Rothrist. A weighted distance is computed with the fraction of weight transported to one retailer over the total weight transported to all retailers. The weighted distance covered by Bevero AG is 35 km, while the other retailers travel a distance of 24 km. Bevero AG uses 40 t trucks that are assumed to be fully loaded (Waeber 2012). The ecoinvent process "transport, lorry >28 t, fleet average/CH" was adjusted to a full load. The pick-up done by the other retailers is modelled with the same transport but with an average load because the loaded weight varies greatly. (Habersatter and Fecker 1998) mention an average distance between the distribution centre and the retail store between 25 km and 50 km. Consequently, an average distance of 37.5 km is used.

Glass bottles

The majority of glass bottles are transported to beer distributors such as Heineken AG and Feldschlösschen AG who complete the final delivery to caterers. Most of the time, the truck does not deliver to one customer, but to several. It is assumed that the truck leaves Rothrist with a full load of bottles. At the first client, the amount ordered is delivered while an average amount of empty bottles estimated for each customer is loaded (Waeber 2012). After the last delivery, all empty bottles are brought back to Rothrist. Therefore, a weighted distance is computed in a similar way as for PET bottles using the total transported weight, including full and empty bottles. The weighted distance is 101 km and a “lorry > 28 t, fleet average CH” is used to be consistent with the PET distribution.

The refrigeration of bottles at retail stores or restaurants is not considered for the purpose of this thesis. It can be assumed that the electricity consumption for storing beverages would be the same at both locations and does not differentiate between glass and PET systems. Moreover, the trips made by consumers to the retail store or to the restaurant were not considered in the present analysis.

2.3.7 Collection and sorting

PET bottle

As stated in section 2.2.2, a distinction was made between “home consumption” and “away from home consumption”. The consumption determines the collection and the disposal routes. Michel 75 cl belongs to the “home consumption” group and will be disposed of in a PET container available at retail stores. It is assumed that people do not rinse PET bottles at home before disposing of them. Rivella 50 cl is consumed on the go and will be either disposed of in a PET container or in garbage. Empty PET bottles could be brought back to retail stores by car but this form of transport was not considered.

(PRS 2011) explains that 35 % of post-consumer PET bottles are collected during collection rounds over the 30’000 collection points and 55 % are collected through retailers and distribution centres. The rest is done by non-PRS members. Indeed, Denner, Lidl, ALDI and Otto’s AG collect the PET bottles themselves. Due to the lack of solid data on collection rounds, it is assumed that Rivella 50 cl is also collected at retail stores. The collected PET bottles are sent to retailers’ distribution centres. The distance of 37.5 km between the retail store and the distribution centre estimated in section 2.3.6 was used. At the distribution centre, PET bottles are compacted into bales[3] and transported to a sorting plant to be separated by colours. There are five sorting facilities in Switzerland:

- TRANS CYCLE Transport & Recycling AG, Neuenhof, AG
- ZISWILER AG, Ostermundigen, BE
- Müller Recycling AG, Frauenfeld, TG
- Plastic-Ti Recycling SA, Giubiasco, TI
- Constantin Recycling AG, Roche, VD

Müller Recycling AG processes 50 % of the post-consumer PET bottles, from which 70 % are delivered by truck, while the rest is delivered by train[4]. An average distance of 80 km between the main distribution centres and Müller Recycling AG is computed, using distribution data from Rivella.

(Klöpffer and Grahl 2009) describe a sorting facility with the following outputs: 58 % PET bottles, 27 % mixed plastics and 15 % sorted rest. However, the authors consider that only transparent bottles are recycled to new bottles. Thus, the mixed plastics fraction is composed of some transparent bottles and a majority of non-transparent bottles. On the Swiss market, ITW Poly Recycling GmbH recycles all coloured and non-coloured bottles[5], while RecyPET AG recycles mainly transparent and a

[3] Oral communication with Jean-François Marty, PRS

[4] Email communication with Thomas Müller, Müller Recycling AG

[5] Email communication with Casper von der Dungen, ITW Poly Recycling GmbH

small fraction of light-blue bottles[6]. ITW Poly Recycling GmbH produces more PET granulate food-grade than RecyPET[3]. Consequently, it is assumed that in Switzerland all coloured PET bottles are sent to the recycling facility. Therefore, the fraction of PET bottles that are recycled is the sum of the 58 % PET bottles and 27 % mixed plastics, giving a sorting efficiency of 85 %. (PRS 2011) explain that the rejects from the sorting process are composed of caps, labels and bottle elements that are from now on recycled instead of being disposed. For Rivella 50 cl and Michel 75 cl, the sum of the cap's weight and the label's weight account for 15 % and 14 % of the sum of the bottle's weight, cap's weight and label's weight. Therefore, all caps and labels are assumed to be removed at the sorting facility. PET bottles are further processed through a post-sorting treatment with 3 % rejects. Consequently, the overall sorting efficiency is 82 % when the post-sorting treatment is included. The authors do not mention the electricity consumption of the sorting plant.

(Chilton, Burnley et al. 2010) mention an electricity consumption between 22 kWh and 27 kWh and 0.87 l of diesel per t input for an English sorting plant. (Intini and Kühtz 2011) give an electricity consumption of 43 kWh and 3.5 l of diesel per t input plastic for an Italian sorting plant. Therefore, an average electricity consumption of 30 kWh per t input is used. (Hishier 2007) inventoried a diesel consumption of 0.59 l for the glass sorting process and this amount is also taken for the PET sorting process.

The 20 % PET bottles which are disposed of in garbage are collected by the municipality. (Doka 2009) indicates an average transportation distance of 10 km to the MSWI.

Glass Bottle

Glass bottles are consumed at restaurants. It is assumed that empty glass bottles are stored in plastic crates without any pre-washing. Emptied glass bottles are collected when filled glass bottles are delivered. Therefore, the distance is already included in the distribution distance explained in section 2.3.6. It is assumed that all glass bottles will be broken at Rothrist due to the intensive handling during delivery, washing and refilling. Broken glass is transported back to Pöchlarn (AU). (Hishier 2007) inventoried the sorting of glass cullets. He mentions a sorting efficiency of 93 %. The transport process in the dataset was removed and replaced by the distance from Rothrist to Pöchlarn. In order to be consistent with the sorting process of PET bottles, the ecoinvent input "glass sorting site" is removed.

2.3.8 Recycling of PET bottles

RecyPET AG in Frauenfeld and ITW Poly Recycling GmbH in Weinfelden are the two recycling plants in Switzerland. RecyPET AG applies the URRC process and produces PET-Flakes since 2009 whereas ITW Poly Recycling GmbH use the Vacurema process since 2003 (PRS 2011). There are many different recycling processes, either mechanical or chemical, depending on the final application of PET-Flakes. (Habersatter and Fecker 1998) inventoried a recycling process. The inputs of the process are compacted PET bottles which are crushed and pre-washed to remove labels. They are then sorted manually, grinded into flakes and washed. By using a flotation separation process, PE caps are removed. Finally, they are dried. The final use of the output PET-Flakes is not mentioned (see Appendix A.3 for the recycling process inputs). Caps and labels have been removed, using the assumption explained in section 2.3.7. The belt for the compacted bottles mentioned in the inventory was also neglected. Thus, the efficiency of the process is increased from 86 % to 95 %. In Table 2.6 the recycling process is compared with literature data.

[6] Email communication with Kornel Büsser, RecyPET AG

Table 2.6 : Comparison of literature values for the energy consumption of post-consumer PET bottles recycling

Source	Scope	Data collection Year	Efficiency [Output/input]	Electricity [kWh/kg PET-Flakes output]	Natural gas
(Habersatter and Fecker 1998)	Swiss	1996	95 %	0.168	0.212*
(Arena, Mastellone et al. 2003)	Italy	1999-2000	76 %	0.278	0.695
(Intini and Kühtz 2011)	Italy	2009	78 %	0.356	0.576
(Chilton, Burnley et al. 2010)	UK	2008-2009	n.a.	0.675	0.298

*Natural gas is given in m3 and a heating value of 39 MJ/m3 is used.

From Table 2.6 it can be seen that (Arena, Mastellone et al. 2003) describe a recycling process which is less efficient and more energy consuming. (Intini and Kühtz 2011) made an LCA case study of a thermal insulation panel made of polyester fibre. Their values were also higher than the Swiss recycling process. Consequently, it was decided to increase the electricity consumption to 0.26 kWh/kg Flakes[7].

[7] Email communication with Casper van den Dungen, ITW Poly Recycling GmbH 04.06.2012

3 Results

In a first step, the environmental impacts of Rivella and Michel comparisons are shown with regard to the ecological scarcity 2006 and the IPCC 2007 methods. Then, the avoided burden results are compared with the recycled content results. Finally, sensitivity analyses regarding the recycling content, the weight, the collection rate, the number of reuse cycles and the travelled distance during the distribution of glass bottles are presented. The results are referred to as environmental impacts or environmental burden. They are interpreted in this section and will be discussed in section 4.

3.1 Vetropack packaging glass

The life cycle inventory described in the previous section defines the basis scenario. The recycled content approach defined in section 2.2.3 is applied to the basis scenario. Therefore, the secondary material is included in the manufacture of the packaging. Post-consumer cullets account for 76 % and 48 % of Rivella brown and Michel white glass bottles. As it was mentioned in section 2.3.2, ecoinvent dataset on the production of packaging glass have different shares of cullets than Rivella and Michel glass bottles. (Doka 2006) developed a method to adjust the environmental impacts of the production of packaging glass when the share of cullets is different than the one defined in ecoinvent. The amounts of primary minerals in white, green and brown German glass are plotted against the corresponding eco-points to find a linear equation. The quantity of primary minerals that were computed for the shares of 76 % and 48 % cullets are entered as input in the equation to find the corresponding amount of eco-points. The same procedure is applied with the GWP values to find the GWP of Michel and Rivella glass bottles (see Appendix A.4 for plot and equation). Table 3.1 shows the eco-points and GWP computed for Rivella and Michel glass bottles.

Table 3.1 : Adjustment of the eco-points and GWP of Rivella and Michel packaging glass using the method developed by (Doka 2006)

Packaging glass	Vetropack [%]	German [%]	German [EP]	Vetropack [EP]	German GWP [kg CO2-eq]	Vetropack GWP [kg CO2-eq]
Michel White glass	48	58	514	534	0.617	0.650
Rivella Brown glass	76	65	506	484	0.599	0.564

3.2 Rivella

3.2.1 Ecological scarcity method

Table 3.2 shows the results for the main life cycle steps of Rivella 33 cl glass bottle and 50 cl PET bottle with regard to the ecological scarcity 2006 method. The results are illustrated in Fig. 3.1. The key message from this table is that the glass bottle has around 2000 EP whereas the PET bottle has 2700 EP. The glass bottle is produced at the beginning of cycle 1 and is used for the following 29 cycles, thus only 8 % of the impacts are due to the bottle production. On the other hand, a new PET preform must be produced at the beginning of each cycle and makes 47 % of the overall impacts. The secondly most important process is the bottling, which accounts for 42 % and 25 % of the impacts of the glass and the PET bottle. For Rivella 33 cl, other important life cycle steps are the cap and the distribution to caterers. The crown cork has a high impact due to the use of chromium steel. It accounts for 33 % of the overall impacts. The distribution of glass bottles has a higher share than the one of PET bottle due to the heavier weight and the longer distance travelled.

Table 3.2 : Comparison between delivering 9.9 l of Rivella in a 50 cl PET bottle or in a 33 cl glass bottle with regard to the ecological scarcity 2006 method. All results are expressed in eco-points (EP) and scaled to 100 %

Life cycle steps	Rivella 33 cl				Rivella 50 cl		
	Cycle 1 [EP/33 cl]	Cycle 2-30 [EP/33 cl]	30 cycles [EP/9.9 l]		Cycle 1-19.8 [EP/0.5 l]	19.8 cycles [EP/9.9 l]	
PET Preform/ Glass bottle	135		135	6.8 %	63	1253	47 %
PET Bottle/Transport Glass Bottle	20		20	1.0 %	10	198	7.4 %
Cap	22	22	647	33 %	7.6	150	5.6 %
label	1.7	1.7	52	2.6 %	2.6	51	1.9 %
Secondary and tertiary packaging	0.16	0.16	4.9	0.25 %	7.8	154	5.8 %
Bottling	17	28	832	42 %	34	674	25 %
Distribution	9.6	9.6	289	15 %	0.48	9.6	0.36 %
Disposal packaging*	0.15	0.15	4.5	0.23 %	2.8	56	2.1 %
MSWI					6.9	137	5.1 %
Total	**205**	**61**	**1985**	**100 %**	**135**	**2682**	**100 %**

* refers to the incineration of the plastic foil for the tray and the pallet

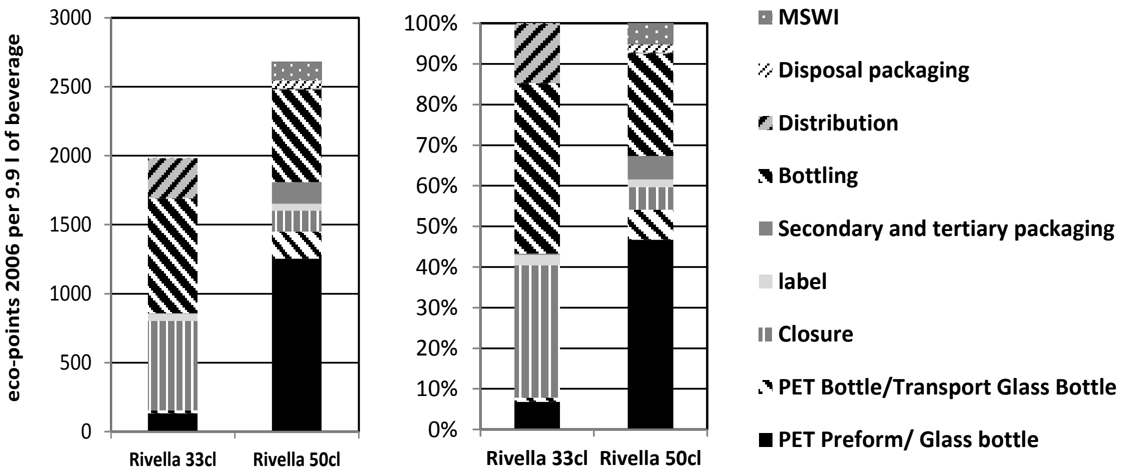

Fig. 3.1 : Comparison of the environmental impacts (left) and shares of the individual life cycle steps (right) between delivering 9.9 l of Rivella in a 50 cl PET bottle or in a 33 cl glass bottle with regard to the ecological scarcity 2006 method

3.2.2 Global warming potential

Table 3.3 shows the results with regard to the IPCC 2007 100 y method. The results are in line with the ecological scarcity method. In total, the glass bottle has an overall performance of 1540 g CO2-eq whereas the PET bottle has around 2500 g CO2-eq. The difference between the glass and the PET bottle is increased to 68 % whereas it is 35 % with the ecological scarcity method. The reason is the contribution from the natural gas used for the injection moulding process. Natural gas has a higher contribution to the GWP than the ecological scarcity. In comparison with the ecological scarcity method, the shares of the production of the glass bottle and the PET preform are increased to 10 % and 55 %, respectively. The contribution from the PET bottle is reduced to 2 % whereas it has a share of 7 % with the ecological scarcity method. This process uses mainly electricity and the electricity from Rothrist is generated from 51.3 % nuclear energy. The nuclear energy and its radioactive waste have a high contribution to the impact category deposited waste and a main contribution to the single score eco-points (see Appendix A.1.2 for the energy generation and its environmental impacts).

Table 3.3 : Comparison between delivering 9.9 l of Rivella beverage in a 50 cl PET bottle or in a 33 cl glass bottle with regard to the IPCC 2007 100 y method. All results are expressed in g CO2-eq and scaled to 100 %

Life cycle steps	Rivella 33 cl				Rivella 50 cl		
	Cycle 1	Cycle 2-30	30 cycles		Cycle 1-19.8	19.8 cycles	
	[gCO2-eq per 33cl]	[gCO2-eq per 33cl]	[gCO2-eq per 9.9l]		[gCO2-eq per 50cl]	[gCO2-eq per 9.9l]	
PET Preform/ Glass bottle	157		157	10 %	70	1379	55 %
PET Bottle/Transport Glass Bottle	21		21	1.4 %	2.1	41	1.6 %
Cap	12	12	347	22 %	9.4	186	7.5 %
label	1.0	1.0	31	2.0 %	1.6	31	1.2 %
Secondary and tertiary packaging	0.21	0.21	6.3	0.41 %	8.8	174	7.0 %
Bottling	6.0	24.	710	46 %	20	399	16 %
Distribution	8.8	8.8	263	17 %	0.45	8.9	0.35 %
Disposal packaging	0.24	0.24	7.1	0.46 %	4.4	87	3.5 %
MSWI					9.7	191	7.7 %
Total	**206**	**46**	**1542**	**100**	**126**	**2498**	**100**

3.3 Michel

3.3.1 Ecological scarcity method

Table 3.4 shows the results for the main life cycle steps of the Michel 100 cl glass bottle and the Michel 75 cl PET bottle with regard to the ecological scarcity method. The results are depicted in Fig. 3.2. In total, the glass bottle has 2560 EP whereas the PET bottle has 4560 EP. The large difference between the PET EP and the glass EP is explained by the production of the PET bottle at each cycle. Indeed, the PET preform accounts for 61 % of the total impacts while the glass bottle makes only 13 % of the total impacts. Due to the fact that the PET bottle is made of 100 % virgin PET, the share is higher than for the Rivella 50 cl PET bottle. The white glass bottle contains less cullets than the brown glass bottle hence the higher contribution from the bottle's manufacture. Per cycle, the Vacu-vent cap has exactly the same environmental impact as the crown cork for the Rivella glass bottle. However, over 15 cycles, its contribution to the impacts is lower because the bottling process contributes 56 % to the results.

Table 3.4 : Comparison between delivering 15 l of Michel in a 75 cl PET bottle or in a 100 cl glass bottle with regard to the ecological scarcity 2006 method. All results are expressed in eco-points (EP) and scaled to 100 %

Life cycle steps	Michel 100 cl				Michel 75 cl		
	Cycle 1	Cycle 2-15	15 cycles		Cycle 1-20	20 cycles	
	[EP/1 l]	[EP/1 l]	[EP/15 l]		[EP/75 cl]	[EP/15 l]	
PET Preform/ Glass bottle	334		334	13 %	139	2783	61 %
PET Bottle/Transport Glass Bottle	46		46	1.8 %	16	314	6.9 %
Cap	21	21	316	12 %	10	199	4.4 %
label	4.6	4.6	69	2.7 %	4.7	94	2.1 %
Secondary and tertiary packaging	0.54	0.54	8.1	0.32 %	7.1	141	3.1 %
Bottling	69	98	1435	56 %	46	928	20 %
Distribution	22	22	334	13 %	0.74	15	0.32 %
Disposal packaging	1.3	1.3	19	0.74 %	4.4	88	1.9 %
Total	**498**	**147**	**2560**	**100 %**	**228**	**4564**	**100 %**

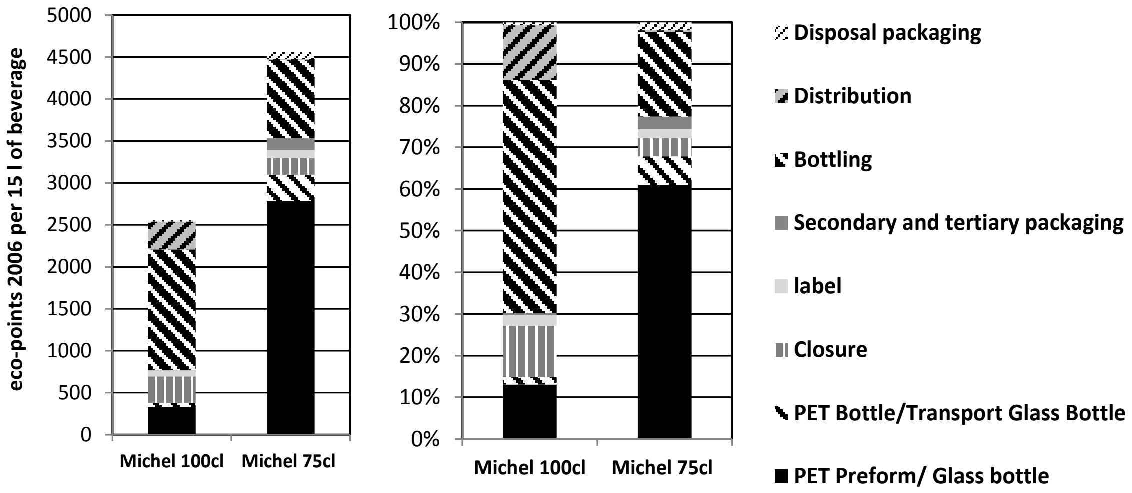

Fig. 3.2 : Comparison of the environmental impacts (left) and shares of the individual life cycle steps (right) between delivering 15 l of Michel juice in a 75 cl PET bottle or in a 100 cl glass bottle with regard to the ecological scarcity 2006 method

3.3.2 Global warming potential

Table 3.5 shows the results with regard to the IPCC 2007 100 y method. The results are consistent with the ecological scarcity results. Similar to the Rivella comparison, the shares for the production of glass and PET bottles are increased to 19 % and 66 %. It must be noticed that while the crown cork for Rivella 33 cl and the Vacuvent cap for Michel 100 cl cap have the same eco-points, the GWP of the Vacuvent cap is higher than the crown cork's GWP. The reason is the difference between the environmental impacts of chromium steel and primary aluminium. Indeed, 1 kg of primary aluminium has 12.2 kg CO2-eq and 12200 EP while 1 kg of chromium steel has 3.86 kg CO2-eq and 8900 EP. Thus, the difference is larger with the GWP due to the contribution from the natural gas emissions of the steel production.

Table 3.5 : Comparison between delivering 15 l of Michel beverage in a 75 cl PET bottle or in a 100 cl glass bottle with regard to the IPCC 2007 100 y method . All results are expressed in g CO2-eq

	Michel 100 cl				Michel 75 cl		
Life cycle steps	**Cycle 1**	**Cycle 2-15**	**15 cycles**		**Cycle 1-20**	**20 cycles**	
	[gCO2-eq per 1l]	[gCO2-eq per 1l]	[gCO2-eq per 15l]		[gCO2-eq per 0.75l]	[gCO2-eq per 15l]	
PET Preform/ Glass bottle	406		406	17 %	158	3151	65 %
PET Bottle/ Transport Glass Bottle	47		47	1.9 %	3.6	72	1.5 %
Cap	21	21	320	13 %	12	247	5.1 %
label	2.8	2.8	41	1.7 %	6.8	137	2.8 %
Secondary and tertiary packaging	0.69	0.69	10	0.42 %	9.1	181	3.8 %
Bottling	36	91	1306	53 %	44	882	18 %
Distribution	20	20	304	12 %	0.7	14	0.28 %
Disposal packaging	0.83	0.83	12	0.51 %	6.9	138	2.9 %
Total	**535**	**137**	**2448**	**100 %**	**241**	**4821**	**535**

3.4 Avoided burden approach

When the avoided burden approach is applied, secondary material is not considered as an input but as an output from the primary product recycling. Therefore, bottles are made of 100 % virgin material. In order to model packaging glass with 100 % primary minerals (or 0 % cullets) the same method used in section 3.1 is applied. It is important to note that 1.19 kg of primary minerals are needed to produce 1 kg of packaging glass. Using this method, 1 kg of packaging glass without cullets has 637 EP and 831 g CO2-eq (see Appendix A.4 TableA 9). In this section, the avoided burden results are compared with the recycled content results.

As it was defined in section 2.2.3, the avoided burden approach gives a credit for the share of primary material that will be recycled at the end of the use phase. The credits correspond to an amount of “PET, bottle grade” and “packaging glass, at plant” determined by the sorting and recycling efficiencies defined in section 2.3.7 and section 2.3.8 for the glass and PET bottles. Based upon a sorting efficiency of 93 % for glass cullets, a credit of 93 % primary glass is granted to Rivella 33 cl and Michel 100 cl. A credit of 62 % primary PET is granted to Rivella 50 cl PET, given a collection rate of 80 %, a sorting efficiency of 82 % and a recycling efficiency of 95 %. Michel 75 cl PET is 100 % collected and therefore gets an overall credit of 78 %.

3.4.1 Rivella

Fig. 3.3 shows the results of the avoided burden and the recycled content (RC) approaches for the Rivella comparison. When the credits are not subtracted from the total, Rivella 33 cl and Rivella 50 cl have larger impacts than Rivella 33cl RC and Rivella 50 cl RC because they are made of 100 % virgin material. The contribution from the bottle production is increased by 23 % and 31 % for PET and glass, respectively. When the credits are subtracted from the total, impacts of Rivella 33 cl are 5 % lower than Rivella 33cl RC. The impacts of Rivella 50cl are reduced by 12 %. The reduction is larger for the PET bottle due to the larger avoided burden. Indeed, PET bottles are recycled after each cycle, while glass bottles are recycled at the end of the 30^{th} cycle. In total, Rivella 33 cl has 1900 EP whereas Rivella 50 cl has 2380 EP. The refillable glass bottle maintains its lower environmental burden when the avoided burden approach is applied.

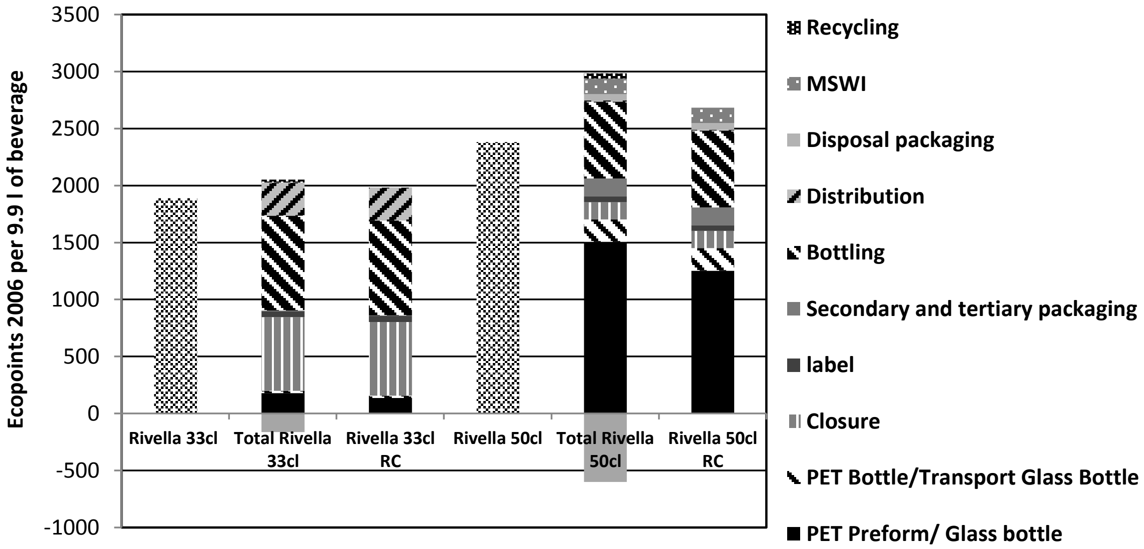

Fig. 3.3 : Comparison between the avoided burden and the recycled content (RC) approaches when 9.9 l of Rivella are delivered in a 50 cl PET bottle or in a 33 cl glass bottle with regard to the ecological scarcity 2006 method

3.4.2 Michel

Fig. 3.4 shows the results of the avoided burden and the recycled content (RC) approaches for the Michel comparison. When the credits are not subtracted from the total, Michel 75 cl and Michel 100 cl have larger impacts due to the additional recycling process. When the credits are subtracted from the total, the impacts are reduced by 10 % and 37 % for Michel 100 cl and Michel 75 cl, respectively. The credits granted to Michel 75 cl are larger than the one granted to Rivella 50 cl because 100 % of Michel 75 cl is collected. Michel 100 cl has 2330 EP whereas Michel 75 cl has 3330 EP. The glass bottle maintains its lower environmental burden when the avoided burden approach is applied.

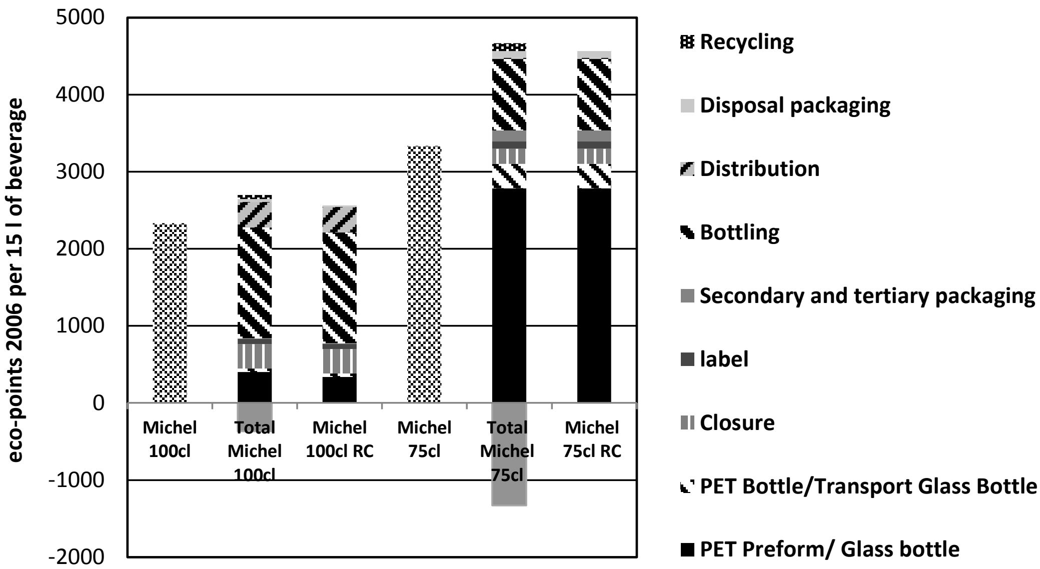

Fig. 3.4 : Comparison between the avoided burden and the recycled content (RC) approaches when 15 l of Michel juices are delivered in a 75 cl PET bottle or in a 100 cl glass bottle with regard to the ecological scarcity 2006 method

3.5 Sensitivity analysis

In a first step, the values of key parameters in the basis scenario are changed to assess their impacts on the results. The following parameters are evaluated for Rivella and Michel comparisons:

- Collection rate Rivella 50 cl and Michel 75 cl
- Recycled content Rivella 50 cl and Michel 75 cl
- Weight Michel 75 cl

In a second step, the contribution from an updated value for the carbon footprint of the production of PET is assessed. In a third step, the breakeven number of refilling cycles at which a glass bottle has the same burden as a PET bottle is assessed. Finally, the breakeven travelled distance during distribution at which a glass bottle has the same impacts as a PET bottle is assessed.

3.5.1 Rivella

The Swiss average collection rate of 80 % in the basis scenario may not reflect the reality. (Sturm, Egli et al. 2005) mention a collection rate between 40 % and 50 % for bottles below 1 l. The ecological scarcity results have been recalculated with a collection rate of 50 %. Furthermore, Rivellla AG wants to achieve a recycled content of 50 % in its PET bottle. Therefore, a scenario with this share is analysed. The Rivella 50 cl bottle's weight seems already well-optimised and was not changed. Fig. 3.5 shows that reducing the collection rate to 50 % increases the total result by 8 %. When the recycled content is increased to 50 %, the total results are decreased to 2500 EP, a reduction of 7 %. Consequently, increasing the recycled content should be done along with awareness campaigns on PET collection otherwise the effects will be compromised.

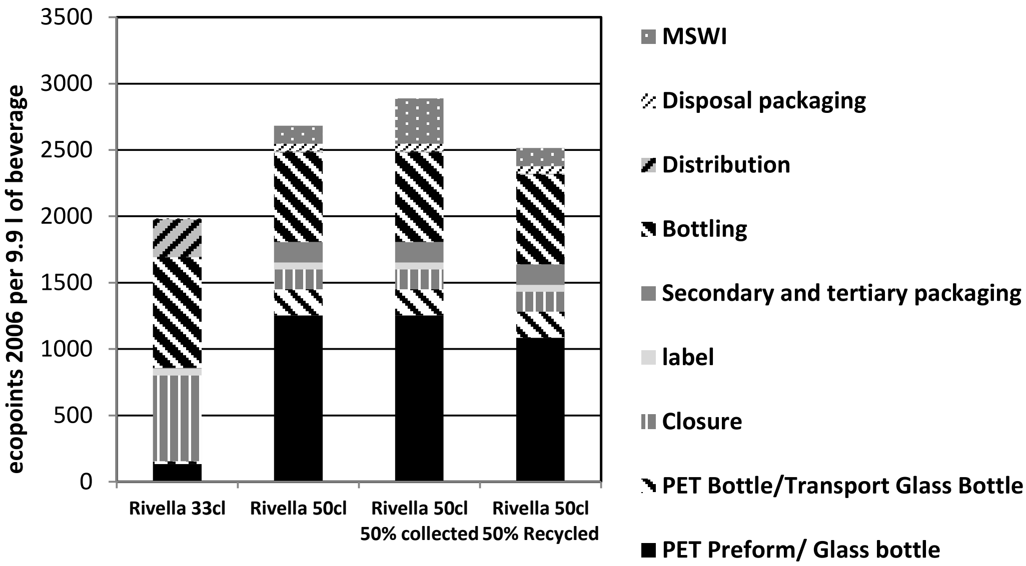

Fig. 3.5 : Results of the Rivella 50 cl PET bottle when the collection rate is decreased to 50 % and the recycled content is increased to 50 % with regard to the recycled content approach and the ecological scarcity 2006 method

3.5.2 Michel

In order to be more realistic, the assumed collection rate of Michel 75 cl will be reduced to 80 % (Sturm, Egli et al. 2005). In a second step, a recycled content of 30 % will be added to the bottle. In a third step, the bottle's weight is reduced to 25 g. The aim is not to choose a realistic weight but to study the effects of the weight's reduction on the environmental impacts. Fig. 3.6 shows the results with the recycled content approach. The incineration of 20 % Michel 75 cl increases the results by 5 % whereas the introduction of 30 % of recycled PET reduces the impacts by 11 %. The reduction of the bottle's weight causes an overall reduction of 16 %. Consequently, the feasibility of introducing recycled material and reducing the weight of the Michel 75 cl bottle should be studied.

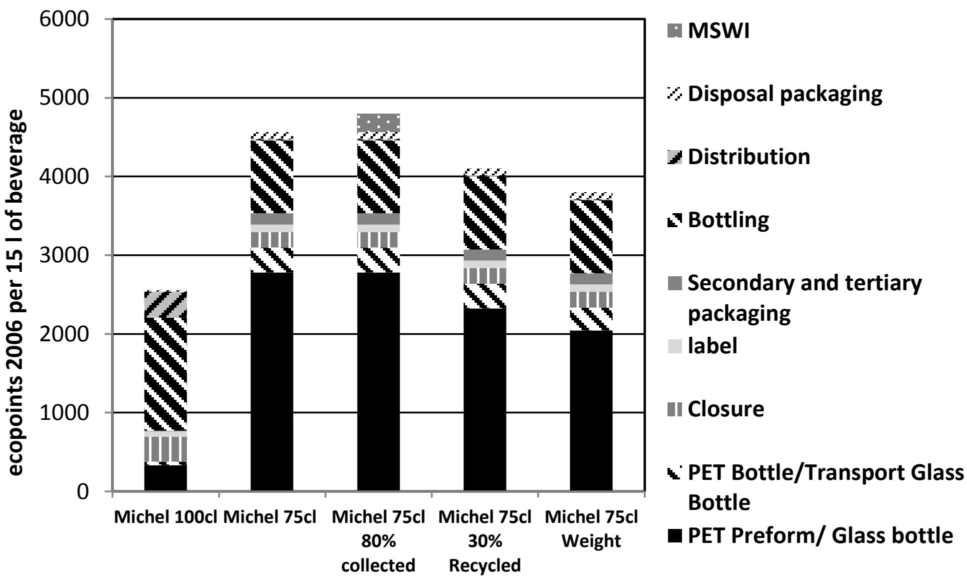

Fig. 3.6 : Results of the Michel 75cl PET bottle when the collection rate is decreased to 80 % and the recycled content is increased to 30 % with regard to the recycled content approach and the ecological scarcity 2006 method

3.5.3 Update primary PET production

(PlasticsEurope 2011) has made a new Environmental Product Declaration (EPD) for bottle-grade PET with data collected in 2009. The updated GWP is 2.15 kg CO2-eq, which represents a reduction of 34 % in comparison with the ecoinvent dataset (Hishier 2007). The reduction is mostly due to optimisation in PTA production. When this new result is applied to Rivella 50 cl PET bottle, the contribution from the primary PET production is reduced by 15 % and the overall results are reduced by 8 %. For Michel 75 cl, the contribution from the primary PET production is reduced by 16 % and the overall results are reduced by 10 % to 4330 g CO2-eq as illustrated in Fig. 3.7.

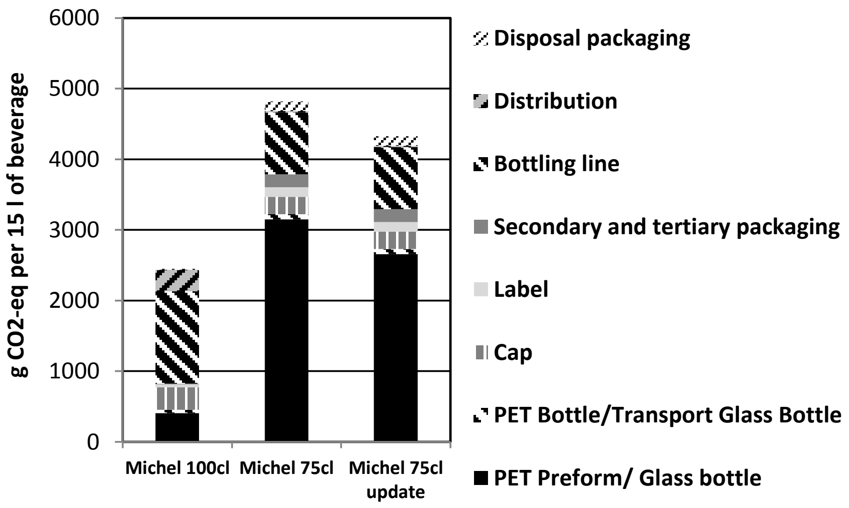

Fig. 3.7 : Comparison of the environmental impacts between delivering 15 l of Michel juice in a 75 cl PET bottle or in a 100 cl glass bottle when the GWP of primary PET production is updated (PlasticsEurope 2011)

3.5.4 Glass bottle versus PET bottle

Breakeven number of refilling cycles

If we compare a new glass bottle to a new PET bottle at Rothrist before the filling process, the glass bottle has a larger environmental burden than the PET bottle due to its weight as described in Fig. 3.8. Thus, it is interesting to analyse the breakeven number of refilling cycles at which the glass bottle and the PET bottle have the same environmental burden.

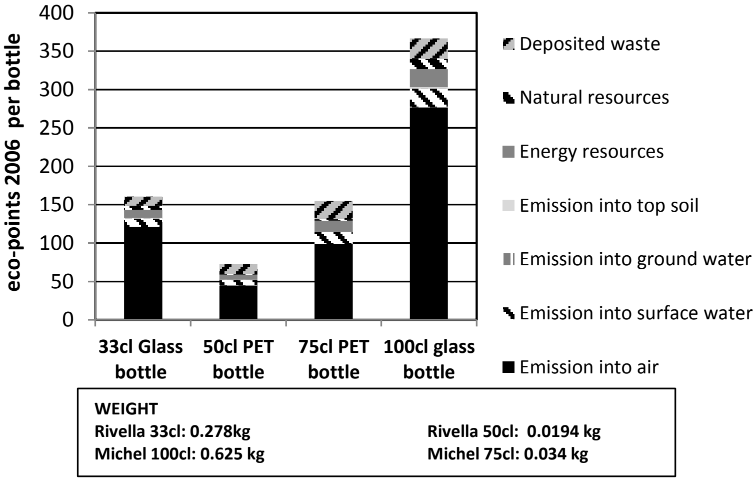

Fig. 3.8 : Eco-points per impact category for glass and PET packaging delivered at Rothrist and their respective weights

Fig. 3.9 illustrates the breakeven number for both Michel and Rivella comparisons. The breakeven point occurs at 1.69 l for Rivella whereas it occurs at 2.28 l for Michel. As soon as the Rivella 33 cl is refilled six times, its environmental impacts will be lower in terms of eco-points. Once the Michel 100 cl is refilled three times, the Michel PET bottle will have higher environmental impacts in terms of eco-points. Breakeven points occur at 1.41 l and 2.16 l for Rivella and Michel when the GWP method is applied. These results are consistent with the ecological scarcity results. In the current situation, Rivella and Michel are reused 30 times and 15 times, respectively. Consequently, optimisation has already been implemented.

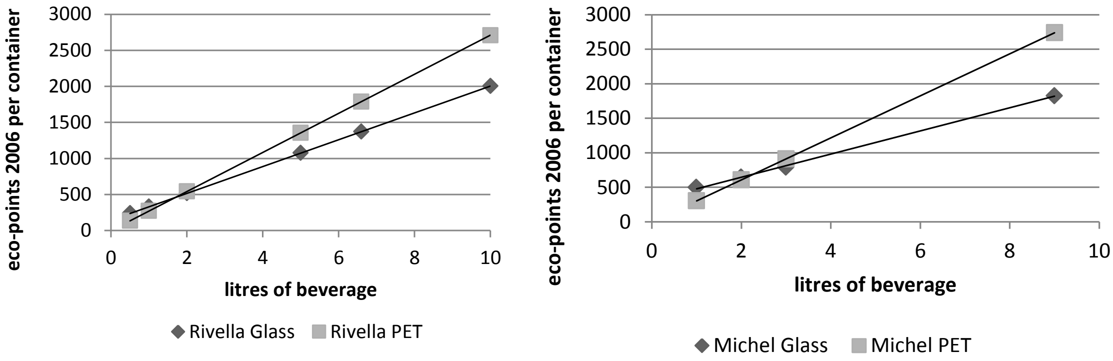

Fig. 3.9 : Identification of the breakeven number of refilling cycles for Rivella (left) and Michel (right) glass bottles with regard to the ecological scarcity method

Breakeven travelled distance during distribution

The travelled distance during distribution is another key difference between glass and PET bottles due to the difference in weight transported. Glass bottles are heavier, so environmental impacts from transportation are larger than when PET bottles are transported. Therefore, it is interesting to estimate the breakeven covered distance at which the environmental impacts from delivering 9.9 l of beverages will be the same for glass and PET bottles. The distribution distance includes the return of glass bottles to Rothrist because it is assumed that delivery and collection occur simultaneously. Fig. 3.10 shows that a Rivella glass bottle needs to be transported over 739 km while a Michel glass bottle must travel a distance of 1475 km to achieve the same environmental impacts as a PET bottle. Michel glass must travel along a longer distance. The reason is the use of 100 % virgin PET, which increases the gap between the environmental burden of Michel glass and PET bottles. These distances are not relevant in a Swiss market. The maximum distance from Rothrist to the furthest clients in Switzerland is 250 km and the maximum distance covered during a round trip is 500 km.

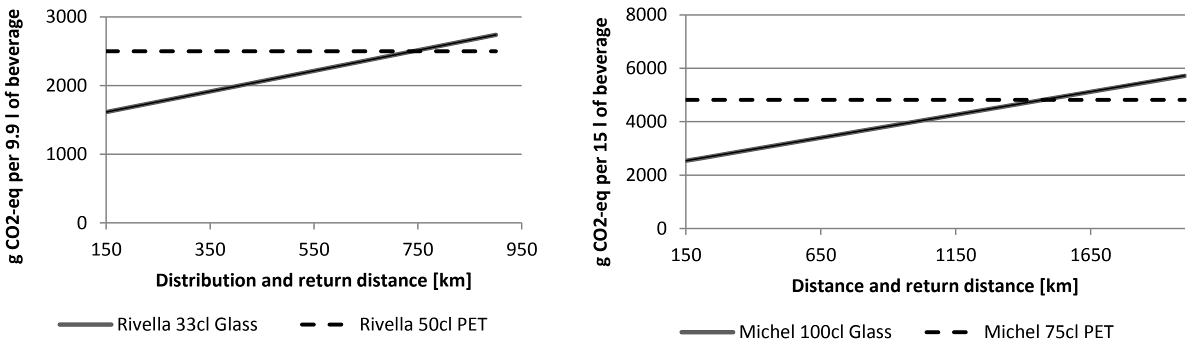

Fig. 3.10 : Identification of the breakeven distribution distance of Rivella (left) and Michel (right) glass bottles to achieve the same GWP of PET bottles

4 Discussion

The results presented in section 3 are interpreted and discussed. In a first step, areas with potential for improvement are identified. In a second step, alternative packaging options are introduced and assessed, using assumptions that can be made without conducting a LCA. From a LCA perspective, the respective benefits of the recycled content and avoided burden approaches are argued, followed by the energy allocation from MSWI. Finally, uncertainties arising from the life cycle inventory are listed. In the following section, glass system refers to Rivella and Michel glass bottles, while PET system refers to Rivella and Michel PET bottles.

4.1 Areas with potential for improvement

It can be concluded from the results in section 3.2 and section 3.3 that refillable Rivella and Michel glass bottles have smaller environmental impacts than the one-way Rivella and Michel PET bottles with regard to the ecological scarcity 2006 and the IPCC 2007 methods.

Several areas within the glass system could be improved. The bottling process contributes at least 40 % to the total environmental impacts. (Helbling 2012) audited the energy and water consumptions at the production factory and suggested some improvement measures regarding Michel's bottling process in line 4. The measure ranked highest priority refers to the use of the wastewater from the cooling tunnel for the washing process in order to spare 50 % of the water consumption of the latter. Other measures suggested include the optimisation of the CIP process to reduce its energy demand by 62 % and the use of available waste hot water for the rinsing process to save 60 % energy. When these measures are applied to the basis scenario, environmental impacts are reduced by 4 % with regard to the ecological scarcity method. Improvement measures regarding the electricity consumption should also be investigated.

Another potential improvement concerns the aluminium cap and the crown cork, the latter contributing 20 % to the Rivella glass' ecological scarcity burden. The potential use of secondary steel and secondary aluminium should be investigated with the manufacturers. Last but not least, the current 48 % share of post-consumer cullets in the Michel bottle could be increased to the German average share of 58 %. This measure does not include the Rivella glass bottle, whose share is already 11 points larger than the German average share.

Already well-optimised areas are the distribution of glass bottles to caterers and the number of refilling cycles. Waeber (2012) will assess logistics in more details and conclusions from his study should be considered. The recirculation rate does not require any improvement. Indeed, the computation of the breakeven number of refilling cycles showed that as soon as the 33 cl glass bottle is reused five times, the 50 cl PET bottle's carbon footprint is higher. Once the glass bottle 100 cl is refilled three times, the 75 cl PET bottle has a larger carbon footprint.

Improvement sectors within the PET system concern the production of PET bottle grade and savings of PET material. Already implemented measures in the PET bottle grade production have led to a new carbon footprint value, which is 34 % lower than the one of the ecoinvent dataset used in this study. However, this updated value is based upon the end result published in the EPD on PET bottle grade (PlasticsEurope 2011). Consequently, the impact measurements could be different with the creation of a new dataset including the pollutant emissions and resources use. The release of the new ecoinvent database version 3 at the end of this month will provide an answer to this issue. Furthermore, the injection moulding process is an energy-intensive process that contributes 40 % to the preform manufacture's burden. No further investigation was carried out but it should be assessed whether improvements were made in comparison with the data in the ecoinvent database. Again, this will soon be answered with the new ecoinvent database.

The sensitivity analysis showed that an increase of the recycled content or a reduction of the bottle's weight would mitigate the environmental burden of PET bottles. If the weight of the Michel bottle were to be reduced from 34 g to 25 g, environmental impacts would be diminished by 16 % with regard to the ecological scarcity method. It is difficult to estimate a realistic weight reduction given the fact that it is a multi-layered bottle with an inner nylon layer. This should be further investigated. The introduction of 30 % recycled content in the Michel bottle reduces environmental impacts by 10 % with regard to the ecological scarcity method. The addition of recycled material to Michel bottles might not be realistic given the mentioned risks of the alteration of the vitamins content and the colour quality during storage. The goal set by Rivella AG to increase the recycled content of the Rivella PET bottle from 30 % to 50 % leads to a reduction of 7% of its burden from an ecological scarcity perspective. If possible, the recycled content should be even higher. Nevertheless, it is difficult to estimate a maximum amount of recycled content that can be contained in a bottle. PRS (2012) mentions that it is technically feasible to achieve high recycled content but the chromatic purity of the bottle requires a certain amount of virgin PET. The quantification of this amount should be assessed for Rivella brown PET bottles.

In order to achieve higher recycled content, the collection rate should be as high as possible. In the basis scenario, the collection rates for Rivella and Michel reflect Swiss average. If the collection rates are reduced to 50 % and 80 % respectively, it means that more bottles are incinerated and the impacts are 5 % to 8 % larger. The IGSU is an interest group for a clean environment in Switzerland, a joint initiative of PRS and the cooperative for aluminium recycling IGORA. The group is dedicated to the fight against littering. Rivella AG could consider joining this group to take part in activities aimed at littering of PET bottles.

4.2 Alternative packaging

Large volume packaging in the catering sector

In the scope of this LCA, refillable glass was the only option analysed for the catering sector but alternatives do exist. Beverage dispensing machines, which are commonly used for beers, are one option. On a small scale, Rivella is already distributed in 10 l and 20 l kegs to refill beverage dispensing machines. A keg is usually made of stainless steel. Its robustness and material quality enable higher recirculation rate that can reach years, as in the case of kegs used for beers[8]. Consequently, the environmental impacts of the packaging's production per volume of beverage supplied would be lower, even negligible. The distribution phase will also benefit from this alternative packaging. For example, a 20 l keg manufactured by the company Maisonneuve KEG has an empty weight of around 9 kg[7]. Therefore, 9 kg of packaging are transported to supply 20 l of beverage. If the same amount is to be delivered in Rivella glass bottles, 17 kg of packaging will be necessary. Therefore, there would be 8 kg less to be transported. However, it is difficult to foresee the outcomes of the use phase. The electricity consumption from operating beverage dispensing machines might exceed the one necessary to refrigerate glass bottles. Moreover, the manufacture of the beverage dispensing machine and its lifespan should also be taken into consideration, as well as the washing of glass in which Rivella will be served to the customer.

The "Express Dispenser System" advertised on Rivella AG's website is used for Michel juices, which are offered at breakfast buffets in hotels (Rivella 2012). The assumption made for the production and distribution of kegs remains valid, however, in this system the beverage dispensing machine is filled with Michel concentrate that is mixed with water when the customer presses the button. In order to preserve taste and ingredients, the concentrate is distributed frozen. Therefore, the use of refrigerated lorry might reduce the benefits from the lighter weight transported. Moreover, the electricity consumption from defrosting the concentrate at the caterer should be added to the electricity consumption from operating the dispenser. Therefore, it seems that the environmental benefits would be more obvious for Rivella carbonated drinks than for Michel juices.

Glass could also be replaced by refillable PET bottles. From a technical point of view, rigorous cleaning and sterilisation procedure are compulsory when this packaging is used. In Switzerland, refillable PET bottles are not available on the market anymore. Coca-Cola was using them but, for reasons that

[8] Communication with A. Marie from Maisonneuve KEG, a subsidiary of Maisonneuve Group

are still unclear, they are not used anymore[9]. Rivella AG, who was also using them at a time, claims that issues with the quality control were too burdensome to carry on with this packaging.

Alternative materials for PET production

Primary PET production is the main contribution to environmental impacts of one-way PET bottles. Therefore, the use of alternative material could be a good option for Rivella AG. There are currently two trends on the packaging market. The first one is the addition of renewable resources to the fossil fuels from which PET is produced. For example, the mineral water company Volvic has launched its new bottle "bioMEG" in a 50 cl and 1.5 l volume. Conventional monoethylene glycol (MEG) is replaced by MEG produced from molasses, a sugar cane by-product. (Volvic 2010) explain that around one third of the 65 % virgin PET is produced from organic matter while the rest of the bottle is 35 % recycled PET. Molasses is also used as an additive in livestock feeds. The respective benefits from using molasses either in a PET bottle or in animal husbandry need to be assessed. Using molasses in a PET bottle avoid the use of conventional MEG, while using molasses in livestock feeds avoid the use of maize silage[10]. The production of 1 kg of maize silage has an environmental impact of 2500 EP, while the production of 1 kg conventional MEG has a burden 1300 EP. If 1 kg of molasses is used instead of 1 kg of maize silage 2500 EP are avoided. If 1 kg of molasses is used instead of 1 kg conventional MEG, 1300 EP are avoided. The larger benefit from avoiding maize silage rules in favour of the use of molasses in animal husbandry. From a global warming potential perspective, 1 kg of maize silage and 1 kg of conventional MEG have a carbon footprint of 0.6 kg CO2-eq and 1.6 kg CO2-eq, respectively. These values support the use of molasses in the PET bottle.
These two contradicting conclusions are explained by the difference between the two impact assessment methods. The focus of the global warming potential is on emissions into air. Consequently, the burden from land degradation from pesticide and fertiliser use is underweighted as it mainly affects soil, surface water and ground water. These compartments are characterised, normalised and weighted in the ecological scarcity method. Therefore, it seems more reasonable to assess the use of renewable resources from the agricultural sector with the ecological scarcity method, leading to the conclusion that it would be more beneficial to use molasses as an additive feedstuff in animal husbandry. One should be careful to remember that most of the companies communicate their environmental performance, using the carbon footprint indicator. The main reason is it is easier to communicate, given the public's awareness of global warming. Greater awareness of the public on the ecological scarcity method and use of this method from industries would solve this issue.
The second trend is the production of biodegradable thermoplastic from fossil and renewable resources since thermoplastic PET is non-biodegradable (PRS 2011). For example, the mineral water company Sant'Anna has launched its new bottle made of polylactic acid (PLA), a biodegradable thermoplastic. However, evidence shows that PLA might negatively influence the recycling process because of the difference in the melting point temperature compared to PET (PRS 2011). In conclusion, alternative materials currently available on the market are not sustainable solution to mitigate the environmental impacts of PET bottles.

4.3 Recycled content approach versus avoided burden approach

The use of the avoided burden approach substantially reduces the environmental impacts of the PET bottle. Due to the fact that a PET bottle is recycled at the end of each cycle, the credits are larger than the ones granted to the glass bottle. However, the refillable glass bottle maintains its better environmental profile. (Frischknecht 2010) explains that the avoided burden approach follows the weak sustainability concept and reflects a risk-seeking attitude whereas the recycled content approach is in line with the strong sustainability concept and reveals a risk-averse behaviour. The author claims that a compromise between the two methods is unreachable and the choice of the method depends on the commissioners and the LCA's audience. This LCA is aimed at a soft drinks manufacturer inter-

[9] Communication with Jean-François Marty, PRS

[10] Fermented maize

ested in investigating its glass and PET bottles' production process. First of all, it is easier to communicate results reflecting the actual situation rather than explaining the reasons for the credits. It takes longer to properly understand the avoided burden approach and the results may be confusing. Secondly, conducting a sensitivity analysis on the recycled content is not possible with the avoided burden approach as the bottles are made of 100 % virgin material. On the other hand, the avoided burden approach considers the fate of materials after their use phase and encourages measures to increase recycling rates as an efficient recycling rate gives more credit to the primary product.
The definition of the strong sustainability is that natural capital is not replaceable with the man-made capital produced by society, while the weak sustainability claims the opposite. A preference for the strong sustainability concept indicates that the recycled content approach is more suitable to represent the results.

4.4 Energy production at MSWI

Even though some electricity and heat are generated at the MSWI when PET bottles are incinerated, they are not considered as secondary products. (Doka 2009) explains that "all burdens of waste incineration and subsequent processes are allocated to the function of waste disposal. Generated heat or electrical energy is free of any burden" (ecoinvent report No. 13 section 2.7 p.21-23). In other terms, a consumer of heat or electricity produced at the MSWI gets benefit from its energy source but a producer will not profit from its high-calorific waste. It can be argued that the electricity and heat generated avoid the consumption of energy from other resources and consequently a credit should be given for this avoided use. However, the aim of the study is to compare glass and PET bottles and giving credits to the PET bottle for its disposal would give the impression that it gets a benefit from being disposed of. (Dinkel 2008) compared the ecological benefits between recycling PET and incinerating it. He made a sensitivity analysis when credits are granted for the disposal. Results showed that it reduced the environmental impacts by 20 % but the PET bottle recycling is still the best option. If a sensitivity analysis was to be made, (Doka 2009) gives several arguments that rule against an energy allocation. First of all, the functional unit in the ecoinvent dataset "disposal, waste" refers to 1 kg of waste. Secondly, energy is not the main purpose of MSWI because if the energy generation process would impede the waste incineration, the former would be adapted and not the latter. Therefore, the author suggests an economic allocation on the basis of revenues paid to incinerator operators. (Jungbluth, Chudacoff et al. 2007) describe the method to do an economic allocation for the incineration of biowaste. This method is applied to the PET bottle. The revenues from the sold heat and electricity are computed based on the net energy generated from the disposal of PET, PE caps and paper label. Then, the comparison with the revenues from the disposal fees give the allocation factors (see Appendix A.5 for the computation of allocation factors). The economic allocation gives credit for the high-calorific components of a PET bottle, i.e. PET bottle and PE cap. Environmental impacts of the disposal of PET bottles become negligible with regard to the ecological scarcity and IPPC 2007 method. Consequently, Rivella 50 cl total eco-points and GWP are decreased by 5 % and 7 %, respectively. In conclusion, the economic allocation should only be implemented for sensitivity analysis and not as a general rule.

4.5 Uncertainties

All processes required to build the life cycle of the glass bottle could be found in the ecoinvent database, with the sole exception of the cap's manufacture. For the PET bottle life cycle, literature values were used for the sorting and the recycling processes. Values for the recycling process date from 1996, an era when recycled PET-Flakes could not be in contact with food and were only used as an inner layer in multi-layered bottles. An update of the electricity consumption was done thanks to comments by ITW Poly Recycling GmbH. However, it would be necessary to investigate the different recycling processes on the Swiss market, namely the URRC process taking place at RecyPET AG and the Vacurema at ITW Poly Recycling GmbH. Moreover, the sorting efficiency is taken from a German study case because Müller AG, which is the main sorting facility in Switzerland does not have any figures on their energy demand and their sorting efficiency.

Furthermore, it should be verified whether the refrigeration of the drink at the retailer is similar to the storage at the restaurant.

Thirdly, the secondary products of glass and PET have been omitted. In reality, glass may be down-cycled to sand while recycled PET replaces virgin PET in the production of fibre, sheet or strapping. (PRS 2011) explain that in 2011, 63 % of the sorted post-consumer PET bottles were reprocessed to a level of sterility that allowed the recycled PET to be used in the manufacture of new bottles. The remaining 27 % that replaced virgin PET in other applications have been omitted in this study. A first attempt to consider the manufacture of PET fibres led to the conclusion that the PET bottle ecoinvent dataset is a reasonable approximation[11]. Strapping and sheets were not investigated.

Several recycling processes were omitted in the avoided burden approach. Recycling processes of PET bottles' labels and caps, which are removed during the sorting process, were not considered. Crown corks are assumed to be separated from waste at the MSWI with a magnetic iron separator, while Vacuvent caps are incinerated. The recycling process of crown corks and Vacuvent caps were not taken into consideration. A further investigation would make the results of the avoided burden approach more accurate.

Several improvements would make the environmental impacts measurements more accurate. First of all, waste of packaging materials occurring at Rothrist should be estimated. The last step of the bottling line consists of a camera scanning to check whether filled bottles contain the minimum quantity labelled and have a cap. If not, bottles are eliminated. The quantification of this amount was not done. Secondly, buildings were omitted throughout the whole life cycle and would increase the burden of both bottles. Thirdly, PET bottles littering should also be accounted for even though it is still unclear how it should be done.

[11] Email communication with Ivo Mersiowsky, DEKRA Consulting GmbH and contacting person mentioned on the PlasticsEurope's website

5 Conclusion and recommendations

Rivella 50 cl PET was compared with Rivella 33 cl glass bottles, while Michel 75 cl PET was compared with Michel 100 cl glass bottles. The life cycle assessment per volume of beverage delivered shows that environmental impacts of glass bottles are lower with regard to the ecological scarcity and the IPCC 2007 methods. The recirculation rate of glass bottles and the large environmental burden from PET production have shown themselves to be the key parameters in favour of refillable glass bottles. As soon as Rivella 33 cl is refilled six times, its environmental impacts will be lower in terms of eco-points than Rivella 50 cl. Once Michel 100 cl is refilled three times, Michel 75 cl will have a larger environmental burden in terms of eco-points. The application of the avoided burden approach reduces the difference between both packaging types, but the refillable glass bottle still has a lower environmental burden.

The suggestion made before conducting the LCA to replace glass bottles by PET bottles in restaurants is not recommended from an ecological perspective. However, it does not lead to the conclusion that glass bottles should replace one-way PET bottles. One-way glass bottles cannot compete with one-way PET bottles because of glass' greater weight.

To conclude that each packaging choice is the best option for its respective market sector is also inadequate. The use of beverage dispensing systems, which offer the advantage of a smaller packaging weight per amount of beverage delivered could be an interesting alternative to glass bottles. The environmental burdens associated with the production of the packaging and the distribution to restaurants would be definitely mitigated. Nevertheless, the energy consumption from operating the beverage dispensing machine needs to be further investigated and a new LCA including this parameter is recommended. As this alternative packaging is already used on a small scale, this recommendations gain even more weight. Consumer habits should also be carefully considered, as customer acceptance of the new system is not given.

Regarding PET bottles, the company's goal to increase the recycled content of Rivella 50 cl from 30 % to 50 % should be implemented. The Michel PET bottle is heavy due to its multi-layered design and is made of 100% virgin PET. Its design's optimisation should be a priority in order to reduce its weight. The introduction of recycled PET in the Michel PET bottle should be thoroughly discussed from a beverage quality perspective. From an overarching LCA perspective, the addition of PET produced from renewable resources is not sustainable. Allocating these resources to livestock feed would be more sustainable.

(Biasio 2003) claims that the ideal bottle does not exist. The present study would agree on that statement. Choosing the ideal packaging reveals itself a complex decision involving many stakeholders: the final consumer, the bottle manufacturer, the soft drinks company and the authorities who enforce laws regarding collection rates.

Last but not least, a water footprint study would be recommended to complete the environmental assessment of Michel and Rivella soft drinks packaging, aiming at comparing water consumption involved in refilling glass bottles and recycling PET bottles.

Bibliography

Aarburg, Abwasserverbandes. (2011). Betriebsdaten 2011. Abwasserverbandes Aarburg. Available from http://www.araaarburg.ch/betriebsdaten.html. Retrieved 05.07.2012.

EW Rothrist AG. (2010). Strommkennzeichnung Ausführliche Informationen Bezugsjahr 2010. Rothrist, Switzerland. Available from: http://www.ewrothrist.ch/?rub=12. Retrieved 29.05, 2012.

Arena, U.; Mastellone, M. L.Perugini, F. (2003): Life Cycle assessment of a plastic packaging recycling system. The International Journal of Life Cycle Assessment 8(2), pp. 92-98, 2003.

Biasio, A. (2003): La bouteille idéale n'existe pas. Environnment 1/04, pp. 53-55, 2003.

Chilton, T.; Burnley, S.Nesaratnam, S. (2010): A life cycle assessment of the closed-loop recycling and thermal recovery of post-consumer PET. Resources Conservation and Recycling 54(12), pp. 1241-1249, 2010.

Detzel, A.; Giegrich, J.; Krüger, M.; Möhler, S.Ostermayer, A. (2004). LCA of one way PET Bottles and recycled products - Final report: Summary. Study on behalf of PETCORE, Brussels. August 2004. IFEU GmbH, Heidelberg, Germany. Available from http://www.ifeu.de/index.php?bereich=oek&seite=verpackungsoekobilanzen. Retrieved 05.06.2012.

Dinkel, F. (2008). Okologischer Nutzen des PET-Recycling Schweiz. Study on behalf of PET Recycling Schweiz, Zürich. Carbotech AG Basel. Available from http://www.petrecycling.ch/de/oekologie.html. Retrieved 20.03.2012.

Doka, G. (2006). Vergleichende Okobilanz für das Recycling und Versanden von Altglas.Study on behalf of VetroSwiss, Glattbrugg. Doka Okobilanzen Zürich, DOKA Okobilanzen, Zürich.

Doka, G. (2009). Life Cycle Inventories of Waste Treatment Services. ecoinvent report No.13. Swiss Centre for Life Cycle Inventories, St Gallen.

Eyman, L. (2012). Okologische und soziale Auswirkungen der Rivella-Getränke. Master Thesis, Eidgenössische Technische Hochchule ETHZ, Institute of Environmental engineering, Ecological System Design.

FOEN. (2010). Waste statistics: Data for 2010. Recycling von Getränkeverpackungen 2010. Available from: http://www.bafu.admin.ch/abfall/01517/01519/11645/index.html?lang=en. Retrieved 30.05.2012.

FOS. (2012). Prestation de transport des véhicules lourds selon le genre de véhicule, l'immatriculation et le genre de trafic (Prestations des véhicules de transport de choses. Séries chronologiques). Document su-f-11.05-GTS-E26. Federal Office of Statistics, Bern, Switzerland. Available from http://www.bfs.admin.ch/bfs/portal/fr/index/themen/11/05/blank/dos/02.html. Retrieved 02.06.2012.

Frischknecht, R. (2010): LCI modelling approaches applied on recycling of materials in view of environmental sustainability, risk perception and eco-efficiency. The International Journal of Life Cycle Assessment 15(7), pp. 666-671, 2010.

Frischknecht, R.; Steiner, R.Jungbluth, N. (2009). The Ecological Scarcity method - Eco-factors 2006. A method for impact assessment in LCA. Environmental studies Federal office for the Environment (FOEN), Bern, Switzerland. Available from http://www.bafu.admin.ch/publikationen/publikation/01031/index.html?lang=de. Retrieved 28.06.2012.

Habersatter, K.Fecker, I. (1998). Inventaires écologiques relatifs aux emballages Volume 1 Cahier de l'environnement No.250/1. FOEN, Federal Office for the Environment, Bern, Switzerland.

Habersatter, K.Fecker, I. (1998). Inventaires écologiques relatifs aux emballages Volume 2. Cahier de l'Environnement No. 250/2. FOEN, Federal Office for the Environment, Bern, Switzerland.

Helbling, Beratung + Bauplanung AG. (2012). Eco Improvement Masterplan Rivella AG Schlussbericht. 14.05.2012. Projekt 313 2061 00. Helbling Beratung + Bauplanung AG, Zürich, Switzerland.

Helbling, Beratung + Bauplanung AG. (2012). Energiestatistik. Energiestatistik.xlsx.

Helbling, Beratung + Bauplanung AG. (2012). Produktionsstatistik. Produktionsstatistik.xlsx.

Hishier, R. (2007). Life Cycle inventories of Packaging and Graphical Papers. ecoinvent-Report No.11. Swiss Centre for Life Cycle Inventories Dübendorf.

Intini, F.Kühtz, S. (2011): Recycling in buildings: an LCA case study of a thermal insulation panel made of polyester fiber, recycled from post-consumer PET bottles. The International Journal of Life Cycle Assessment 16(4), pp. 306-315, 2011.

ISO. (2006a). International Standard ISO 14040: Environmental management - Life cycle assessment - Principles and framework. International Organization for Standardization, Geneva, Switzerland. 2006.

ISO. (2006b). International Standard ISO 14044: Environmental management - Life cycle assessment - Requirements and guidelines. ISO 14044:2006. International Organization for Standardization, Geneva, Switzerland. 2006.

Jungbluth, N.; Chudacoff, M.; Dauriat, A.; Dinkel, F.; Doka, G.; Faist Emmenegger, M.; Gnansounou, E.; Kljun, N.; Schleiss, K.; Spielman, M.; Stettler, C.Sutter, J. (2007). Life Cycle Inventories of Bioenergy ecoinvent report No. 17. Swiss Centre for Life Cycle Inventories, , Dübendorf.

Klöpffer, W.Grahl, B. (2009). Illustration der Komponent Sachbilanz am Praxisbeispiel. Okobilanz (LCA): Ein Leitfaden für Ausbildung und Beruf, pp 144-182. Weinheim, Germany, Wiley VCH, 2009

Knecht, K.; Lanners, S.Martignoni, A. (2012). LCA of Michel juices. Bachelor Thesis, Eidgenössische Technische Hochchule ETHZ, Institute of Environmental engineering, Ecological System Design.

PlasticsEurope. (2011). Environmental Product Declaration (EPD) of Polyethylene Terephthalate (PET) (Bottle grade). . May 2011. PlasticsEurope Brussels. Available from http://www.plasticseurope.org/plastics-sustainability/eco-profiles/browse-by-list.aspx.

PRS. (2011). Geschäftsbericht 2011. Verein PET-Recycling Schweiz, Zürich. Available from http://www.petrecycling.ch/de/geschaeftsbericht.html. Retrieved 15.06.2012.

PRS. (2011). Les bouteilles repousseront-elles demain? PRS-Interne Environnement. 15.06.2011. PRS. Available from http://www.petrecycling.ch/fr/news/slideshow/les-bouteilles-repousseront-elles-demain. Retrieved 28.06.2011.

PET Recycling Schweiz. (2012). Littering Pet Recycling. Available from: http://www.petrecycling.ch/fr/littering.html-0. Retrieved 30.06.2012.

Rivella,,AG. (2012). Rivella Express Dispensersystem. Available from: http://www.rivella.com/ch/de/express-dispensersysteme/. Retrieved 09.07, 2012.

Shen, L.; Nieuwlaar, E.; Worrell, E.Patel, M. (2011): Life cycle energy and GHG emissions of PET recycling: change-oriented effects. The International Journal of Life Cycle Assessment 16(6), pp. 522-536, 2011.

Solomon, S.; Qin, D.; Manning, M.; Chen, Z.; Marquis, M.; Averyt, K. B.; Tignor, M.Miller, H. L. (2007). Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge, United Kingdom and New York, NY, USA. Available from http://www.ipcc.ch/publications_and_data/publications_ipcc_fourth_assessment_report_wg1_report_the_physical_science_basis.htm.

Spielman, M.; Bauer, C.; Dones, R.Tuchschmid, M. (2007). Transport Services ecoinvent report No.14. Swiss Centre for life cycle inventories, , Dübendorf.

Sturm, A.; Egli, N.; Vaterlaus, S.; Worm, H.Gilgen, P. W. (2005). Pfand auf PET-Getränkeflaschen. May 2005. Ellipson AG, Basel, Switzerland. Available from http://www.petrecycling.ch/de/pfand.html. Retrieved 10.06.2012.

Tuchschmid, M.Halder, M. (2010). Mobitool - Grundlagenbericht - Hintergrund, Methodik und Emissionsfaktoren. Mobitool, Bern, Switzerland.

ViaMichelin. (2007). Michelin Travel Partner. Available from: http://fr.viamichelin.ch/. 2012.

Volvic. (2010). Volvic- Une marque citoyenne Première bouteille 20% d'origine végétale. Available from: http://www.volvic.fr/une_marque_citoyenne/volvic__1ere_bouteille_20_dorigine_vegetale/. Retrieved 20.03.2012.

Waeber, O. (2012). Ökobilanzierung des Logistiknetzwerks - Aktuelle Umweltwirkungen und mögliche Verbesserungen. Master Thesis, Eidgenössische Technische Hochchule ETHZ, Department of Management, Technogoly and Economics

Acknowledgments

I am thankful to Prof. Dr. Stefanie Hellweg that I was allowed to work on this Thesis. I appreciated the inputs given to me, especially about the modelling of the recycling process, which allowed me to have a better grasp of the subject.

This Master Thesis would not have been possible without Michael Bürgi, the coordinator of the Seed Sustainability project between Rivella AG and ETHZ.

I would like to thank my supervisor Dr. Andy Spörri and his PhD student Grégoire Meylan for their support and advice throughout these four months. I am very grateful to lea Eymann who started her Master Thesis on the same project three weeks before me. We could discuss all the issues relating to data, allocation, assumptions, etc. Oliver Waeber came later to the project, but he was crucial for the distribution data. Without him, I would never have understood the glass distribution model.

Mr. O. Weibel, Mr. D. Baumann and Mr. S. Höltschi were my contacts at Rivella AG. I communicated with them by emails and I must acknowledge their patience toward my many questions. I would like to thank Mr. J.-F. Marty from PET-Recycling Switzerland for his clarifications on the PET collection system as well as Mr. C von den Dungen from ITW Poly Recycling for his explanations on the recycling of transparent and coloured PET bottles.

Dr. Niels Jungbluth from ESU-Services was a great help to me in completing the recycling process modelling.

I wrote your name countless in this report, but I would to thank you personally for all your critics and comments on this report. I promise I will not use “thus” anymore. I would also like to thank my proofreader Elizabeth. I also want to thank my family and my friends who supported me during this study, and always had a nice word to motivate me.

Appendix

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A.1. Bottling lines at Rothrist

A.1.1. Energy generation

The shares for non-renewable and renewable energies are different than the ones used in the ecoinvent dataset “Electricity mix/CH U” (AG 2010). Consequently, the electricity consumption at Rivella AG is assessed with a new ecoinvent dataset. The shares of the new dataset are given in TableA 1. All the electricity is produced in Switzerland apart from 26 % nuclear power, which is allocated to French nuclear power.

TableA 1 : Shares of non-renewable and renewable energy in the electricity mix at Rothrist (AG 2010)

Energy source	Switzerland [%]	Imports [%]
Hydropower	22.2	0
Solar	0.0388	0
Wind	0.0264	0
Biomass	0.3784	0
Nuclear	51.3	26

TableA 2 shows the losses during production and distribution of hot water and steam. The hot water is produced by two boilers, which are fuelled with natural gas. The ecoinvent dataset “natural gas, burned in industrial furnace >100 kW” is used. Steam is produced from oil and natural gas. The same inputs defined in the ecoinvent dataset “Steam, for chemical process” are used.

TableA 2 : Losses in the hot water and steam production and distribution (Helbling 2012)

losses	Hot water boilers 1 and 2	Steam boiler
Switching on/off	3.8 %	4.5 %
Operation	14.4 %	14.4 %
Distribution	5 %	5 %

A.1.2. Environmental impacts of the electricity mix

TableA 3 shows the environmental impacts of 1 MJ electricity, medium, voltage, at Rothrist with regard to the ecological scarcity 2006 method. The deposited waste compartment contributes 63 % to the total results. The reason is that electricity at Rothrist is generated with 51.3 % nuclear energy. (Frischknecht, Steiner et al. 2009) explain that the absence of a long-term solution for a repository site for high-level and long-lived wastes was the reason why they computed a high weighting factor for deposited waste. Therefore, nuclear energy is given a larger burden with the ecological scarcity method than the IPCC 2007 method.

TableA 3 : Results of 1 MJ electricity medium voltage, at Rothrist with regard to the ecological scarcity 2006 method

Impact category	Unit	Total	Share
Emission into air	Pt	3.43	3 %
Emission into surface water	Pt	30.1	25 %
Emission into ground water	Pt	0.01	0 %
Emission into top soil	Pt	0.42	0 %
Energy resources	Pt	9.78	8 %
Natural resources	Pt	0.27	0 %
Deposited waste	Pt	75	63 %
Total	**Pt**	**119**	**100 %**

A.1.3. Energy consumption at Rothrist

TableA 9 shows the final results using the amount of primary material computed in TableA 7 and TableA 8 and the linear equations given in FigureA 1.

TableA 9 shows the processes which have been considered to estimate the energy consumption of Rivella and Michel PET and glass bottles (Helbling 2012). Since the beverage is not considered in the analysis, the following processes have been excluded:

- Preparation of the juices
- Preparation of the syrup
- Heating and air conditioning for the buildings
- Cold machines for cooling tanks, laboratories and cold store
- Miroma
- High-Temperature, Short-Time (HTST) pasteurization at line 1, 4 and 5
- Cooling tunnel in line 4
- Icy water cold medium for the beverage

TableA 4 Hot water, Electricity, Steam and Osmosis water consumption at Rivella AG in Rothrist (Helbling 2012)

Process	Hot water [MWh/a]	Electricity [MWh/a]	Steam [MWh/a]	Water [m3/a]	Osmosis water [m3/a]
Steam for line 1 Filling, Sleevematic/line 4 Capping/line 5, Filling			1290	1806	
line 1		1204			
line 1 Wasser-HTST[1)]	88				5371
line 1 PAA Rinser[2)]	49				
line 1 Cap rinser	18				
line 1 CIP	310			6021	
line 2		280			
line 2 Bottles washing machine	436			9866	
line 2 CIP				2970	
line 4		503		339	
line 4 Bottles washing machine	353			4305	
line 4 Rinser	85			2543	
line 4 CIP	221			4760	
line 5		956			13270
line 5 PAA rinser	123				
line 5 PAA Cap rinser	73				
line 5 CIP	145			2815	
CIP line 1+5	560			10800	
Hot water for domestic use	563			2885	
Air compressor '92		1042		27084	8000
Base load	1856				
Rest		596			
Rest (Seal water, washing machine losses, external cleaning…)				87469	

[1)] Water is High-Temperature, Short-Time pasteurized before being used for cleaning caps and bottles

[2)] PAA means peracetic acid and is a antimicrobial agent

A.2. Crown cork production

Habersatter and Fecker (1998) have listed the inventory of the production of 1'000'000 crown cork caps, weighting 2.178 g each. A conversion factor is used to adjust the input values to Rivella 33 cl's crown cork weight. TableA 5 shows the original inventory. The conversion value of 39 MJ/m3 is used to assess the energy consumption of natural gas. Silver coating and adhesives are modelled with the ecoinvent dataset "chemicals, inorganic".

TableA 5 : Inventory for the crown cork production (Habersatter and Fecker 1998)

Input	Unit	Amount
ECCS- Steel	kg	2368.6
Silver coating	kg	5.94
Adhesive	kg	11.32
LDPE Granulate	kg	175
Electricity	kWh	397.16
Natural gas	m^3	22.6
Steel to recycling	kg	382.6
Steel to disposal	kg	4.3
PE to disposal	kg	3.0

A.3. Recycling process

Habersatter and Fecker (1998) have inventoried a recycling process, which is depicted in TableA 6. The amount of biogas mentioned in the inventory is allocated to natural gas. A conversion value of 39 MJ/m3 is used to assess the gas energy demand. The antifoaming and wetting agents are modelled with the ecoinvent dataset "chemicals, inorganic, at plant". The caps and labels are removed because it is assumed that they are all removed at the sorting facility. Therefore, the input of PET-bottles is reduced to 1043.4 kg.

TableA 6 : Inventory for the production of 1000 kg PET-Flakes from post-consumer PET bottles (Habersatter and Fecker 1998)

Input/Output recycling process	Unit	Amount
PET-Bottles (compacted into PET bales)	kg	1158
Antifoaming agents	kg	0.53
Wetting agents	kg	1.58
Electricity	kWh	168
Natural gas	m^3	19.2
Biogas	m^3	0.39
Emissions into air		none
Fresh water consumption	m^3	2.63
Wastewater	m^3	2.11
BOD	kg	0.052
COD	kg	0.284
DOC	kg	0.069
TOC	kg	0.072
Suspended solids	kg	0.003
Disposal of labels to MSWI	kg	68
Recycling of PET fine fractions	kg	47
Recycling of crushed PE	kg	42

A.4. Vetropack packaging glass

TableA 7 and TableA 8 show the quantity of primary minerals that were computed for the shares of 48 % and 76 % cullets in white and brown packaging glass, respectively.

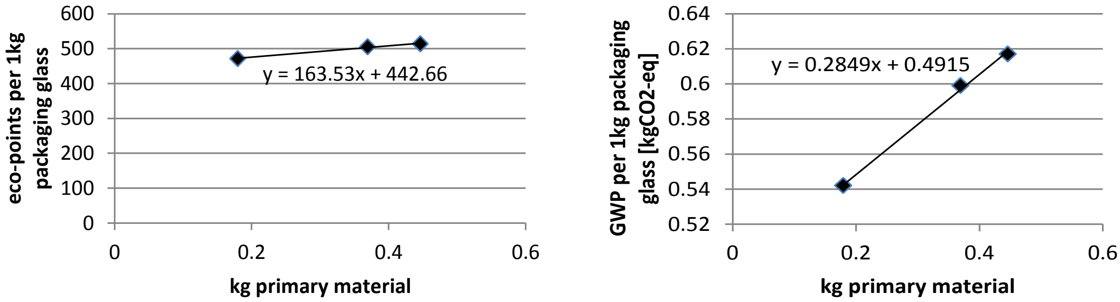
TableA 7 : Amount of primary material in the Vetropack white packaging glass using the ecoinvent dataset « packaging glass, white, at plant/DE"

	White glass/DE						
		ecoinvent		Old shares	New shares	new ecoinvent	ecoinvent
	%	[kg]	%	%	%	%	[kg]
internal cullets	6%						
cullets, sorted	59%	0.625	58%	0.42	0.52	0.48	0.514
sand	20%	0.251	23%	56%	29%	0.29	0.313
soda	6%	0.0761	7%	17%	9%	0.09	0.0950
limestone	4%	0.0471	4%	11%	5%	0.05	0.0588
dolomite	3%	0.0435	4%	10%	5%	0.05	0.0543
feldspar	2%	0.0286	3%	6%	3%	0.03	0.0357
Sum	100%	1.0713	100%	1.00	0.52	1.00	1.071

TableA 8 Amount of primary material in the Vetropack brown packaging glass using the ecoinvent dataset « packaging glass, brown, at plant/DE

	Brown glass/DE						
		ecoinvent		Old shares	New shares	new ecoinvent	ecoinvent
	[%]	[kg]	[%]	[%]	[%]	[%]	[kg]
internal cullets	6%						
cullets,sorted	65%	0.689	65%	0.35	0.24	0.76	0.804
sand	15%	0.195	18%	0.53	13%	0.13	0.134
soda	5%	0.0607	6%	0.16	4%	0.04	0.0417
limestone	3%	0.0402	4%	0.11	3%	0.03	0.0276
dolomite	3%	0.0362	3%	0.10	2%	0.02	0.0249
feldspar	3%	0.0374	4%	0.10	2%	0.02	0.0257
Sum	100%	1.0585	100%	1.00	24%	1.00	1.0585

The amounts of primary minerals in white, green and brown German packaging glass are plotted against the corresponding eco-points and GWP to find a linear equation. FigureA 1 shows the linear equations for the eco-points and GWP results.



FigureA 1 Eco-points (left) and GWP (right) as a function of the amount of primary material per kg packaging glass

TableA 9 shows the final results using the amount of primary material computed in TableA 7 and TableA 8 and the linear equations given in FigureA 1.

TableA 9 : Eco-points and GWP for German packaging glass and Vetropack glass

	Input Primary material [kg per kg glass]	**EP** [EP]	**GWP** [kg CO2-eq]
White glass/DE	0.4463	514	0.617
Brown glass/DE	0.3695	506	0.599
Green glass/DE	0.1797	471	0.542
White glass/Vetropack	0.5571	534	0.650
Brown glass/Vetropack	0.2540	484	0.564
Glass, 100 % primary material	1.19	637	0.831

A.5. Economic allocation of disposal in MSWI

Jungbluth, Chudacoff et al. (2007) describe the method for an economic allocation of the incineration of biowaste. This method is applied to the PET bottle. Values for the net waste thermal energy and waste electric energy produced from the incineration of PET, PE and paper are taken from the ecoinvent dataset on the disposal of PET, PET and paper. They are multiplied with the average selling prices of heat and electricity given by the authors. The addition of the revenues from disposal fees gives the total revenues. The allocation factors are the share of each revenue to the total. TableA 10 shows the allocation factors for the incineration of the PET bottle. TableA 10 and TableA 11 show the allocation factors for the paper label and the PE cap, respectively.

TableA 10 : Economic allocation factors for the disposal of Rivella PET bottle to MSWI

	Unit	Disposal service	Sold heat	Sold electricity
Value amount	kg	1		
Value amount	MJ		5.03	2.46
Fees	CHF/kg	0.2		
Prices	CHF/MJ		0.090	0.283
Revenue	CHF	0.200	0.453	0.696
Allocation factors		**14.83 %**	**34 %**	**52 %**

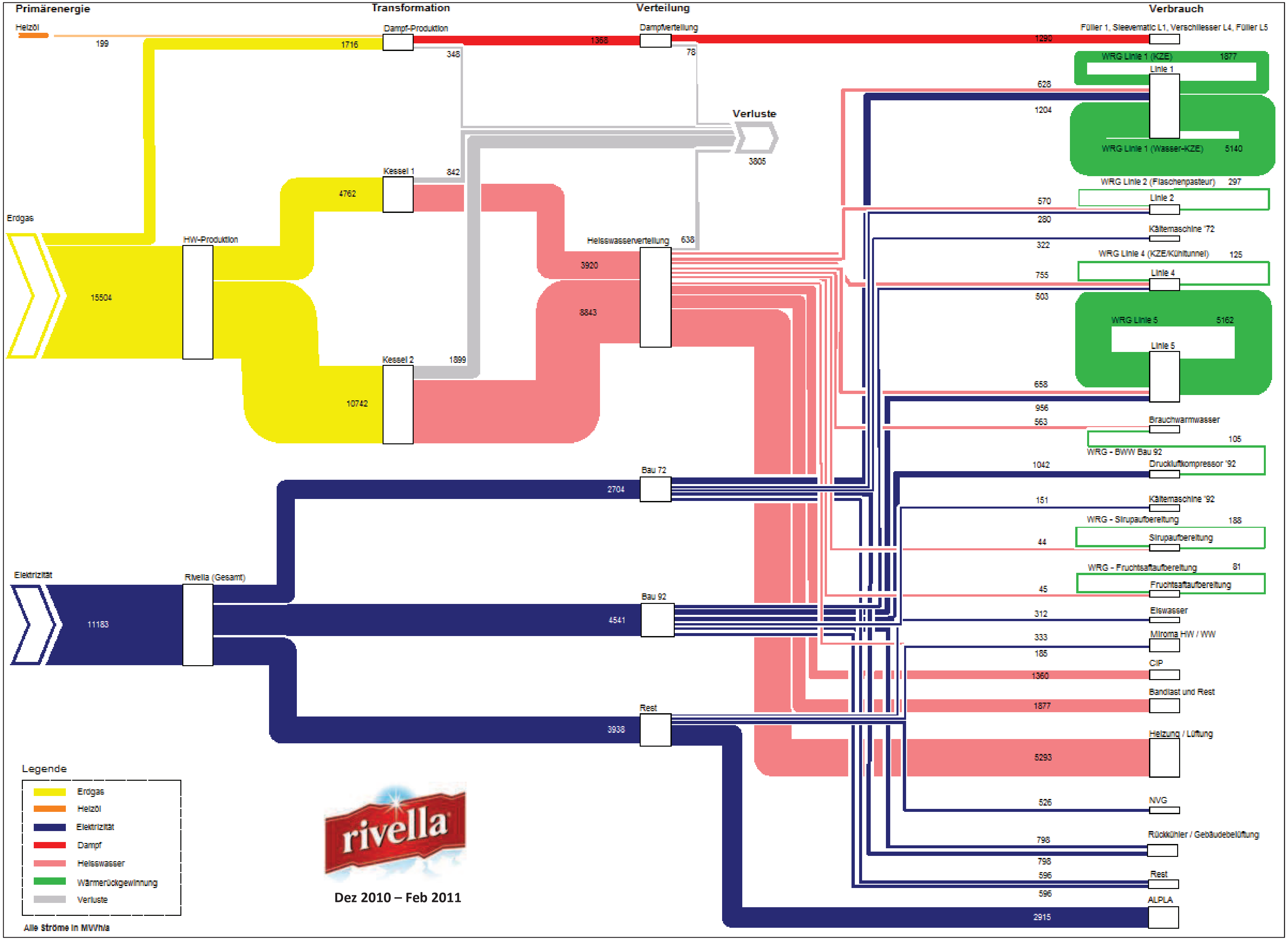
TableA 11 : Economic allocation factors for the disposal of Rivella paper label to MSWI

		Disposal service	Sold heat	Sold electricity
Value amount	kg/MJ	1		
Value amount	MJ		2.77	1.32
Fees	CHF/kg	0.2		
Prices	CHF/MJ		0.09	0.2828
Revenue	CHF	0.200	0.249	0.373
Allocation factors		**24.31 %**	**30.3 %**	**45.4 %**

TableA 12 : Economic allocation factors for the disposal of Rivella PE cap in MSWI

		Disposal service	Sold heat	Sold electricity
Value amount	kg	1		
Value amount	MJ		10.02	5
Fees	CHF/kg	0.2		
Prices	CHF/MJ		0.09	0.2828
Revenue	CHF	0.2	0.9018	1.414
Allocation factors		**7.950 %**	**36 %**	**56 %**

A.6. Sankey energy and Process flow diagram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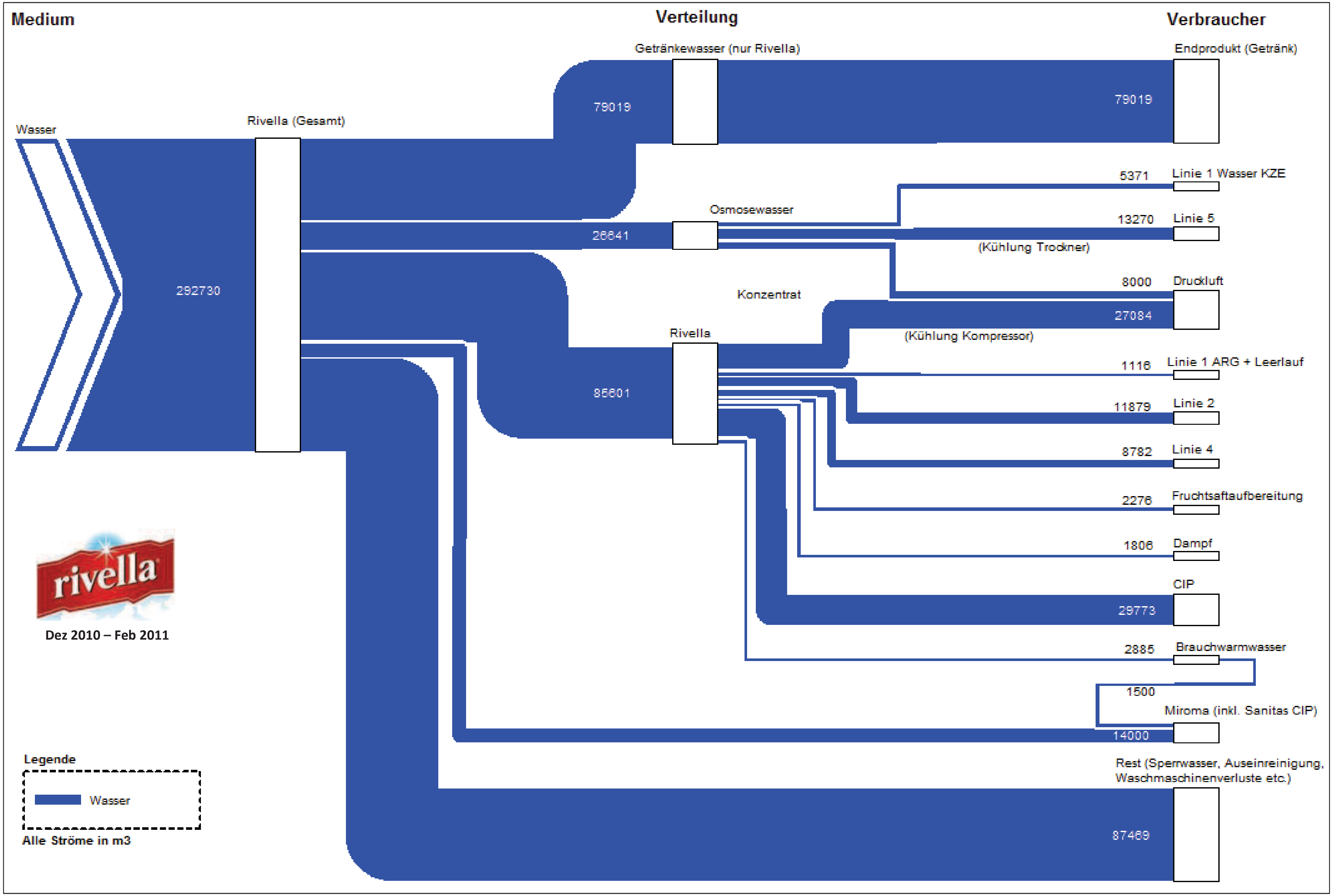
Transformation
Verteilung
Verbrauch
Heizöl
199
Erdgas
15504
Elektrizität
11183
Dampf-Produktion
1716
348
1368
Kessel 1
4762
842
Kessel 2
10742
1899
HW-Produktion
Rivella (Gesamt)
Dampfverteilung
78
Verluste
3805
Heisswasserverteilung
638
3920
8843
Bau 72
2704
Bau 92
4541
Rest
3938
Füller 1, Sleevematic L1, Verschliesser L4, Füller L5
1290
WRG Linie 1 (KZE)
1877
Linie 1
628
1204
WRG Linie 1 (Wasser-KZE)
5140
WRG Linie 2 (Flaschenpasteur)
297
Linie 2
570
280
Kältemaschine '72
322
WRG Linie 4 (KZE/Kühltunnel)
125
Linie 4
755
503
WRG Linie 5
5162
Linie 5
658
956
Brauchwarmwasser
563
105
WRG - BWW Bau 92
Druckluftkompressor '92
1042
151
Kältemaschine '92
WRG - Sirupaufbereitung
188
Sirupaufbereitung
44
WRG - Fruchtsaftaufbereitung
81
Fruchtsaftaufbereitung
45
Eiswasser
312
Miroma HW / WW
333
185
CIP
1360
Bandlast und Rest
1877
Heizung / Lüftung
5293
NVG
526
Rückkühler / Gebäudebelüftung
798
798
Rest
596
596
ALPLA
2915
Legende
Erdgas
Heizöl
Elektrizität
Dampf
Heisswasser
Wärmerückgewinnung
Verluste
Alle Ströme in MWh/a
Dez 2010 – Feb 2011



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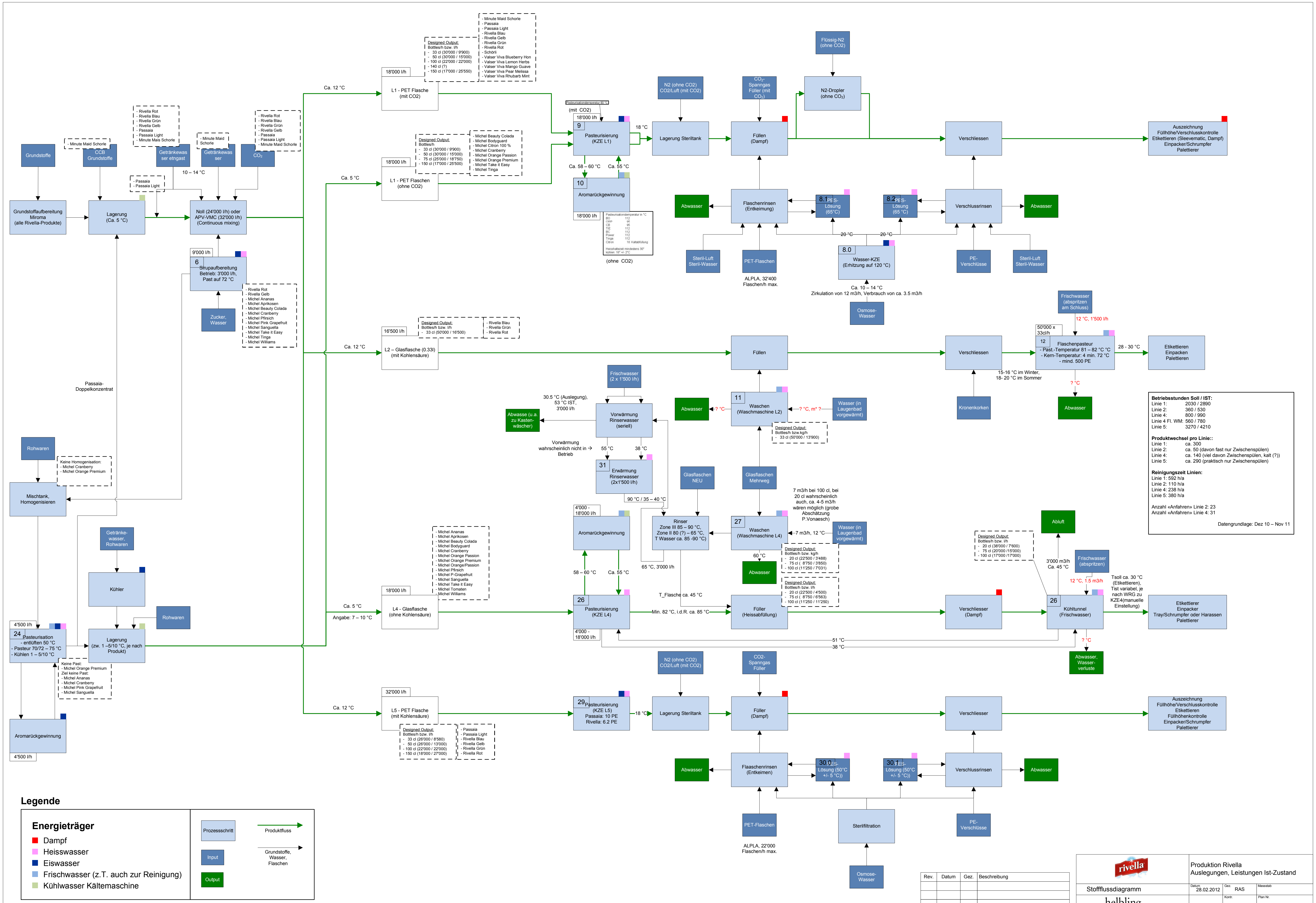

Rev.	Datum	Gez.	Beschreibung
0	09.01.12	BRF	erstellt

rivella

Produktion Rivella
Auslegungen, Leistungen Ist-Zustand

Stoffflussdiagramm

Datum 28.02.2012 | Gez. RAS | Massstab
Kont. | Plan Nr. 313206100_01
Grösse A2 | Vis.

helbling