Interactive product development in recycling systems

- A case study of the Norwegian deposit system for PET bottles

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Abstract

In this paper we have applied the interactive product development approach in combination with the life cycle system approach and put up a framework to evaluate and understand eco-efficiency development of production- and service system, included recycling system. The framework is thereafter applied in a case study of the Norwegian deposit- and recycling system for recyclable one-way PET bottles. The eco-efficiency of this system is quantified before the network of resources and resource interfaces that are believed to have contributed mostly to the development of the selected focal resource of the system, the baled PET bottles sold to recycler in 2002, is identified.

Introduction

The consumption of the plastic polyethylene terephthalate (PET) for beverage bottles purposes has increased considerably every year during the last decade. In the year 2000, 150 billions, or 6 billions kg, one-way recyclable PET bottles were consumed on the global basis (Tomra annual report 2001). In order to take care of the resources used

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bottles represent, and to avoid that these bottles will cause a litter problem in streets or take up space at landfill, recycling systems are established. These systems are usually built up as a result of deposit laws or (voluntary) agreements based on extended producer responsibility for producer and importers of packaging.

In Norway a deposit and recycling system for one-way PET bottles started up in May 2000. In 2002 1150 tones used sorted baled PET bottles, out of 1800 tones consumed, were sold to recyclers in Europe and Asia (Grytli 2003, personal communicatio)

Many studies carried out with various methods have focused on whether recycling is appropriate from an economical- and environmental point of view. Less emphasize has been put on understanding why systems have evolved as they have. The life cycle system approach and the use of the methods of life cycle analyses are widely applied for analysis of the environmental- and/or economic performance (emissions and material- and cash flow) of various types of processes and product- and service systems, including plastic packaging recycling systems, see for example Bruvoll (1999), GUA (1999), Eggels et al (2000), Raadal et al (1999), and Wollrad and Schmied (2000). With these methods, it is also possible to identify where in the recycling loop the most important contributions to the overall performance is. However, in order to acquire a deeper understanding of the creation and development of a recycling product system it is not sufficient to only quantify the cash- and material flow *within* the system to produce the product. For this purpose we have selected the interactive resource development perspective within industrial network theory. This perspective has been used to technological development in a number of studies (Håkansson and Waluszevski 2002a, Wedin 2001, Von Corswant

2003), even though, as far as we know, it has not been applied to understanding product development within recycling systems. It should though be mentioned that recycling was an issue in Håkansson and Waluszevski (2002b) study of development of IKEA's green catalogue paper.

The purpose of this paper is to apply the interactive product development approach on the deposit and recycling of one-way PET bottles in Norway in order to complement the life cycle system approach. We want to illustrate how combining these approaches can be a fruitful approach to understand the eco-efficiency development of the recycling system. The life cycle system approach provides quantitative information on environmental and economic efficiency that can be valuable input to a qualitative analysis by the interactive product development approach. The paper starts with a presentation of theoretical foundation and analytical framework, proceeds with a presentation of the case, before we apply the framework to analyze the case.

Theoretical foundation and analytical framework

This chapter will give a brief overview of the theoretical foundation and analytical framework of life cycle eco-efficiency analysis for systems and the same for interactive resource development in networks. This is followed by a short discussion of the differences between the two frameworks and our aim with combining the two. The chapter ends with a summary of the analytical framework

Life cycle eco-efficiency system analysis

In this section we will present the background for the eco-efficiency indicators for life cycle systems.

The system approach as well as the life cycle perspective is common to life cycle costing (LCC) as well as environmental life cycle assessment (LCA). By using these methods environmental and/or economical performance of a product, process or activity can be quantified. LCA is defined as a systematic mapping and evaluation of health, ecological and resource impact throughout the entire life-cycle of a product from resource extraction to final disposal (ISO, 1997). An LCA comprises four major stages: goal definition, inventory, impact assessment and interpretation and improvement assessment. If we look at the indicator of greenhouse gas emissions, for instance, it should, in the case of a plastic bottle, be calculated by adding CO_2 and other greenhouse gas emissions from the activities of raw material extraction, production of the bottle, bottling, use (storage in fridge etc), collection, sorting, transport and recycling.

However, it is also possible to acquire information about emissions from each of the defined activities in the system, if for example information about how large the transport's contribution to the overall emissions is sought.

The impact indicators from the impact assessment can be used as input to eco-efficiency indicators.

Eco-efficiency was popularised in 1992 in Stephan Schmidheiny's book "Changing course" (Schmidheiny 1992). Since then the concept has been further developed and applied by among others WBCSD (Verfaillie and Bidwell 2000, WBCSD 2000), Fussler (1996), Organisation for Economic Co-operation and Development (OECD 1998), Global Reporting Initiative (1998) and the Norwegian Research Council (2000). The concept has been widely adopted among companies to measure and improve the value added while progressively reducing the environmental influence per product or service to the market. The WBCSD have trough testing developed the following "generally applicable indicators", which they argue are "applicable to virtually all businesses" (Verfaillie and Bidwell 2000):

- <u>Product or service value</u>: *Quantity of product/service sold, net sales*

- <u>Environmental influence:</u> *Energy consumption, water consumption, material consumption, greenhouse gas emissions, ozone depleting substance emissions*

However, the WBCSD approach has mainly emphasized the creation stage and to some extent the user stage of products or services. The "generally applicable" indicators are developed to measure what is "under direct management control" of a company, not to measure the eco-efficiency of the whole life cycle of a process, product or a service. However, as we will show in the analysis section, it can be meaningful to modify and combine and the life cycle approach and WBCSD's generally applicable indicators.

Interactive resource development in networks

Within the NETLOG approach at Norwegian School of Management-BI, the basic idea is that is not sufficient to study actors, activities and resources along one supply, distribution or recycling chain like it is done in life cycle analysis and supply chain analysis in order to acquire information about change (Gadde et al 2002). The life cycle system analytical framework presented above will undoubtedly belong to this category. The reason is that an actor (e.g. recycler), an activity (e.g. transport) and a resource (e.g. bottle) often belong to more than one chain or system, and their participation and interdependencies with actors, activities and resources in other production, distribution and recycling chains will influence their performance in the defined chain/system.

Networks have until recently mainly been studied from an activity (and actor) perspective. However, according to (Gadde et al 2002) it can be argued that resources are the foundation of activities and are thus a very interesting factor to study. Resources are regarded as "facilitators of operations" in supply and distribution networks, included in reverse logistics- or recycling systems

Beside, while actors are connected to identity, and activity to efficiency, resources are connected to change, development and innovation which are the focus of our framework.

But how can we study development of products and other heterogeneous resources?

Resources in industrial networks can be divided into four types: "Products" and "facilities" which represent the technical/physical dimension and "business units" and "business relationship" which cover the organizational aspects (Gadde et al 2002). All four types of resources are highly dependent on each other. In order to produce a product, we need a facility that is owned by a business unit and in order to sell the product we need a business relationship. All of them must be included if the intention is to understand technological development in an industrial setting.

The framework for analyzing how resources are developed, the present use of them, as well as potentials for developing the use of resources in network, is illustrated in figure 1 (Wedin 2001). To study resources in network it is necessary to define a starting point, a focal resource. As an example, a resource network triad consists of three business units, three business relations, three production facilities and three products. In a network triad there are hence eleven possible resource interfaces between the focal resource (here chosen to be a facility) and the rest of the resource elements. We have illustrated five of these resource interfaces in the figure. The resource interfaces are created and developed as a result of interaction between the resource elements Hence, the focal resource, and the other resources and their characteristics and features are developed.

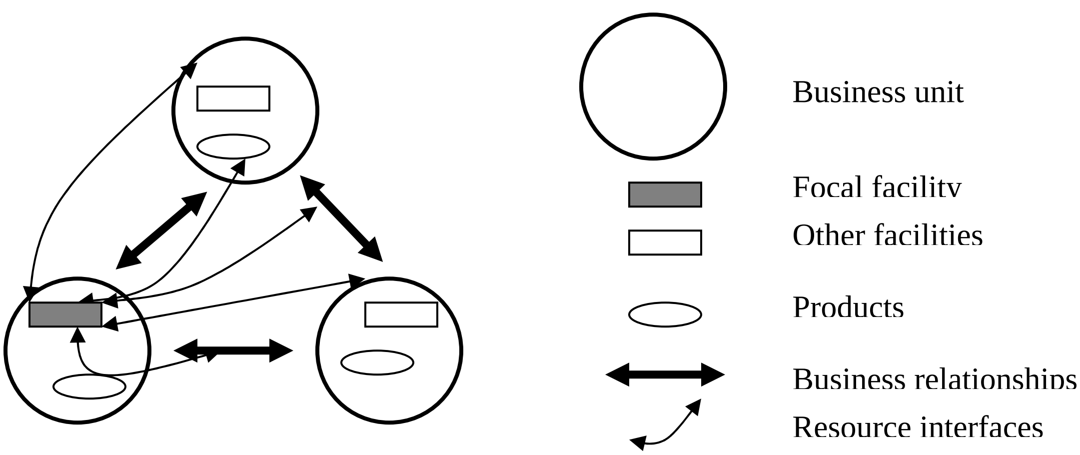

Figure 1: A framework to analyze resources in a network triad

Life cycle system approach vs network approach

There are conflicting views whether or not the system approach and network approach are completely different fields of research. According to von Corswant (2003) the industrial network approach has been inspired by the open systems theory (Scott 1998).

Within the NETLOG-approach, however, the basic idea is that actors, activities and resources belong to more than one chain/system, and their participation and interdependencies with actors, activities and resources in other production, distribution and recycling chains will influence their performance in the defined chain/system (Gadde et al 2002). Influence from resources from the "outside" of the life cycle system should thus be considered and analyzed to understand the development of resources, and thus the performance, in the defined system.

We would argue that another important difference between life cycle (system) analysis and analysis of industrial network is the degree of rigidity. In life cycle analyses clear system borders, system performance and functional unit is defined, while there seems not to be the same degree of pre-determined fixed starting point when analyzing networks of actors, activities and resources. 'A network has no clear boundaries, nor any centre or apex' (Håkansson and Snehota 1989, p.40). Or as Gadde and Håkansson (2001, p.181) put it: 'From an analytical point of view it would be possible to find an optimal solution by defining a clear-cut networks with one specific boundary. But network boundaries are always arbitrary – they are based on perceptions and are continuously changed' Further they argue that it is '…. impossible to come up with a 'master network strategy' taking every aspect into consideration….strategies are always partial and they are valid only for the time being, and must continuously be changed and altered (p.183).

In this paper we are, however, not mainly concerned with the differences or similarities between the approaches. We are rather focusing on why and how the approach of interactive resource development within industrial network theory can contribute to explain the (lack of) eco-efficiency revealed by life cycle analyses.

A summary of the analytical framework

Here a brief summary of the analytical framework is given.

In order to quantify eco-efficiency of a product, process or service and thereafter examine how this resource and its resource characteristics have developed we propose to carry out the following:

1. Identify system borders and functional unit of the product, process or service to study.
2. Develop appropriate eco-efficiency indicators on the basis of WBCSD's generally applicable indicators.
3. Quantify the life cycle eco-efficiency of the defined system
4. Identify most contributing activities to the system's eco-efficiency
5. Select and describe a focal resource (within the system) and its eco-efficiency related characteristics.
6. Identify the focal resource's network of connected resource (characteristics) and resource interfaces
7. Find the resources and resource interfaces that have made a major contribution to the development of the eco-efficiency characteristics of the focal resource.

Presentation of PET bottles in the ”Resirk system”

The increasing use of one-way recyclable PET bottles in recent years in Norway is mainly a result of the Norwegian Ministry of Environment’s decision to reduce environmental tax on one-way beverage packages to a level dependent on the national recycling rates for the current packaging type. The table below shows the relation between the environmental tax per PET bottle and national recycling rates. The tax reduction as well as the basis for calculation of recycling rates only applies for PET bottles which are a participating in the deposit and recycling system “Resirk”. This system is organized and operated by the brewery- and retailer owned non-profit organization Norsk Resirk Ltd, which was launched in 1998, and is approved by, and reports, to the Norwegian Pollution Control Authority.

Recycling rate [%]	Environmental/ packaging tax [NOK/bottle]
0	3,37
25	3.37
50	2.00
75	1.48
95	0.85
100	0.85

1 EUR = 8 NOK (per 28 April 2003)

Table 1: Environmental and packaging tax per PET bottle as a function of national recycling rate

Today more than 130 different types of PET bottles and more than 200 various cans are participating in the Resirk system. In 2002 1800 tones PET bottles were consumed, while 1150 tones, or around 70 %, were collected for recycling purpose. As we can see from figure 2 several actors are a part of the Resirk system for one-way bottles. Norsk

Resirk Ltd has incomes from administration, and supplier, fee from breweries, from sale of the product baled PET to foreign recycler, and from non-claimed deposit. Their costs include, among others, handling fee, pick up fee and baling

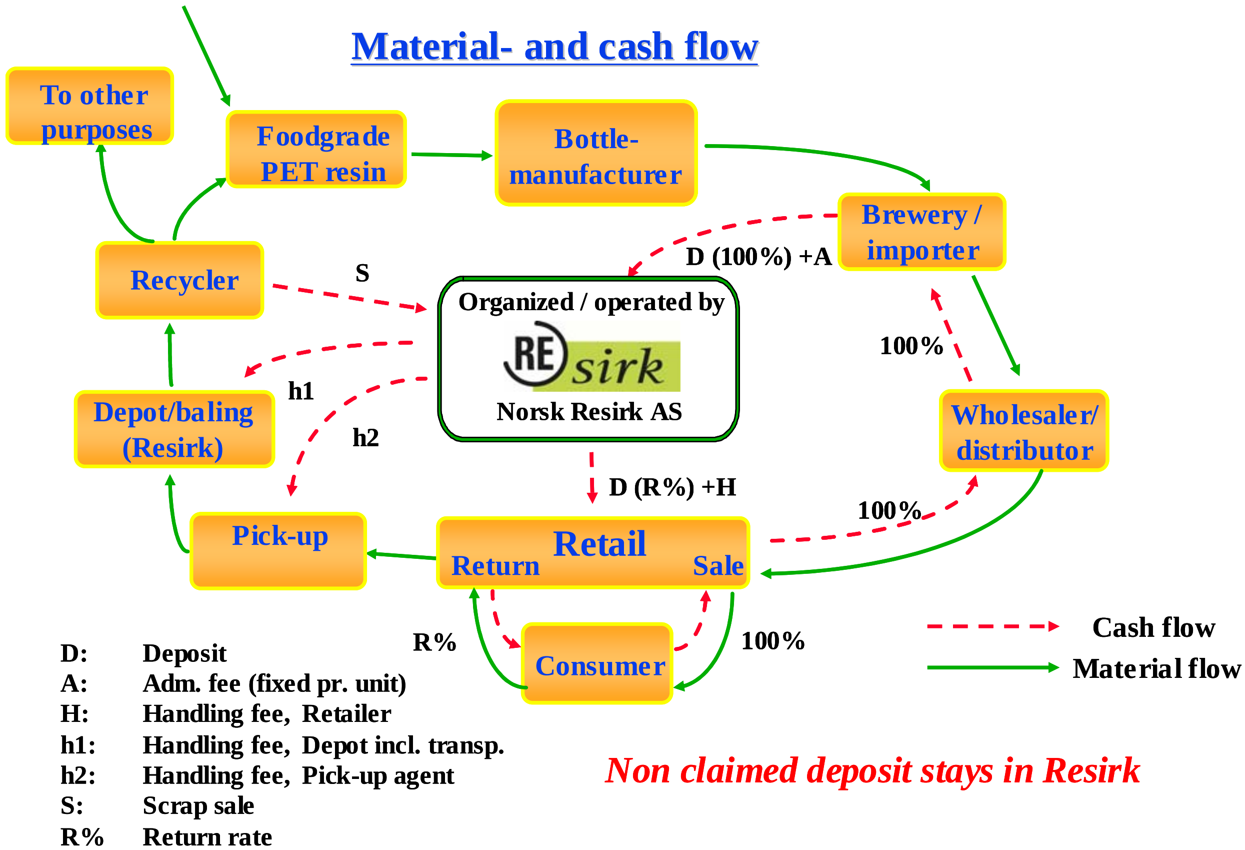

Figure 2: Material- and cash flow in the PET bottles part of the Resirk system.

Analysis – Eco-efficiency and resource development

In this part of the paper we will apply the presented analytical framework on the PET bottles in the Resirk-system. First the eco-efficiency of this system will be quantified. Thereafter, the interactive resource development approach will be applied to examine the development of the eco-efficiency characteristics for the selected focal resource in the system.

System borders and function

The system borders were set to include all the 1800 tones of PET bottles in the Resirk system that producers and importers paid administration fee for in 2002. We are looking at the return, pick up and baling part of the system (see figure 2), which is the part of the recycling system that Norsk Resirk organize. The function of the Resirk system is thus set to be:

To return, compact, pick up, sort, bale and sell PET bottles to recyclers.

Eco-efficiency indicators

Based on the WBCSD's generally applicable indicators previously presented, the following indicators are found appropriate for eco-efficiency evaluation of the Resirk system (Eik et al 2002):

- *Net costs [NOK/ton bale)*
- *Material efficiency [return rate]*
- *Global warming potential [ton CO_2-equivalent/ton bale] emissions*

In the following we will briefly explain how the eco-efficiency indicators should be quanitified for the PET bottles in the Resirk system. We will also present preliminary and approximate eco-efficiency results.

Explanation and calculation of eco-efficiency indicators

Net cost

With this indicator we quantify Norsk Resirk's overall costs of bringing used bottles from consumers to baled bottles ready to be sold to recycler. The term *Net* cost indicates that sales price of the baled bottles is included in this indicator.

The net cost for "producing" baled bottles from used PET bottles was around 20000 NOK (= 2500 EUR) per ton in 2002

Material efficiency

The higher return rate the more material efficient is the recycling system. A return rate of 100 % means that all used bottles end up as baled bottles, while no return at all means no bale production. The return rate of PET bottles in 2002 was 70 %.

CO_2- emissions

The environmental impact indicator of CO_2-emissions is calculated on the basis of emissions from transport, sorting, re-processing and, not at least, avoided emissions when recycled PET is applied as an alternative to virgin PET resin.

The value of this indicator in 2002 are assumed to be approximately -0.9 ton CO_2 per ton baled material produced. This means that for every ton baled material produced in the Resirk system 900 kg CO_2 is saved.

Activities contributing most to the system's eco-efficiency

By carrying out the interpretation phase in the life cycle analyses, we have found that the design of the bottle, what is done in the post consumer phase, compaction of bottles in reverse vending machine, and the final sorting are the activities that influences mostly on the eco-efficiency indicators of the system.

The design of the bottle influences the sales price of the bale, which is included in the *net cost* indicator. The post consumer phase is very important because this is where consumers choose to return or not return the bottle to reverse vending machines in supermarkets or to other bringing point. This influences both the *material efficiency* and the CO_2*-emissions*. The bottles are compacted in the reverse vending machine, and the degree of compaction contributes highly to the pick-up costs and thus the *net costs* of the system. The final sorting at the baling depot is very important in order to produce a high quality bale. This influences the sales price and thus the *net costs.*

Focal resource and its eco-efficiency characteristics

In this part of the analysis we will select a focal resource and examine how the eco-efficiency characteristics of the focal resource of the systems are being developed. In the IMP-approach there is no strict rule of what focal resource to select. However, in studies carried out on interactive resource development the focal resource is chosen on the basis of what product, facility, business unit and business relationship one are concerned about. It should be repeated that each resource has a unique network of connected resources.

We are defining the focal resource to be the product of the recycling part of the Resirk system for PET bottles, namely the *baled bottles* sold to recycler. We will particularly focus on the eco-efficient characteristics of *net cost to acquire* the PET bale. In the following we will identify the resources and resource interfaces that have influenced on the net cost characteristic of the PET bale.

Interactive resource development of baled PET

Through more than ten qualitative research interviews with actors that have to do with the PET bale we have discovered interaction and resource interfaces between the focal resource and other resources. The ones that have had most influence on the net cost of the bale sold to recycler are given in figure 3.

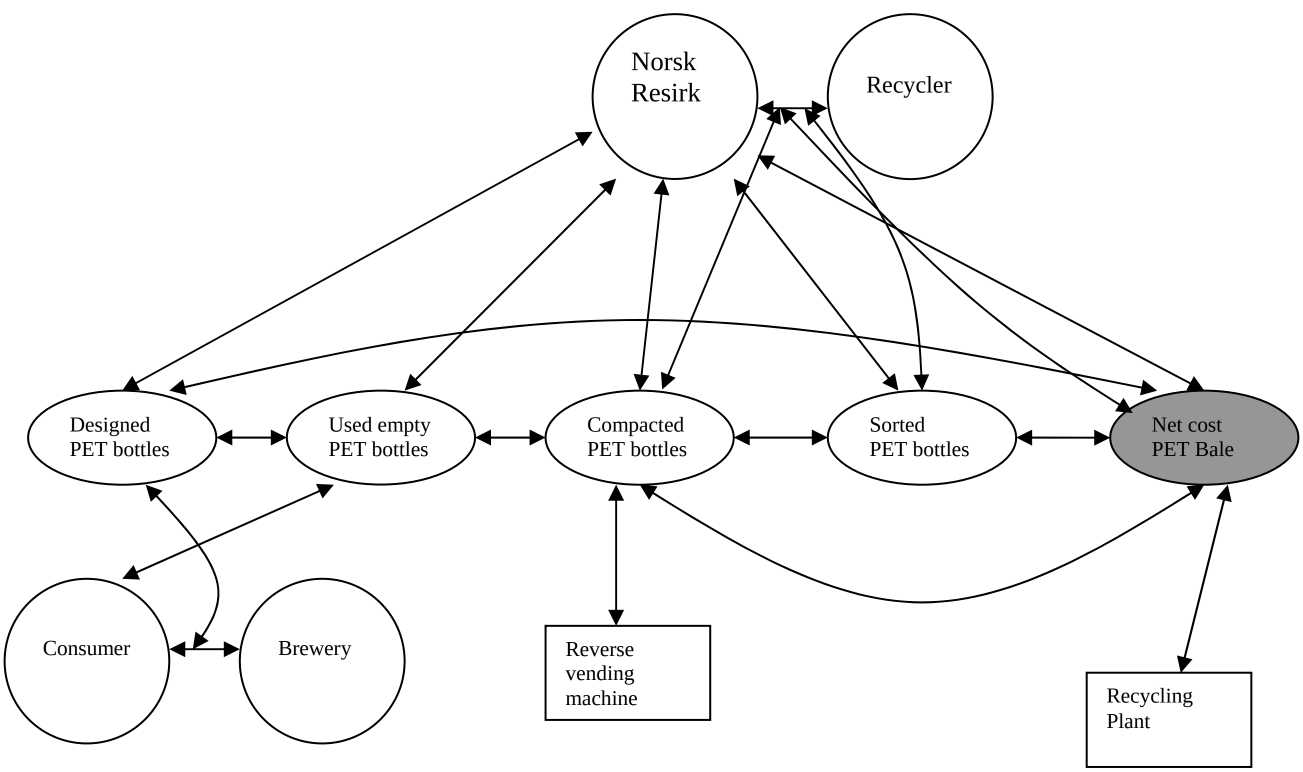

Figure 3: The most influential resources and resource interface on the net cost of the focal

The eco-efficiency characteristics net cost of the bale are *directly* influenced by:

- The product “Sorted PET bottles” to be baled which are decisive to decrease the amount of non-PET material in the bale and thus to increase the sale price
- The product “Compacted PET bottles” since the degree of compaction and degree of filling of compacted bottles are highly influencing on the transport costs and thus the net costs
- The product “Designed PET bottles” because the colour of the PET bottle is decisive for the sales price of the bale.
- The facility “Recycling plant” because the production equipment will influence on the quality demand (and the price) of the focal.
- The business unit Norsk Resirk which owns the PET
- The business relationship between “Norsk Resirk” and “Recycler” because they negotiate on needed quality and corresponding price.

Of *indirectly* influence it is worth to mention the business unit “Consumer” which are deciding the return rate of used bottles, and is influencing the colour of the PET bottles in its relationship with the business unit “Brewery”.

Summary

In this paper we have presented an analytical framework for quantification and understanding of eco-efficiency of recycling systems. In the life cycle system eco-efficiency part of the framework, the eco-efficiency of the recycling system ca be quantified and most eco-efficiency contributing activities can be revealed. In the interactive resource development approach, the development of a selected focal resource in the system can be analysed. This focal resource are developed and gained its eco-efficiency related characteristics through interaction and resource interfaces with embedded resources. This framework is applied on the Resirk system for one-way recyclable PET bottles in Norway. The eco-efficiency analysis shows that the net costs and material efficiency are rather high, while CO_2-emissions indicator shows a considerable contribution to overall savings of this greenhouse gas. The product in the recycling part of the Resirk system, the PET bale sold to recycler, is defined to be the focal resource of the network of related resources. The eco-efficiency characteristics net cost of this focal resource is developed through interaction and resource interfaces with various research items, the most important ones believed to be the products “Sorted PET bottles”, “Compacted PET bottles” and “Designed PET bottles”, the facility “Recycling Plant”, the business unit “Nors Resirk” and the business relationship between “Norsk Resirk” and the Recycler.

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