TransWaste
Formalisation of informal sector activities in collection and transboundary shipment of wastes in and to CEE

Deliverable 3.2.3 and 3.2.5

Comparison of LCA for informal collected waste

and

Comparison of LCA for formal collected waste

6th period of the project TransWaste

Funded by CENTRAL EUROPE

November 2012

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CONTENT

List of Tables

List of Figures

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1 Structure of the report

Deliverable 3.2.3 and Deliverable 3.2.5 are summarized in one report as an comparative assessment was carried out for the formal and the informal collected waste. The data inventory and the scope and boundaries are for both systems similar and need therefore to be fused in one report for better readability. The differences between formal and informal collected waste can furthermore be highlighted. The results of the formal and the informal collected waste are finally compared and the most beneficial processes defined.

Furthermore the report is structured into the three pillars of sustainability. The environmental, the social and the economic assessment for formal and informal collected waste were carried out separately. The procedure and calculations were examined by different project partners. The conclusion sums up the results of all three pillar of the assessment and draws an interpretation of the results.

The intermediate report submitted in the previous period, 5^{th} period, was reviewed and improvements were carried out. This report can therefore replace the previous intermediate report.

Although this report already contains some results of indicator products for the formalized scenario, the comparison of the formal, informal and formalized scenario was not carried out and will be published in D 3.4.1 which is due in the 7^{th} period.

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2 ENVIRONMENTAL ASSESSMENT

2.1 Introduction

The role of the informal sector in waste management strategies in Central Europe cannot be neglected anymore. Waste management companies and associations in Central Europe suffer from losses of valuable materials, which are collected by people in the informal sector coming predominantly from Eastern European countries. Yet, not only so called valuable materials, like metals and waste electrical and electronic equipment (WEEE) are collected but also bulky items, like furniture or household accessories, simply commodities and textiles. In fact they collect everything which can be reused and therefore resold again. In Eastern European countries, like Hungary or Romania there is still a high demand on second-hand commodities.

These informal collection activities are coming along with complaints by various stakeholders such as waste management associations, municipalities or citizens. Littering and unadequate disposal of unsold goods are some of the most reported problems associated with informal activities. Leaching of heavy metals from littering or illegal disposal of WEEE causes serious damages to the environment. Such environmental burdens are accompanied with environmental benefits resulting from reusing goods which are sold by informal collectors. By reusing goods the life time of an item is prolonged and the production of a new product is avoided. This saves energy and resources.

In the framework of the project TransWaste carried out within the CENTRAL EUROPE Programme co-financed by the European Research and Development Fund (ERDF), environmental burdens and benefits from informal activities are evaluated. Representative products for the assessment are chosen according to the following criteria: primarily products which are favoured by informal collectors and which are taken in big amounts; secondly products which are interesting to evaluate in an environmental point of view (e.g. containing hazardous substances). The outcomes of investigation shall help to support further discussions with stakeholders involved in informal sector activities in Central Europe.

2.2 Procedure

Environmental effects are estimated using the methodology of Life Cycle Assessment (LCA) for different scenarios of formal and informal waste collection and treatment. The database ecoinvent® v2.0 is used as data inventory for basic processes, like material production (metals, plastics, etc.) as well as for product assembly. Data from literature is taken for illegal disposal. Additionally data from investigations carried out during the project are considered especially for informal sector activities. The software tool GaBi 4 is used for supporting the calculations.

The following environmental categories were used for the evaluation of the environmental effects:

- Abiotic Depletion (ADP) [kg Sb-Equiv.]
- Acidification Potential (AP) [kg SO_2-Equiv.]
- Eutrophication Potential (EP) [kg Phosphate-Equiv.]
- Global Warming Potential (GWP 100 years) [kg CO_2-Equiv.]
- Human Toxicity Potential (HTP) [kg DCB-Equiv.]
- Ozone Layer Depletion Potential (ODP, steady state) [kg R11-Equiv.]
- Photochem. Ozone Creation Potential (POCP) [kg Ethene-Equiv.]

CML 2001 was used as methodology.

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Signs	Description
-	Informal scenario has less emissions than formal scenario
+	Informal scenario has more emissions than formal scenario

2.3 Scope and boundary

2.3.1 Scenarios

Scenarios considered in the environmental assessment cover both formal and informal activities. The formal scenario is necessary to provide a baseline scenario without informal collections at all. The informal scenario includes the collection, transboundary shipment and reuse of collected goods as well as unadequate disposal in connection with the activities. Figure 1 shows the scenarios in detail for origin and receiving countries. In the scope of TransWaste Austria and Germany are counted to origin countries and Poland, Hungary and Slovakia to the receiving countries.

In the formal scenario indicator products are produced and used at home for a respective amount of years. The used used indicator products are taken to the waste collection centre and sent to disposal according to national waste management system. This process is carried out in both the origin country and the receiving country. As the used product is not reused in the receiving country in the formal scenario a new product need to be produced (I_Formal).

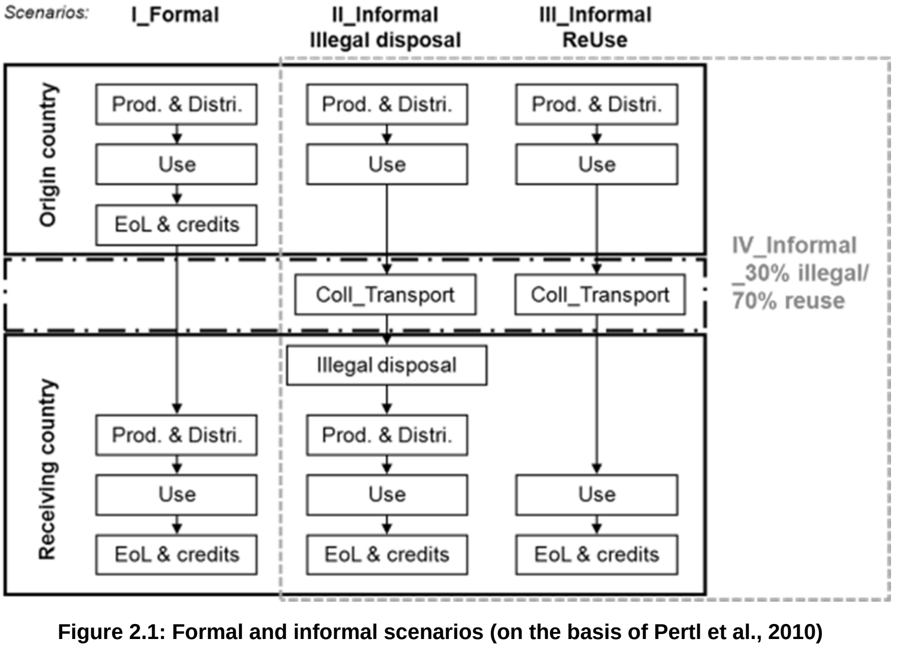
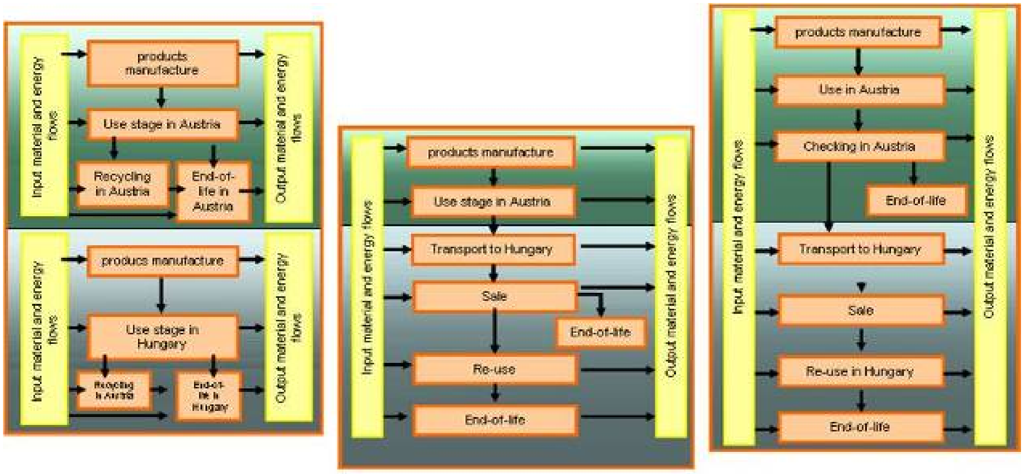


Figure 2.1: Formal and informal scenarios (on the basis of Pertl et al., 2010)

Also in the informal scenarios indicator products are produced and used at home for a respective amount of years. The used indicator products are taken to the waste collection centre, but then the difference to the formal scenario occurs. Informal collectors take the used indicator products and bring them to their home countries (receiving countries). It was assumed that 30% of the devices can't be resold and are assumed to be disposed illegally (II_Informal Illegal disposal). 70% of the devices are sold and reused (III_Informal ReUse). At the end of the second lives the indicator products are disposed of in a formal way, but in the receiving country.

The scenarios are modelled for three different situations. Materials are taken from Austria to Hungary (AT-HU), from Austria to Slovakia (AT-SK) and from Germany to Poland (DE-PL).



I_Formal **IV_Informal (II+III)** **V_Formalized**

Figure 2.2: Formal, informal and formalized scenarios on the example of AT-HU

Summarized the following scenarios and terms are used in this assessment:

Table 2.1: Scenario descriptions and terms used

Scenario	Description	Term used in this document
Formal	Process activities are carried out in a formal way.	Formal
Informal	Process activities are carried out in an informal way. One part is disposed illegally; one part can be reused (Status quo). (30% informal disposal/70% reuse)	30/70
Formalized	Former informal process activities are carried out in a formalized way. (5% informal disposal/95% reuse)	5/95

2.3.2 Indicator products

Certain indicator products were chosen by the partners in TransWaste for the assessment. The following characteristics were chosen for indicator products:

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- Products, which are sold at the flea market in Devecser
- Products, which are preferred by the informal collector
- Products, which are relevant according to their environmental effects
- Products, which are relevant for our stakeholders

The following indicator products are therefore assessed in the next chapters:

- Plastic garden chair
- Steel product
- Wood panel (treated)
- Textiles
- Tyres
- Desktop computer
- CRT screen
- Fridge
- Washing machine
- Bicycle
- Couch
- Lawnmower
- LCD TV

2.3.3 Transport

In the scope of the assessement the following transports and means of transports were considered:

- Transport by households to the WCC: 2 km with passenger car. It was assumed that an average household needs to drive 2 km to bring their waste to the WCC (round trip).
- Transport by informal collectors from WCC to the markets to sell the products: 300 km with van (<3.5t). Former investigations have shown that 300 km is the average driving distance of informal collectors (round trip) for the cases AT-HU and AT-SK and that the most used means of transport is the van with <3.5t. For DE-PL cases the distance is longer; it is estimated as 200 km as a minimum and 800 km as a maximum. However, for the environmental assessment the distance of 300 km was also taken for DE-PL to ensure better comparability between the core regions.
- Transport by recycling and disposal companies to recycling and disposal facilities: 200 km with 16 t lorry. The distance was estimated.

Transportation which is not included in the assessment is the way from the market, where reusable items are sold to the households, where the items are used. The customer characterisation of the market was not investigated in the course of the project. Therefore it is not known if the customers come from the region or from the further East of the countries, or even from abroad. The distance for transport can therefore not been estimated. Yet, the transportation from the shops, where new products are bought to the households is also not considered. As these transportation routes are similar and appear in all scenarios, no differences in the transport is expected in this case. Therefore this transportation route can be neglected in the assessment.

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2.3.4 Credits in the EoL phase

For the environmental assessment benefits from recycling and from waste incineration with electricity and heat usage were considered as credits.

For the recycling certain credits were given on the basis of the amount of materials which are recycled. The according credits are stated in each chapter. Inverse datasets of primary materials are given as credits.

For the waste incineration benefits arise in form of heat and electricity. The efficiency of waste incineration plants was considered on the basis of Ecoinvent datasets, as the efficiency of plants from each country is hard to quantify. Ecoinvent (Doka, 2003) uses for waste a calorific value of 11.74 MJ/kg. Outputs in average operation with an input of 1 kg waste are 2.164 MJ heat and 1.007 MJ of electricity. It leads to an overall efficiency rate of 27%. Credits on heat and electricity production are therefore given based on an electricity generation efficiency of 9% and heat generation efficiency of 18%.

2.4 Data inventory

2.4.1 Plastic garden chair

2.4.1.1 System characterisation

Figure 2.3: Plastic garden chair of SIEGER (left), plastic garden chair collected by informal collectors (right)

A plastic garden chair of SIEGER was chosen for the assessment. It is made of polypropylen (PP).

Table 2.2: Scenario description – plastic garden chair

	Phase	Formal scenario	Informal scenario	
			Informal_EoL (30%)	**Informal_Reuse (70%)**
○	Production	Production of new plastic	Production of new plastic chair	

		chair		
	Use	Use of plastic chair	Use of plastic chair	
	EoL	Collection in WCC. Disposal: AT: WIP: 98,5, MR: 1%, RU: 0,5% DE: MR: 61.4%; WIP: 28.9%, MBT: 6.5%; TT: 3.2%;	Collection by informal bulky waste collector and transported to Hungary.	
Receiving country	Production	Production of new plastic chair	-	Sale of used plastic chair at flea market
	Use	Use of plastic chair	-	Use of used plastic chair
	EoL	Collection in WCC. Disposal: HU: LF: 91.1%; WIP: 8.9% PL: LF: 85%; TT: 12.5%; MR: 5%; MBT: 2%; WIP: 0.5% SK: LF: 78%; WIP: 17%, MR: 5%	Illegal disposal (landfilled) HU: 100% LF PL: 100% LF SK: 100% LF	Collection in WCC. Disposal: HU: LF: 91.1%; WIP: 8.9% PL: LF: 85%; TT: 12.5%; MR: 5%; MBT: 2%; WIP: 0.5% SK: LF: 78%; WIP: 17%, MR: 5%

ID … Illegal disposal
LF … Landfill without treatment in advance
LFwT … Landfill with mechanical treatment
MBT … Mechanical biological treatment
MR … Material recycling
O … Other
RU … ReUse
TT … Thermal treatment
WIP… waste incineration plant

2.4.1.2 Formal scenario

In the formal scenario a plastic garden chair is produced under European conditions and bought by the consumer in the origin country as well as in the receiving country. It is used and when not needed anymore disposed of, meaning given to bulky waste collections. In Austria a plastic garden chair will end up in the bulky waste fraction and is then shredded and taken to a waste incineration. Only a small percentage is recycled and reused. In Germany the plastic garden chair will end up to 61.4% at material recycling plant and to 28.9% at waste incineration. 3.2% end in another thermal treatment plant and 6.5% in a MBT. In Hungary the situation is different. 8.9% end up at waste incineration. The disposal route of the rest is unspecified. It is assumed that the rest is landfilled. In Slovakia 17% ends up at waste incineration, only 5% at material recycling and the major part, 78% is landfilled. In Poland the majority, 65% is also landfilled. 20% is mechanically treated and then landfilled. The mechanical treatment was neglected in the assessment. 0.5% ends up at waste incineration plants and 12.5% at another thermal treatment plant. 2% is sent to MBT.

The production of the chair out of polypropylene granulate is assumed to undergo an extrusion process to form a semi-finished product out of granulate and then to be thermoformed to receive the final product. No emissions were considered which originate in the use phase of the product. For the material recycling a recycling rate of 80% was assumed, meaning that the recycling replaces 80% of primary produced polypropylene. As no data on the mechanical and biological treatment process are available, it was modelled following a shredder plant and an incineration, as a plastic chair would end up in the high caloric fraction of the MBT. It is possibly overestimated as the shredding process in Ecoinvent considers WEEE shredding. The electricity consumption for shredding polypropylene is presumably lower, but due to lack of data this process is taken as an assumption. Concerning other thermal treatment, no corresponding data is available. It was therefore modelled as waste incineration.

Table 2.3: Data inventory on formal scenario, plastic garden chair

Name of the process	**Formal – Plastic garden chair**
Process description	A plastic garden chair is produced out of PP and used at home for an unspecific amount of years. The chair is taken to the waste collection centre and disposed of according to national waste management system.
Reference unit	kg
Area of application	Production of chair under consideration of European conditions, end of life under national conditions (electricity, waste management system) and Swiss conditions (esp. waste incineration)
Completeness of the process	Use and reuse of chair is excluded as no emissions are expected in this phase. Transport to the collection centre (passenger car, 2 km) included. Transport to disposal facilities included (lorry 16-32t, 200 km). Emissions from the recycling process are not included.
Credits	Benefits for recycling of polypropylene with a recycling rate of 80% Calorific value of PP: 44 MJ/kg
Comments on credits	Inverse datasets of primary materials were given as credits Credits on heat and electricity production are given based on an electricity generation efficiency of 9% and heat generation efficiency of 18%.
Used processes	Production: RER: polypropylene, granulate, at plant RER: extrusion, plastic pipes RER: thermoforming, with calendering Disposal:

	CH: disposal, polypropylene, 15.9% water, to sanitary landfill CH: disposal, polypropylene, 15.9% water, to municipal incineration
Comments on the choice of used processes	The choice of the processes for production of the chair is taken because of hints in the documentation in the Ecoinvent report (Hischier, 2007) and assumptions.
Factor for functional unit	1 piece is 2 kg (assumed)

2.4.1.3 Informal scenario

In the informal scenario a division of 30% illegal disposal and 70% resale was assumed. The illegal disposal was assessed like the formal landfilling. A burning in open fire places was not considered.

Table 2.4: Data inventory on informal scenario, plastic garden chair

Name of the process	**Informal – Plastic garden chair**
Process description	A plastic garden chair is produced out of PP and used at home for an unspecific amount of years. The used chair is taken by informal collectors who bring it to receiving countries. 30% of the devices can't be resold. It is assumed that this part is dumped in uncontrolled sites. 70% of the devices are sold and reused for the same amount of years as a new chair. At the end of their lives they are disposed of in a formal way.
Reference unit	kg
Area of application	Production of garden chair under consideration of global conditions, end of life: waste management system under national conditions, energy use under European conditions (RER) and technology under Swiss conditions (esp. waste incineration)
Completeness of the process	Use and reuse of chair is excluded as no emissions are expected in this phase. Transport to the collection centre (passenger car, 2 km) included. Transport to disposal facilities included (lorry 16-32t, 200 km). Emissions from the recycling process are not included. The disposal of unsold products was assessed like the formal landfilling. A burning in open fire places was not considered. Transport from origin to receiving country by informal collectors included (van, 300 km).
Credits	Benefits for recycling of polypropylene with a recycling rate of 80% Calorific value of PP: 44 MJ/kg
Comments on credits	Inverse datasets of primary materials were given as credits Credits on heat and electricity production are given based on an

	electricity generation efficiency of 9% and heat generation efficiency of 18%.
Used processes from Ecoinvent (product specific)	Production: RER: polypropylene, granulate, at plant RER: extrusion, plastic pipes RER: thermoforming, with calendering Disposal: CH: disposal, polypropylene, 15.9% water, to sanitary landfill CH: disposal, polypropylene, 15.9% water, to municipal incineration
Comments on the choice of used processes	The choice of the processes for production of the chair is taken because of hints in the documentation in the Ecoinvent report (Hischier, 2007) and assumptions.
Factor for functional unit	1 piece is 2 kg (assumed)

2.4.1.4 Results

The results of the assessment of a garden chair show in each scenario a great influence of the production process and the disposal process, as well as the transport to the receiving country by informal collectors in case of the ODP.

When considering the results of scenario AT-HU, shown in Figure 2.4 and Table 2.5, it can be noticed that the informal scenario is in all categories better than the formal scenario, except with EP and ODP. The reason for this is that the disposal of a garden chair in Hungary mainly happens via landfill. The EP is therefore affected from the landfilling of the PP chair in both formal and informal scenario. As in the informal scenario those 30% which can’t be sold and end up at landfill without reuse another product will be bought instead, the emissions affecting the EP in the disposal phase is therefore increasing. The ODP is affected from the waste incineration of the PP chair. As the calorific value with 44 MJ/kg is very high, the benefits from incineration in Austria are also high. The relative results of the ODP are therefore outstanding from the results of other categories. Those benefits only occur in the formal scenario as the end of life phase in Austria is affected. In the informal scenario where the end of life phase is in Hungary, it doesn’t occur.

The results of the formalized scenario, in Table 2.5, show a decrease of the EP because of the achieved waste prevention in the formalized scenario compared to the informal scenario. The formalized scenario therefore shows better results as the formal scenario in all considered categories, except the ODP which is due to the high benefits from the waste incineration in Austria.

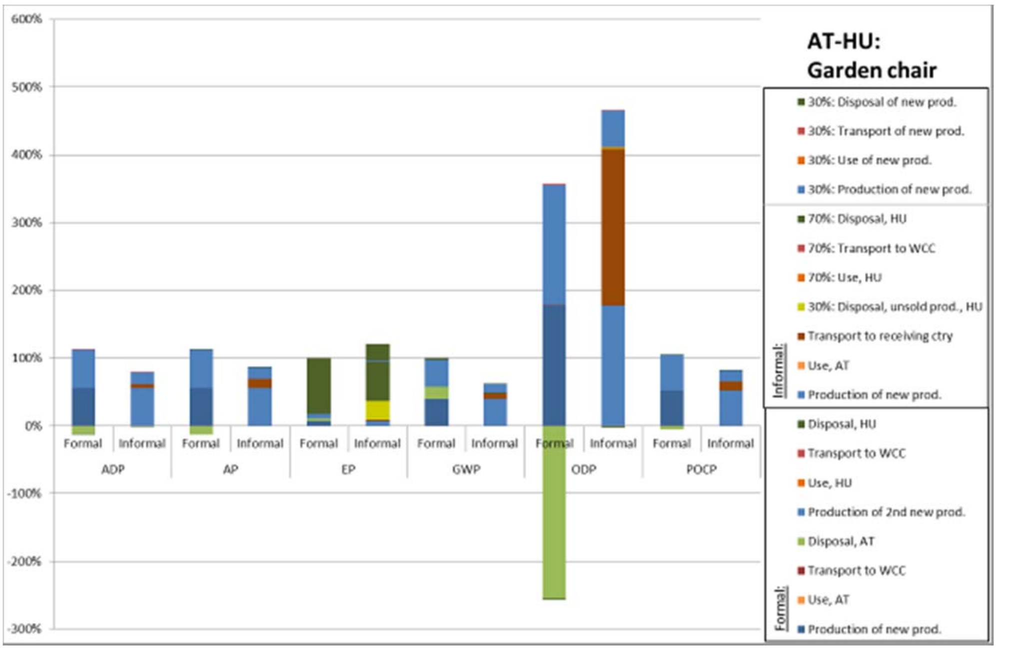

Figure 2.4: Relative results of formal and informal scenario by environmental indicators, plastic garden chair, AT-HU

Table 2.5.: Absolute results of each scenario by environmental indicators, garden chair, 1 kg collected product, AT-HU

Env. Category	Unit	Formal	Informal 30/70		Formalized 5/95	
ADP	Kg Sb-Equiv.	7,07E-02	5,54E-02	-	4,54E-02	-
AP	Kg SO_2-Equiv.	2,00E-02	1,73E-02	-	1,44E-02	-
EP	Kg Phosphate-Equiv.	1,79E-02	2,16E-02	+	1,73E-02	-
GWP	Kg CO_2-Equiv.	7,55E+00	4,71E+00	-	3,94E+00	-
HTP	kg DCB-Equiv.	3,96E+00	3,20E+00	-	2,60E+00	-
ODP	Kg R11-Equiv.	3,49E-08	1,62E-07	+	1,46E-07	+
POCP	kg Ethene-Equiv.	4,32E-03	3,53E-03	-	2,96E-03	-

The relative results of the AT-SK scenario, see Figure 2.4, are comparable with the AT-HU scenario. The end of life phase is the crucial factor for the higher emissions of the informal scenario considering EP and ODP. The absolute results, shown in Table 2.6, are also in the same dimension as in the AT-HU scenario.

The results of the formalized scenario of AT-SK show also fewer emissions than the formal scenario, except when considering the ODP.

The DE-PL scenarios show a slightly different picture, as the incineration of the chair doesn't play a significant role like in the AT-HU and AT-SK scenarios. In Germany the majority goes to material recycling. The benefits of the material recycling are in this case less than from incineration. However, EP and ODP also show higher emissions of the informal scenario compared to the formal scenario. The EP is affected by the landfilling in Poland and the ODP is clearly affected by the transport to Poland by informal collectors. The absolute results, shown in Table 2.7, are in the same dimension like the results of AT-HU and AT-SK except for the ODP.

In the formalized scenario the EP decreases compared to the informal scenario, but not to the formal scenario. The formalized scenario for DE-PL shows therefore less emission than the formal scenario except for EP and ODP.

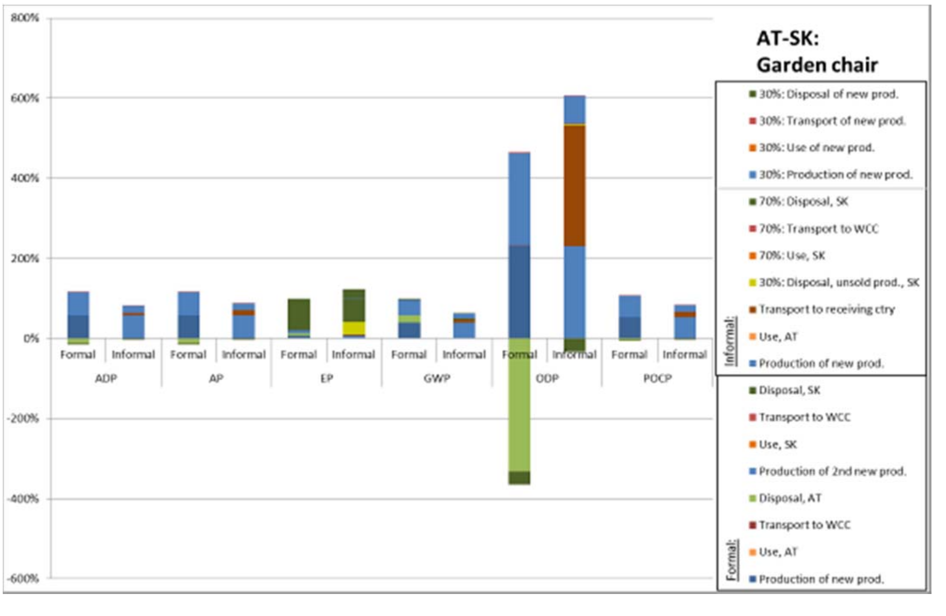

Figure 2.5: Relative results of formal and informal scenario by environmental indicators, plastic garden chair, AT-SK

Table 2.6: Absolute results of each scenario by environmental indicators, garden chair, 1 kg collected product, AT-SK

Env. Category	Unit	Formal	Informal 30/70		Formalized 5/95	
ADP	Kg Sb-Equiv.	6,88E-02	5,34E-02	-	4,34E-02	-
AP	Kg SO_2-Equiv.	1,96E-02	1,68E-02	-	1,39E-02	-
EP	Kg Phosphate-Equiv.	1,58E-02	1,95E-02	+	1,52E-02	-
GWP	Kg CO_2-Equiv.	7,57E+00	4,73E+00	-	3,97E+00	-
HTP	kg DCB-Equiv.	3,80E+00	3,04E+00	-	2,44E+00	-
ODP	Kg R11-Equiv.	2,68E-08	1,54E-07	+	1,37E-07	+
POCP	kg Ethene-Equiv.	4,23E-03	3,44E-03	-	2,87E-03	-

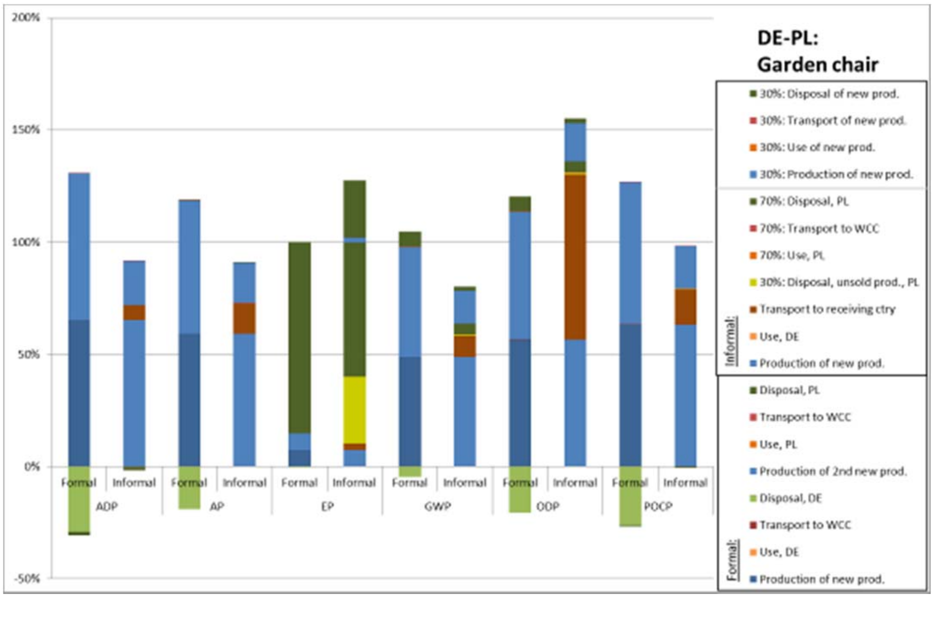

Figure 2.6: Relative results of formal and informal scenario by environmental indicators, plastic garden chair, DE-PL

Table 2.7: Absolute results of each scenario by environmental indicators, garden chair, 1 kg collected product, DE-PL

Env. Category	Unit	Formal	Informal 30/70		Formalized 5/95	
ADP	Kg Sb-Equiv.	6,09E-02	5,48E-02	-	4,48E-02	-
AP	Kg SO_2-Equiv.	1,90E-02	1,73E-02	-	1,44E-02	-
EP	Kg Phosphate-Equiv.	1,62E-02	2,06E-02	+	1,63E-02	+
GWP	Kg CO_2-Equiv.	6,07E+00	4,88E+00	-	4,11E+00	-
HTP	kg DCB-Equiv.	3,19E+00	3,17E+00	-	2,57E+00	-
ODP	Kg R11-Equiv.	1,10E-07	1,70E-07	+	1,54E-07	+
POCP	kg Ethene-Equiv.	3,56E-03	3,48E-03	-	2,91E-03	-

2.4.2 Steel product

2.4.2.1 System characterisation

A steel product out of low-alloyed or unalloyed steel may be lifter, a standpipe etc., pieces which were seen at the market in Devecser and which are sold because of their use as a product and not because of their material value. It is compared in the assessment, whether the disposal and recycling of metal pieces of stainless steel is environmentally advantageous or the reuse and disposal after a longer life time.

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Figure 2.7: Metal pieces sold at the market in Devecser for their functionality (pictures were taken 24th September 2011)

Table 2.8: Scenario description – Steel product

	Phase	Formal scenario	Informal scenario	
			Informal_EoL (30%)	**Informal_Reuse (70%)**
Origin country	Production	Production of new steel product	Production of new steel product	
	Use	Use of steel product	Use of steel product	
	EoL	Collection in WCC. Disposal: AT: MR: 100% DE: MR: 100%	Collection by informal bulky waste collector and transported to Hungary.	
Receiving country	Production	Production of new steel product	-	Sale of used steel product at flea market
	Use	Use of steel product	-	Use of used steel product
	EoL	Collection in WCC. Disposal: HU: MR: 100% PL: MR: 62%, LF: 38% SK: MR: 100%	Illegal disposal (landfilled) HU: 70%MR, 30%LF PL: 70%MR, 30%LF SK: 70%MR, 30%LF	Collection in WCC. Disposal: HU: MR: 100% PL: MR: 62%, LF: 38% SK: MR: 100%

ID … Illegal disposal

LF … Landfill without treatment in advance

LFwT … Landfill with mechanical treatment
MBT … Mechanical biological treatment
MR … Material recycling
O … Other
RU … ReUse
TT … Thermal treatment
WIP… waste incineration plant

2.4.2.2 Formal scenario

In the formal disposal scenario the majority of steel products are recycled. Only in Poland the recycling of 61.6% takes place. The rest ends up at landfills.

Table 2.9: Data inventory on formal scenario, steel product

Name of the process	Formal – Steel product
Process description	A steel product out of low-alloyed steel is produced and used at home for an unspecific amount of years. The steel product is taken to the waste collection centre and disposed of according to national waste management system.
Reference unit	kg
Area of application	Production of steel device under consideration of European conditions, end of life: waste management system under national conditions and technology under Swiss conditions.
Completeness of the process	Use and reuse of the steel product is excluded as no emissions are expected in this phase. Transport to the collection centre (passenger car, 2 km) included. Transport to disposal facilities included (lorry 16-32t, 200 km). Emissions from recycling process are included.
Credits	Benefits for the recycling of steel with a recycling rate of 89.6%
Comments on credits	Inverse datasets of primary materials were given as credits minus emissions from recycling process.
Used processes	Production: RER: steel, low-alloyed, at plant Disposal: CH: disposal, dust, unalloyed EAF steel, 15.4% water, to residual material landfill
Comments on the choice of used processes	As no process for the landfilling of steel exists in the Ecoinvent-database, a similar process “CH: disposal, dust, unalloyed EAF steel, 15.4% water, to residual material landfill” was chosen.

Factor for functional unit	Density of steel product: 200 kg/m³

2.4.2.3 Informal scenario

Table 2.10: Data inventory on informal scenario, steel product

Name of the process	**Informal – Steel product**
Process description	A steel product is produced and used at home for an unspecific amount of years. The used product is taken by informal collectors who bring it to receiving countries. 70% of the devices are sold and reused for the same amount of years as a new product. At the end of their lives they are disposed of in a formal way according to national waste management system. 30% of the devices can't be resold. 70% of unsold products are assumed to end up at material recycling and 30% to landfill.
Reference unit	kg
Area of application	Production of steel device under consideration of European conditions, end of life: waste management system under national conditions and technology under Swiss conditions.
Completeness of the process	Use and reuse of the steel product is excluded as no emissions are expected in this phase. Transport to the collection centre (passenger car, 2 km) included. Transport to disposal facilities included (lorry 16-32t, 200 km). Emissions from recycling process are included. Transport from origin to receiving country by informal collectors included (van, 300 km).
Credits	Benefits for the recycling of steel with a recycling rate of 89.6%
Comments on credits	Inverse datasets of primary materials were given as credits minus emissions from recycling process.
Used processes	Production: RER: steel, low-alloyed, at plant Disposal: CH: disposal, dust, unalloyed EAF steel, 15.4% water, to residual material landfill
Comments on the choice of used processes	As no process for the landfilling of steel exists in the Ecoinvent-database, a similar process "CH: disposal, dust, unalloyed EAF steel, 15.4% water, to residual material landfill" was chosen.

Factor for functional unit	Density of steel product: 200 kg/m³

2.4.2.4 Results

The results of the assessment of a steel product show clearly the major impact of the production of the steel. Due to the avoided production of reused steel products the emissions of the informal scenario are a little lower than the formal scenario. This can be noticed in all three cases AT-HU (Figure 2.8), AT-SK (Figure 2.9) and DE-PL (Figure 2.10). An exception is the ODP. Here the transport to the receiving country by the informal collectors increases the emissions in the informal scenario that much so that the total emissions are higher than the ones from the formal scenario.

When considering the absolute results, it can be seen that the difference between formal and informal scenario are in each case AT-HU (Table 2.11), AT-SK (Table 2.12) and DE-PL (Table 2.13) rather marginal. The benefits due to the material recycling in the formal scenario are therefore comparable with the benefits of the reuse of the steel product in the informal scenario. An exception is the HTP. Here the emissions of the informal scenario are in each case significantly lower than in the formal scenario. The absolute results of AT-HU and AT-SK are exactly the same as the same processes were taken in these cases.

In the formalized scenario those steel products don't occur anymore, as metals won't be allowed to take. Results for the formalized scenario are therefore not given. The formal scenario would instead apply for steel products in the formalization process.

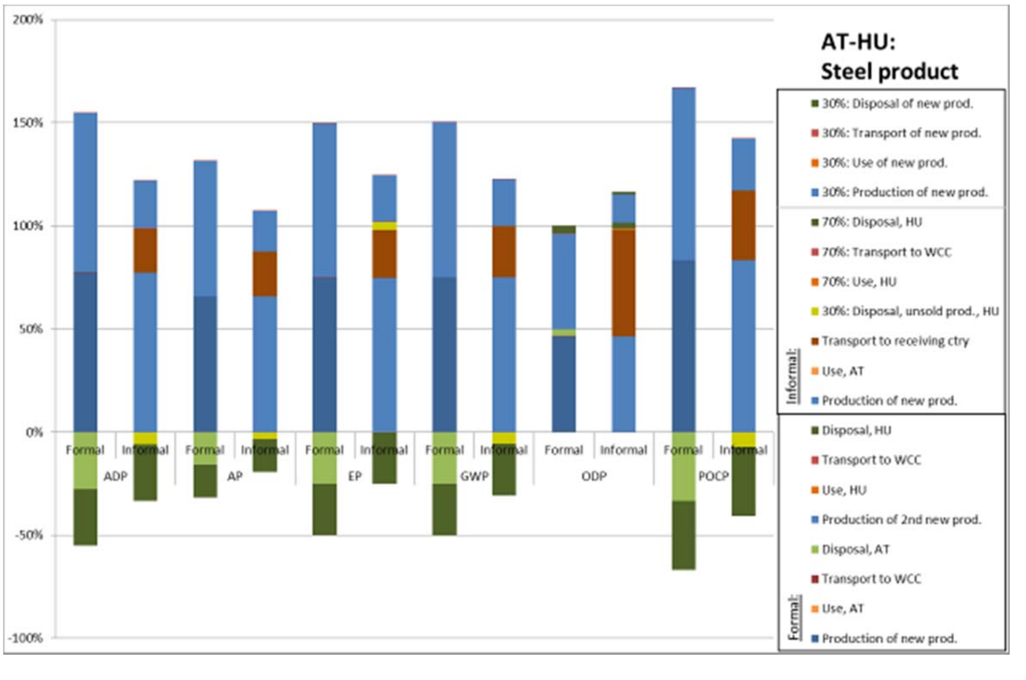

Figure 2.8: Relative results of formal and informal scenario by environmental indicators, steel product, AT-HU

Table 2.11: Absolute results of each scenario by environmental indicators, steel product, 1 kg collected product, AT-HU

Env. Category	Unit	Formal	Informal 30/70		Formalized 5/95	
ADP	Kg Sb-Equiv.	1,86E-02	1,65E-02	-	See formal	
AP	Kg SO_2-Equiv.	1,17E-02	1,03E-02	-	See formal	
EP	Kg Phosphate-Equiv.	2,08E-03	2,07E-03	-	See formal	
GWP	Kg CO_2-Equiv.	2,33E+00	2,14E+00	-	See formal	
HTP	kg DCB-Equiv.	7,00E+00	4,79E+00	-	See formal	
ODP	Kg R11-Equiv.	1,55E-07	1,80E-07	+	See formal	
POCP	kg Ethene-Equiv.	1,66E-03	1,68E-03	+	See formal	

This project is implemented through the CENTRAL EUROPE Programme co-financed by the ERDF

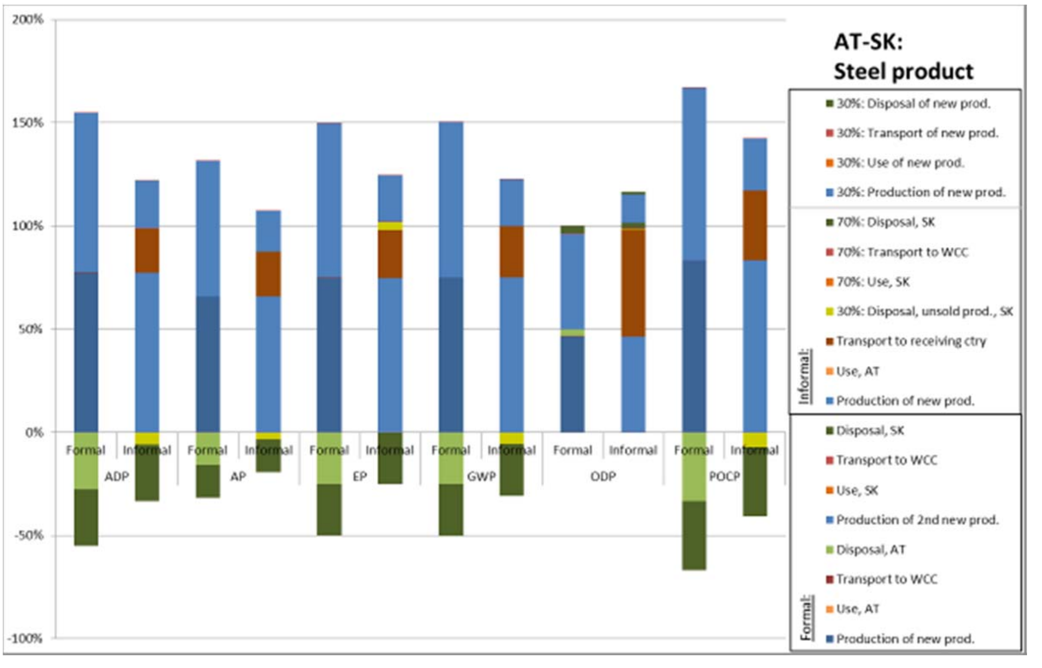

Figure 2.9: Relative results of formal and informal scenario by environmental indicators, steel product, AT-SK

Table 2.12: Absolute results of each scenario by environmental indicators, steel product, 1 kg collected product, AT-SK

Env. Category	Unit	Formal	Informal 30/70		Formalized 5/95	
ADP	Kg Sb-Equiv.	1,86E-02	1,65E-02	-	See formal	
AP	Kg SO_2-Equiv.	1,17E-02	1,03E-02	-	See formal	
EP	Kg Phosphate-Equiv.	2,08E-03	2,07E-03	-	See formal	
GWP	Kg CO_2-Equiv.	2,33E+00	2,14E+00	-	See formal	
HTP	kg DCB-Equiv.	7,00E+00	4,79E+00	-	See formal	
ODP	Kg R11-Equiv.	1,55E-07	1,80E-07	+	See formal	
POCP	kg Ethene-Equiv.	1,66E-03	1,68E-03	+	See formal	

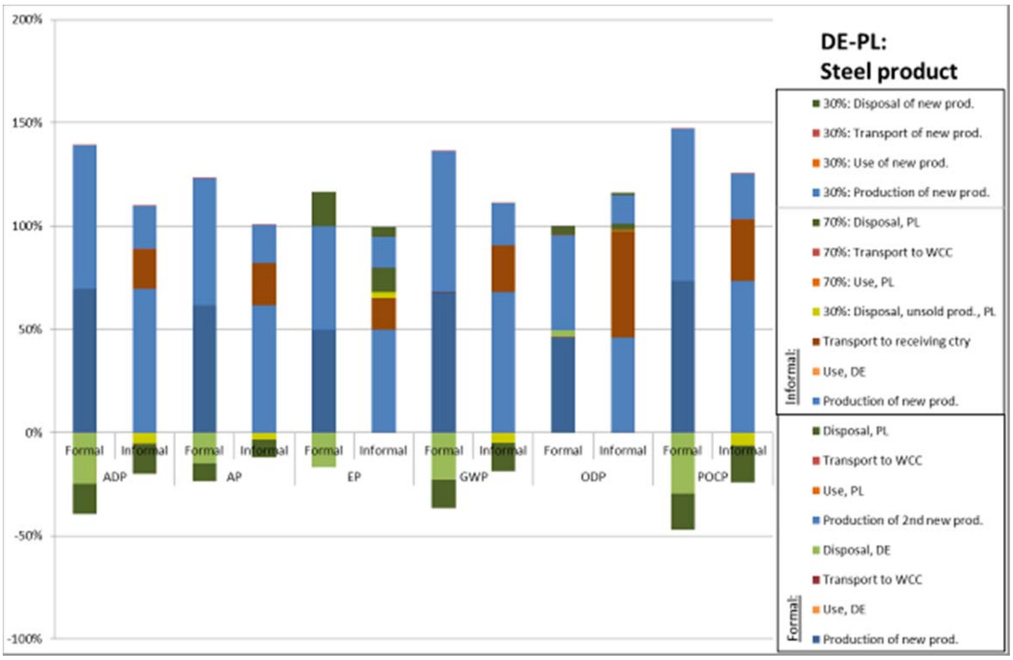

Figure 2.10: Relative results of formal and informal scenario by environmental indicators, steel product, DE-PL

Table 2.13: Absolute results of each scenario by environmental indicators, steel product, 1 kg collected product, DE-PL

Env. Category	**Unit**	**Formal**	**Informal** 30/70		**Formalized** 5/95	
ADP	Kg Sb-Equiv.	2,07E-02	1,86E-02	-	See formal	
AP	Kg SO_2-Equiv.	1,25E-02	1,11E-02	-	See formal	
EP	Kg Phosphate-Equiv.	3,12E-03	3,11E-03	-	See formal	
GWP	Kg CO_2-Equiv.	2,57E+00	2,38E+00	-	See formal	
HTP	kg DCB-Equiv.	7,42E+00	5,21E+00	-	See formal	
ODP	Kg R11-Equiv.	1,56E-07	1,81E-07	+	See formal	
POCP	kg Ethene-Equiv.	1,88E-03	1,91E-03	+	See formal	

2.4.3 Wood panel (treated)

Figure 2.11: Wood panel (cupboard, etc.)

2.4.3.1 System description

Treated wooden panels are collected separately in waste collection centres. Usually they are sent to waste incineration in Austria and Germany. Only seldom a material recycling via a particle board industry, where old wood and wood residues are treated and used for the production of particle boards, is used. Informal collectors collect treated wooden panels in form of book shelves, cupboards, tables or doors for the purpose of reusing them. Only some items, which can't be sold where reported to be cut down and used for heating their homes.

In the assessment a door for inner usage was chosen to represent items which are made of treated wood panels. The scenarios look therefore as follows:

Table 2.14: Scenario description – wood panel (treated)

	Phase	Formal scenario	Informal scenario	
			Informal_EoL (30%)	**Informal_Reuse (70%)**
Origin country	Production	Production of a new wood panel (treated)	Production of a new wood panel (treated)	
	Use	Use of wood panel (treated)	Use of wood panel (treated)	
	EoL	Collection in WCC. Scrap tyre is used in cement industry as auxiliary fuel in Austria. AT: WIP: 98.5%; MR: 1%; RU: 0.5%	Collection by informal bulky waste collector and transported to Hungary.	

		DE: as no info available, the same as AT assumed.		
Receiving country	Production	Production of new wood panel (treated)	-	-
	Use	Use of wood panel (treated)	-	-
	EoL	Collection in WCC. Disposal: HU: LF: 90.6%, WIP:8.9%; RU: 0.5% PL: LF: 88.8%; TT: 3.7%; MBT: 2.7%; MR: 0.7%; LFwT; 3.4% WIP: 0.6% SK: as no info available, the same as HU assumed.	Chipping and burning in furnace for heating HU: 100% ID PL: 100% ID SK: 100% ID	Collection in WCC. Disposal: HU: LF: 90.6%, WIP:8.9%; RU: 0.5% PL: LF: 88.8%; TT: 3.7%; MBT: 2.7%; MR: 0.7%; LFwT; 3.4% WIP: 0.6% SK: as no info available, the same as HU assumed.

ID … Illegal disposal
LF … Landfill without treatment in advance
LFwT … Landfill with mechanical treatment
MBT … Mechanical biological treatment
MR … Material recycling
O … Other
RU … ReUse
TT … Thermal treatment
WIP… waste incineration plant

2.4.3.2 Formal scenario

Table 2.15: Data inventory on formal scenario – wood panel (treated)

Name of the process	Formal – wood panel (treated)
Process description	Treated wood panels are produced and used in form of book shelves, cupboards, tables or doors for the inner usage. Used wood panels are collected in waste collection centres and disposed according to national waste management system.
Reference unit	kg
Area of application	Production of wood panel under consideration of European conditions, end of life: waste management system under national conditions and technology under Swiss conditions.
Completeness of the process	Production of treated wood panels is included. Use phase is excluded, as no emissions are assumed in this phase. Production of infrastructure (e.g. sawmill, furnace) is also excluded. Transport to the collection centre (passenger car, 2 km) and to disposal facilities (lorry, 200 km)

	included. Efforts in the recycling process are excluded.
Credits	Benefits for the recycling of treated wood Calorific value: 17 MJ/m²
Comments on credits	The benefits from the avoided production of a new inner door are considered. Credits on heat and electricity production are given based on an electricity generation efficiency of 9% and heat generation efficiency of 18%.
Used processes from Ecoinvent (product specific)	Production: RER: door, inner, wood, at plant UCTE: electricity, medium voltage, production UCTE, at grid RER: transport, lorry >16t, fleet average RER: power sawing, with catalytic converter GLO: diesel, burned in building machine Disposal: disposal, building, door, inner, wood, to final disposal CH: disposal, wood untreated, 20% water, to sanitary landfill
Comments on the choice of used processes	To remove the CO_2-uptake an invert process of sawn timber of 0,0793 m³ was calculated for use for one m² wood input. Although sawn timber and wood chips are used for the production of door, inner, wood, only sawn timber was used for the adaptation as a matter of being time effective. The input efforts for the timber production were taken from industrial residual softwood production.
Factors for functional unit	Area: 27,6 kg/m²

2.4.3.3 Informal scenario:

In the informal scenario the wood panels which are collected in WCC are taken from informal collectors and transported to their country for resale at home. 30% of the transported items can't be resold. It is assumed that this part is burnt in the furnace at home. The wood panels need to be chipped before burning. This chipping was assumed to be done with a motor saw. Additionally the emissions for burning a laminated wooden panel need to be considered as hazardous substances may be released via flue gas to the atmosphere and via ash to soil. These aspects were considered according to Haider (2011), who uses values for scrap wood from Speckels (2001) and EMPA (s. a.).

Table 2.16: Data inventory on informal scenario – wood panel (treated)

Name of the process	**Informal – wood panel (treated)**
Process description	Treated wood panels are produced and used in form of book shelves, cupboards, tables or doors for the inner usage. Used wood panels are collected and transported by informal collectors to their receiving countries. 70% of the transported items can be resold and are reused. 30% can't be resold. It is assumed that this part is chipped and burnt in the furnace at home.
Reference unit	kg
Area of application	Production of wood panel under consideration of European conditions, end of life: waste management system under national conditions and technology under Swiss conditions.
Completeness of the process	Production of treated wood panels is included. Use phase is excluded, as no emissions are assumed in this phase. Production of infrastructure (e.g. sawmill, furnace) is also excluded. Transport to the collection centre (passenger car, 2 km) and to disposal facilities (lorry, 200 km) included. Efforts in the recycling process are excluded. Transport from origin to receiving country by informal collectors included (van, 300 km). Emissions of the chipping by motor saw included and the missions due to burning of treated wood panels in home furnaces (30kW) without flue gas cleaning system is also included.
Credits	Benefits for the recycling of treated wood Calorific value: 17 MJ/kg, 469.2 MJ/m²
Comments on credits	The benefits from the avoided production of a new inner door are considered. Credits on heat and electricity production are given based on an electricity generation efficiency of 9% and heat generation efficiency of 18%.
Used processes from Ecoinvent (product specific)	Production: RER: door, inner, wood, at plant UCTE: electricity, medium voltage, production UCTE, at grid RER: transport, lorry >16t, fleet average RER: power sawing, with catalytic converter GLO: diesel, burned in building machine Disposal: disposal, building, door, inner, wood, to final disposal

	CH: disposal, wood untreated, 20% water, to sanitary landfill
Comments on the choice of used processes	To remove the CO_2-uptake in the production an invert process of sawn timber of 0.0793 m³ was calculated for use for one m² wood input. Although sawn timber and wood chips are used for the production of door, inner, wood, only sawn timber was used for the adaptation as a matter of being time effective. The input efforts for the timber production were taken from industrial residual softwood production.
Factors for functional unit	Area: 27,6 kg/m²

2.4.3.4 Results

The results of the assessment of treated wood panels don't show significant tendencies. Although the production processes are highly affecting the results, also the transport by informal collectors and the end of life phase are affecting some categories significantly.

In all three cases (AT-HU, AT-SK and DE-PL) the disposal phase influences the EP enormously, as in HU, SK and PL landfilling is the most common end of life option. The GWP is influenced by the disposal in the origin country, as the results of the assessment show that the incineration of wood causes more emissions than the benefits from won energy and heat. Yet, as the CO_2-release from wood as counted as CO_2-neutral, these emissions would be negligible. This correction factor would cause that the formal scenario has a lower GWP than the informal scenario.

The results of the informal scenario show slightly higher emissions in case of ADP and AP and greater emissions in case of HTP, ODP and POCP in case of AT-HU (see Table 2.17), AT-SK (see Table 2.18) as well as DE-PL (see Table 2.19).

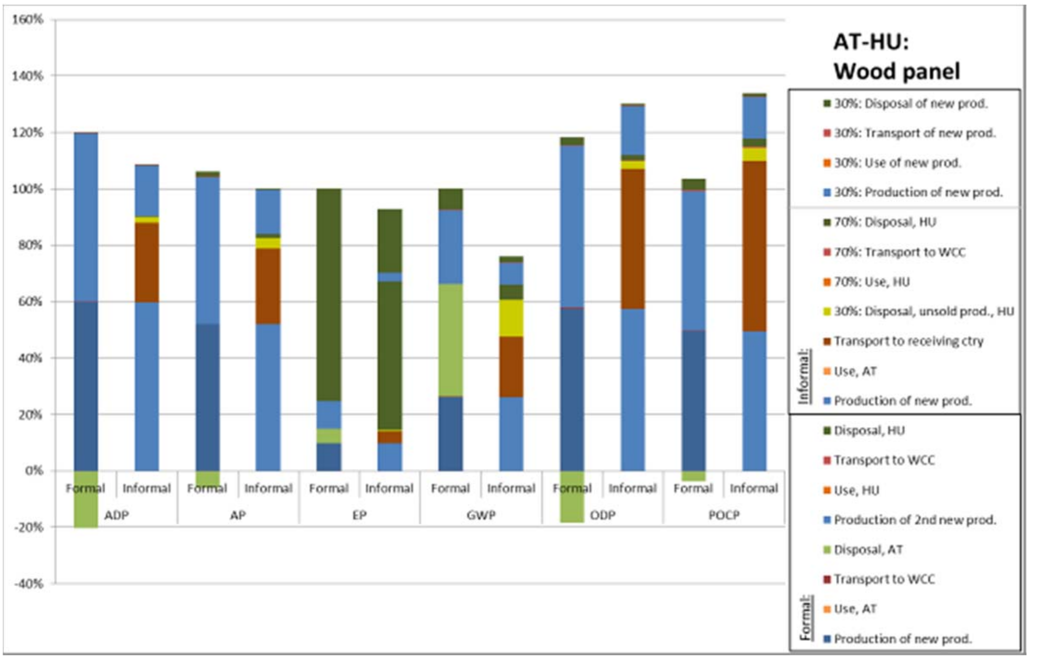

Figure 2.12: Relative results of formal and informal scenario by environmental indicators, wood panel, AT-HU

Table 2.17: Absolute results of each scenario by environmental indicators, wood panel, 1 kg collected product, AT-HU

Env. Category	Unit	Formal	Informal 30/70		Formalized 5/95	
ADP	Kg Sb-Equiv.	1,42E-02	1,54E-02	+	1,30E-02	-
AP	Kg SO_2-Equiv.	9,46E-03	9,48E-03	+	7,95E-03	-
EP	Kg Phosphate-Equiv.	1,13E-02	1,05E-02	-	1,02E-02	-
GWP	Kg CO_2-Equiv.	2,71E+00	2,06E+00	-	1,59E+00	-
HTP	kg DCB-Equiv.	7,56E-01	1,39E+00	+	6,60E-01	-
ODP	Kg R11-Equiv.	1,63E-07	2,12E-07	+	1,85E-07	+
POCP	kg Ethene-Equiv.	9,26E-04	1,24E-03	+	1,09E-03	+

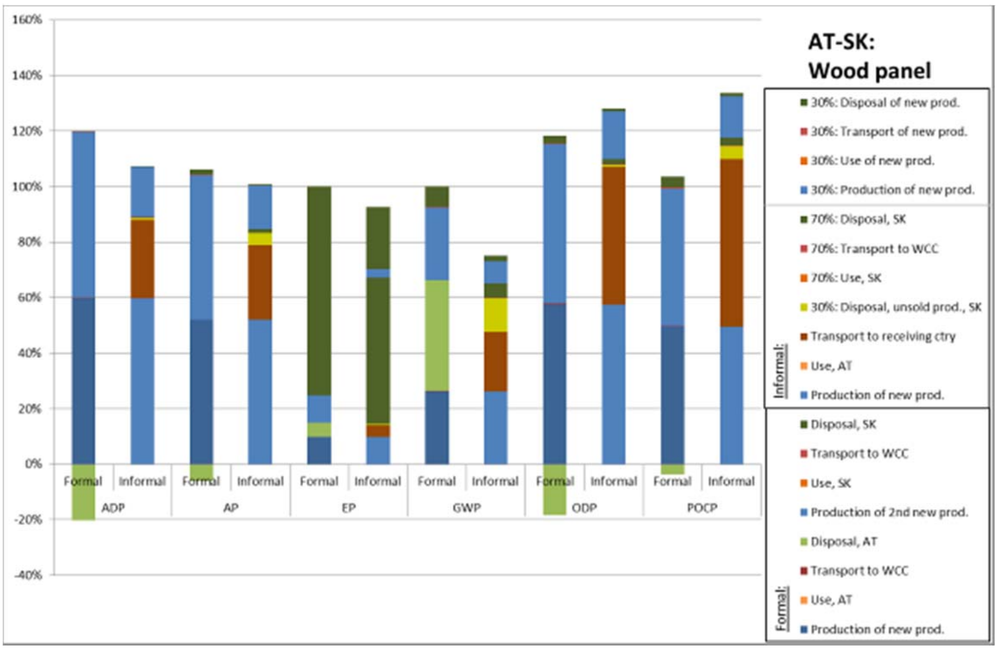

Figure 2.13: Relative results of formal and informal scenario by environmental indicators, wood panel, AT-HU

Table 2.18: Absolute results of each scenario by environmental indicators, wood panel, 1 kg collected product, AT-SK

Env. Category	Unit	Formal	Informal 30/70		Formalized 5/95	
ADP	Kg Sb-Equiv.	1,42E-02	1,52E-02	+	1,30E-02	-
AP	Kg SO_2-Equiv.	9,46E-03	9,54E-03	+	7,97E-03	-
EP	Kg Phosphate-Equiv.	1,13E-02	1,05E-02	-	1,02E-02	-
GWP	Kg CO_2-Equiv.	2,71E+00	2,04E+00	-	1,59E+00	-
HTP	kg DCB-Equiv.	7,56E-01	1,39E+00	+	6,60E-01	-
ODP	Kg R11-Equiv.	1,63E-07	2,08E-07	+	1,84E-07	+
POCP	kg Ethene-Equiv.	9,26E-04	1,24E-03	+	1,09E-03	+

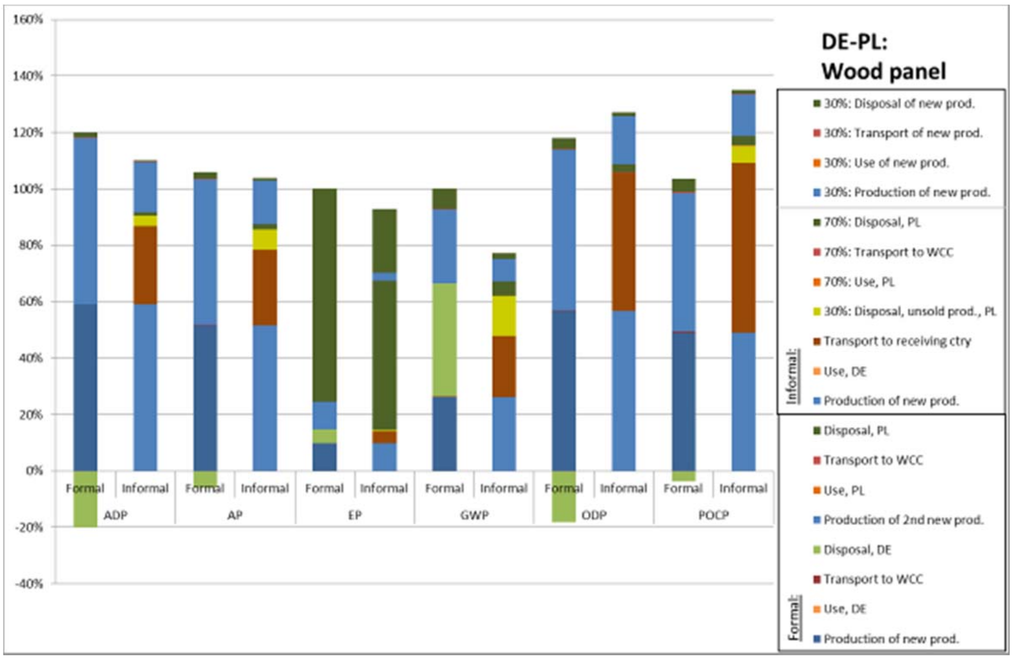

Figure 2.14: Relative results of formal and informal scenario by environmental indicators, wood panel, DE-PL

Table 2.19: Absolute results of each scenario by environmental indicators, wood panel, 1 kg collected product, DE-PL

Env. Category	Unit	Formal	Informal 30/70		Formalized 5/95	
ADP	Kg Sb-Equiv.	1,43E-02	1,58E-02	+	1,32E-02	-
AP	Kg SO_2-Equiv.	9,53E-03	9,88E-03	+	8,08E-03	-
EP	Kg Phosphate-Equiv.	1,15E-02	1,07E-02	-	1,03E-02	-
GWP	Kg CO_2-Equiv.	2,70E+00	2,09E+00	-	1,59E+00	-
HTP	kg DCB-Equiv.	7,57E-01	1,40E+00	+	6,64E-01	-
ODP	Kg R11-Equiv.	1,65E-07	2,09E-07	+	1,86E-07	+
POCP	kg Ethene-Equiv.	9,33E-04	1,26E-03	+	1,10E-03	+

2.4.4 Textiles

Figure 2.15: Different types of textiles

2.4.4.1 System characterisation

The most commonly used textile fibre is cotton (Palm, 2011). Together with polyester, which is the second most used textile fire (Palm, 2011) these two materials cover the major composition of textiles. During the production of these materials the energy input, the water usage, the usage of pesticides during the cultivation of cotton and the usage of toxic chemicals during dying processes are the most important consideration points. Yet, data on the production phase of textiles are unfortunately rare.

Palm 2011 tried to evaluate the environmental effects of textiles and showed that data used in publications are often rough estimates and also the most common data providers for life cycle assessment don't provide data on textiles. The Ecoinvent database contains though data for cotton but not for polyester. The reason for it can be explained by the complex production systems of textiles and the ignorance of even retailers upon the supply chain.

Several Swedish publications determined the global warming potential of textiles with an assumed composition of 50% cotton and 50% polyester. The results are summarized below.

Table 2.20: GWP per kg textile from different sources

Global Warming Potential (kg CO_2-Eq.)	Source
16,9	Sundqvist & Palm 2010
15	Ljunggren Söderman et al. 2011
25	Persson 2010

Apart from Swedish publications which evaluated the environmental performance of textiles, the Danish ministry of the environment published a study called EDIPTEX in 2007 (Laursen et al., 2007). In EDIPTEX an environmental assessment on six different clothes were carried out:

- A t-shirt of 100% cotton
- A jogging suit of nylon microfibers with a cotton lining
- A work jacket of polyester and cotton
- A blouse of viscose, nylon and elastane
- A tablecloth of cotton
- A floor covering of nylon and polypropylene

This range of considered clothes is similar to those products which are taken by the informal collectors. Therefore this choice of textiles was adopted for the purpose of TransWaste as well.

Swedish and Danish studies consider the EDIP methodology for the environmental assessment. Results are therefore expressed in the unit $PE_{MWDK2000}$. It stands for person-equivalent for target or accepted emissions in 2000 globally, regionally as well as locally. The results can therefore not taken for the purpose of the assessment in TransWaste. It was decided to use the data inventory of the EDIPTEX study and combine it with Ecoinvent database as far as possible.

The functional unit of the textiles is each 1 kg.

Table 2.21 shows the material composition, total mass of the product, total material losses and chosen Ecoinvent datasets for each considered textile.

The material input for the different kinds of textiles was taken from Laursen et al. (2007) and assessed with data from Ecoinvent database. Some fibres are not existent in Ecoinvent, so similar materials were chosen instead, like for elastane a tube insulation made of elastomers was taken to earn similar environmental effects. To model environmental effects from production of polyester, polyester resin were taken instead to show approximate effects.

In the production phase energy in form of electricity and heat is needed for various steps. The energy use for cultivation and fibre production is included in most of the assessed input materials.

The energy use for further processing steps, as knitting or dyeing, is though not included. According to Laursen et al. (2007) most of the primary energy consumption is based on the use phase and on the production of fertilizers in the cultivation phase. Those most relevant energy inputs are therefore considered. The usage of toxic chemicals during dying processes was determined as relevant by Palm (2011) and is therefore also included.

Table 2.21: Data inventory for different kinds of textiles

Product	Material	Mass	Material losses (total)	Processes from Ecoinvent
T-shirt	100% cotton	250 g	150 g	GLO: textile, woven cotton, at plant CH: disposal, textiles, soiled, 25% water, to municipal incineration
jogging suit	Nylon microfibers with cotton lining (50%/50%)[1]	706 g	257 g	GLO: textile, woven cotton, at plant RER: nylon 66, at plant CH: brass, at plant <e-ep> CH: disposal, plastics, mixture, 15.3% water, to municipal incineration CH: disposal, textiles, soiled, 25% water, to municipal incineration
work jacket	65% polyester, 35% cotton[2]	850 g	291 g	GLO: textile, woven cotton, at plant RER: polyester resin, unsaturated, at plant CH: brass, at plant <e-ep> CH: disposal, plastics, mixture, 15.3% water, to municipal incineration CH: disposal, textiles, soiled, 25% water, to municipal incineration
blouse	70% viscose 25% nylon 5% elastane	200 g	25 g	GLO: viscose fibres, at plant RER: nylon 66, at plant1 DE: tube insulation, elastomer, at plant
tablecloth	100% cotton	384 g	260 g	GLO: textile, woven cotton, at plant CH: disposal, textiles, soiled, 25% water, to municipal incineration
floor covering	nylon, polypropylene[3]	2633 g/m²	533 g	RER: polypropylene, granulate, at plant RER: nylon 66, at plant RER: latex, at plant CH: disposal, polypropylene, 15.9% water, to municipal incineration CH: disposal, plastics, mixture, 15.3% water, to municipal incineration CH: disposal, rubber, unspecified, 0% water, to municipal incineration

[1] … top: 200 g cotton, 200 g nylon; trousers: 150 g cotton, 150 g nylon; zipper: 6 g brass (brass was considered by the author)

[2] …500 g polyester, 270 g cotton; buttons: 10 x 3.6 g brass, zipper: 40 g brass; 4 g polyester

[3] … 133 g polypropylene, 1100 g nylon, 1400 latex foam

Material losses occur in various stages during the production of textiles. Losses due to knitting processes and due to dyeing are considered to be incinerated. Material losses from cotton yarn production (10%) are contained in the Ecoinvent-dataset “GLO: textile, woven cotton, at plant” and are considered to be landfilled. Laursen et al. (2007) stated 1.43 cotton fibres are needed for 1 kg cotton yarn. Therefore a material loss of 30% was considered, which is higher than that from Ecoinvent. For a reason of simplicity all material losses from Laursen et al. (2007) were adopted. The 10% contained in Ecoinvent is therefore additionally considered to receive a more conservative solution.

Material losses from making up of the textile were considered as 10% according to Laursen et al. (2007). Incineration was also chosen in Laursen et al., 2007, as the heat is used again in the production process. In ecoinvent the incineration according to Swiss standard is assumed, which does not fit with the incineration in countries where the material for textiles are produced. As the influence of the incineration process of waste from knitting to the total life cycle is neglecting this circumstance was no longer attracted. The effect may concern more local hazards which may be found in toxicity potential. Yet, as data on that is lacking it was not considered in the assessment.

For the use phase of the textiles the washing, tumbler drying and ironing was considered. For floor covering the hovering was considered. Some assumptions, like the number of washings/hooverings for each type of textile and the electricity use for tumbler drying and ironing, were taken from Laursen et al. (2007). It is 0.08 MJ per minute of ironing a textile, 0.29 MJ per kg drying in a tumble dryer and around 0.1 MJ per m² hoovering. The electricity use for a washing machine was used from Pertl et al. (2010) for two different production years – 2000 and 2010. Additionally an amount 20 g detergent for each washing was assumed. The following data inventory was used for the use phase.

Product	**Number of washings/hovering per lifetime**	**Tumbler drying (Yes/No)**	**Ironing (Yes/No)**
T-shirt	50	Y	Y (3 min)
jogging suit	24	Y	N
work jacket	40	Y	N
blouse	25	N	N
tablecloth	25	N	Y (10 min)
floor covering	120	N	N

For the purpose of assessing a representative composition of textiles taken by informal collectors it was necessary to compile all considered types of textiles. As no basic data on the composition of textiles taken by informal collectors was available, estimations were carried out. According to weighing tests carried out during TransWaste an average density of 144 kg/m³ for textiles taken in one van by informal collectors was determined. The composition is though not known. The different textiles were therefore added to 144 kg per one m³ by estimating that one carpet with 4 m² is included. The distribution among the different types of textiles to receive one m³ is shown in Table 2.22.

Table 2.22: Composition of one m³ of textile mixture

Type of textile	Mass per textile	No. Pieces	Total mass	Relative share
T-shirt	0,25	150	37,5	26%
Jogging suit	0,706	40	28,24	20%
Work jacket	0,85	39	33,15	23%
Blouse	0,2	80	16	11%
Tablecloth	0,384	50	19,2	13%
Floor covering	2,633	4	10,532	7%
Mixture of textiles			144,622	100%

Table 2.23: Scenario description – textiles

<table>
<tr><th rowspan="2"></th><th rowspan="2">Phase</th><th rowspan="2">Formal scenario</th><th colspan="2">Informal scenario</th></tr>
<tr><th>Informal_EoL (30%)</th><th>Informal_Reuse (70%)</th></tr>
<tr><td rowspan="3">Origin country</td><td>Production</td><td>Production of new textiles</td><td colspan="2">Production of new textiles</td></tr>
<tr><td>Use</td><td>Use of textiles</td><td colspan="2">Use of textiles</td></tr>
<tr><td>EoL</td><td>Collection in WCC. Disposal:
AT: 80% RU, 20% WIP
DE: 89% MR, 10% RU, 1% WIP</td><td colspan="2">Collection by informal bulky waste collector and transported to Hungary.</td></tr>
<tr><td rowspan="3">Receiving country</td><td>Production</td><td>Production of new textiles</td><td>-</td><td>Sale of used textiles at flea market</td></tr>
<tr><td>Use</td><td>Use of textiles</td><td>-</td><td>Use of used textiles</td></tr>
<tr><td>EoL</td><td>Collection in WCC. Disposal:
HU: 91.1% LF, 8.9% WIP
PL: 80.2% LF, 1.3% MR, 8.2% RU, 10.3% WIP
SK: 78% LF, 5% MR, 17% WIP</td><td>Informal disposal (landfilled)
HU: 100% ID
PL: 100% ID
SK: 100% ID</td><td>Collection in WCC. Disposal:
HU: 91.1% LF, 8.9% WIP
PL: 80.2% LF, 1.3% MR, 8.2% RU, 10.3% WIP
SK: 78% LF, 5% MR, 17% WIP</td></tr>
</table>

ID … Illegal disposal
LF … Landfill without treatment in advance
LFwT … Landfill with mechanical treatment
MBT … Mechanical biological treatment

MR … Material recycling
O … Other
RU … ReUse
TT … Thermal treatment
WIP… waste incineration plant

2.4.4.2 Formal scenario

Table 2.24: Data inventory on formal scenario, textiles

Name of the process	**Formal – textiles**
Process description	A mixture of textiles (T-shirt, jogging suit, work jacket, blouse, table cloth, floor covering) is produced and used at home for 3 years. The used textiles are taken to the waste collection centre and disposed of according to national waste management system.
Reference unit	kg
Area of application	Production of textiles under consideration of global conditions, use under national conditions (electricity), end of life under national conditions (waste management system) and Swiss conditions (esp. waste incineration)
Completeness of the process	Transport to the collection centre (passenger car, 2 km) included, use of textiles of 3 years included (washing, tumble drying, ironing, hovering in case of floor covering). Transport to recycling and disposal facilities is included (lorry, 200km).
Credits	Credits for cotton, latex, elastane, nylon, viscose, polyester, polypropylene according to the compositions of each type of textile. Calorific value: 13 MJ/kg
Comments on credits	Inverse datasets of primary materials were given as credits Textiles can be used as filling material for mattress or for cleaning rags. For metals contained in the zippings of the textiles no credits were given in case of material recycling and of reuse. Credits on heat and electricity production are given based on an electricity generation efficiency of 9% and heat generation efficiency of 18%.
Used processes	Production: See Table 2.21

Comments on the choice of used processes	Power used for shredding in the material recycling process was estimated as 2 MJ per kg
Factor for functional unit	Density of textile mixture: 144.62 kg/m³

2.4.4.3 Informal scenario

Table 2.25: Data inventory on informal scenario, textiles

Name of the process	**Informal – textiles**
Process description	A mixture of textiles (T-shirt, jogging suit, work jacket, blouse, table cloth) is produced and used at home for 3 years. The used textiles are taken by informal collectors who bring it to receiving countries. 30% of the textiles can't be resold. It is assumed that this part is landfilled. 70% of the devices are sold and reused for the same amount of years as new textiles (3 years). At the end of their lives they are disposed of in a formal way.
Reference unit	kg
Area of application	Production of textiles under consideration of global conditions, use under national conditions (electricity), end of life under national conditions (waste management system) and Swiss conditions (esp. waste incineration)
Completeness of the process	Transport to the collection centre (passenger car, 2 km) included, use of textiles of 3 years included (washing, tumble drying, ironing, hovering in case of floor covering). Transport to recycling and disposal facilities is included (lorry, 200km). Transport by informal collectors to receiving countries included (van, 300km).
Credits	Credits for cotton, latex, elastane, nylon, viscose, polyester, polypropylene according to the compositions of each type of textile. Calorific value: 13 MJ/kg
Comments on credits	Inverse datasets of primary materials were given as credits Textiles can be used as filling material for mattress or for cleaning rags. For metals contained in the zipping of the textiles no credits were given in case of material recycling and of reuse. Credits on heat and electricity production are given based on an electricity generation efficiency of 9% and heat generation efficiency of 18%.
Used processes	Production:

	See Table 2.21
Comments on the choice of used processes	Power used for shredding in the material recycling process was estimated as 2 MJ per kg Illegal disposal was modelled as landfilling.
Factor for functional unit	Density of textile mixture: 144.62 kg/m³

2.4.4.4 Results

According to several publications, see Palm (2011), Farrant et al. (2010), the environmental impacts of virgin textiles is rather significant. The GWP from the production of textiles is compared to other waste very high. Farrant et al. (2010) mentions that the reuse of clothes can significantly reduce the environmemtnal burdens. Also the collection, processing and transport of reused clothes is insignificant compared to the avoided production process of new clothes, states Farrant et al. (2010).

The results of the assessment of textiles show the significant impact of the production phase of textiles. For that reason the informal scenarios show fewer impacts in each case. The formal disposal show though more benefits in the formal scenarios due to increased recycling and reuse options in the origin countries, whereas landfilling is dominating the formal disposal in receiving countries. Therefore no or very little (in case of PL) benefits occur in the disposal phase of the receiving countries.

In Table 2.26, Table 2.27 and Table 2.28 it can be seen, that the informal scenario and also the formalized scenario show in each environmental category less emissions than in the formal scenario. The rather high emission results compared to other indicator products result from the yarn production from cotton fibres, which is modelled in Ecoinvent with partly Chinese and partly US electricity mix. The Chinese electricity mix contributes most to the emissions.

Kommentar [BSR1]: The Bay-Logi's models don't contain the energy utilization of the production phase, because these data couldn't be got

Kommentar [SSch2]: This is the energy utilization which is automatically included in the datasets when we use Ecoinvent. I have read it up in the Ecoinvent report and looked it up in the GaBi datasets where these high emissions come from.

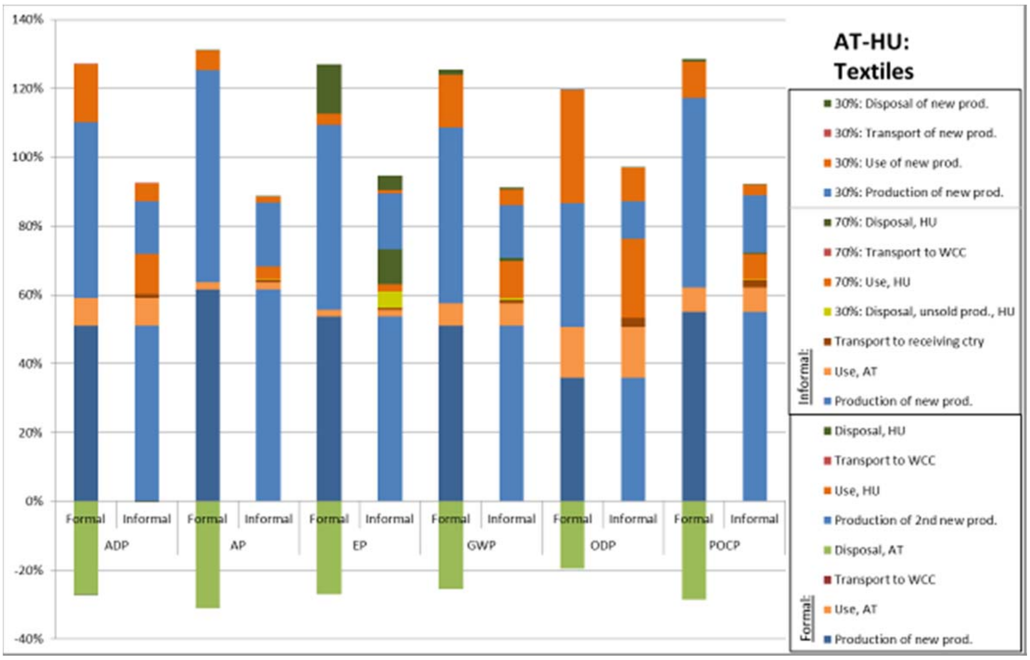

Figure 2.16: Relative results of formal and informal scenario by environmental indicators, textiles, AT-HU

Table 2.26: Absolute results of each scenario by environmental indicators, textiles, 1 kg collected product, AT-HU

Env. Category	Unit	Formal	Informal 30/70		Formalized 5/95	
ADP	Kg Sb-Equiv.	3,73E-01	3,45E-01	-	2,97E-01	-
AP	Kg SO_2-Equiv.	4,21E-01	3,73E-01	-	3,08E-01	-
EP	Kg Phosphate-Equiv.	7,45E-02	7,06E-02	-	5,77E-02	-
GWP	Kg CO_2-Equiv.	5,98E+01	5,45E+01	-	4,67E+01	-
HTP	kg DCB-Equiv.	2,15E+01	1,90E+01	-	1,61E+01	-
ODP	Kg R11-Equiv.	3,04E-06	2,95E-06	-	2,68E-06	-
POCP	kg Ethene-Equiv.	2,63E-02	2,42E-02	-	2,06E-02	-

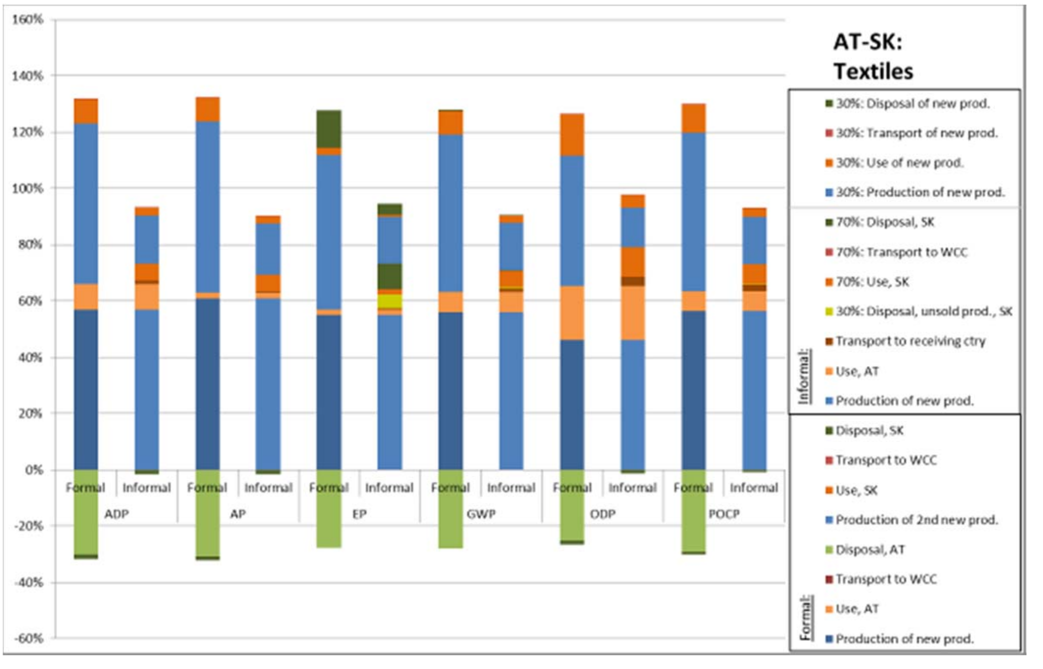

Figure 2.17: Relative results of formal and informal scenario by environmental indicators, textiles, AT-SK

Table 2.27: Absolute results of each scenario by environmental indicators, textiles, 1 kg collected product, AT-SK

Env. Category	Unit	Formal	Informal 30/70		Formalized 5/95	
ADP	Kg Sb-Equiv.	3,34E-01	3,05E-01	-	2,58E-01	-
AP	Kg SO_2-Equiv.	4,26E-01	3,78E-01	-	3,13E-01	-
EP	Kg Phosphate-Equiv.	7,30E-02	6,91E-02	-	5,61E-02	-
GWP	Kg CO_2-Equiv.	5,45E+01	4,92E+01	-	4,14E+01	-
HTP	kg DCB-Equiv.	2,14E+01	1,90E+01	-	1,60E+01	-
ODP	Kg R11-Equiv.	2,37E-06	2,28E-06	-	2,00E-06	-
POCP	kg Ethene-Equiv.	2,57E-02	2,37E-02	-	2,00E-02	-

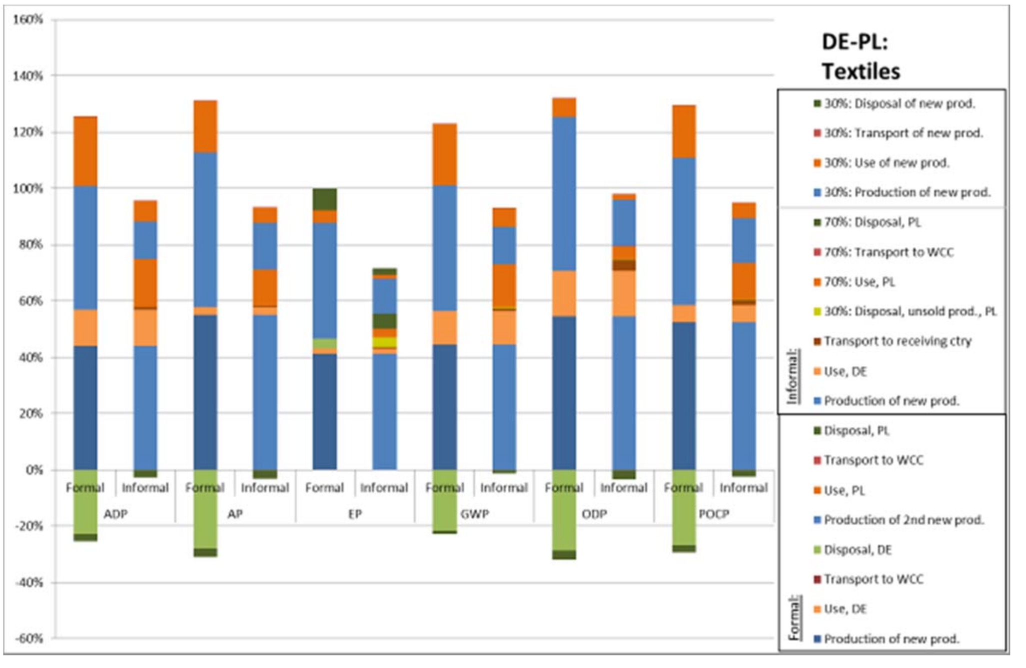

Figure 2.18: Relative results of formal and informal scenario by environmental indicators, textiles, DE-PL

Table 2.28: Absolute results of each scenario by environmental indicators, textiles, 1 kg collected product, DE-PL

Env. Category	Unit	Formal	Informal 30/70		Formalized 5/95	
ADP	Kg Sb-Equiv.	4,33E-01	4,02E-01	-	3,54E-01	-
AP	Kg SO_2-Equiv.	4,72E-01	4,25E-01	-	3,60E-01	-
EP	Kg Phosphate-Equiv.	9,75E-02	6,98E-02	-	5,68E-02	-
GWP	Kg CO_2-Equiv.	6,85E+01	6,28E+01	-	5,49E+01	-
HTP	kg DCB-Equiv.	2,53E+01	2,11E+01	-	1,82E+01	-
ODP	Kg R11-Equiv.	2,01E-06	1,90E-06	-	1,62E-06	-
POCP	kg Ethene-Equiv.	2,76E-02	2,55E-02	-	2,18E-02	-

2.4.5 Tyres

Figure 2.19: Tyres (Photo by Bay-Logi)

2.4.5.1 System characterisation

A tyre consists mainly of rubber and steel wires, with some textiles. Tyres from passenger cars are made of styrene-butadiene rubber whereas truck tyres are made from natural rubber (Reschner, 2006). The composition of a tyre depends on the tyre type. Steel accounts for 15 to 30% of a tyre and textiles for 5 to 15% (ART, n.d.; Reschner, 2006).

The production of a new tyre was both in case of origin and receiving countries assessed for European conditions. For the assessment a winter tyre for a passenger car without rims with the Dimension 185/60 R14T was considered. A tyre with this dimension has a weight of 8 kg (Reifenkaufhaus, 2009). It was therefore assumed that a tyre consists of 65 % rubber, 25 % steel and 10 % textiles (ART, n.d.) of 8 kg.

Retreading is a common way of reusing an old tyre. However, the importance of retreading has decreased. As the price of new imported tyres only differs slightly from the price of retreaded tyres, the demand has fallen. Additionally, modern tyres have a sensitive sidewall, which is not suitable for reuse. Truck tyres are particularly suited for retreading, and can be retreaded up to three times (Reschner, 2006).

Due to the high amount of rubber, the tyres provide a good opportunity for material recovery. Energy is also recovered during disposal of scrap tyres, with a heating value of around 32 MJ/kg, thus making a tyre a good auxiliary fuel. Whether a used tyre is recycled or incinerated, it needs to go through a debeader. In particular, the steel rings from truck tyres have to be released, to avoid abrasion in the shredder (Reschner, 2006).

Scrap tyres have been used as alternative fuel in the cement industry in Austria over the last 25 years (VÖZ, 2006). In view of the high temperatures needed in rotary kilns, used tyres have come to represent a suitable alternative for coke or coal. In addition to the savings of fossil fuel, the use of scrap tyres has the advantage of being a residue-free treatment. At a temperature of 1.450 °C the steel in the tyre is oxidised. Iron oxide can subsequently be reused as one of the key components of cement (Reschner, 2008). Organic hazardous substances are destroyed by the high temperatures in the rotary kiln and the long exposure time. The tyre ashes are used in the clinker and heavy metals are also binded in the clinker (VÖZ, 2006).

Two types of material recycling generally exist: mechanical and cryogenic pulverisation process (MPP and CPP). The first involves shredding at ambient temperature. Textiles are removed using wind sifters and steel by means of a magnet. The shredded rubber has a size of 6 to 10 mm. A further milling to the desired size for further treatment is required. Machines used in finely grinding the rubber include secondary granulators, high speed rotary mills, extruders, screw presses or cracker mills. While the ambient process does not require a cooling phase, the cryogenic process cools the chips to hinder embrittlement of the material. After pre-shredding the chips are cooled in a tunnel with liquid nitrogen to a temperature of -100 °C. Steel and textiles are decomposed and the rubber is milled to a size of 0.4 to 6 mm by a hammer mill. This wide spectrum of particle size after just one step is typical of the cryogenic process. After milling steels, textiles and dust are removed. The chips are dried and classified. If more chips of the size of 0.4 mm are required, additional milling steps can be added (Reschner, 2006).

The MPP produced to types of pulverised tyres: pulverised tyres < 2mm and fine pulverised tyres <0.7 mm. One means of material recovery involves the producing of thermoplastic elastomers (TPEs) by incorporating tyre powder into thermoplastics. However, adhesion between the tyre powder and the polymer matrix is very weak due to the crosslinked structure of the tyre rubber powder. Therefore, the tyre powder should be devulcanized or partially devulcanized to facilitate mixing of the matrixes (Zhang et al., 2008). The fine pulverised tyres from the MPP were therefore assumed to replace thermoplastic elastomers. Polyurethane, flexible foam, was taken as substitution materials. In case of pulverised tyres < 2mm synthetic rubber was taken as substitution material.

Used tyres can also be incinerated together with municipal solid waste or as an auxiliary fuel in coal-fired power plants. For this kind of incineration the used tyres have to be grinded in advance.

No emissions were considered in the use phase of a tyre. Tyres are after use in the origin country collected in waste collection centres in Austria and Germany. 50% of the tyres end up in cement industry, 49.5% in material recycling plants and 0.5% are reused in Austria. The disposal routes in Germany were calculated following the waste statistics of Germany. Waste incineration plants, combustion plants and other treatment plants were stated in the statistics. It was assumed that material recycling is covered by other treatment plants. In receiving countries the collection of tyres also take place and are send afterwards to thermal treatment plants, material recycling and landfill (see shares to specific countries in Table 2.29). Other disposal routes are not considered in the assessment.

As no information is available concerning the use of mechanical or cryogenic pulverisation process as material recycling in specific countries, a mixture was taken (50% MPP and 50% CPP). Emissions from landfilling of scrap tyres were not considered as no corresponding data was available. For the reuse of a used tyre it was estimated that one used tyre corresponds to half the lifetime of a new tyre. Retreading was considered as a form of reuse. No additional inputs were considered for the retreading process.

Table 2.29: Scenario description – tyre

	Phase	Formal scenario	Informal scenario	
			Informal_EoL (30%)	Informal_Reuse (70%)
C	Production	Production of new tyre	Production of a tyre	

	Use	Use of tyre	Use of tyre	
	EoL	Collection in WCC. Scrap tyre is used in cement industry as auxiliary fuel in Austria. AT: TT: 58%; MR: 37%, RU: 6% DE: TT: 61%; WIP: 1%; MR:38%	Collection by informal bulky waste collector and transported to Hungary.	
Receiving country	Production	Production of new tyre	-	Sale of used tyre at flea market
	Use	Use of tyre	-	Use of used tyre
	EoL	Collection in WCC. Disposal: HU: TT: 50%; MR: 45%; O: 5% PL: TT: 46%; MR: 23%, LF: 18%, RU: 12%; O: 1% SK: TT: 30%; MR: 30%; LF: 40%	Illegal disposal (landfilled) HU: 100% LF PL: 100% LF SK: 100% LF	Collection in WCC. Disposal: HU: TT: 50%; MR: 45% PL: TT: 46%; MR: 23%, LF: 18%, RU: 12% SK: TT: 30%; MR: 30%; LF: 40%

ID … Illegal disposal
LF … Landfill without treatment in advance
LFwT … Landfill with mechanical treatment
MBT … Mechanical biological treatment
MR … Material recycling
O … Other
RU … ReUse
TT … Thermal treatment
WIP… waste incineration plant

2.4.5.2 Formal scenario

Table 2.30: Data inventory on formal scenario, tyres

Name of the process	**Formal – tyres**
Process description	Tyres are produced and used at home for 4 years. The used tyres are taken to the waste collection centre and disposed of according to national waste management system.
Reference unit	kg
Area of application	Production of tyres under consideration of European conditions (textiles from India), end of life under national conditions in case of waste

	management system and under European conditions in case of electricity and heat.
Completeness of the process	Transport to the collection centre (passenger car, 2 km) included. Emissions in the use and reuse of tyres (e.g. tyre abrasion) are not considered. Transport to recycling and disposal facilities is included (lorry, 200 km).
Credits	For the Co-combustion benefits for 1 kg tyre on coal as substitute material (0,877kg) and iron minerals (0,25kg) are given. For the waste-to-energy process benefits for 1 kg tyre on electric power (0,476MJ) and iron minerals (0,22kg) are given. For the CPP benefits for 1 kg tyre on iron (0,265kg) and on PUR (0,675kg) are given. For the MPP benefits for 1 kg tyre on synthetic rubber (0,225kg) and on PUR (0,456kg) are given.
Comments on credits	Inverse datasets of primary materials were given as credits. The fine pulverised tyres from the recycling process were assumed to replace thermoplastic elastomers. Polyurethane, flexible foam, was taken as substitution materials. In case of pulverised tyres < 2mm synthetic rubber was taken as substitution material.
Used processes from Ecoinvent (product specific)	Production: RER: steel, low-alloyed, at plant RER: wire drawing, steel RER: latex, at plant IN: textile, kenaf, at plant
Comments on the choice of used processes	Processes in the End-of-life phase are established based on Corti and Lombardi (2004)
Factor for functional unit	1 piece is 8 kg

2.4.5.3 Informal scenario

The production of a tyre is modelled according to European conditions as in the formal scenario. The tyre is used in the origin country and then taken by informal collectors and transported to the receiving country. 30% of the tyres can't be sold and are assumed to be landfilled. 70% of the tyres can be sold and are disposed of after a second life time in a formal way.

Table 2.31: Data inventory on informal scenario, tyres

Name of the process	**Informal – tyres**

Process description	Tyres are produced and used at home for 4 years. The used tyres are taken by informal collectors who bring it to receiving countries. 30% of the tyres can't be resold. It is assumed that this part is landfilled. 70% of the devices are sold and reused. At the end of their lives they are disposed of in a formal way.
Reference unit	kg
Area of application	Production of tyres under consideration of European conditions (textiles from India), end of life under national conditions in case of waste management system and under European conditions in case of electricity and heat.
Completeness of the process	Transport to the collection centre (passenger car, 2 km) included. Emissions in the use and reuse of tyres (e.g. tyre abrasion) are not considered. Transport to recycling and disposal facilities is included (lorry, 200 km). Transport from origin to receiving country by informal collectors included (van, 300 km).
Credits	For the Co-combustion benefits for 1 kg tyre on coal as substitute material (0,877kg) and iron minerals (0,25kg) are given. For the waste-to-energy process benefits for 1 kg tyre on electric power (0,476MJ) and iron minerals (0,22kg) are given. For the CPP benefits for 1 kg tyre on iron (0,265kg) and on PUR (0,675kg) are given. For the MPP benefits for 1 kg tyre on synthetic rubber (0,225kg) and on PUR (0,456kg) are given.
Comments on credits	Inverse datasets of primary materials were given as credits. The fine pulverised tyres from the recycling process were assumed to replace thermoplastic elastomers. Polyurethane, flexible foam, was taken as substitution materials. In case of pulverised tyres < 2mm synthetic rubber was taken as substitution material.
Used processes from Ecoinvent (product specific)	Production: RER: steel, low-alloyed, at plant RER: wire drawing, steel RER: latex, at plant IN: textile, kenaf, at plant
Comments on the choice of used processes	Processes in the End-of-life phase are established based on Corti and Lombardi (2004)
Factor for functional unit	1 piece is 8 kg

2.4.5.4 Results

Results of the assessment of tyres show specific tendencies in most of the categories. An exception is the ODP. In most of the categories burdens are shown because of production processes as well as transport and benefits because of the end of life phase. The informal scenario shows in all three cases slightly less emissions than the formal scenario considering ADP, AP, EP and HTP. This is due to the avoided production phase because of reuse, which even can't compete with the benefits from the end of life phase of the origin countries. Considering the GWP the informal scenario show higher emissions, because of the greater benefits from the end of life phase of tyres, as tyres have a high calorific value.

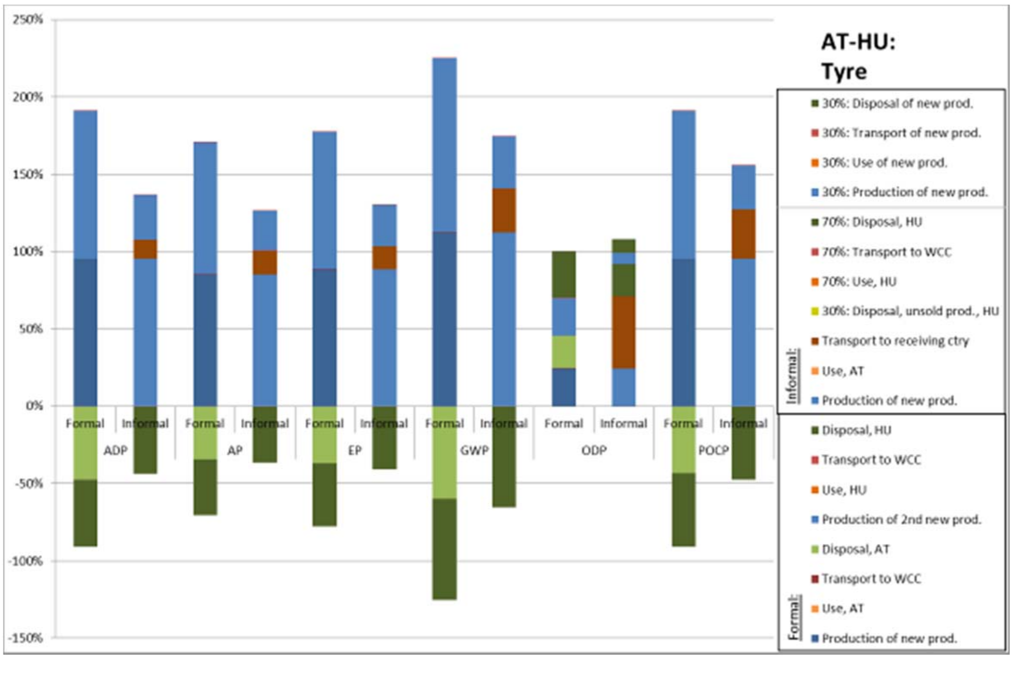

Figure 2.20: Relative results of formal and informal scenario by environmental indicators, tyre, AT-HU

Table 2.32: Absolute results of each scenario by environmental indicators, tyre, 1 kg collected product, AT-HU

Env. Category	Unit	Formal	Informal 30/70		Formalized 5/95	
ADP	Kg Sb-Equiv.	3,24E-02	3,01E-02	-	2,24E-02	-
AP	Kg SO_2-Equiv.	1,66E-02	1,49E-02	-	1,14E-02	-
EP	Kg Phosphate-Equiv.	3,27E-03	2,92E-03	-	2,20E-03	-
GWP	Kg CO_2-Equiv.	2,06E+00	2,25E+00	+	1,67E+00	-
HTP	kg DCB-Equiv.	1,62E+00	1,26E+00	-	1,01E+00	-
ODP	Kg R11-Equiv.	1,73E-07	1,87E-07	+	1,77E-07	+
POCP	kg Ethene-Equiv.	1,77E-03	1,91E-03	+	1,49E-03	-

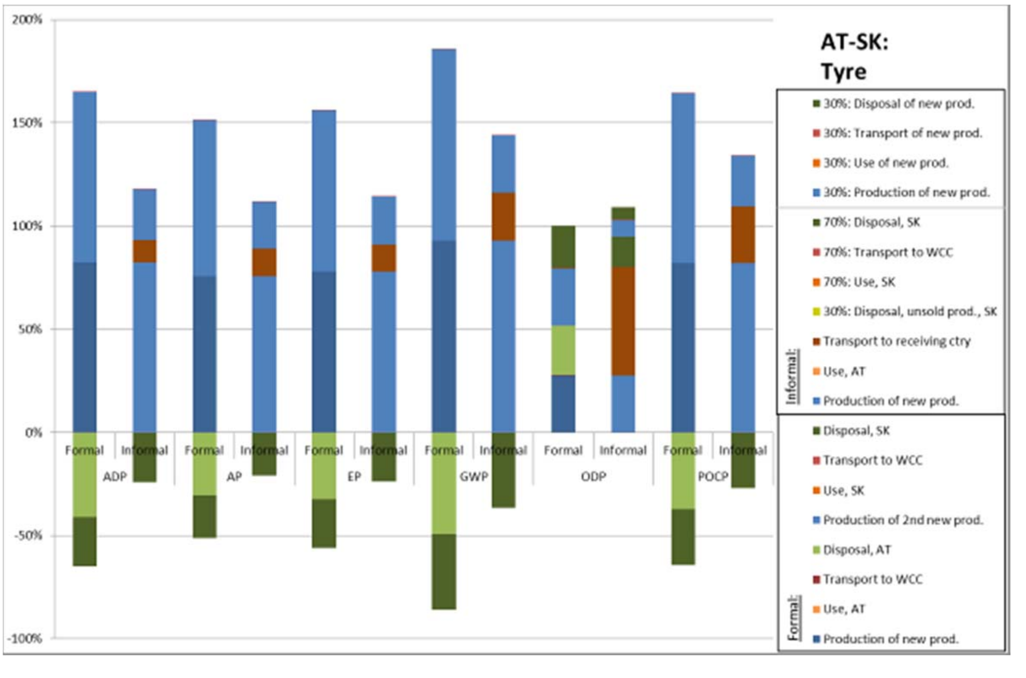

Figure 2.21: Relative results of formal and informal scenario by environmental indicators, tyre, AT-SK

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Table 2.33: Absolute results of each scenario by environmental indicators, tyre, 1 kg collected product, AT-SK

Env. Category	Unit	Formal	Informal 30/70		Formalized 5/95	
ADP	Kg Sb-Equiv.	3,75E-02	3,52E-02	-	2,74E-02	-
AP	Kg SO_2-Equiv.	1,87E-02	1,70E-02	-	1,35E-02	-
EP	Kg Phosphate-Equiv.	3,72E-03	3,37E-03	-	2,65E-03	-
GWP	Kg CO_2-Equiv.	2,50E+00	2,69E+00	+	2,11E+00	-
HTP	kg DCB-Equiv.	1,69E+00	1,33E+00	-	1,08E+00	-
ODP	Kg R11-Equiv.	1,53E-07	1,68E-07	+	1,57E-07	+
POCP	kg Ethene-Equiv.	2,05E-03	2,20E-03	+	1,77E-03	-

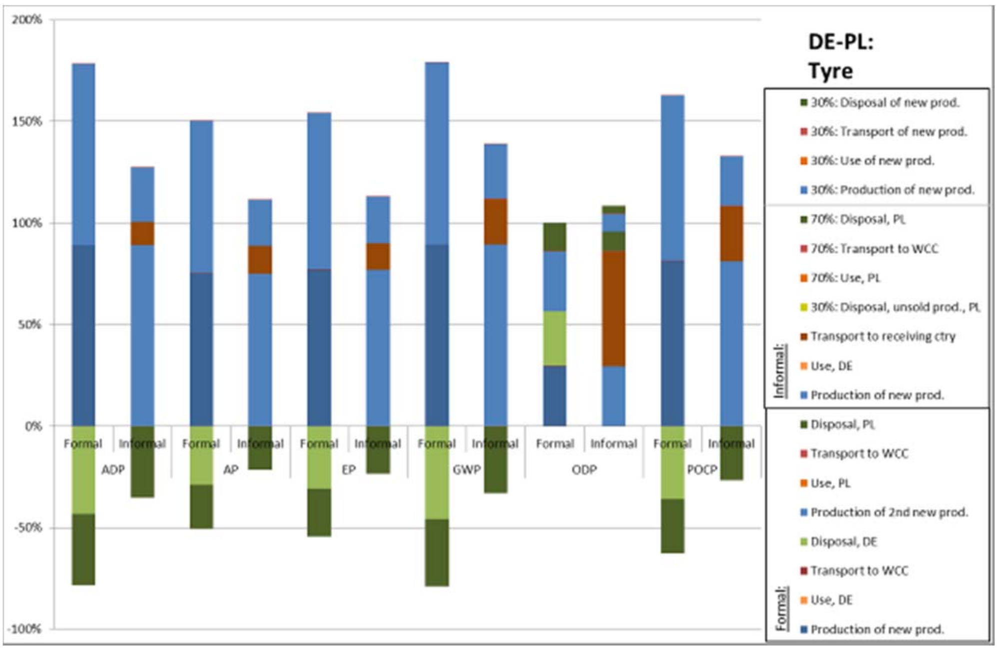

Figure 2.22: Relative results of formal and informal scenario by environmental indicators, tyre, DE-PL

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Table 2.34: Absolute results of each scenario by environmental indicators, tyre, 1 kg collected product, DE-PL

Env. Category	Unit	Formal	Informal 30/70		Formalized 5/95	
ADP	Kg Sb-Equiv.	3,47E-02	3,20E-02	-	2,43E-02	-
AP	Kg SO_2-Equiv.	1,88E-02	1,69E-02	-	1,34E-02	-
EP	Kg Phosphate-Equiv.	3,76E-03	3,37E-03	-	2,64E-03	-
GWP	Kg CO_2-Equiv.	2,59E+00	2,73E+00	+	2,16E+00	-
HTP	kg DCB-Equiv.	1,68E+00	1,30E+00	-	1,05E+00	-
ODP	Kg R11-Equiv.	1,43E-07	1,55E-07	+	1,45E-07	+
POCP	kg Ethene-Equiv.	2,07E-03	2,20E-03	+	1,78E-03	-

2.4.6 Desktop computer (without screen)

Figure 2.23: Desktop computer

2.4.6.1 System characterisation

A desktop computer is modelled without screen or monitor. Its mass considered for the purpose of TransWaste was determined as 11.3 kg. For the production of a desktop computer datasets from Hischier et al. (2007) were taken.

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The results in Ecoinvent represent an “annual hour” and not an “hour of operation”. In Ecoinvent it was assumed that most of the computers and printers are still plugged in when not in use (even during holidays). The dataset represents 1 hour of the entire (first) life-time of a device, and not only 1 hour of real operation time. It is assumed that a desktop computer is working in the “off” mode during 125 days a year when not in use and 240 days per year in use. In the days where the computer is in use, the computer is offmode 16.5 hours a day, standby 2 hours a day and active 5.5 hours a day (Hischier et al., 2007). This assumption was considered and modelled together with national conditions (electricity usage).

Table 2.35: Scenario description – desktop computer (without screen)

	Phase	Formal scenario	Informal scenario	
			Informal_EoL (30%)	Informal_Reuse (70%)
Origin country	Production	Production of a new computer	Production of a new computer	
	Use	Use of computer	Use of computer	
	EoL	Collection in WCC. Disposal: AT: 99,5% MR, 0,05% RU DE: 99,5% MR, 0,05% RU	Collection by informal bulky waste collector and transported to Hungary.	
Receiving country	Production	Production of new computer	-	Sale of used computer at flea market
	Use	Use of computer	-	Use of used computer
	EoL	Collection in WCC. Formal disposal HU: 85,2% MR, 14,3% LF, 0,05% RU PL: 74,1% LF, 20,3% MR, 2,9% LFwT, 2,2% MBT, 0,5% WIP SK: 95% MR, 5% LF	Informal disposal HU: 50% LF, 45% ID, 5% MR PL: 50% LF, 45% ID, 5% MR SK: 50% LF, 45% ID, 5% MR	Collection in WCC. Formal disposal HU: 85,2% MR, 14,3% LF, 0,05% RU PL: 74,1% LF, 20,3% MR, 2,9% LFwT, 2,2% MBT, 0,5% WIP SK: 95% MR, 5% LF

ID … Illegal disposal
LF … Landfill without treatment in advance
LFwT … Landfill with mechanical treatment
MBT … Mechanical biological treatment
MR … Material recycling
O … Other
RU … ReUse
TT … Thermal treatment
WIP… waste incineration plant

2.4.6.2 Formal scenario:

In the formal scenario of a computer and a CRT monitor the production of the devices is modelled with global references. The use phase is modelled according to parameters stated in Ecoinvent. The EOL phase was also considered according to respective national conditions.

Table 2.36: Data inventory on formal scenario, desktop computer (without screen)

Name of the process	**Formal – Desktop computer (without screen)**
Process description	A computer is produced and used at home for 5 years. The used computer and CRT monitor are taken to the waste collection centre and disposed of according to national waste management system.
Reference unit	kg
Area of application	Production of computer under consideration of global conditions, use of computer under national conditions (electricity), end of life: waste management system under national conditions, electricity usage under European conditions and technology under Swiss conditions (esp. waste incineration)
Completeness of the process	Transport to the collection centre (passenger car, 2 km) included, use of PC and monitor of 5 years included. Transport to recycling and disposal facilities is included (lorry, 200km).
Credits	For one desktop computer with a mass of 11.3 kg: 0.81 kg Aluminium; 0.60 kg Copper; 6.34 kg Steel Calorific value: 8 MJ/kg
Comments on credits	Inverse datasets of primary materials were given as credits Credits on heat and electricity production are given based on an electricity generation efficiency of 9% and heat generation efficiency of 18%.
Used processes	From Ecoinvent GLO: desktop computer, without screen, at plant RER: use, computer, desktop with CRT monitor, home use GLO: mechanical treatment, desktop computer <e-ep>
Comments on the choice of used processes	The use dataset was adapted to national electricity usage and for a computer only (active mode: 60 W, standby: 25 W, off-mode: 2 W). The dataset for mechanical treatment of the devices was used as unit process and modified for assessing material recycling. The corresponding disposal datasets were manually allocated. For Aluminium, Copper and Iron benefits were given (see credits). For

	materials used as RDF benefits on heat and electricity were given. The disposal of a desktop computer in a waste incineration plant is modelled with a shredder and certain components incinerated. The incineration of a PWB was not modelled due to lack of data. The incineration of cables was modelled with copper. Furthermore the three major materials, aluminium, steel and copper were modelled to be incinerated in a plant. The disposal of a desktop computer at a landfill was solely modelled by aluminium and steel going to sanity and inert material landfill respectively. No other data has been available.
Factor for functional unit	1 piece is 11.3 kg

2.4.6.3 Informal scenario

In the informal scenario both ways of disposal were considered: The illegal disposal and the disposal in a formal way in the receiving country. The formal disposal was already described in the formal scenario. The illegal disposal of a desktop computer needs special considerations.

By illegal dumping wastes usually end up beyond technical plants like authorized landfills and waste incineration plants in open dumpsites. For this reason toxic substances may be released directly and without treatment in the environment. If waste is burned illegally, the burning process is carried out presumably incompletely and many unburned substances are emitted. When incinerated with low temperatures significant amounts of dioxins can be build. Generally it can be stated that the illegal burning of wastes can generate up to 1000 times more toxic substances as in controlled waste incineration with flue gas cleaning systems. One kilogram of waste which is burned illegally can produce the same amount of dioxins as 400,000 kilograms of wastes which is burned in authorized waste incineration plants (Doka, 2000).

For the purpose of TransWaste the illegal burning of cables to generate copper was investigated. The emissions of the wild burning were calculated by the elemental composition of the product and the corresponding transfer coefficients in the air (air emissions) and in the soil (residues). The transfer coefficients were taken from a waste incineration plant without flue gas cleaning according to Doka (2000). It was assumed by Doka (2000) that the distribution of chemical elements to ashes and air emissions is similar than in waste incineration plants. Furthermore it was assumed that ashes are washed to the soil.

As Polyethylene (HDPE) is more common as isolation material, this type of plastic was calculated for illegal burning. The chemical formula of polyethylen is C_2H_4. The atomic weight is 28.05 g/mol.

Table 2.37: Product specific emissions of polyethylene

g elements/kg elements in waste	air emissions from flue gas	water emissions from residues	soil emissions from residues
Transfer coefficients of wild burning (Doka, 2000)			
H	1000	0	0
C	991,87	8,1289	0
1 kg HDPE (C_2H_4)			
H	143,7106	0	0
C	849,3278	6,9607	0

Next to the product specific emissions also process specific emissions from the burning need to be considered. These emissions are dependent from the type of the burning (temperature, mixture, oxygen supply, etc.). In a study of Gu (2010) plastic from cables were burned in a laboratory test. Emitted particles were collected. The results are shown in Table 2.38. These results were considered for the data inventory.

Table 2.38: Results for the particles from burning of waste plastics from cables, PVC and PE (Gu, 2010)

compound	concentrations
organic carbon (mg/g)	380
elemental carbon (mg/g)	194
n-Alkanes (µg/g)	110
PAHs (µg/g)	12730
Phthalates (µg/g)	18980
n-fatty acids(µg/g)	29650

Yet, not only the uncontrolled burning of e-waste creates emissions also the uncontrolled dumping may create hazards. According to Li (2009b) PC and CRT television and monitors are the most significant components in E-waste streams. Toxic substances may leach from those electronic devices which can affect the environment when not disposed of in a proper way. Various studies tested the leaching behaviour of electronic waste (Li, 2009a and 2009b; Spalvins, 2008). They have in common, that lead (Pb) is the most toxic heavy metal to find in leachates from electronics. That is why PB needs to be included when modelling the informal scenario where electronics are not reused but dumped illegally.

Table 2.39: Data inventory on informal scenario, desktop computer (without screen)

Name of the process	**Informal – Desktop computer (without screen)**
Process description	A computer is produced and used at home for 5 years. The used computer is taken by informal collectors who bring it to receiving countries. 70% of the devices are sold and reused for 5 years. At the end of their lives they are disposed of in a formal way. 30% of the devices can't be resold. 45% of them are dismantled in an informal way, meaning that cables and steel are removed and sold. 50% of them are directly landfilled and 5% are recycled in a formal way.
Reference unit	kg
Area of application	Production of computer under consideration of global conditions, use of computer under national conditions (electricity), end of life under national conditions (electricity and waste management system) and under Swiss conditions (esp. waste incineration).
Completeness of the process	Transport to the collection centre (passenger car, 2 km) included; a reuse of 5 years is included; lead emissions are included as heavy metals to agricultural soil; emissions from cable burning are included. The recycling rates of manually and of automatically dismantled devices was not considered. Transport to recycling and disposal facilities is included (lorry, 200km). Transport by informal collectors included (van, 300km).
Credits	Credits on aluminium, copper and steel are only allocated to the amount which is adequately disposed of (70%). For the part which is disposed of illegally (30%) only credits on cables and steel is given.
Comments on credits	Inverse datasets of primary materials were given as credits Credits on heat and electricity production are given based on an electricity generation efficiency of 9% and heat generation efficiency of 18%.
Used processes	From Ecoinvent GLO: desktop computer, without screen, at plant RER: use, computer, desktop with CRT monitor, home use GLO: mechanical treatment, desktop computer <e-ep>
Comments on the choice of used processes	The use dataset was adapted to national electricity usage and for a computer only (active mode: 60 W, standby: 25 W, off-mode: 2 W). The dataset for mechanical treatment of the devices was used as unit process and modified for assessing material recycling. The corresponding disposal datasets were manually allocated. For

	Aluminium, Copper and Iron benefits were given (see credits). For materials used as RDF benefits on heat and electricity were given. The disposal of a desktop computer in a waste incineration plant is modelled with a shredder and certain components incinerated. The incineration of a PWB was not modelled due to lack of data. The incineration of cables was modelled with copper. Furthermore the three major materials, aluminium, steel and copper were modelled to be incinerated in a plant. The disposal of a desktop computer at a landfill was solely modelled by aluminium and steel going to sanity and inert material landfill respectively. No other data has been available.
Factor for functional unit	1 piece is 11.3 kg

2.4.6.4 Results

The results of the assessment of a computer show clearly that the use phase is dominating in all considered categories. The informal scenarios have in each category lower emissions than the formal scenarios. This is mainly due to the avoided production because of reuse. The end of life phase of the computer plays a rather insignificant role when the whole life cycle is considered.

The formalized scenarios show also lower emissions than the formal scenarios and than the informal scenarios.

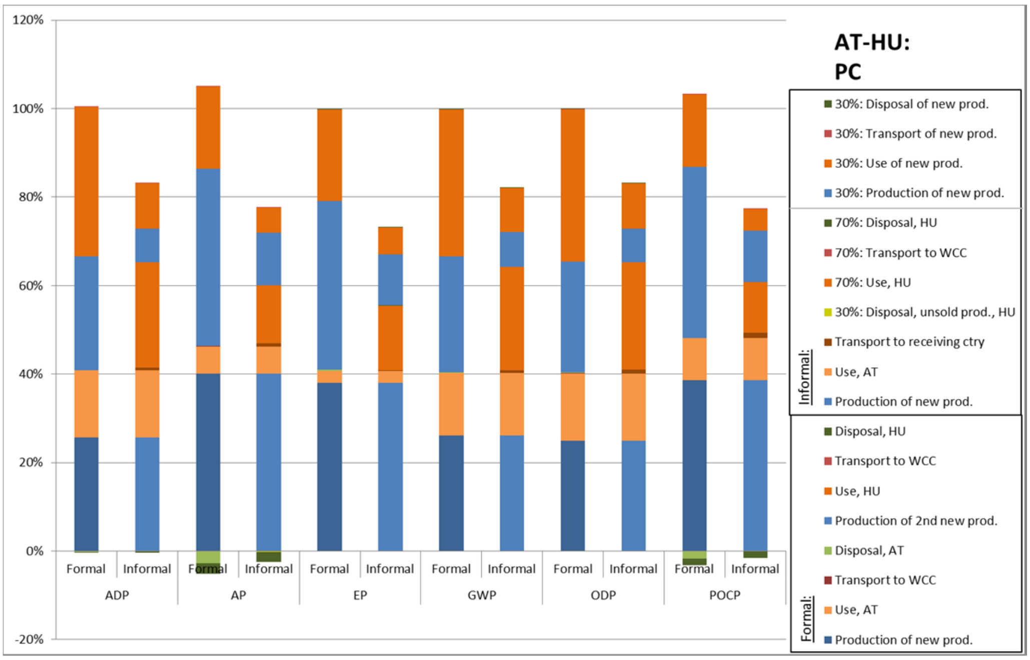

Figure 2.24: Relative results of formal and informal scenario by environmental indicators, PC, AT-HU

Table 2.40: Absolute results of each scenario by environmental indicators, PC, 1 kg collected product, AT-HU

Env. Category	Unit	Formal	Informal 30/70		Formalized 5/95	
ADP	Kg Sb-Equiv.	6,76E-01	5,60E-01	-	5,17E-01	-
AP	Kg SO_2-Equiv.	3,92E-01	2,95E-01	-	2,56E-01	-
EP	Kg Phosphate-Equiv.	5,85E-01	4,29E-01	-	3,73E-01	-
GWP	Kg CO_2-Equiv.	9,08E+01	7,46E+01	-	6,86E+01	-
HTP	kg DCB-Equiv.	1,82E+02	1,30E+02	-	1,08E+02	-
ODP	Kg R11-Equiv.	9,47E-06	7,88E-06	-	7,29E-06	-
POCP	kg Ethene-Equiv.	4,62E-02	3,50E-02	-	3,06E-02	-

Kommentar [BSR4]: I don't understand these!

Kommentar [SSch3]: I changed the results because I have found a mistake.

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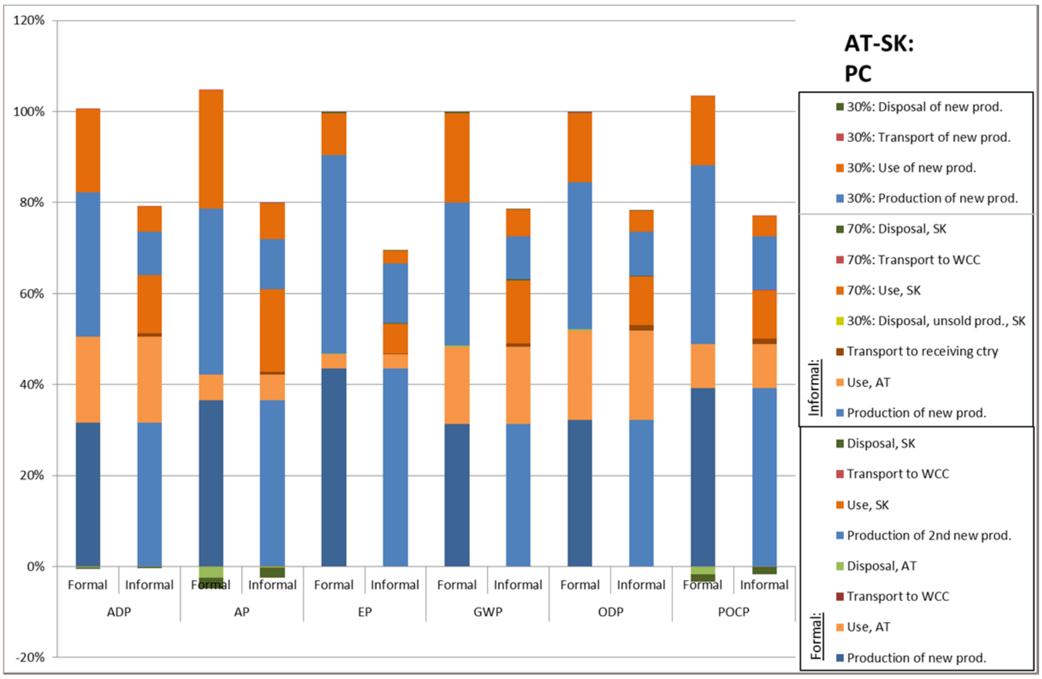

Figure 2.25: Relative results of formal and informal scenario by environmental indicators, PC, AT-SK

Table 2.41: Absolute results of each scenario by environmental indicators, PC, 1 kg collected product, AT-SK

Env. Category	**Unit**	**Formal**	**Informal** 30/70		**Formalized** 5/95	
ADP	Kg Sb-Equiv.	5,47E-01	4,31E-01	-	3,88E-01	-
AP	Kg SO_2-Equiv.	4,31E-01	3,33E-01	-	2,95E-01	-
EP	Kg Phosphate-Equiv.	5,12E-01	3,56E-01	-	3,00E-01	-
GWP	Kg CO_2-Equiv.	7,56E+01	5,94E+01	-	5,35E+01	-
HTP	kg DCB-Equiv.	1,77E+02	1,25E+02	-	1,03E+02	-
ODP	Kg R11-Equiv.	7,33E-06	5,74E-06	-	5,15E-06	-
POCP	kg Ethene-Equiv.	4,55E-02	3,43E-02	-	2,99E-02	-

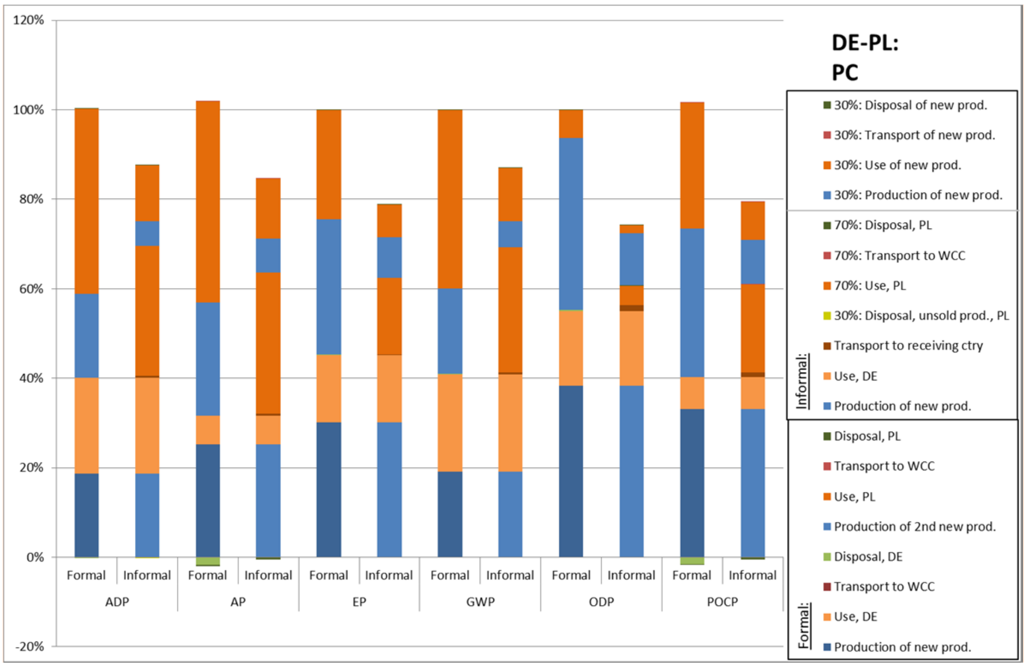

Figure 2.26: Relative results of formal and informal scenario by environmental indicators, PC, DE-PL

Table 2.42: Absolute results of each scenario by environmental indicators, PC, 1 kg collected product, DE-PL

Env. Category	Unit	Formal	Informal 30/70		Formalized 5/95	
ADP	Kg Sb-Equiv.	9,28E-01	8,12E-01	-	7,69E-01	-
AP	Kg SO_2-Equiv.	6,24E-01	5,25E-01	-	4,86E-01	-
EP	Kg Phosphate-Equiv.	7,40E-01	5,84E-01	-	5,28E-01	-
GWP	Kg CO_2-Equiv.	1,24E+02	1,08E+02	-	1,02E+02	-
HTP	kg DCB-Equiv.	2,07E+02	1,54E+02	-	1,33E+02	-
ODP	Kg R11-Equiv.	6,17E-06	4,58E-06	-	3,99E-06	-
POCP	kg Ethene-Equiv.	5,39E-02	4,26E-02	-	3,81E-02	-

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2.4.7 CRT screen/monitor

Figure 2.27: CRT Screen/Monitor

2.4.7.1 System characterisation

CRT screens or also called monitors were also taken by informal collectors during the investigations. A CRT screen with the mass of 19.86 kg was chosen for the purpose of LCA modelling in TransWaste.

The life-time for a CRT monitor was considered to be 5 years, both for new product and used product. So the time in use is 5 x 365 x 24 hrs. For the calculations of the years in use it was considered that the CRT screen is offmode 16.5 hours a day, standby 2 hours a day and active 5.5 hours a day and 240 days a year. The rest of the year (125 days) it is offmode.

Table 2.43: Scenario description – CRT screen

	Phase	Formal scenario	Informal scenario	
			Informal_EoL (30%)	Informal_Reuse (70%)
Origin country	Production	Production of a new CRT screen	Production of a new CRT screen	
	Use	Use of CRT screen	Use of CRT screen	
	EoL	Collection in WCC. Disposal: AT: 99,5% MR, 0,05% RU DE: 99,5% MR, 0,05% RU	Collection by informal bulky waste collector and transported to Hungary.	
Receiving country	Production	Production of new CRT screen	-	Sale of used CRT screen at flea market
	Use	Use of CRT screen	-	Use of used CRT screen
	EoL	Collection in WCC. Formal disposal HU: 85,2% MR, 14,3% LF, 0,05%	Informal disposal HU: 50% LF, 45% ID, 5% MR PL: 50% LF, 45% ID, 5% MR	Collection in WCC. Formal disposal. HU: 85,2% MR, 14,3% LF,

		RU PL: 74,1% LF, 20,3% MR, 2,9% LFwT, 2,2% MBT, 0,5% WIP SK: 92% MR, 8% LF	SK: 50% LF, 45% ID, 5% MR	0,05% RU PL: 74,1% LF, 20,3% MR, 2,9% LFwT, 2,2% MBT, 0,5% WIP SK: 92% MR, 8% LF

ID … Illegal disposal
LF … Landfill without treatment in advance
LFwT … Landfill with mechanical treatment
MBT … Mechanical biological treatment
MR … Material recycling
O … Other
RU … ReUse
TT … Thermal treatment
WIP… waste incineration plant

2.4.7.2 Formal scenario

Table 2.44: Data inventory on formal scenario, CRT screen

Name of the process	**Formal –CRT screen**
Process description	A CRT screen is produced and used at home for 5 years. The used CRT screen is taken to the waste collection centre and disposed of according to national waste management system.
Reference unit	kg
Area of application	Production of CRT screen under consideration of global conditions, use of CRT screen under national conditions (electricity), end of life: waste management system under national conditions, energy use under European conditions (RER) and technology under Swiss conditions (esp. waste incineration)
Completeness of the process	Transport to the collection centre (passenger car, 2 km) included, use of monitor of 5 years included. Transport to recycling and disposal facilities is included (lorry, 200km).
Credits	Benefits from recycling for one CRT screen with a mass of 19.86 kg: 0.47 kg Aluminium; 0.70 kg Copper; 2.05 kg Steel Heat and electricity benefits in case of incineration: High calorific value: 16 MJ/kg for CRT screen
Comments on credits	Credits on material recycling are based on inversive datasets of new materials plus emissions from recycling process. Credits on heat and electricity production are given based on an

	electricity generation efficiency of 9% and heat generation efficiency of 18%.
Used processes	From Ecoinvent (main streams) GLO: CRT screen, 17 inches, at plant RER: use, computer, desktop with CRT monitor, home use GLO: mechanical treatment, CRT screen <e-ep> - modified
Comments on the choice of used processes	The use dataset was adapted to national electricity usage and for a CRT screen only (active mode: 90 W, standby: 20 W, off-mode: 3 W). The dataset for mechanical treatment of the devices was used as unit process and modified for assessing material recycling. The corresponding disposal datasets were manually allocated. For Aluminium, Copper and Iron benefits were given (see credits). For materials used as RDF benefits on heat and electricity were given. The disposal of a desktop computer in a waste incineration plant is modelled with a shredder and certain components incinerated. The incineration of a PWB was not modelled due to lack of data. The incineration of cables was modelled with copper. Furthermore the major materials aluminium, steel, copper, plastic and glass were modelled to be incinerated in a plant. The disposal of a CRT screen at a landfill was solely modelled by aluminium, steel, glass and plastics mixture going to sanitary and inert material landfill respectively. No other data has been available.
Factor for functional unit	1 piece is 19.86 kg

2.4.7.3 Informal scenario

Table 2.45: Data inventory on informal scenario, CRT screen

Name of the process	**Informal – CRT screen**
Process description	A CRT screen is produced and used at home for 5 years. The used computer is taken to the waste collection centre where informal collectors take it and bring it to receiving countries. 30% of the devices can't be sold. 45% of this part is illegally disposed (Cables and steel are removed and sold, plastic from cables is burnt. The rest is landfilled), 50% goes to landfill and 5% is assumed to be recycled. 70% of the devices are sold and reused for 5 years. At the end of their lives they are disposed of in a formal way.

Reference unit	kg
Area of application	Production of CRT screen under consideration of global conditions, use of CRT screen under national conditions (electricity), end of life waste management system under national conditions, energy use under European conditions (RER) and technology under Suiss conditions (esp. waste incineration).
Completeness of the process	Transport to the collection centre (passenger car, 2 km) included; a reuse of 5 years is included; lead emissions from illegal disposal are included as heavy metals to agricultural soil; emissions from cable burning are included. The recycling rates of manually and of automatically dismantled devices was not considered. The transport to disposal and recycling facilities (lorry, 200km) and transport by informal collectors (van, 300km) are included.
Credits	Credits on aluminium, copper and steel are only allocated to the amount which is adequately disposed of (70%). For the part which is disposed of illegally (30%) credits on cables and steel is given.
Comments on credits	Credits on material recycling are based on inversive datasets of new materials plus emissions from recycling process. Credits on heat and electricity production are given based on an electricity generation efficiency of 9% and heat generation efficiency of 18%.
Used processes	From Ecoinvent GLO: CRT screen, 17 inches, at plant RER: use, computer, desktop with CRT monitor, home use GLO: mechanical treatment, CRT screen <e-ep>
Comments on the choice of used processes	The use dataset was adapted to national electricity usage and for a CRT screen only (active mode: 90 W, standby: 20 W, off-mode: 3 W). The dataset for mechanical treatment of the devices was used as unit process and modified for assessing material recycling. The corresponding disposal datasets were manually allocated. For Aluminium, Copper and Iron benefits were given (see credits). For materials used as RDF benefits on heat and electricity were given. The disposal of a desktop computer in a waste incineration plant is modelled with a shredder and certain components incinerated. The incineration of a PWB was not modelled due to lack of data. The incineration of cables was modelled with copper. Furthermore the major materials aluminium, steel, copper, plastic and glass were modelled to be incinerated in a plant. The disposal of a CRT screen at a landfill was solely modelled by

	aluminium, steel, glass and plastics mixture going to sanitary and inert material landfill respectively. No other data has been available.
Factor for functional unit	1 piece is 19.86 kg

2.4.7.4 Results

The results of the assessment of a CRT screen who a significant impact of the use phase. The production phase and the end of life phase show minor impacts in all considered categories. The informal scenarios have slightly lower emissions than the formal scenarios because of the avoided production due to reuse. In the formalized scenarios the emissions are even less.

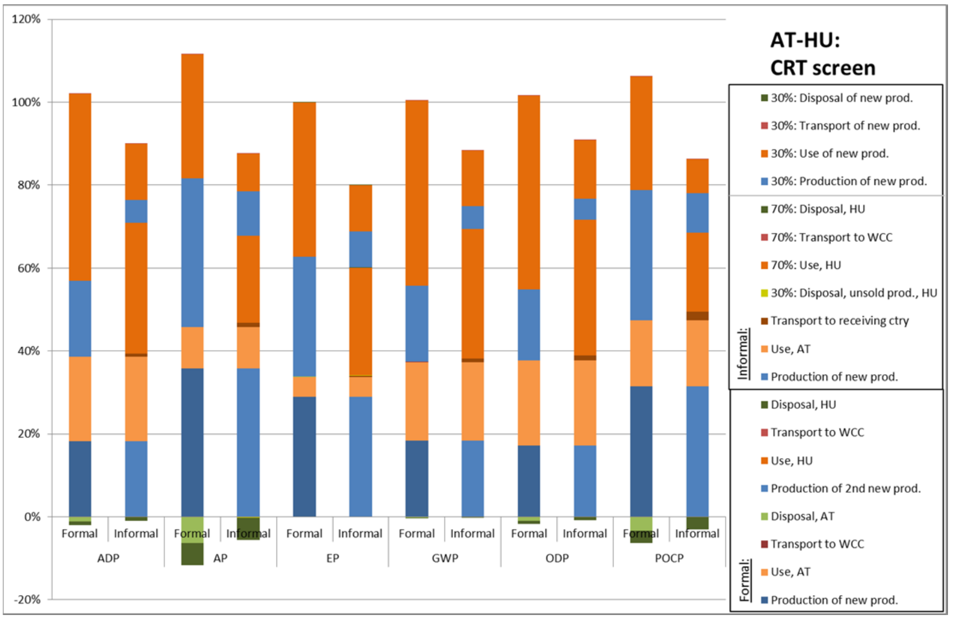

Figure 2.28: Relative results of formal and informal scenario by environmental indicators, CRT screen, AT-HU

Table 2.46: Absolute results of each scenario by environmental indicators, CRT screen, 1 kg collected product, AT-HU

Env. Category	Unit	Formal	Informal 30/70		Formalized 5/95	
ADP	Kg Sb-Equiv.	5,13E-01	4,56E-01	-	4,33E-01	-
AP	Kg SO_2-Equiv.	2,46E-01	2,02E-01	-	1,80E-01	-
EP	Kg Phosphate-Equiv.	3,29E-01	2,63E-01	-	2,39E-01	-
GWP	Kg CO_2-Equiv.	6,84E+01	6,02E+01	-	5,71E+01	-
HTP	kg DCB-Equiv.	1,33E+02	1,02E+02	-	8,30E+01	-
ODP	Kg R11-Equiv.	7,05E-06	6,35E-06	-	6,05E-06	-
POCP	kg Ethene-Equiv.	2,77E-02	2,31E-02	-	2,09E-02	-

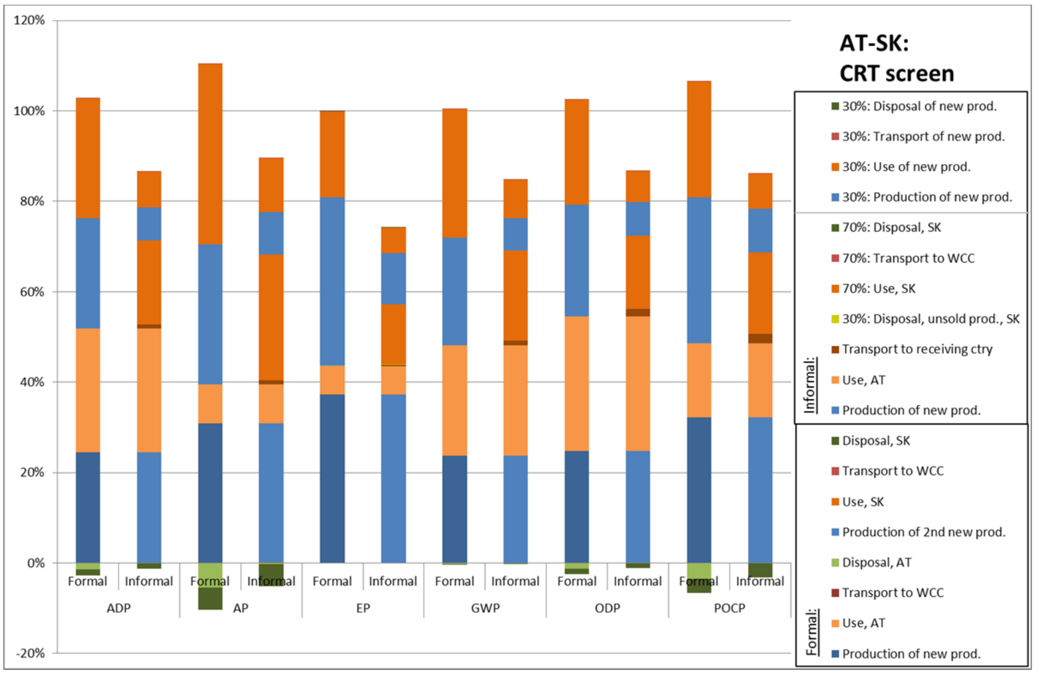

Figure 2.29: Relative results of formal and informal scenario by environmental indicators, CRT screen, AT-SK

Table 2.47: Absolute results of each scenario by environmental indicators, CRT screen, 1 kg collected product, AT-SK

Env. Category	Unit	Formal	Informal 30/70		Formalized 5/95	
ADP	Kg Sb-Equiv.	3,82E-01	3,26E-01	-	3,03E-01	-
AP	Kg SO_2-Equiv.	2,85E-01	2,40E-01	-	2,19E-01	-
EP	Kg Phosphate-Equiv.	2,55E-01	1,89E-01	-	1,66E-01	-
GWP	Kg CO_2-Equiv.	5,30E+01	4,49E+01	-	4,17E+01	-
HTP	kg DCB-Equiv.	1,28E+02	9,72E+01	-	7,85E+01	-
ODP	Kg R11-Equiv.	4,88E-06	4,18E-06	-	3,88E-06	-
POCP	kg Ethene-Equiv.	2,70E-02	2,24E-02	-	2,02E-02	-

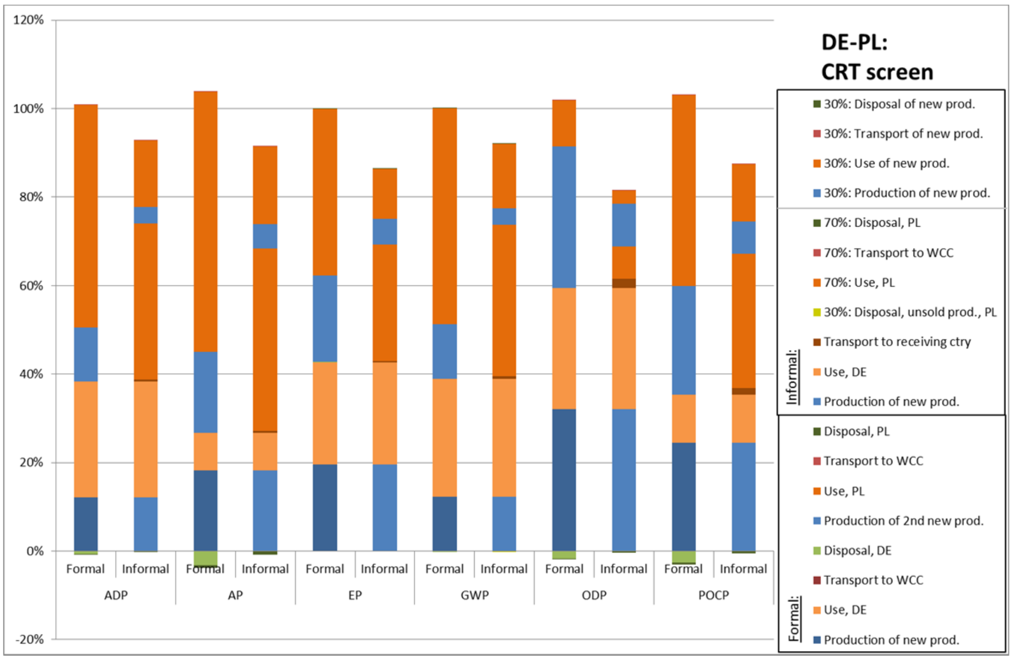

Figure 2.30: Relative results of formal and informal scenario by environmental indicators, CRT screen, DE-PL

Table 2.48: Absolute results of each scenario by environmental indicators, CRT screen, 1 kg collected product, DE-PL

Env. Category	**Unit**	**Formal**	**Informal** 30/70		**Formalized** 5/95	
ADP	Kg Sb-Equiv.	7,70E-01	7,13E-01	-	6,90E-01	7,70E-01
AP	Kg SO_2-Equiv.	4,82E-01	4,37E-01	-	4,16E-01	4,82E-01
EP	Kg Phosphate-Equiv.	4,87E-01	4,21E-01	-	3,97E-01	4,87E-01
GWP	Kg CO_2-Equiv.	1,02E+02	9,42E+01	-	9,10E+01	1,02E+02
HTP	kg DCB-Equiv.	1,55E+02	1,24E+02	-	1,06E+02	1,55E+02
ODP	Kg R11-Equiv.	3,77E-06	3,07E-06	-	2,77E-06	3,77E-06

POCP	kg Ethene-Equiv.	3,55E-02	3,08E-02	-	2,87E-02	3,55E-02

2.4.8 Fridge

2.4.8.1 System characterisation

The environment assessment of an average refrigerator from 2000 with CFCs (R11 as foaming agent and R134a as cooling agent) and from 2010 without CFCs weighing 38.1 kg is based on a material composition from literature data (Dehoust & Schüler, 2007, Steiner et al., 2005 and Barba-Gutiérrez et al., 2008). Energy consumption for manufacturing and necessary transports for distribution from factory to store and from store to consumer is taken from mentioned studies. No differences between an appliance bought in origin or receiving countries were made as electric appliances are produced globally and in most cases imported from other countries.

The use phase of 20 years is divided in 10 years use in the origin country and 10 years use in the receiving country including the nation-specific energy mix. Energy consumption for new and old appliances was taken from literature (Rüdenauer & Gensch, 2005). Literature data for new appliances was derived from 2005 and proved by additional web research to verify the factor for an appliance from 2010 for the environmental assessment.

The formal waste management of a fridge is occupied from material recycling in most of the countries except Poland. In Austria and in Germany it is assumed that 99.5% of the fridges in their countries are recycled. The rest is reused in a formal way. In Hungary and in Slovakia it is assumed that 85.5% and 95% respectively is recycled. The rest is landfilled and a small amount is reused. In Poland the majority (86.7%) is landfilled. The rest is distributed to options like shredder and landfill (3.4%), MBT (2.6%), recycling (6.7%) and a small amount is incinerated (0.6%).

Table 2.49: Scenario description – fridge

	Phase	Formal scenario	Informal scenario	
			Informal_EoL (30%)	**Informal_Reuse (70%)**
Origin country	Production	Production of a new fridge (with CFC's)	Production of a new fridge (with CFC's)	
	Use	Use of fridge	Use of fridge	
	EoL	Collection in WCC. Disposal: AT: MR: 99.5%, RU: 0.5% DE: MR: 99.5%, RU: 0.5%	Collection by informal bulky waste collector and transported to Hungary.	
Receivin g	Production	Production of new fridge (without CFC's)	-	Sale of used fridge at flea market
	Use	Use of fridge	-	Use of used fridge

	EoL	Collection in WCC. Formal disposal HU: MR: 85.5%; LF: 14%; RU: 0.5% PL: LF: 86.7%; MR: 6.7%; LFwT: 3.4%; MBT: 2.6%; WIP: 0.6% SK: MR: 95%; LF: 5%	Informal disposal HU: ID: 50%; LF: 45%; MR: 5% PL: ID: 50%; LF: 45%; MR: 5% SK: ID: 50%; LF: 45%; MR: 5%	Collection in WCC. Formal disposal HU: MR: 85.5%; LF: 14%; RU: 0.5% PL: LF: 86.7%; MR: 6.7%; LFwT: 3.4%; MBT: 2.6%; WIP: 0.6% SK: MR: 95%; LF: 5%

ID … Illegal disposal
LF … Landfill without treatment in advance
LFwT … Landfill with mechanical treatment
MBT … Mechanical biological treatment
MR … Material recycling
O … Other
RU … ReUse
TT … Thermal treatment
WIP… waste incineration plant

2.4.8.2 Formal scenario

Table 2.50: Data inventory on formal scenario, fridge

Name of the process	**Formal –fridge**
Process description	A fridge is produced and used at home for 10 years. The used fridge is taken to the waste collection centre and disposed of according to national waste management system.
Reference unit	kg
Area of application	Production of fridge under consideration of European conditions, use of fridge under national conditions (electricity), end of life: waste management system under national conditions, energy use under European conditions (RER) and technology under Swiss conditions (esp. waste incineration).
Completeness of the process	Transport to the collection centre (passenger car, 2 km) included, use of fridge of 10 years included. Transport to recycling and disposal facilities is included (lorry, 200km).
Credits	Benefits from recycling for one fridge with a mass of 38.1 kg: 1.35 kg Aluminium; 26 kg Steel; 3.9 kg PUR Heat and electricity benefits in case of incineration: High calorific value: 8 MJ/kg for CRT screen

Comments on credits	Credits on material recycling are based on inversive datasets of new materials plus emissions from recycling process. Credits on heat and electricity production are given based on an electricity generation efficiency of 9% and heat generation efficiency of 18%.
Used processes	Production: RER: polyethylene, HDPE, granulate, at plant RER: copper, at regional storage RER: aluminium, production mix, at plant RER: synthetic rubber, at plant GLO: chemicals organic, at plant RER: glass fibre reinforced plastic, polyamide, injection moulding, at plant RER: polystyrene, high impact, HIPS, at plant RER: polyurethane, flexible foam, at plant RER: polypropylene, granulate, at plant RER: reinforcing steel, at plant RER: acrylonitrile-butadiene-styrene copolymer, ABS, at plant UCTE: electricity, medium voltage, production UCTE, at grid UCTE: natural gas, burned in power plant In case of fridge with CFCs, additionally the following: RER: refrigerant R134a, at plant RER: trichloromethane, at plant In case of fridge without CFCs, additionally the following: RER: butane-1,4-diol, at plant and RER: pentane, at plant
Comments on the choice of used processes	
Factor for functional unit	1 piece is 38.1 kg

2.4.8.3 Informal scenario

Table 2.51: Data inventory on informal scenario, fridge

Name of the process	**Informal –fridge**

Process description	A fridge is produced and used at home for 10 years. The used fridge is taken by informal collectors. 30% of the devices can't be sold. 45% of this part is illegally disposed (steel and aluminium are removed and sold. The rest is landfilled), 50% goes to landfill and 5% is assumed to be recycled. 70% of the devices are sold and reused for 10 years. At the end of their lives they are disposed of in a formal way.
Reference unit	kg
Area of application	Production of fridge under consideration of European conditions, use of fridge under national conditions (electricity), end of life: waste management system under national conditions, energy use under European conditions (RER) and technology under Swiss conditions (esp. waste incineration).
Completeness of the process	Transport to the collection centre (passenger car, 2 km) included, use of fridge of 10 years included. Transport to recycling and disposal facilities is included (lorry, 200km). Transport by informal collectors to receiving countries is included (van, 300km).
Credits	Benefits from recycling for one fridge with a mass of 38.1 kg: 1.35 kg Aluminium; 26 kg Steel; 3.9 kg PUR Heat and electricity benefits in case of incineration: High calorific value: 8 MJ/kg for CRT screen
Comments on credits	Credits on material recycling are based on inversive datasets of new materials plus emissions from recycling process. Credits on heat and electricity production are given based on an electricity generation efficiency of 9% and heat generation efficiency of 18%.
Used processes	Production: RER: polyethylene, HDPE, granulate, at plant RER: copper, at regional storage RER: aluminium, production mix, at plant RER: synthetic rubber, at plant GLO: chemicals organic, at plant RER: glass fibre reinforced plastic, polyamide, injection moulding, at plant RER: polystyrene, high impact, HIPS, at plant RER: polyurethane, flexible foam, at plant RER: polypropylene, granulate, at plant

	RER: reinforcing steel, at plant RER: acrylonitrile-butadiene-styrene copolymer, ABS, at plant UCTE: electricity, medium voltage, production UCTE, at grid UCTE: natural gas, burned in power plant In case of fridge with CFCs, additionally the following: RER: refrigerant R134a, at plant RER: trichloromethane, at plant In case of fridge without CFCs, additionally the following: RER: butane-1,4-diol, at plant and RER: pentane, at plant
Comments on the choice of used processes	
Factor for functional unit	1 piece is 38.1 kg

2.4.8.4 Results

The assessment of a fridge show interesting results. The use phase is dominating in the most scenarios, except in ODP where the end of life phase is very significant. This significance is due to the CFC release in the illegal disposal. As illegal disposal also applies in the official disposal in the countries, it also effects this process step. The informal scenarios show in all considered categories higher emissions than the formal scenarios. This is due to the higher energy demand of old appliances and to the energy mix in the receiving countries. This indicator product is therefore very exceptional compared to the other indicator products used in this study. Differences appear in the country specific scenarios, as the ratio between the formal and the illegal disposal is different. The formal disposal in Poland is dominated by landfilling of regrigerators, which lead to high emissions. The ratio between the illegal disposal and the formal disposal is therefore not so high as for example in Slovakia or Hungary, where the majority of the appliances are recycled in the formal disposal scenario.

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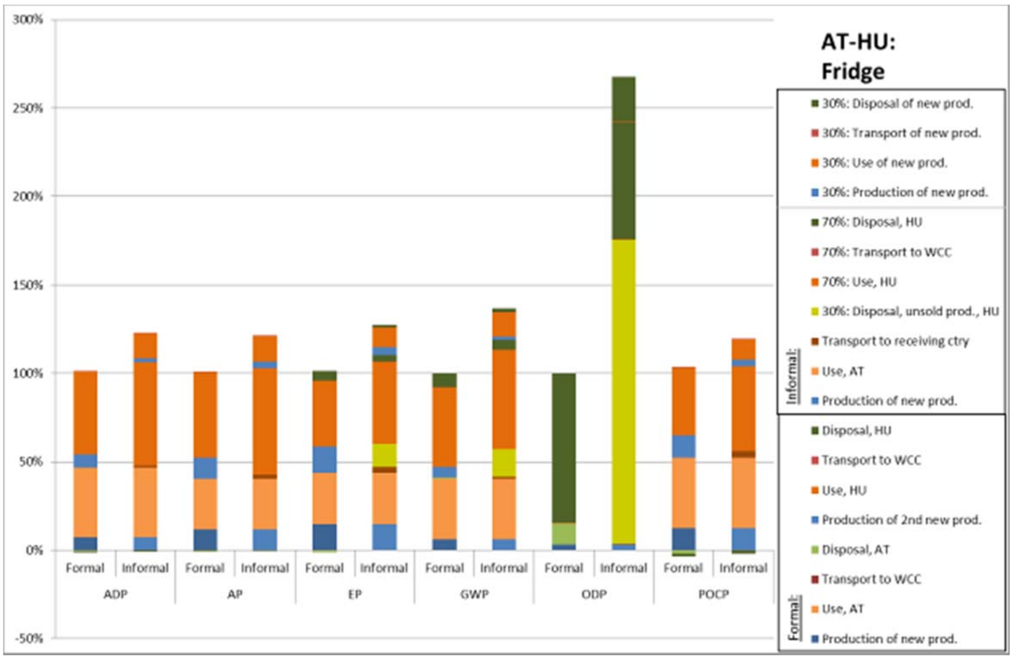

Figure 2.31: Relative results of formal and informal scenario by environmental indicators, Fridge, AT-HU

Table 2.52: Absolute results of each scenario by environmental indicators, fridge, 1 kg collected product, AT-HU

Env. Category	Unit	Formal	Informal 30/70		Formalized 5/95	
ADP	Kg Sb-Equiv.	3,68E-01	4,49E-01	+	4,77E-01	+
AP	Kg SO_2-Equiv.	1,28E-01	1,54E-01	+	1,63E-01	+
EP	Kg Phosphate-Equiv.	1,40E-02	1,79E-02	+	1,68E-02	+
GWP	Kg CO_2-Equiv.	5,67E+01	7,75E+01	+	7,44E+01	+
HTP	kg DCB-Equiv.	2,20E+01	2,15E+01	-	2,19E+01	-
ODP	Kg R11-Equiv.	9,94E-04	2,66E-03	+	1,26E-03	+
POCP	kg Ethene-Equiv.	1,66E-02	1,94E-02	+	2,02E-02	+

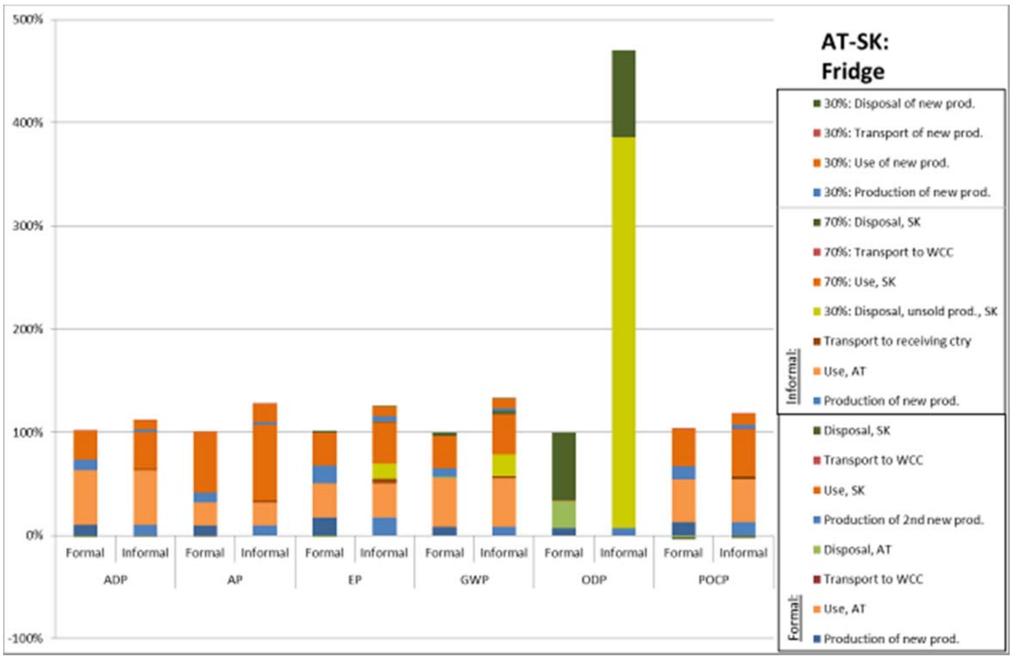

Figure 2.32: Relative results of formal and informal scenario by environmental indicators, fridge, AT-SK

Table 2.53: Absolute results of each scenario by environmental indicators, fridge, 1 kg collected product, AT-SK

Env. Category	Unit	Formal	Informal 30/70		Formalized 5/95	
ADP	Kg Sb-Equiv.	2,73E-01	3,02E-01	+	3,10E-01	+
AP	Kg SO_2-Equiv.	1,61E-01	2,06E-01	+	2,21E-01	+
EP	Kg Phosphate-Equiv.	1,21E-02	1,52E-02	+	1,39E-02	+
GWP	Kg CO_2-Equiv.	4,10E+01	5,48E+01	+	4,92E+01	+
HTP	kg DCB-Equiv.	2,25E+01	2,22E+01	-	2,26E+01	+
ODP	Kg R11-Equiv.	4,52E-04	2,13E-03	+	7,28E-04	+
POCP	kg Ethene-Equiv.	1,60E-02	1,86E-02	+	1,92E-02	+

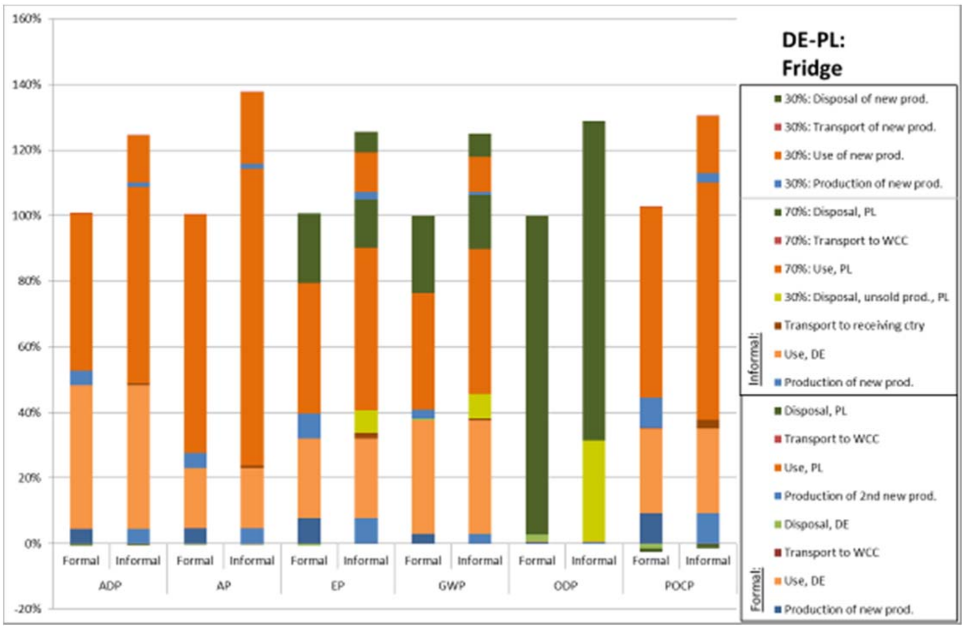

Figure 2.33: Relative results of formal and informal scenario by environmental indicators, fridge, DE-PL

Table 2.54: Absolute results of each scenario by environmental indicators, fridge, 1 kg collected product, DE-PL

Env. Category	Unit	Formal	Informal 30/70		Formalized 5/95	
ADP	Kg Sb-Equiv.	6,18E-01	7,66E-01	+	8,18E-01	+
AP	Kg SO_2-Equiv.	3,28E-01	4,50E-01	+	4,93E-01	+
EP	Kg Phosphate-Equiv.	2,69E-02	3,37E-02	+	3,38E-02	+
GWP	Kg CO_2-Equiv.	1,18E+02	1,47E+02	+	1,47E+02	+
HTP	kg DCB-Equiv.	2,91E+01	3,23E+01	+	3,40E+01	+
ODP	Kg R11-Equiv.	5,56E-03	7,16E-03	+	5,74E-03	+
POCP	kg Ethene-Equiv.	2,22E-02	2,86E-02	+	3,06E-02	+

A comparison between 'III_ReUse' and 'I_form_EoL' shows a breakthrough of the new refrigerator after one year because of the high energy consumption of the old appliance (see Figure 2.34) in case of GWP.

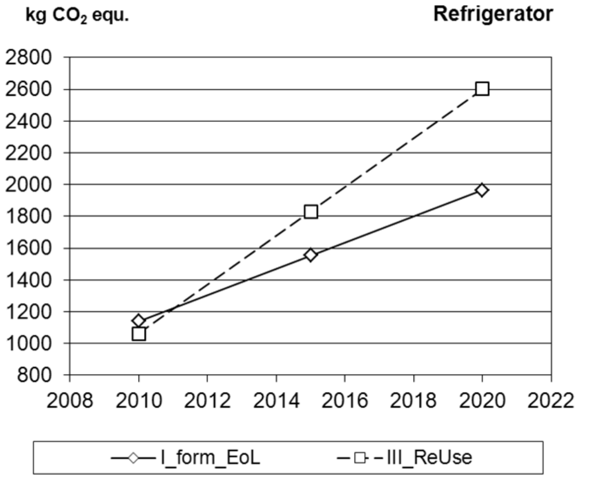

Figure 2.34: Comparison of further use and replacement of a refrigerator including formal EoL Figure

2.4.9 Washing machine

Figure 2.35: Washing mashine

The assessment of the washing machine is out of Pertl et al. (2010).

2.4.9.1 System characterisation

Production data of a washing machine (76.0 kg) could not be found in literature. Therefore already calculated LCA-results (Rüdenauer et al., 2005) were taken into account.

Due to the lack of data same emissions for production were assumed for appliances from 2000 and 2010. No differences between an appliance bought in Austria or Hungary were made as electric appliances are produced globally and in most cases imported from other countries.

The use phase of 20 years is divided in an Austrian and a Hungarian phase of 10 years including the nation-specific energy mix. Energy consumption for new and old appliances was taken from literature a washing machine (Rüdenauer et al., 2005). Literature data for new appliances was derived from 2005 and proved by additional web research to verify the factor for an appliance from 2010 for the environmental assessment.

Table 2.55: Energy and water consumption of old vs. new washing machines

	Energy consumption	Water consumption
Year 2000 - washing machine	1.5 kWh/washing	0.1 m³/washing
Year 2010 - washing machine	0.85 kWh/washing	0.04 m³/washing

Data on the energy and water consumption of old (2000) and new (2010) washing machines as well as on costs were evaluated by web research for Austria and verified concerning the comparability for Hungary.

Environmental effects in the EoL phase are mainly depending on recycling processes. State of the art technology was considered for calculating credits for the substitution of raw materials and for energy production for scenarios I & III (Dehoust & Schüler, 2007 and Rüdenauer et al., 2005). For the 'II_Coll_EoL'-scenario only dismantling of metals by collectors was considered. All other materials were assumed to be landfilled or incinerated.

Table 2.56: Material content of a washing machine

	Average material content
Aluminium	4.12 kg
Copper	0.75 kg
Steel	26.47 kg

Table 2.57: Scenario description – washing machine

	Phase	Formal scenario	Informal scenario	
			Informal_EoL (30%)	Informal_Reuse (70%)
Origin country	Production	Production of a new washing machine	Production of a new washing machine	
	Use	Use of washing machine	Use of washing machine	

	EoL	Collection in WCC. Disposal: AT: MR DE: -	Collection by informal bulky waste collector and transported to Hungary.	
Receiving country	Production	Production of new washing machine	-	Sale of used washing machine at flea market
	Use	Use of washing machine	-	Use of used washing machine
	EoL	Collection in WCC. Disposal: HU: MR PL: - SK: -	Landfilling HU: Dismantling of metals, the rest landfilled PL: - SK: -	Collection in WCC. Disposal: HU: MR PL: - SK: -

ID … Illegal disposal

LF … Landfill without treatment in advance

LFwT … Landfill with mechanical treatment

MBT … Mechanical biological treatment

MR … Material recycling

O … Other

RU … ReUse

TT … Thermal treatment

WIP… waste incineration plant

2.4.9.2 Results

As no data inventory for a washing machine was available, the results of Pertl et al. (2010) were taken. GWP was the only considered environmental category. Furthermore another display option is shown hear, as it is based on the results of Pertl et al. (2010). It is structured according to life cycle stages. Scenario 'III_ReUse' shows the least environmental burdens.

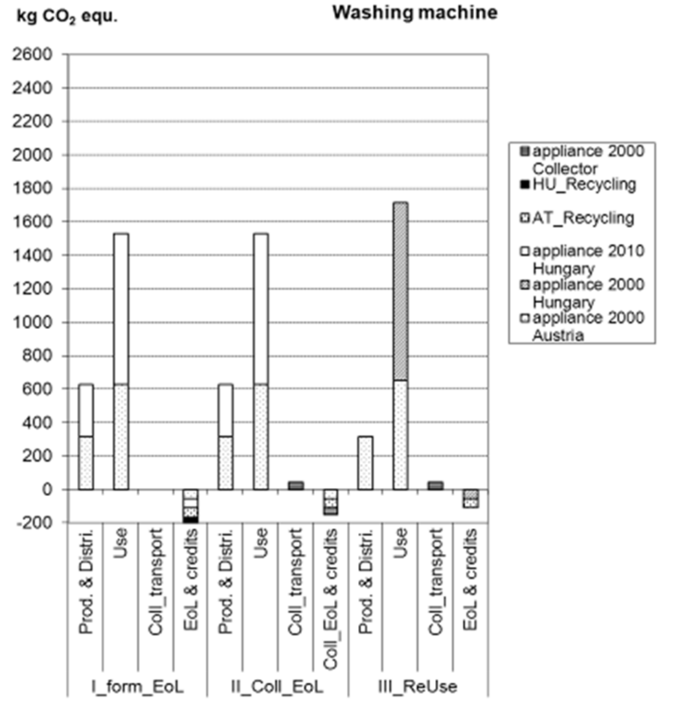

Figure 2.36: GWP emissions of a washing machine in comparison of different scenarios (AT-HU)

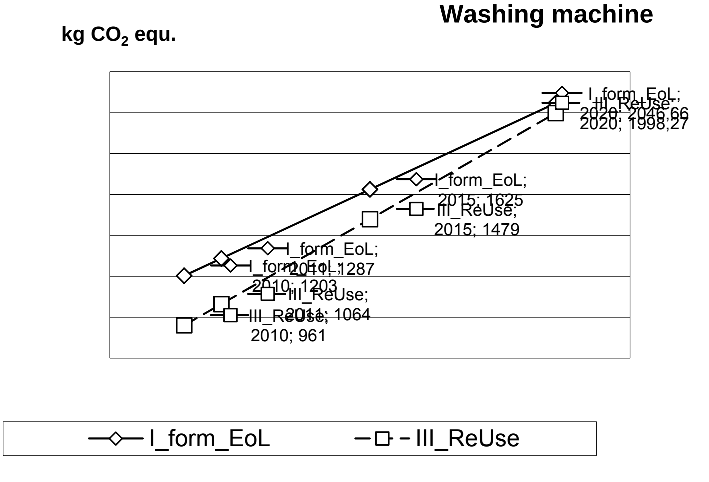

Figure 2.37: Comparison of further use and replacement of a washing machine including formal EoL

Figure 2.37 shows that a further use of a washing machine results in environmental benefits also after 10 years.

2.4.10 Bicycle

2.4.10.1 System characterization

Figure 2.38: Bicycle is the object for LCA

The definition of the product chosen is a bicycle for man, 26”, and steel frame.

Although wide scale of the bicycles gets into the lomis system in the course of bulky waste collection, only one was selected for life cycle assessment. The data collection was rather difficult, as no adequate information was available, and no information was received from the Hungarian bicycle producers. The Hungarian Bicyclist Club supported the analysis with data.

The components for bicycle production are indicated on the figure below. During the model building the power demand of the assembly was neglected. The model consists of the base materials and the base material production. The data used is from the Ecoinvent database.

Table 2.58: Component of a mountain bike (Source: Hungarian bicyclist club - Miskolc)

Mountenbike (steel) for man	Component	Substratum	Piece	Mass (gramm)
Back axle-box	Axle	steel	1	60
Back axle-box	Bearing	steel	1	50
Back axle-box	free-wheel mechanic	steel	1	120
Back axle-box	Back sprocket line	steel	1	300
Back axle-box	hub	aluminium	1	150
Bowdens	Bowden wire	steel	4	40
Bowdens	Bowden house (spiral)	steel	4	50
Bowdens	Bowden house (spiral) plastic cover	plastic	4	10
Brakes	Steel parts of brake, spirals	steel	4	30
Brakes	Brake wings	aluminium	2	100
Brakes	Aluminium parts of brakes	aluminium	4	70
Drive	front sprocket wheel (little)	steel	1	120
Drive	Stell part of pedal (axels, bearing)	steel	2	100
Drive	Spocket	steel	1	330
Drive	Front gear, frame, spiral	steel	1	60
Drive	Steel parts of back gear	steel	1	150
Drive	Steel parts of gear mechanic	steel	2	80
Drive	winch	aluminium	2	450
Drive	Back spocket wheel (big)	aluminium	2	120
Drive	Aluiminium parts of pedals	aluminium	2	100
Drive	Front gear mechanic	aluminium	1	120
Drive	Aluminium parts of bacjk gear	aluminium	1	160
Drive	Aluminium parts of gear mechanic	aluminium	2	40
Drive	plastic parts of gear mechanic	plastic	2	10
Fork (telescopic)	Spirals,...	steel	1	1000
Fork (telescopic)	shafts, house	aluminium	1	800
Frame	Frame	steel	1	2000
frame of wheel	shaft	steel	3	90
frame of wheel	frame of wheel	aluminium	2	300
frame of wheel	Strip of wheel	plastic	2	40
Front axle-box	Axle	steel	1	50
Front axle-box	Bearing	steel	1	40
Front axle-box	hub	aluminium	1	100
Helm	wheel bearing	steel	1	150
Helm	wheel shaft	aluminium	1	250
Helm	wheel	aluminium	1	220
Helm	wheel horn	aluminium	2	90
Helm	wheel grip	rubber	2	80
Lubrication	Lubricant (grease, oil)	lubricant	1	60
Middle bearing	drive bearing	steel	1	350
Saddle	saddle stick	steel	1	150
Saddle	saddle tube	aluminium	1	300
Saddle	saddle face	plastic	1	200
Spoke	Spoke	steel	72	8
Spoke	Spoke female screw	cooper	72	2
tyre	inside tyre	rubber	2	300
tyre	outside tyre	rubber, steel, plastic	2	600

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Table 2.59: The applied amount of the component of bicycle for life-cycle assessment

Component	*Steel*	*Aluminium*	*Rubber*	*Rubber, steel, plastic*	*Plastic*	*Copper*	*Lubricant*	*Sum (gramm)*
gramm	6616	4780	760	1200	340	144	60	13900

The components of the tyre of the bicycle came from literature. Based on this the tyre components are synthetic rubber (85%), steel billet and textile (15%). These latter components went in equal rate to the model (Source: www.muszakiaknak.com/anyagismeret/a-gumi.html)

Table 2.60: The applied processes from Ecoinvent database

Component	**Data source**
Steel	RER: steel, low-alloyed, at plant– Ecoinvent database – RER - 2008
Aluminium	RER: aluminium, production mix, at plant– Ecoinvent – RER - 2008
Rubber	Synthetic rubber, at plant – Ecoinvent – RER - 2008
Polyurethane	polyurethane, rigid foam, at plant – Ecoinvent – RER - 2008
Copper	ID: copper, primary, at refinery– Ecoinvent – RER - 2008
Lubricating oil	lubricating oil, at plant - Ecoinvent – RER – 2008
Textile	textile refinement, cotton - Ecoinvent – RER – 2008

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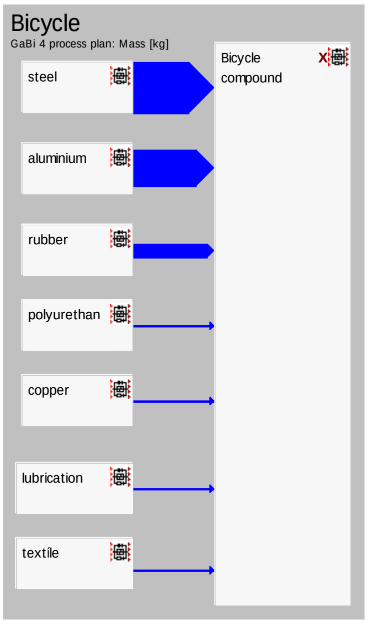

Figure 2.39: GaBi model of a bicycle

Product specific model had to be applied in the case of bicycle, due to its metal parts, both in the legal and informal scenarios. Most of the parts of the bicycle are recycled into secondary base materials in the end of the life phase. We have dealt with three types of the transport routes: the Austrian- Hungarian / Austrian-Slovakia / Germany-Poland cases.

The scenarios look therefore as follows:

Table 2.61: Scenario description – bicycle

		Formal_EoL	**Informal_EoL**	**Informal_ReUse**
Origin country	Production	Production of new bicycle in Austria/ Germany.	Production of a bicycle in Austria/Germany.	
	Use	Use of bicycle	Use of bicycle	
	EoL	Collection in WCC. Big part of the scrap bicycle (AT_99,5%; DE_99%) is used at material recycling centre in Austria.	Collection by informal bulky waste collector and transported to HU, SK, PL.	
Receiving country	Production	Production of new bicycle in destination country.	-	Sale of used bicycle at flea market (70% of the transported goods)

	Use	Use of bicycle	-	Use of used bicycle in the destination country.
	EOL	Big part of the scrap bicycle is used at material recycling center in destination country.(HU_99%) (SK_5% material recycling, 78% landfill, 17%incineration) (PL_ 12,5% material recycling, 65,1% landfill, 0,5% incineration, 20% mech. Treatment, 2% MBT).	Big part of the scrap bicycle is used at material recycling center, due to the metal parts. (30% of the transported product).	Big part of the scrap bicycle is used at material recycling centre. (There rules the rates of the county specific official waste collection system.)

Mass of an average bicycle for man, 26”, and steel frame: 13,9 kg.

2.4.10.2 Formal scenario:

Benefits arise due to the recycling of bicycle parts. 929,84 MJ benefits per bicycle could be reached if almost all parts would be recyclable, and the production of a new product could be avoided. The credit model contains an average shredder and separation technology, energy utilization of the rubber part and metal recycling. These values show an ideally case.

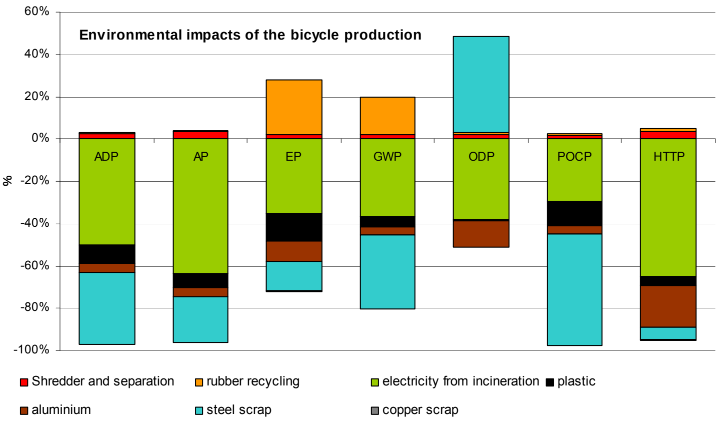

Figure 2.40: Benefits from the recycling of the parts of the bicycle

The bicycle contains almost useful parts point of view material recycling. Although rubber part uses for recovery in the cement industry gives significant benefits from all.

The average driving distance for passenger cars from their households to the recycling centre was estimated as 2 km. The average driving distance for 16 t lorries from the recycling centre to treatment facilities was estimated as 200 km.

As a reference unit 1 piece was considered.

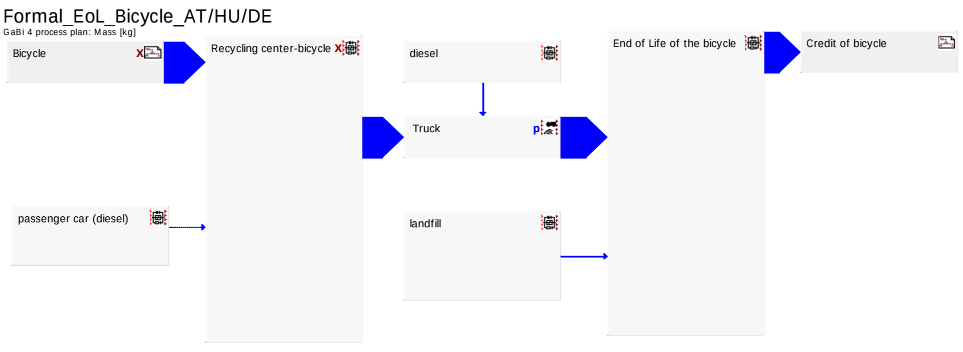

Figure 2.41: GaBi model of bicycle formal End-of Life (AT, DE, HU)

Table 2.62: Data inventory on formal scenario – used bicycle

Name of the process	**Formal – used bicycle**
Process description	Used bicycles are collected in waste collection centres. Big part of it is used for the production of new metal products and little part (rubber) is utilized at cement industry.
Reference unit	piece
Area of application	Components of a bicycle. Collection and disposal of the bicycles in energy country.
Completeness of the process	Production of the base materials of the bicycle is included. Bicycle assembly is excluded. Production of infrastructure (works) is also excluded. Transport to the collection centre (passenger car, 2 km) and to recycling centre (lorry, 200 km) included
EoL Credits	The big part of the used bicycle (one piece) is utilized as metal base material (AT, DE, HU) The used tyre part is utilized for heating in the cement industry. The models contain the country specific values.
Comments on the choice of used processes	It was analysed an average bicycle for man, which components showed wide scale. It was chosen the most ideal base materials, which didn't stand away from none of actual components (these consist of same base material).

Other comments	.

2.4.10.3 Informal scenario:

At the examination all transported goods, 30% non-reusable and 70% reusable product go to the model – the whole amounts of the bicycle are transported to the destination countries (HU, SK, PL) in three type of routes. Since the big parts of bicycles can be sold as metal scrap, these turn into base material after the recycling.

The informal scenario doesn’t contain WCC / transfer station.

Table 2.63: Data inventory on informal scenario – used bicycle

Name of the process	**Informal – used bicycle**
Process description	Used bicycles are collected at the households and transported by informal collectors to be sold as re-used product (70%) – if it good - or metal waste (30%) – if it be out of work. The missing (30%) amount of the reusable product is replaced with new product with the same amounts.
Reference unit	piece
Area of application	Production and collection of bicycles in Austria/Germany, transportation to the destination countries (HU, SK, PL), selling them to the customers or recycling centre.
Completeness of the process	Production of the base materials of the bicycle is included. Bicycle assembly is excluded. Production of infrastructure (works) is also excluded. Transportation (small lorry (7,5t), 300 km) to the market and from the market to the recycling centre (diesel car, 2 km) included
EoL Credits	Recycling - The big part of the used bicycle (one piece) is utilized as metal base material. The used tyre part is utilized for heating in the cement industry. It’s same of the destiny of the used bicycles – it becomes waste after the transport or the reuse stage. Country specific models contain the own waste treatment technology of the destination countries.
Comments on the choice of used processes	The Ecoinvent database was used. In case of the examined products (here is the bicycle) the own model was built by the information and data of the producers.

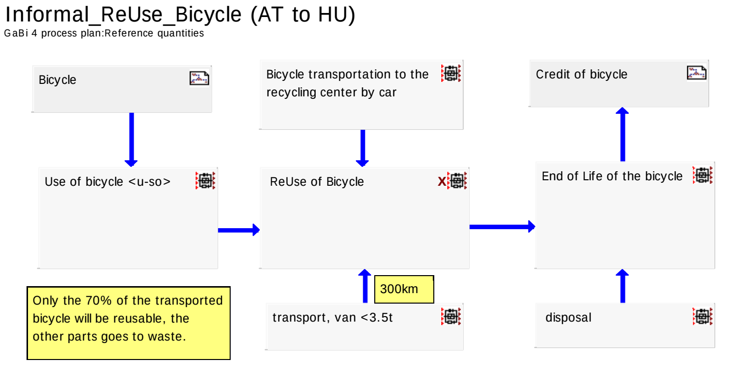

Figure 2.42: Informal scenario of bicycle, where the big parts (70%) of the products go to reuse (AT to HU)

2.4.10.4 Results

The two scenarios in consideration are comparable only if the formal scenario is duplicated in values (as matters of fact, two life cycles are calculated). In the informal scenario, it was considered the amount and disposal of the 30% waste.

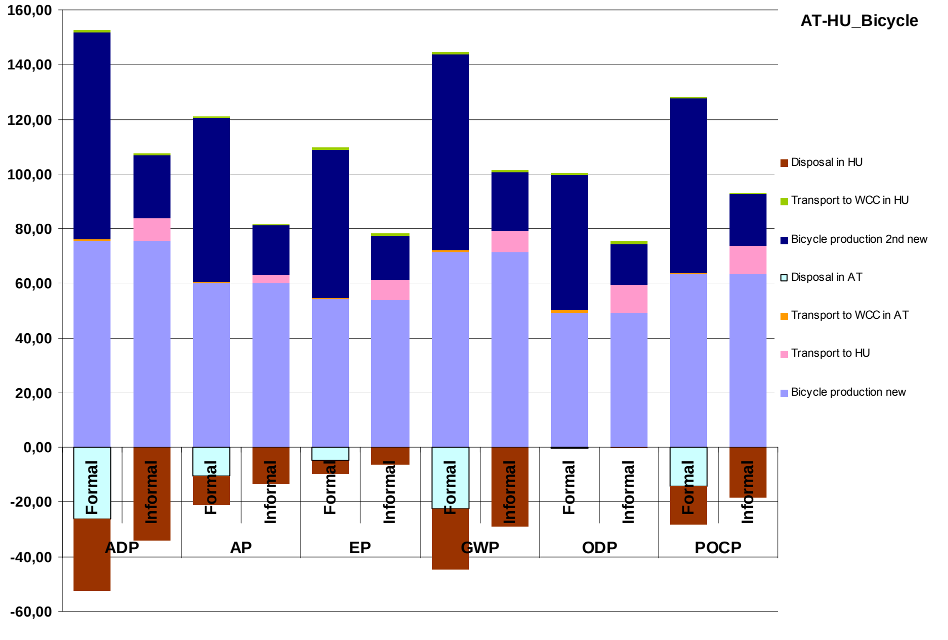

Figure 2.43: Absolute results of the formal-informal scenarios with involvement of Austria and Hungary by environmental indicators (Bicycle)

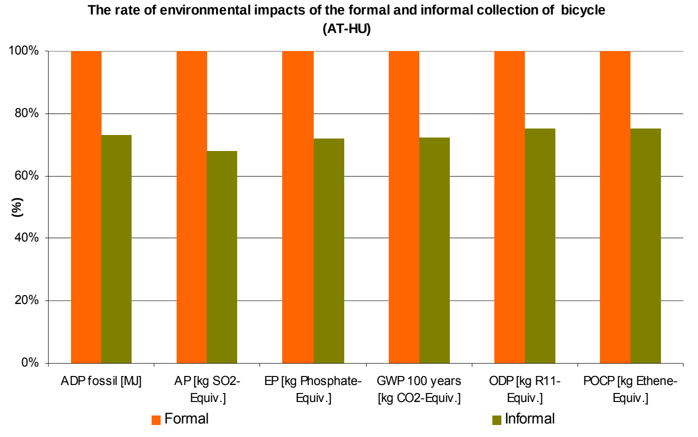

Figure 2.44: The ratio of the formal-informal scenarios (Austria and Hungary) by environmental indicators (Bicycle)

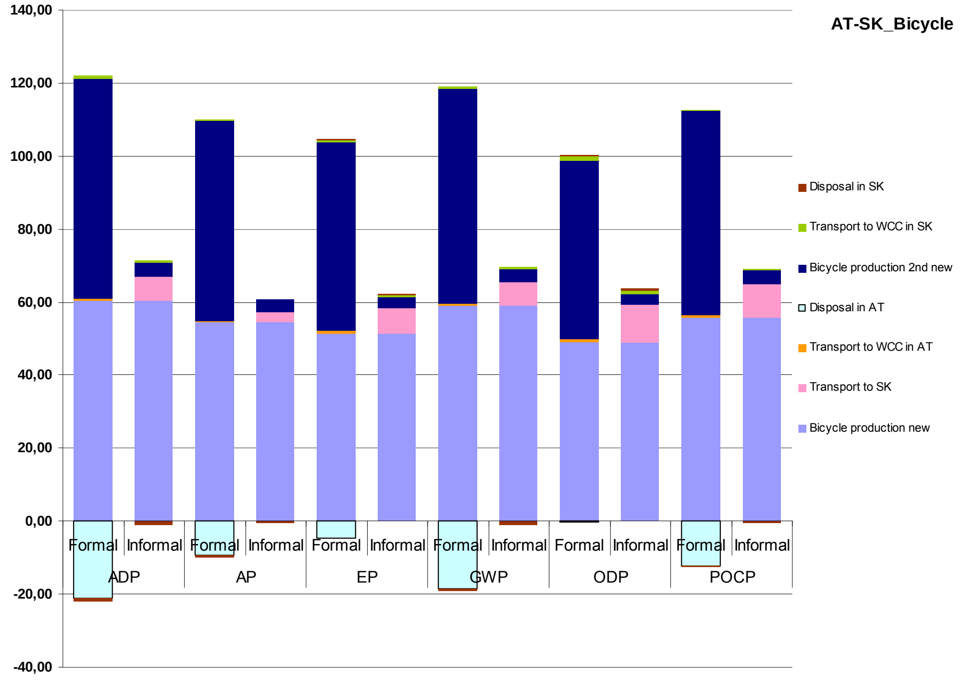

Figure 2.45: Absolute results of the formal-informal scenarios with involvement of Austria and Slovakia by environmental indicators (Bicycle)

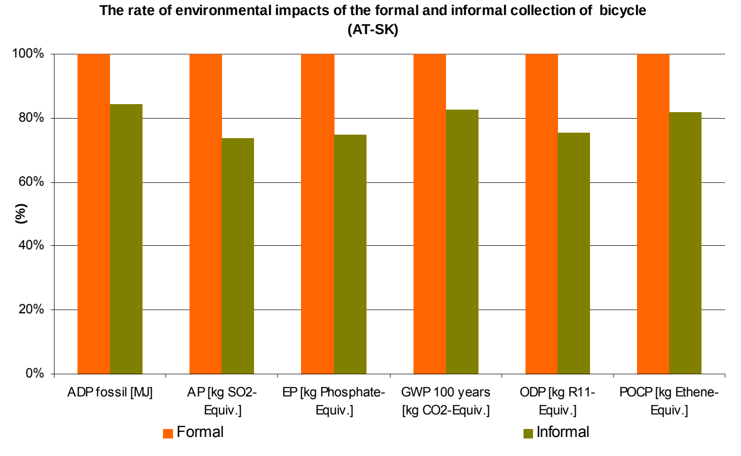

Figure 2.46: The ratio of the formal-informal scenarios (Austria and Slovakia) by environmental indicators (Bicycle)

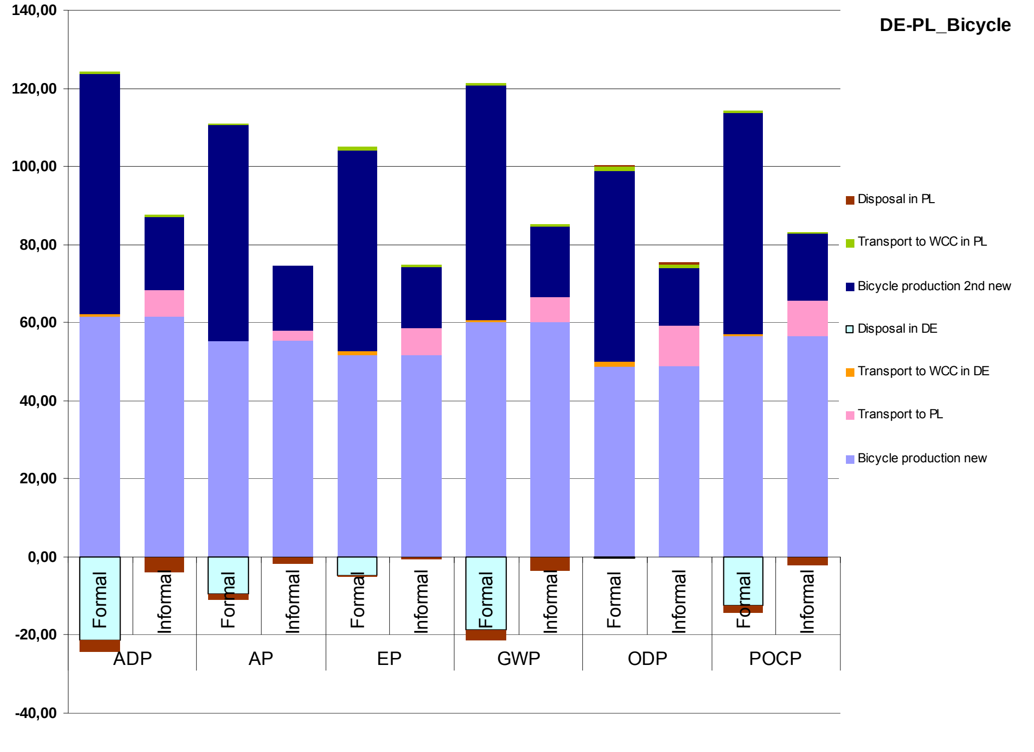

Figure 2.47: Absolute results of the formal-informal scenarios with involvement of Germany and Poland by environmental indicators (Bicycle)

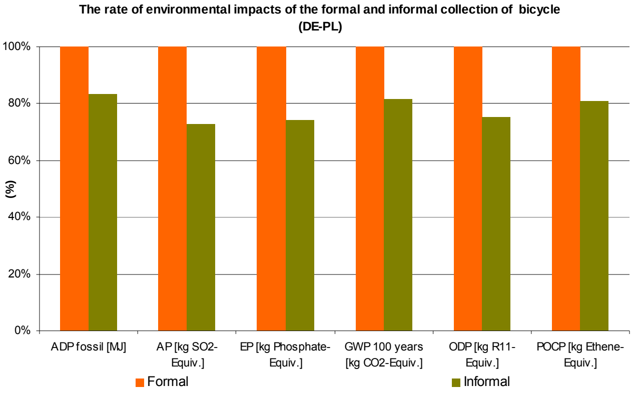

Figure 2.48: The ratio of the formal-informal scenarios (Germany and Poland) by environmental indicators (Bicycle)

In all scenarios, which were examined in the six major impact categories, the environmental impact of the bicycle production is the highest (90-98% of the whole impacts). Since the product can be recycled as secondary material in the most countries, therefore the waste disposal affects the final values. The transportation distance and the type of the vehicle affect the values in the informal scenario, but their rate isn't significant compared to bicycle production stage. Due to the metal content, the bicycle recycling could give high environmental benefit. This could be seen in case of 3 countries – Austria, Germany and Hungary.

The high environmental values come from the metal parts – utilization of aluminium and steel as seen from the metal content. Beside recovery of these compounds, energy utilization of the rubber part gives benefits.

In all three cases the transport and re-use of the bike to other destination country gives significant environmental gain with avoiding the production of a new bike.

If the collection and transport could be formalized, result values would be the same as informal, because of the value of metal content, which is recycled in both cases.

Table 2.64: Absolute results of the scenarios by environmental indicators (Bicycle_AT-HU)

Environment Category (CML2001-nov.09.)	Unit	Formal	Informal (30/70)	Formalized (5/95)
Abiotic Deplation Potential (ADP)	[MJ]	1,08E+03	7,86E+02	6,52E+02
Acidification Potential (AP)	[kg SO2-Equiv.]	8,00E-01	5,43E-01	4,43E-01
Eutrophication Potential (EP)	[kg Phosphate-Equiv.]	7,15E-02	5,13E-02	4,24E-02
Global Warming Potential (GWP 100 years)	[kg CO2-Equiv.]	8,36E+01	6,05E+01	5,01E+01
Ozone Layer Depletion Potential (ODP)	[kg R11-Equiv.]	8,78E-06	6,59E-06	5,50E-06
Photochem. Ozone Creation Potential (POCP)	[kg Ethene-Equiv.]	7,02E-02	5,27E-02	4,39E-02
Human Toxicity Potential (HTP)	[kg DCB-Equiv.]	2,12E+02	1,40E+02	1,13E+02

Table 2.65: Absolute results of the scenarios by environmental indicators (Bicycle_AT-SK)

Environment Category (CML2001-nov.09.)	Unit	Formal	Informal (30/70)	Formalized (5/95)
Abiotic Deplation Potential (ADP)	[MJ]	1,35E+03	1,14E+03	9,37E+02
Acidification Potential (AP)	[kg SO2-Equiv.]	8,81E-01	6,47E-01	5,27E-01
Eutrophication Potential (EP)	[kg Phosphate-Equiv.]	7,51E-02	5,60E-02	4,62E-02
Global Warming Potential (GWP 100 years)	[kg CO2-Equiv.]	1,01E+02	8,37E+01	6,88E+01
Ozone Layer Depletion Potential (ODP)	[kg R11-Equiv.]	8,83E-06	6,66E-06	5,55E-06
Photochem. Ozone Creation Potential (POCP)	[kg Ethene-Equiv.]	7,98E-02	6,52E-02	5,40E-02
Human Toxicity Potential (HTP)	[kg DCB-Equiv.]	2,17E+02	1,46E+02	1,18E+02

Table 2.66: Absolute results of the scenarios by environmental indicators (Bicycle_DE-PL)

Environment Category (CML2001-nov.09.)	Unit	Formal	Informal (30/70)	Formalized (5/95)
Abiotic Deplation Potential (ADP)	[MJ]	1,32E+03	1,10E+03	9,08E+02
Acidification Potential (AP)	[kg SO2-Equiv.]	8,72E-01	6,36E-01	5,18E-01
Eutrophication Potential (EP)	[kg Phosphate-Equiv.]	7,46E-02	5,54E-02	4,57E-02
Global Warming Potential (GWP 100 years)	[kg CO2-Equiv.]	9,96E+01	8,14E+01	6,69E+01
Ozone Layer Depletion Potential (ODP)	[kg R11-Equiv.]	8,83E-06	6,65E-06	5,54E-06
Photochem. Ozone Creation Potential (POCP)	[kg Ethene-Equiv.]	7,88E-02	6,38E-02	5,29E-02
Human Toxicity Potential (HTP)	[kg DCB-Equiv.]	2,15E+02	1,44E+02	1,17E+02

Detailed results on bicycle production stage are indicated below. It contains the data of the base material production without the assembly.

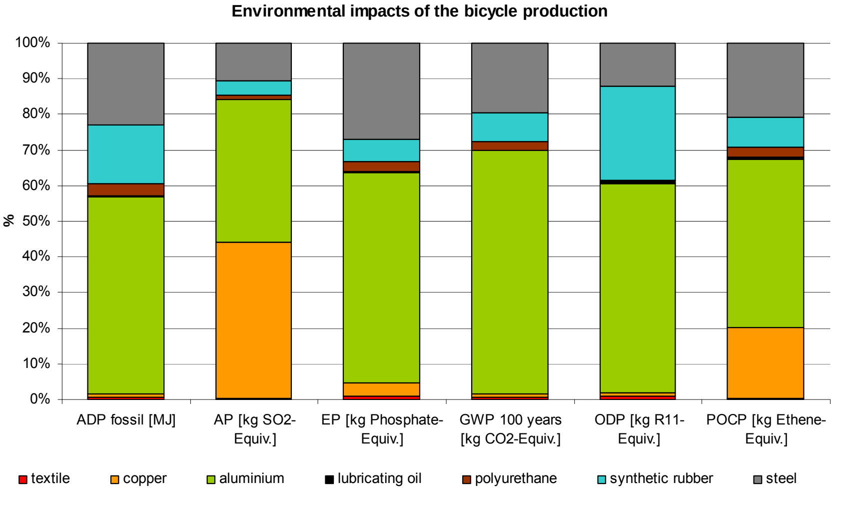

Figure 2.49: The normalized values of impacts of the bicycle production in six impact categories

In these six impact categories, the production of the aluminium component was the biggest considering environmental load. The impacts of the other components have less than the impacts of metal parts.

2.4.11 Couch

Figure 2.50: Couch is the object of the LCA

2.4.11.1 System characterization

The definition of the product selected for life-cycle analysis is “couch for three sitting person, which could pull out”. This product is popular among used item collectors as customers demand it.

Unfortunately literature data was insufficient for the LCA of a couch, thus a furniture manufacturer (Abaúj Bútor) had been contacted in Borsod-Abaúj-Zemplén County. The contact person – responsible for engineering tasks – served with detailed information on the product they produce. This information complies with an average specification of such furniture.

The summarized compound of couch production is indicated in the table below. As the energy demand for assembly was not considered in the model, the parts production and material demand is calculated. The source of data used is the Ecoinvent database.

Table 2.67: Component of a couch (Source: Abaúj furniture factory, Encs city in Hungary)

parts	components	dm3	m3	m2	m	kg
1	textil				8	
2	sawn timber	50				
	screw nail					0,5
	natur shaving plate		0,06			
	fitment - wallboard			2		1
	pine sawn timber	2				
3	iron parts					20
4	foam					12
5	upholstery					4

Conversions of data received from the producer:

Table 2.68: Conversion table for couch modelling

component	mass	unit
textil	345	g/m2
hardwood	720	kg/m3
natur shaving plate	500	kg/m3
pine sawn timber	430	kg/m3
upholstery (polyethylene, viskose)		

Values used for the model based on the aforementioned conversions:

Table 2.69: The applied amount of the component of couch for life-cycle assessment

flows	mass (kg)	mass (m3)
textil	4,132	
Soft wood	31	0,0521
Hard wood	37,36	0,061
steel profile	20	
Polyurethane	12	
polyethylene, viskose	4	
sum	108,492	

The applied processes from Ecoinvent database:

Component	Data source
Textil	polyester resin, unsaturated, at plant – Ecoinvent - 2008
wood chips	industrial residue wood, from planing, softwood, kiln dried, u=10%, at plant– Ecoinvent - 2008
wood fibre board	practicle board, indoor use, at plant,– Ecoinvent-2008
steel	RER: steel, low-alloyed, at plant– Ecoinvent - 2008
polyurethane	polyurethane, flexible foam, at plant – Ecoinvent - 2008
polyethylene, viscose	viscose fibres, at plant – Ecoinvent-2008

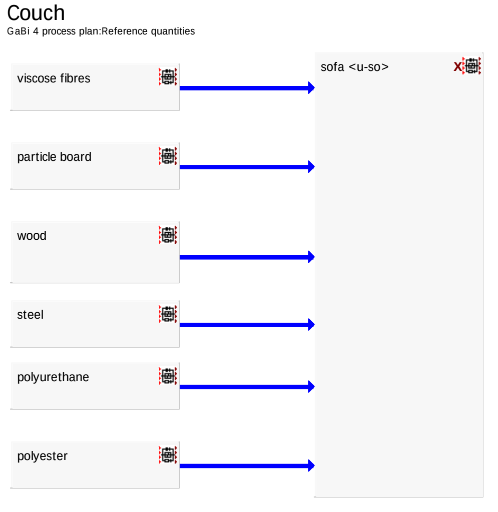

Figure 2.51: GaBi model of a couch

While the first scenario considered includes only the formal activities (without illegal waste collection), the second one focuses on informal waste collection. It includes negative environmental impacts such as waste incineration in the households.

The scenarios look therefore as follows:

Table 2.70: Scenario description – couch

		Formal_EoL	**Informal_EoL**	**Informal_ReUse**
Origin country	Production	Production of new couch in Austria/Germany	Production of new couch in Austria/Germany	
	Use	Use of couch	Use of couch	
	EoL	Collection in WCC. Big part of the scrap couch (99,5%) goes to waste incineration in Austria. 61,4% material recycling, 28,9% waste incineration, 3,2% thermal treatment and 6,5% MBT in DE.	Collection by informal bulky waste collector and transported to Hungary/ Slovakia/ Poland.	
Recei ving countr	Production	Production of new couch in HU/SK/PL	-	Sale of used couch at flea market (70% of the transported

				goods)
	Use	Use of couch	-	Use of used couch
	EOL	One part (8,9%) of the scrap couch goes to waste incineration, and the other part goes to landfill in Hungary. 5% material recycling, 78% landfill, 17% incineration in SK. 65,1% landfill, 0,5% waste incineration, 12,5% other treatment, 20% MT and 2% MBT.	45% of the waste goes to illegal waste incineration, 45% goes to illegal landfill and the rest part (10%) goes to formal WCC.	Based on the country specific formal waste treatment system.

Mass of an average couch for 3 person, pull out: 108,5 kg.

2.4.11.2 Formal scenario:

Product specific model should be used in the case of a couch as in case of all products considered. In case of every products there were three hypotheses, which were three types of the transport ways. The models were built in every case, which included the different EOL stages. While 99,5% of products are incinerated in Austria, only 8,9% utilised this way in Hungary, where the main stream is deposited in landfill. The big part of the couch waste (61,4%) goes to recycling in Germany, (78%) goes to landfill in Slovakia and (65,1%) goes to landfill, too in Poland. Formal scenario works this way.

There is a benefit in the result due to the recycling of couch parts, which gain is identified if 100% of all parts would be recycled. This comes from the avoided production phase of new parts. The efforts of the effectively recoverable parts come from recycling of the steel and the energetic utilization of wood. This value can change with the level of recycling and reuse, and the technology used (such as incineration with energy recovery instead of material recycling).

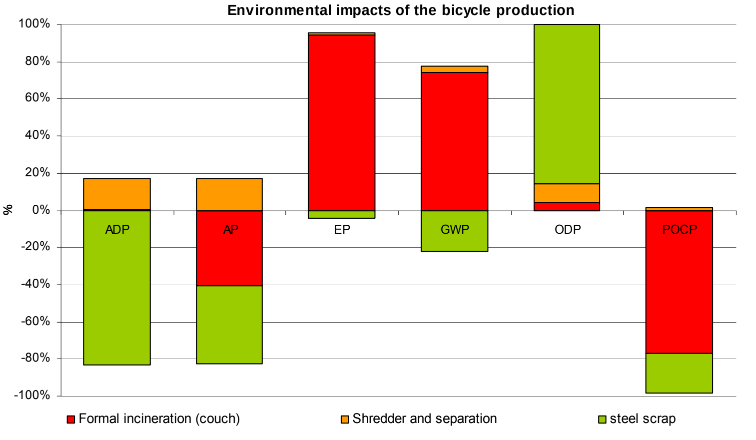

Figure 2.52: Benefits from the recycling of the parts of the couch

The average driving distance for passenger cars from their households to the recycling centre was estimated as 2 km. The average driving distance for 16 t lorries from the recycling centre to treatment facilities was estimated as 200 km.

As a reference unit 1 piece was considered.

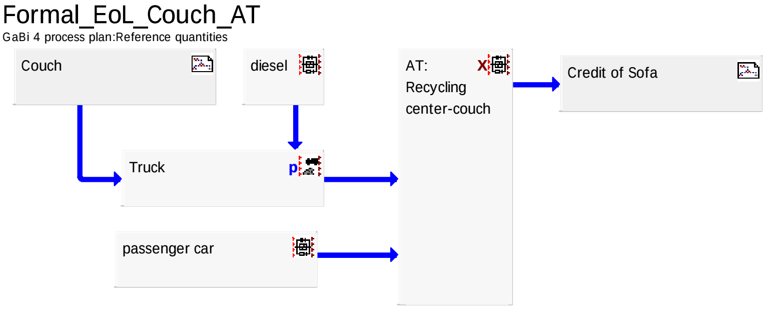

Figure 2.53: GaBi model of couch formal End-of Life in Austria

Table 2.71: Data inventory on formal scenario – used couch

Name of the process	**Formal – used couch**
Process description	By the couch production, the process contains the transport phase and country specific EoL phase.
Reference unit	piece
Area of application	Components of a couch. Collection and disposal of the couches in every examined country.
Completeness of the	Production of the base materials of the couch is included. Couch

process	assembly is excluded. Production of infrastructure (works) is also excluded. Transport to the collection centre (passenger car, 2 km) and to recycling centre (lorry, 200 km) included
EoL Credits	Used couches – in Austria- are collected in waste collection centres and utilised in municipal waste incineration. The system is different in the other countries. (In Hungary, because these products go by the way of municipal waste, so 8,9% of couches go to the municipal waste incineration, and the other parts go to landfill.) The credit was counted from the steel recycling, the energy utilization of wood and other parts of the couch.
Comments on the choice of used processes	The base was the ecoinvent database; by this some processes were applied from the PE database. In case of the examined products (here is the couch) the own model was built by the information and data of the producers. It was analysed an average couch, which parameters are 3 sitting person and pull-out.
Other comments	The data source is from Abaúj furniture factory.

2.4.11.3 Informal scenario:

This product is also popular among the used item collectors, there is a demand for it. As for all the products analysed, the whole quantity is transported through the border then 30 % of the transported amount can't be sold or reused and 70 % are reusable. The 30% can end up in the formal waste management system, in illegal waste disposal or in households as fuel for the stoves due to the high energy content. The ratios of such methods are hard identifying. The estimate values used were 10 % for the formal waste management system, 45 percent for household incineration and the remaining 45 % for illegal waste dumps.

WCCs and transfer stations were not added to the informal model.

Table 2.72: Data inventory on informal scenario – used couch

Name of the process	**Informal – used couch**
Process description	Used couches are collected at the households and transported by informal collectors to be sold as re-used product, the unusable parts turn into waste (30% of all). . The missing (30%) amount of the reusable product is replaced with new product in as many amounts.
Reference unit	piece
Area of application	Production and collection of couches in Austria/Germany, transportation to Hungary, selling in Hungary/Slovakia/Poland at the flea market to the customers.

Completeness of the process	Production of the base materials of the couch is included. Couch assembly is excluded. Production of infrastructure (works) is also excluded. Transportation (small lorry (< 3.5t), 300 km) to the market and from the market to the recycling centre (diesel car, 2 km) included
EoL Credits	We counted with the formal EoL, and the illegal waste burning. We had no data from the illegal waste dumping. The credit values came from the useful part recycling (metal) and the other part (mainly the wood part) energy utilisation.
Comments on the choice of used processes	The illegal waste burning process was modelled by us, because it couldn't be found in the GaBi/Ecionvent database. The source of the data of the illegal burning: HAIDER 2011 according to SPECKELS 2001, EMPA S.A.
Other comments	We neglected the product and the reusable product transport from the market to the using place.

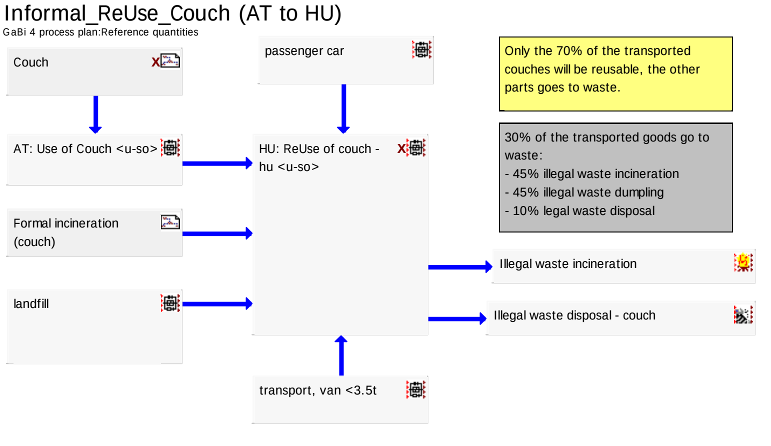

Figure 2.54: Informal scenario of couch, where the big parts (70%) of the products go to reuse

2.4.11.4 Results

The two scenarios in consideration are comparable only if the formal scenario is duplicated in values (as matters of fact, two life cycles are calculated). Besides this new products should be used for the second life cycle stage in the informal scenario to replace the unusable 30% of used products.

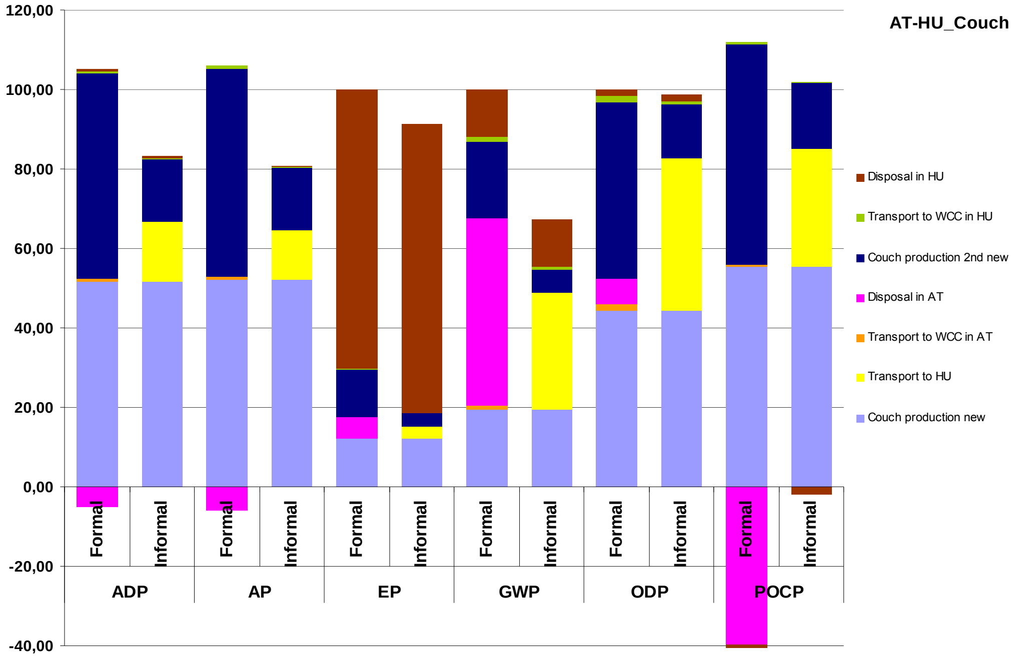

Figure 2.55: Absolute results of the formal-informal scenarios with involvement of Austria and Hungary by environmental indicators (Couch)

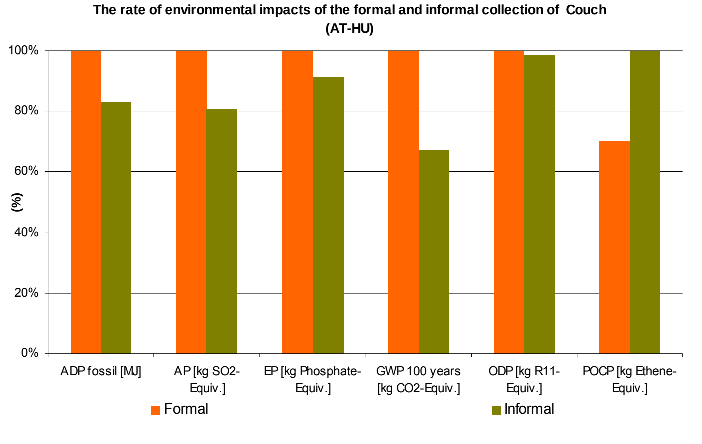

Figure 2.56: The ratio of the formal-informal scenarios (Austria and Hungary) by environmental indicators (Bicycle)

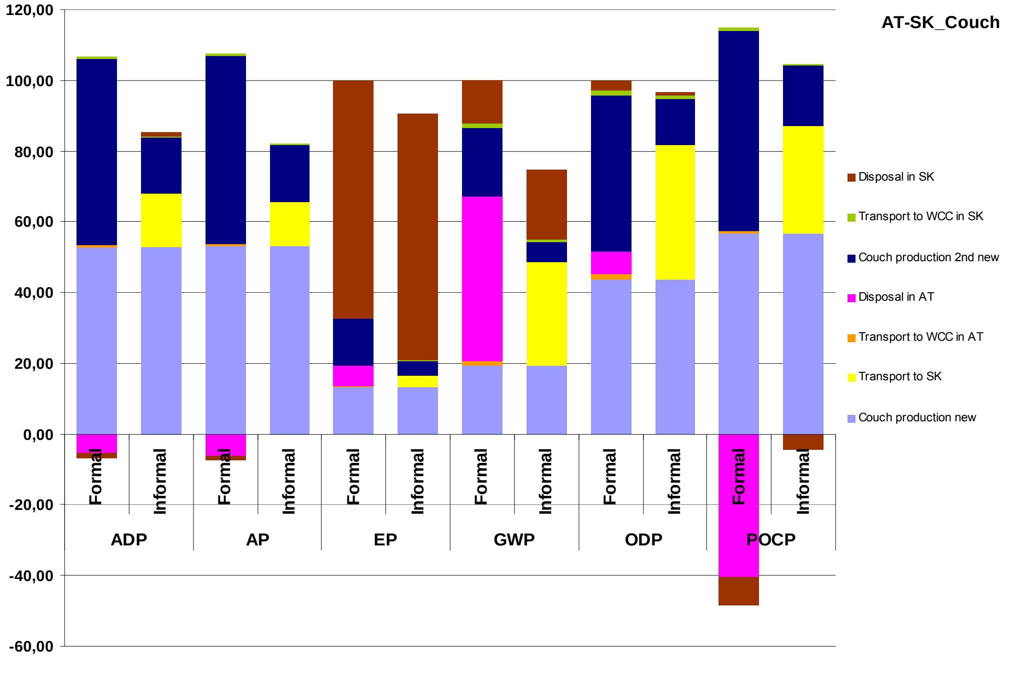

Figure 2.57: Absolute results of the formal-informal scenarios with involvement of Austria and Slovakia by environmental indicators (Couch)

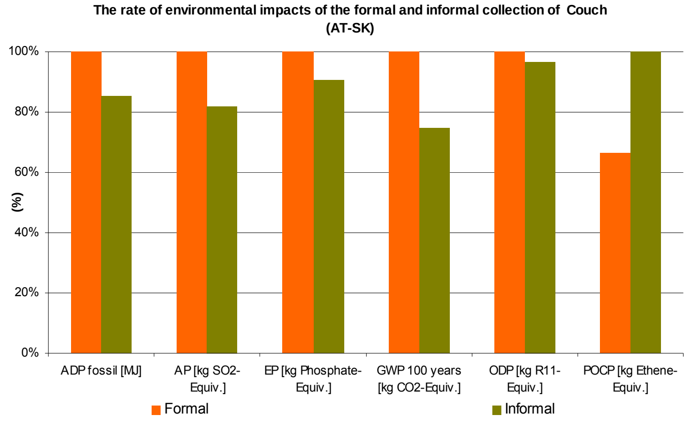

Figure 2.58: The ratio of the formal-informal scenarios (Austria and Slovakia) by environmental indicators (Bicycle)

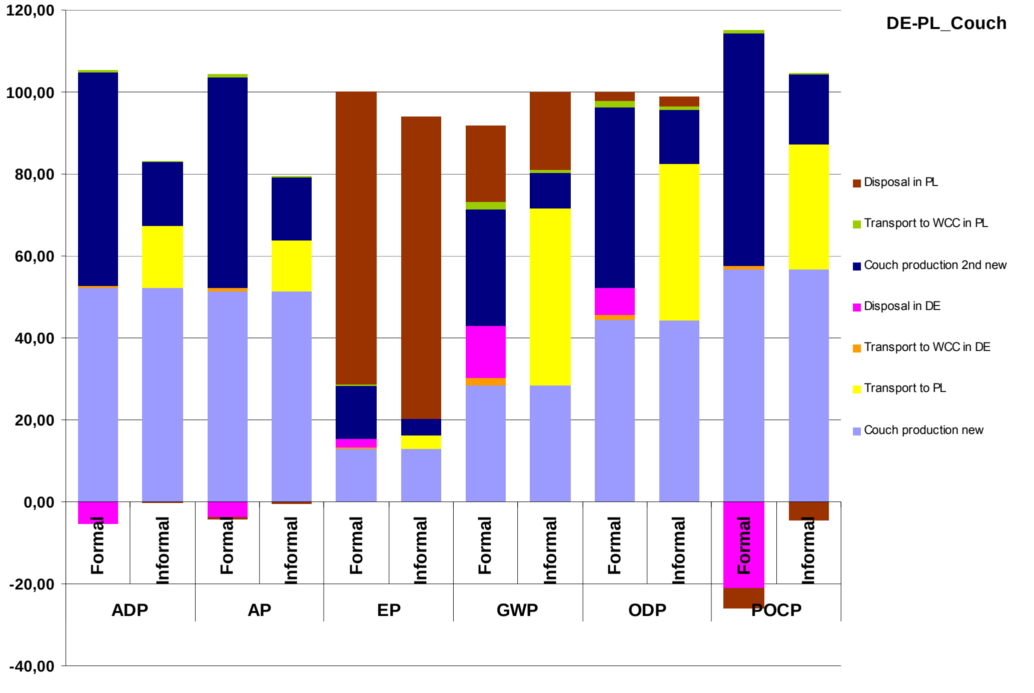

Figure 2.59: Relative results of the formal-informal scenarios with involvement of Germany and Poland by environmental indicators (Couch)

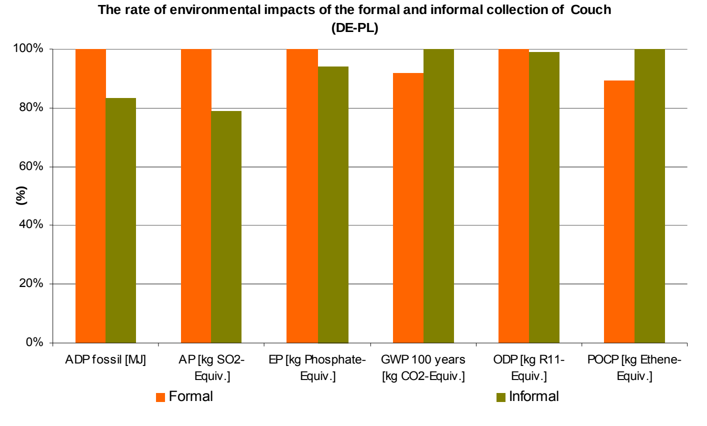

Figure 2.60: The ratio of the formal-informal scenarios (Germany and Poland) by environmental indicators (Couch)

Both scenarios – formal and informal – contain several mode of the waste disposal. While waste incineration, disposal and recycling appear in the formal, illegal waste dumping and illegal waste incineration is included in the informal. The aim of this latter is the heating of the houses. Although we can define this as environmental benefit because the owner doesn't need to use other energy recourses (natural gas, electric heating, etc.), but this act accompanies more pollution than environmental benefit.

In the six reliable impact categories only one difference raised. In the photochemical ozone creation potential category, the formal scenario proves better than informal. The causes of it are the energy utilization (benefit) from the formal waste incineration and the environmental impact of the product transportation to the re-user country. There are no so much differences between the two scenarios than the case of the couch. This product has bigger size, so the van can't transport many of this product. The 90% of the couch production are from the ADP, AP, ODP impacts. The effects of the deposit are the biggest of the whole impacts in the EP category. In those counties (HU, SK, PL) where the deposit of the couch waste is the landfill technology gives more environmental impact mainly in the eutrophication potential category. The waste incineration gets influence the climate changing unfavourably near the waste deposit. Although the total impacts of the couch production gives positive values due to the wood components of the product, which are carbon storage. The ecotoxicity categories show differences, because in those categories the impacts of the illegal waste incineration and dumping appear. The next table shows the absolute values.

If collection and selling go in formalized way the values of the impact categories approximate to the values of the formal way, except in two categories where pass them. The best improving is in the ecotoxicity categories.

Table 2.73: Absolute results of each scenario by environmental indicators (AT-HU)

Environment Category (CML2001-nov.09.)	Unit	Formal	Informal (30/70)	Formalized (5/95)
Abiotic Deplation Potential (ADP)	[MJ]	4,65E+03	3,87E+03	3,26E+03
Acidification Potential (AP)	[kg SO2-Equiv.]	1,48E+00	1,19E+00	9,98E-01
Eutrophication Potential (EP)	[kg Phosphate-Equiv.]	1,33E+00	1,22E+00	1,19E+00
Global Warming Potential (GWP 100 years)	[kg CO2-Equiv.]	1,70E+02	1,15E+02	1,07E+02
Ozone Layer Depletion Potential (ODP)	[kg R11-Equiv.]	1,85E-05	1,83E-05	1,62E-05
Photochem. Ozone Creation Potential (POCP)	[kg Ethene-Equiv.]	1,33E-01	1,89E-01	1,62E-01
Human Toxicity Potential (HTP)	[kg DCB-Equiv.]	2,46E+02	1,20E+05	1,36E+02

Table 2.74: Absolute results of each scenario by environmental indicators (AT-SK)

Environment Category (CML2001-nov.09.)	Unit	Formal	Informal (30/70)	Formalized (5/95)
Abiotic Deplation Potential (ADP)	[MJ]	4,57E+03	3,19E+03	3,10E+03
Acidification Potential (AP)	[kg SO2-Equiv.]	1,45E+00	9,65E-01	9,52E-01
Eutrophication Potential (EP)	[kg Phosphate-Equiv.]	1,20E+00	7,98E-01	2,04E-01
Global Warming Potential (GWP 100 years)	[kg CO2-Equiv.]	1,71E+02	1,11E+02	8,76E+01
Ozone Layer Depletion Potential (ODP)	[kg R11-Equiv.]	1,88E-05	1,54E-05	1,55E-05
Photochem. Ozone Creation Potential (POCP)	[kg Ethene-Equiv.]	1,22E-01	1,57E-01	1,57E-01
Human Toxicity Potential (HTP)	[kg DCB-Equiv.]	1,31E+02	2,48E+02	1,29E+02

Table 2.75: Absolute results of each scenario by environmental indicators (DE-PL)

Environment Category (CML2001-nov.09.)	Unit	Formal	Informal (30/70)	Formalized (5/95)
Abiotic Deplation Potential (ADP)	[MJ]	4,62E+03	3,84E+03	3,26E+03
Acidification Potential (AP)	[kg SO2-Equiv.]	1,50E+00	1,18E+00	9,93E-01
Eutrophication Potential (EP)	[kg Phosphate-Equiv.]	1,23E+00	1,16E+00	1,13E+00
Global Warming Potential (GWP 100 years)	[kg CO2-Equiv.]	1,07E+02	1,16E+02	1,13E+02
Ozone Layer Depletion Potential (ODP)	[kg R11-Equiv.]	1,86E-05	1,84E-05	1,62E-05
Photochem. Ozone Creation Potential (POCP)	[kg Ethene-Equiv.]	1,64E-01	1,84E-01	1,57E-01
Human Toxicity Potential (HTP)	[kg DCB-Equiv.]	2,35E+02	1,20E+05	1,37E+02

The impact of the formal collection is higher than the informal values in the examined categories, because this contains two couch productions in same time.

In the production stage, the values of the plastic part (textile, PUR foam and the textile for the pillow) give the big part of the impacts. At the same time the wood built into the couch means benefits (these are the timber, fibreboard and the other wood parts.) because of the CO_2 intake which was consumed during the lifetime of a tree.

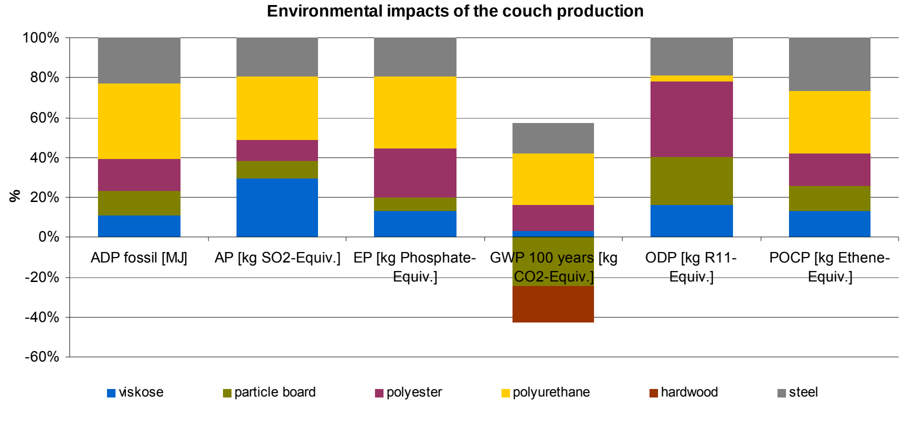

Figure 2.61: Environmental impacts of the couch production

2.4.12 Lawnmower

2.4.12.1 System characterization

The definition of the product selected for life-cycle analysis is “electric lawnmower (1500W capacity, 46 cm cutting width)”.

This project is implemented through the CENTRAL EUROPE Programme co-financed by the ERDF

Figure 2.62: Lawnmower is the object of the LCA

Table 2.76: Data of the chosen lawnmower (Source: AL-KO)

Technological data	470 E Premium
Max. grass surface	900 m²
Cutting width	46 cm
Cutting height	30 - 80 mm
Cutting height settings	Per wheel/per axle, 7 stage
Motor	E-Motor
Piston displacement (cm³) / kW /turn/minute	- / 1,6 / -
Wheel drive	-
Knife house	Steel plate
Volumentric capacity of grass collector	65 l
Wheel Ø mm e/h	200/280 ball-bearinged
Mass	30 kg

Detailed BOM of lawnmower production is indicated in the table below. As the energy demand for assembly was not considered in the model, the parts production and material demand is calculated. The source of data used is the Ecoinvent database.

During data collection a Hungarian producer was contacted. This producer puts out such product in high volume. Detailed information was received on the part materials and mass from the producer.

Some parts of the product (e.g. electric motor) arrive to the producer as subassembly. Thus detailed information on such parts is not available. Instead of this, data from a previous work from Bay-Logi was added into the model.

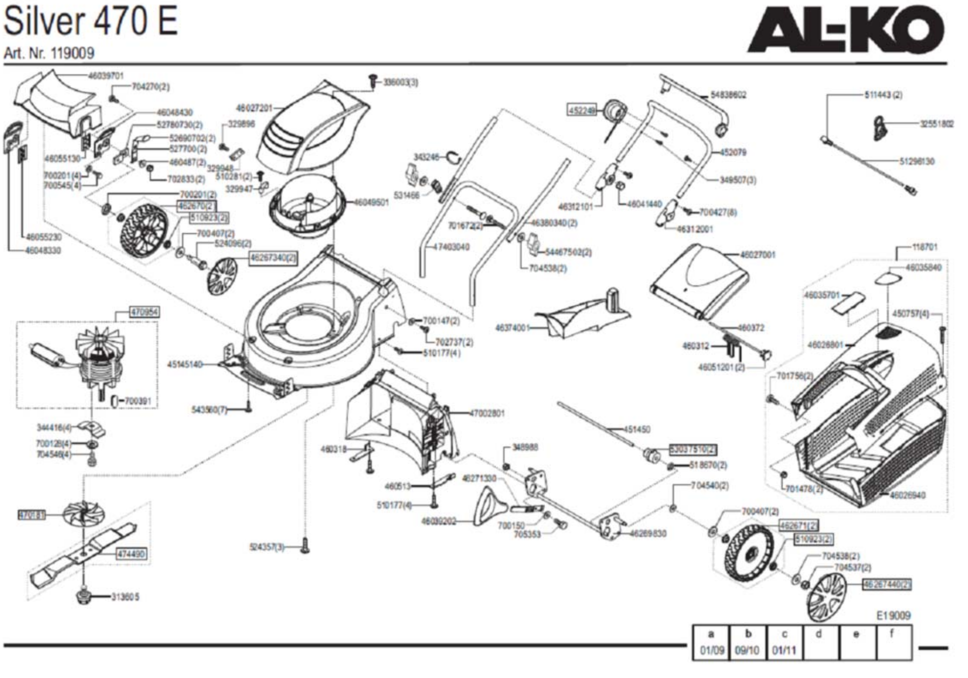

Figure 2.63: Assembly of a lawnmower (Source: AL-KO)

Table 2.77: Component of a lawnmower (Source: Hungarian biggest lawnmower producer: AL-KO Co. - Alsónémedi)

Component	material	mass (kg)
Electromotor	mixed	11
lawnmower knife-house	compound steel	5,5
steel tube pusher wing	steel	1,2
lawnmower knife (46 cm)	steel	0,9
Condenser	oxygenated aluminium and electrolit	0,15
Electric contact and cable	copper and rubber	0,8
wheel and wheel trim	PP	1
Housing and fittings	PP	4,5
axels and metal fittings	metal	2
paper wrapping	paper	3
Gross of electric lawnmower		**30**

Table 2.78: The applied amount of the component of lawnmower for life-cycle assessment

Parts of GaBi modell	mass (kg)
steel	2,1
oxidated aluminium (Al2O3)	0,135
deep drawed compound steel	5,5
electrolit	0,015
copper	0,22536
rubber	0,57464
polypropilene	5,5
metal	2
electromotor	11

The data received refers to a lawnmower available on the market. The protective cardboard for transportation was neglected during the model building. An electric motor model from a previous LCA project was added as follows in the table:

Table 2.79: The components of the electromotor (Source: Bay-Logi)

Lawnmower - electromotor	Mass (g)
ROTARY PART	**5112,36**
anker	
axle	1026,14
ferrite core	1957,78
plastic	243,03
commutator	
copper	99,24
bakelite	184,30
insulation plate	41,86
sealer	33,75
spreader	67,51
shield ring	13,50
copper wire	985,64
ventillator	94,51
ball-bearing	148,52
Polyester resin	27,54
resin	189,03
STANDING PART	**5887,64**
ferrite core	4145,08
paper strip	135,02
copper wire	1350,19
plastic part (begin)	54,01
plastic part (close)	54,01
interlocking	27,00
interlocking	27,00
Polyester resin	81,82
wad	13,50
summa	11000,00

Table 2.80: The applied processes from Ecoinvent database

Component	**Data source**
Steel	RER: steel, low-alloyed, at plant– Ecoinvent database – RER - 2008
Aluminium in the condenser	Aluminium, production mix, at plant– Ecoinvent – RER - 2008
Rubber	RER: synthetic rubber, at plant– Ecoinvent – RER - 2008
Polypropylene	polypropylene, granulate, at plant – Ecoinvent – RER - 2008
Copper	RER: copper oxide, at plant - RER– 2008
Steel II.	RER: reinforcing steel, at plant- Ecoinvent – RER - 2008
Boric acid in the condenser	boric acid, anhydrous, powder, at plant- Ecoinvent – RER - 2008
Electromotor in the lawnmower	Electromotor plan – BayLogi - 2006

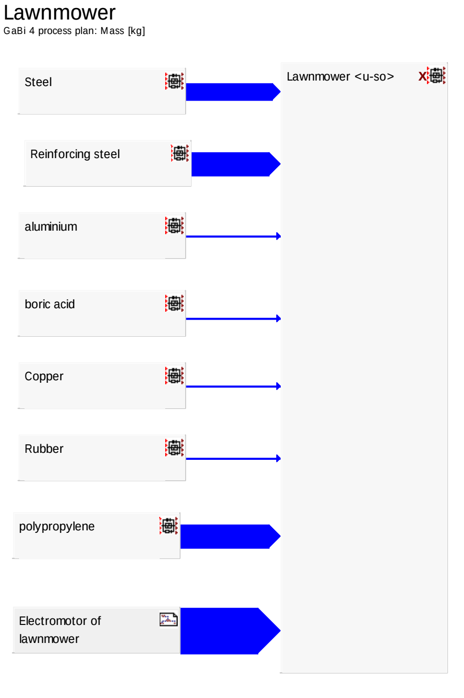

Figure 2.64: GaBi model of a lawnmower production

Product specific model was used in the case of the lawnmower, as metal parts are recycled in the EOL stage in both legal and illegal scenarios. All cases were investigated.

The scenarios look therefore as follows:

Table 2.81: Scenario description – lawnmower

		Formal_EoL	**Informal_EoL**	**Informal_ReUse**

Origin country	Production	Production of new lawnmower in Austria/GermanyEurope	Production of a lawnmower in Austria/Germany	
	Use	Use of lawnmower with country specific electricity mix	Use of lawnmower with country specific electricity mix	
	EoL	Collection in WCC. The big part of the scrap lawnmower goes to material recycling.	Collection by informal used item collector and transported to Hungary/Slovakia/Poland.	
Receiving country	Production	Production of new lawnmower in Hungary/Slovakia/Poland	-	Sale of used lawnmower at flea market
	Use	Use of lawnmower with country specific electricity mix	-	Use of used lawnmower with country specific electricity mix
	EOL	Collection in WCC. HU/SK/PL expected the big part of the scrap lawnmower goes to material recycling, in Poland goes to landfill.	In case of the lawnmower - due to the utilisable and saleable parts – it makes no sense counting with illegal waste dumping and illegal waste incineration (30% of the transported product).	Based on the country specific formal waste collection and treatment system. (70% of the transported product)

Mass of an average lawnmower: 27 kg.

2.4.12.2 Formal scenario:

Benefits arise at recycling of lawnmower parts – steel, aluminium, copper and polypropylene. The previous technologies of the extraction of the gainful materials are the shredder and separation.

The recycling stage of the formal and informal scenarios contains these benefit values.

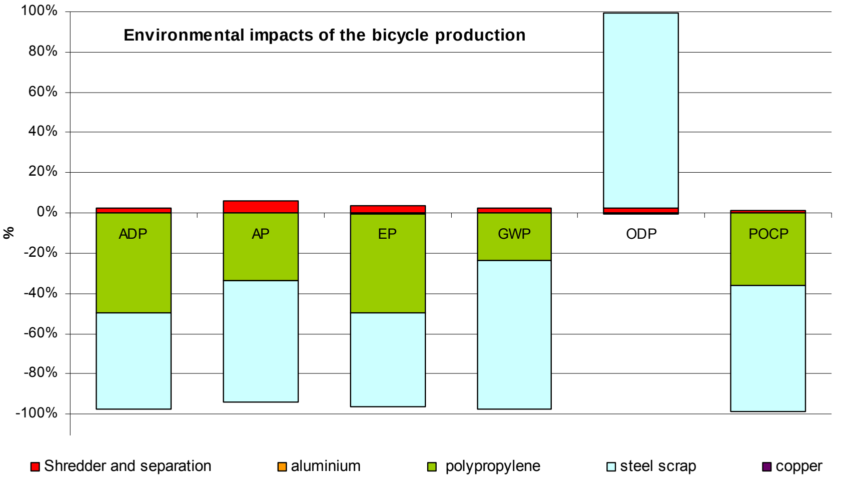

Figure 2.65: Benefits from the recycling of the parts of the lawnmower

The average driving distance for passenger cars from their households to the recycling centre was estimated as 2 km. The average driving distance for 16 t lorries from the recycling centre to treatment facilities was estimated as 200 km.

As a reference unit 1 piece was considered.

Output: 1500W

Energy demand during use is estimated as follows:

Table 2.82: The values of the lawnmower consumption

Consumption	
Rating (W)	1500
Expection of life (year)	5
Prevalence of using (time/year)	10
Time of a using (hour)	2
The consumption value of the full using time (kWh)	150

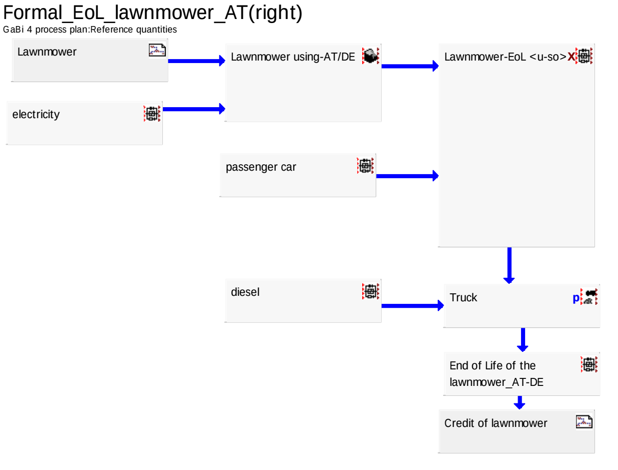

Figure 2.66: GaBi model of lawnmower formal End-of Life of Austria

The GaBi models of the Formal scenarios were built with the difference is in the rates of the waste disposal.

Table 2.83: Data inventory on formal scenario – used lawnmower

Name of the process	**Formal – used lawnmower**
Process description	Used lawnmowers are collected in waste collection centres. The majority goes to material recycling in all countries except Poland.
Reference unit	piece
Area of application	Components of a lawnmower. Collection and disposal of the lawnmowers in all countries with credit values.
Completeness of the process	Production of the base materials of the lawnmower is included. Lawnmower assembly is excluded. Production of infrastructure (works) is also excluded. Transport to the collection centre (passenger car, 2 km) and to recycling centre (lorry, 200 km) included
EoL Credits	The big part of the used lawnmower (one piece) is utilized as metal base material.
Comments on the choice of used processes	It was analysed an average electric lawnmower, which components can show wide scale. It was chosen the most ideal base materials, which didn't stand away from none of actual components (these consist of same base material).
Other comments	It was used the GaBi model of electromotor which was made by BayLogi in 2006.

2.4.12.3 Informal scenario:

The lawnmower is widely used in houses and gardens. As the average lifespan of such products is 5-7 years, no significant technology changes arise in the meantime. While 1500 Wh energy demand is used for a new product, the consumption of a used product is estimated to 10 % higher for the same task. As for all the products analysed, the whole quantity is transported through the border including the 30 % waste besides the 70 % reusable. The metal parts can be easily recycled, thus these goes to material market.

WCCs and transfer stations were not added to the informal model.

Table 2.84: Data inventory on informal scenario – used lawnmower

Name of the process	Informal – used lawnmower
Process description	Used lawnmowers are collected at the households and transported by informal collectors to be sold as re-used product – if it good, - or metal waste – if it be out of work. The missing (30%) amount of the reusable product is replaced with new product in as many amounts.
Reference unit	piece
Area of application	Production and collection of lawnmowers in Austria/Germany, transportation to Hungary/Slovakia/Poland, selling them to the customers.
Completeness of the process	Production of the base materials of the bicycle is included. Bicycle assembly is excluded. Production of infrastructure (works) is also excluded. Transportation (small lorry (7,5t), 300 km) to the market and from the market to the recycling centre (diesel car, 2 km) included
EoL Credits	Recycling process contains the shredder and separation technology with the benefit of the steel, aluminium, copper and polypropylene materials recycling.
Comments on the choice of used processes	The base was the Ecoinvent database. In case of the examined products (here is the lawnmower) the own model was built by the information and data of the producers.
Other comments	We neglected the product and the reusable product transport from the market to the using place.

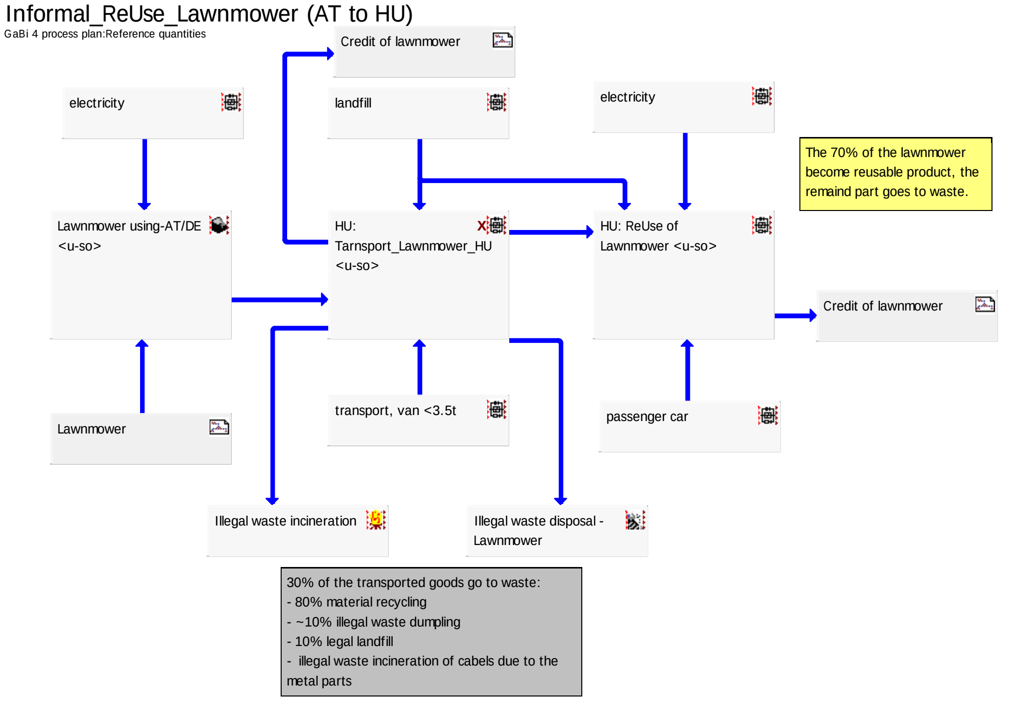

Figure 2.67: Informal scenario of lawnmower, where the big parts (70%) of the products go to reuse (AT-HU scenario)

2.4.12.4 Results

The two scenarios in consideration are comparable only if the formal scenario is duplicated in values (as matters of fact, two life cycles are calculated). 30 % waste arose in the second life cycle stage in the informal scenario. As an addition the 10 percent increase in energy demand for the used product is also added to the model. Repair phases are neglected, and the second use phase is estimated to the same in length as the first use phase.

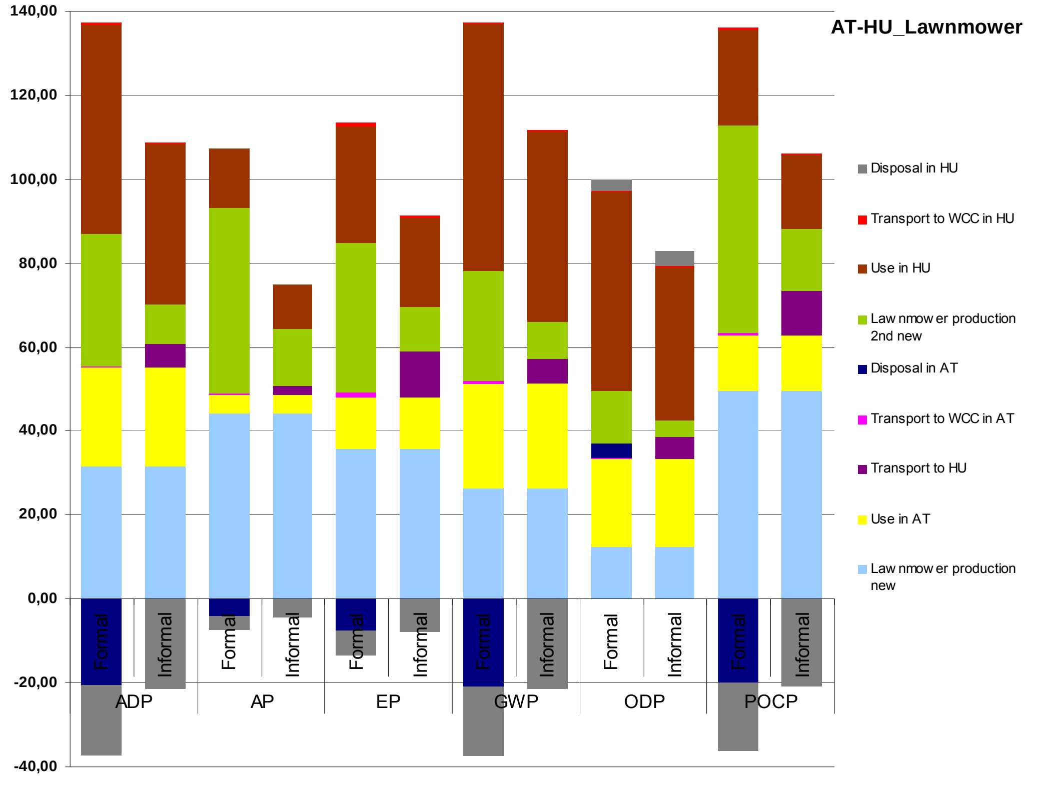

Figure 2.68: Relative results of the formal-informal scenarios with involvement of Austria and Hungary by environmental indicators (Lawnmower)

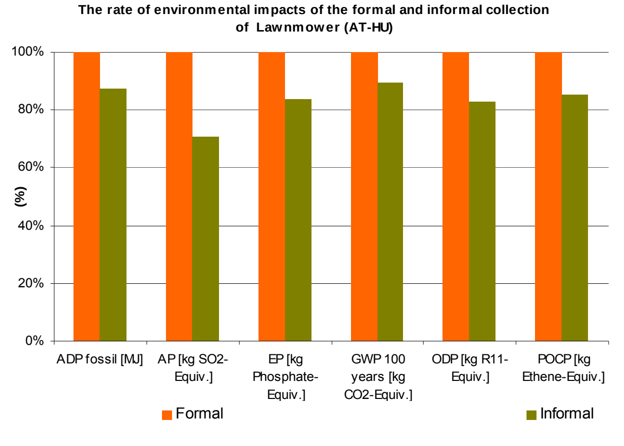

Figure 2.69: The ratio of the formal-informal scenarios (Austria and Hungary) by environmental indicators (Lawnmower)

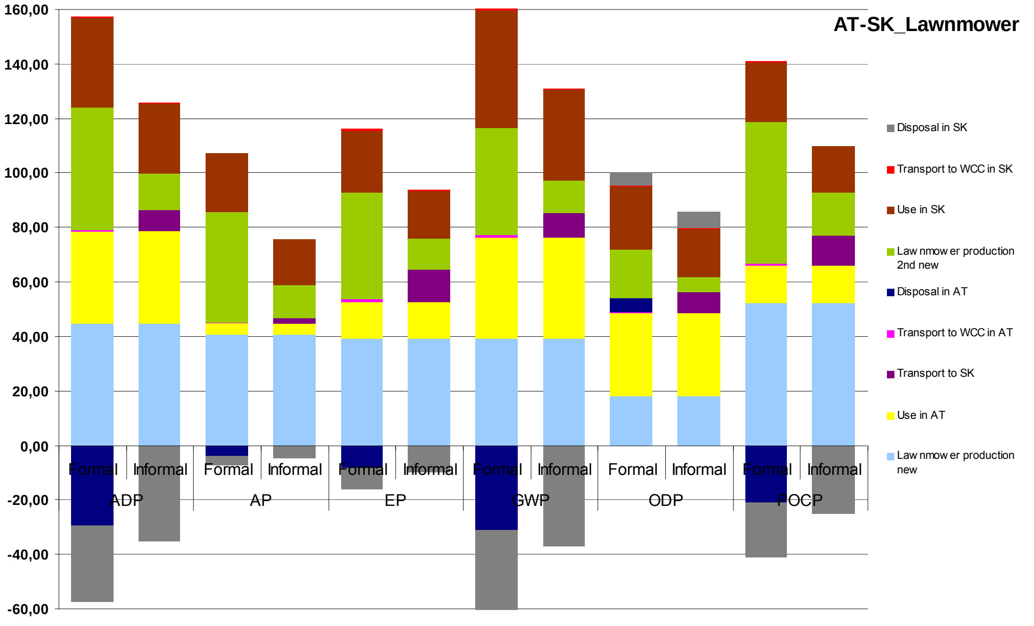

Figure 2.70: Relative results of the formal-informal scenarios with involvement of Austria and Slovakia by environmental indicators (Lawnmower)

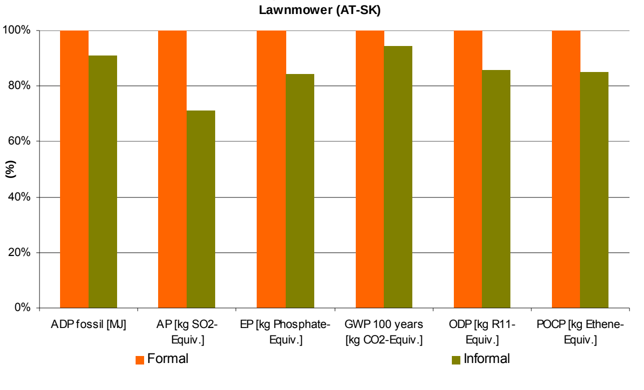

Figure 2.71: The ratio of the formal-informal scenarios (Austria and Slovakia) by environmental indicators (Lawnmower)

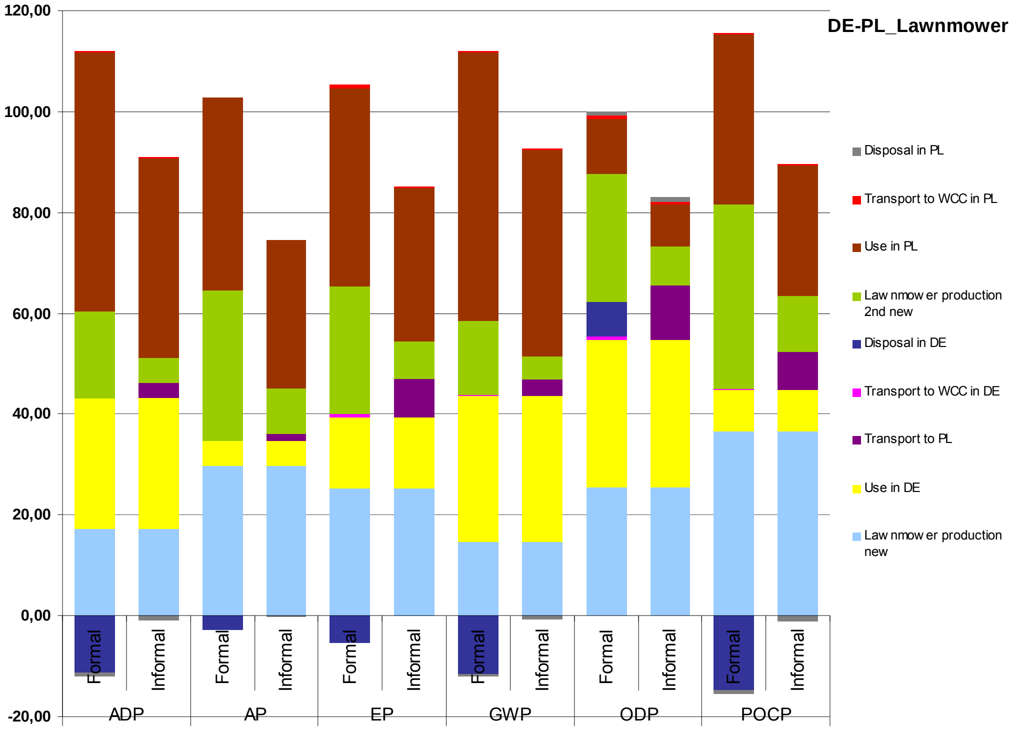

Figure 2.72: Relative results of the formal-informal scenarios with involvement of Germany and Poland by environmental indicators (Lawnmower)

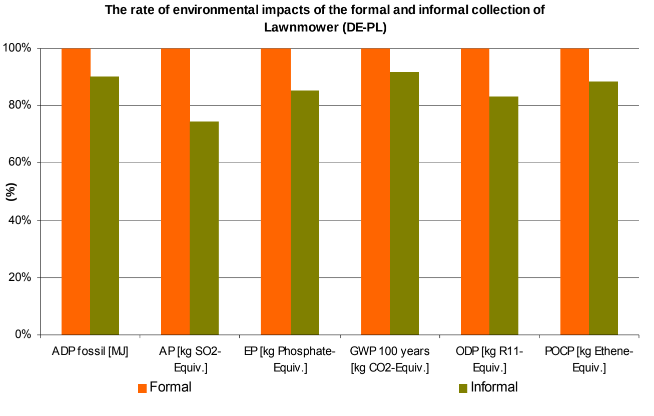

Figure 2.73: The ratio of the formal-informal scenarios (Germany and Poland) by environmental indicators (Lawnmower)

The environmental impacts of the lawnmower have positive and negative directions. It gives environmental saving by the metal content of the waste lawnmower and it gives environmental load

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by the lawnmower production and energy utilization of the using and reusing. The previous figures show normalized values on 100% in every categories.

In all the six impact categories calculated the environmental load of energy demand for production and use are the highest. The high impact of the 10% rise in energy demand for the second use phase can be clearly seen. This can be interpreted as a result of the country-specific energy mix models. (For example while the energy production in Hungary is mainly based on nuclear (38%) and fossil fuels (24%), the Austrian energy production uses renewable resources and hydropower (67%) and it is not negligible that the polish energy mix is founded on electricity from black and brown coal.)

The values of the formal case are higher the informal case. This is explained with impacts of the duplicate of the lawnmower production. Although it appears the impacts the used lawnmower transportation to another country and the higher energy consumption in the reuse stage at the informal case after all this gives lower values in point of environmental impacts. The countries have different waste management technologies, therefore these appear in the values, too. The most saving is given in Austria, due to the huge rate of the material recycling (it can be shown in GWP, ADP and POCP).

The tables show three scenarios. The first is the formal collection, the second is the informal collection – with illegal waste incineration and illegal waste dumping - and the third case is the formalised case, where the 95% of the used product is reused and the 5% go to waste – this case doesn’t contain illegal acts. It can be shown that the formalized case approaches to the values of the formal case and it passes it in one category (GWP). This is explained with rising of the energy consumption of the more reusable products.

Table 2.85: Absolute results of each scenario by environmental indicators (AT-HU)

Environment Category (CML2001-nov.09.)	Unit	Formal	Informal (30/70)	Formalized (5/95)
Abiotic Deplation Potential (ADP)	[MJ]	3,14E+03	2,75E+03	3,06E+03
Acidification Potential (AP)	[kg SO2-Equiv.]	2,21E+00	1,56E+00	1,42E+00
Eutrophication Potential (EP)	[kg Phosphate-Equiv.]	9,44E-02	7,90E-02	7,90E-02
Global Warming Potential (GWP 100 years)	[kg CO2-Equiv.]	2,12E+02	1,89E+02	2,18E+02
Ozone Layer Depletion Potential (ODP)	[kg R11-Equiv.]	3,31E-05	2,74E-05	3,04E-05
Photochem. Ozone Creation Potential (POCP)	[kg Ethene-Equiv.]	1,35E-01	1,15E-01	1,12E-01
Human Toxicity Potential (HTP)	[kg DCB-Equiv.]	9,66E+01	2,72E+02	7,58E+01

Table 2.86: Absolute results of each scenario by environmental indicators (AT-SK)

Environment Category (CML2001-nov.09.)	Unit	Formal	Informal (30/70)	Formalized (5/95)
Abiotic Deplation Potential (ADP)	[MJ]	2,21E+03	2,01E+03	2,09E+03
Acidification Potential (AP)	[kg SO2-Equiv.]	2,40E+00	1,70E+00	1,62E+00
Eutrophication Potential (EP)	[kg Phosphate-Equiv.]	8,62E-02	7,25E-02	7,06E-02
Global Warming Potential (GWP 100 years)	[kg CO2-Equiv.]	1,42E+02	1,34E+02	1,45E+02
Ozone Layer Depletion Potential (ODP)	[kg R11-Equiv.]	2,27E-05	1,95E-05	1,97E-05
Photochem. Ozone Creation Potential (POCP)	[kg Ethene-Equiv.]	1,28E-01	1,09E-01	1,05E-01
Human Toxicity Potential (HTP)	[kg DCB-Equiv.]	9,82E+01	2,73E+02	7,75E+01

Table 2.87: Absolute results of each scenario by environmental indicators (DE-PL)

Environment Category (CML2001-nov.09.)	Unit	Formal	Informal (30/70)	Formalized (5/95)
Abiotic Depletion Potential (ADP)	[MJ]	5,75E+03	5,18E+03	5,75E+03
Acidification Potential (AP)	[kg SO2-Equiv.]	3,29E+00	2,44E+00	2,55E+00
Eutrophication Potential (EP)	[kg Phosphate-Equiv.]	1,33E-01	1,14E-01	1,19E-01
Global Warming Potential (GWP 100 years)	[kg CO2-Equiv.]	3,83E+02	3,51E+02	3,94E+02
Ozone Layer Depletion Potential (ODP)	[kg R11-Equiv.]	1,62E-05	1,34E-05	1,28E-05
Photochem. Ozone Creation Potential (POCP)	[kg Ethene-Equiv.]	1,84E-01	1,63E-01	1,63E-01
Human Toxicity Potential (HTP)	[kg DCB-Equiv.]	1,39E+02	3,07E+02	1,19E+02

As production has high impact in most of the categories, detailed analysis is added here. These data includes only raw material production without the assembly phase.

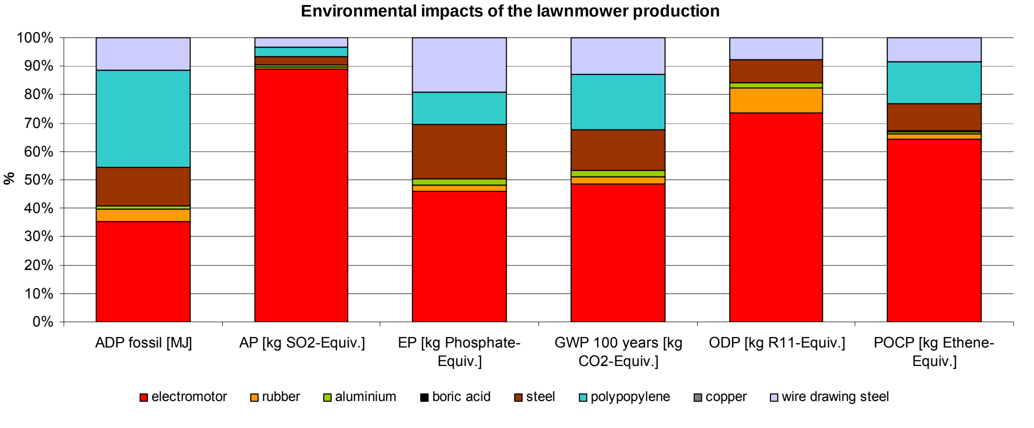

Figure 2.74: Normalized value of the environmental impacts of the lawnmower production in 6 impact categories

The production of electric motor, polypropylene, and rubber parts has the highest environmental impact. Other parts are identifiable on the diagram, but have much lower impact.

2.4.13 LCD TV

2.4.13.1 System characterization

The definition of the chosen product is LCD TV (26’’ screen). Lots of households have this type of the television and it is also popular equipment at the lomis. They can sell these easily as all electric and electronic equipment.

The base of the modelling for the LCA of the television was the collection of the literature data. We found exact description and compound list in the study of Merck KGaA. We got adequate information on the mass of this television (one type of the LG television).

Figure 2.75: LCD TV is the object of the LCA

Determination	26"-os LCD TV (66 cm)
Size (without stand)	(652x421x29mm); 2665cm2
Mass (without stand)	5kg
Mass of the stand	1kg

The component list of the television production can be seen below. The yellow part shows the parts of the display panel. The energy flows of the assembly were not considered, thus only base material production went into the model. The source was the Ecoinvent database.

Table 2.88: Component of a LCD TV (Source: Merck KGaA)

Compound	rate(%)	kg
Stand (80% metal, 20% PP)		1,0000
PCB (boards)	3,1	0,1565
PMMA (polymetylmetacrilato)	54,2	2,7080
Metals (stainless steel/aluminium)	20,7	1,0345
Plastic frame (polycarbonate)	2,3	0,1150
others (rubber)	0,2	0,0120
display (LCD)	19,5	0,9740
plastic(PET)	55,0	0,5357
electronic	3,7	0,0360
lights (Hg-lamp/LED)	2,6	0,0253
metal	23,7	0,2308
glas	15,0	0,1461
Summa	100,0	6,0000

Conversions were needed to feed of the base data into GaBi Software (Table 2.89). The television and the display panel have electronic parts, which were modelled, too (Figure 2.78).

Table 2.89: Conversion table for PCB of the LCD TV modelling (Source: Bay-Logi-WEEE collection and environmental friendly disassembly - 2001)

Compound of PCB	%	kg (TV)	kg (display)
plastic(halogenated)	50	0,07825	2,82E-05
Copper	22	0,03443	1,241E-05
aluminium	1	0,001565	5,64E-07
tin	8	0,01252	4,512E-06
iron	3	0,004695	1,692E-06
glass	4	0,00626	2,256E-06
others	12	0,01878	6,768E-06

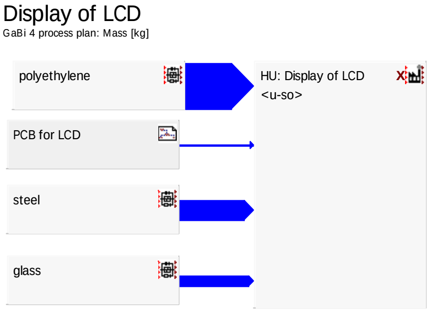

Figure 2.78: GaBi models of the components of the LCD TV parts

We supposed two scenarios in the LCA of the LCD. One of them shows the formal activity without informal waste collection, the second scenario presents the informal collection and where the negative environmental impacts are also considered accounted, for example illegal waste dumping.

The scenarios look therefore as follows:

Table 2.92: Scenario description – LCD TV

		Formal_EoL	**Informal_EoL**	**Informal_ReUse**
Origin country	Production	Production of new LCD TV in Austria/Germany	Production of new LCD TV in Austria/Germany	
	Use	Use of LCD TV with country specific electricity mix	Use of LCD TV with country specific electricity mix	
	EoL	Collection in WCC. Big part of the scrap LCD TV (99,5%) goes to recycling in Austria and Germany.	Collection by informal used item collector and transported to Hungary/Slovakia/ Germany.	
Receiving country	Production	Production of new LCD TV in Hungary	-	Sale of used LCD TV at flea market
	Use	Use of LCD TV with country specific electricity mix	-	Use of used LCD TV with country specific electricity mix
	EOL	The biggest part (79,5%) of the scrap LCD TV goes to recycling, and the other part goes to landfill in Hungary. In Slovakia, the system is almost same than	One part of the scrap LCD TV goes to landfill or recycling centre, and the less part is gone to illegal landfill (30% of the transported product will be come waste).	Here predominates the country specific official waste management system.

		Germany (the remained part goes to landfill). The Poland system is other, because the big part goes to landfill (82,4%) and the other parts go to recycling, incineration, MT and MBT.		

Mass of an average LCD TV (26” screen), pull out: 6 kg.

Table 2.93: The used values to using stage of the television

Definition to the television	Value	Unit
Energy consumption - on-mode	80	W
Energy consumption - stand-by mode	1,1	W
Average using time	4	h/day
Expectation of life	7	year
The whole consumption under the lifespan	880	kWh

2.4.13.2 Formal scenario:

In case of LCD TV - as every other products of the project - a product specific model was applied. In this model, we have dealt with country specific cases, which were different in the EoL stage. These rates influence the formal scenario.

Benefit is the recycling of the components of the LCD TV. Although, it is known that every European country has a collection quota, which they have to achieve, the benefit is difficult to define, because of the lack of exact data on the recovered components, and the processing technology. In case of the LCD TV, this value was not defined.

The average driving distance for passenger cars from their households to the recycling centre was estimated as 2 km. The average driving distance for 16 t lorries from the recycling centre to treatment facilities was estimated as 200 km.

As a reference unit 1 piece was considered.

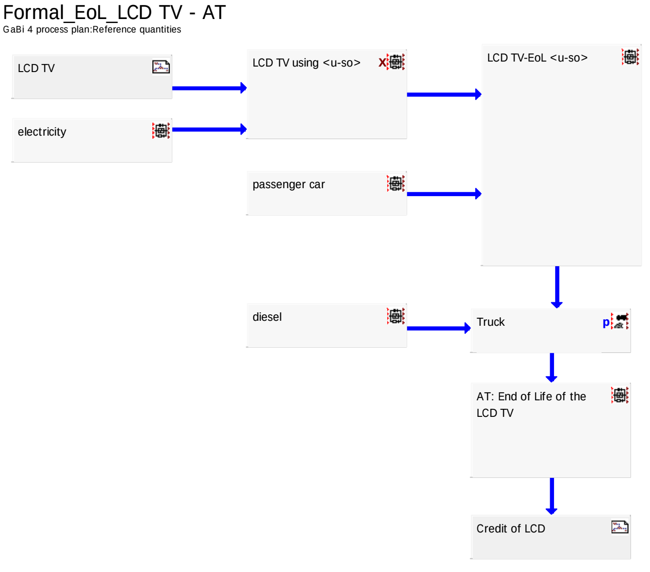

Figure 2.79: GaBi model of LCD TV formal End-of Life in Austria

Both models– the Austrian and the Hungarian model- contain country specific waste treatments.

The benefit comes from the material recycling of the product. The figure shows the values of the environmental savings – material recycling from the plastic and metal parts and the values of the environmental loading – dismantling of the product and in one category the steel scrap.

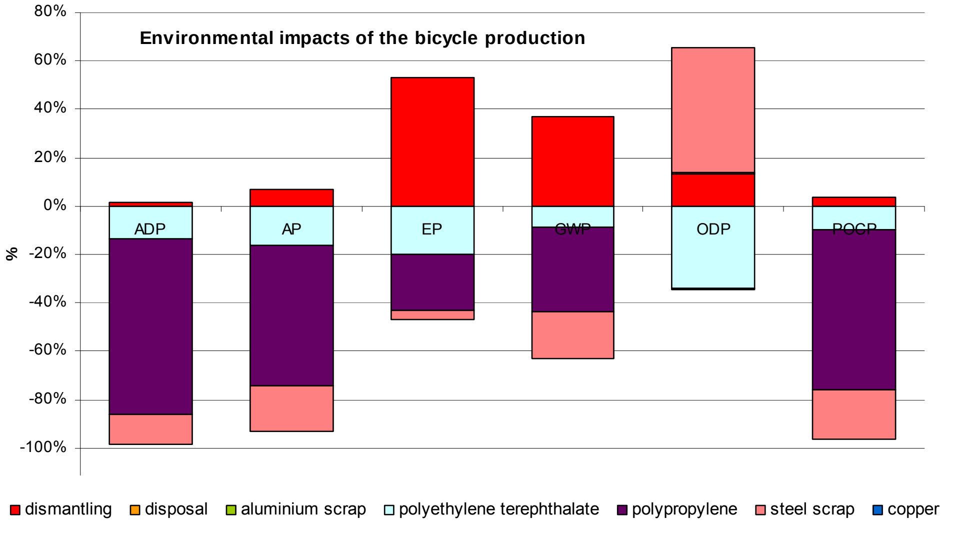

Figure 2.80: Benefits from the recycling of the parts of the LCD-TV

This project is implemented through the CENTRAL EUROPE Programme co-financed by the ERDF

Table 2.94 Data inventory on formal scenario – used LCD TV

Name of the process	**Formal – used LCD TV**
Process description	By the LCD TV production, the process contains the transport phase and country specific EoL phase.
Reference unit	piece
Area of application	Components of a LCD TV. Collection and disposal of the LCD televisions in every country.
Completeness of the process	Production of the base materials of the LCD TV is included. LCD TV assembly is excluded. Production of infrastructure (works) is also excluded. Transport to the collection centre (passenger car, 2 km) and to recycling centre (lorry, 200 km) included
EoL Credits	Used LCD televisions – in Austria- are collected in waste collection centres and utilised in recycling centre as secondary base material. The credit values contain the dismantling technology and the benefit of the utilizable materials (steel, polyethylene, aluminium, copper, polypropylene)
Comments on the choice of used processes	It was analysed an average LCD TV 26"screen.
Other comments	The data sources are from Merck KGaA; Bay-Logi

2.4.13.3 Informal scenario:

The LCD TV is a preferred product by the informal used item collectors, same as all the electronic and electric equipment. On one hand stocks of these products are changing fast, as there is a continuous demand. On the other hand, the price of the amount sold compensates the investment in correct measure. In the formal scenario, the EoL of LCD was built in the life-cycle assessment software. It is presumable, that one part of this gets into the formal waste collection system (recycling or waste landfill), but the other part gets into illegal waste dumps. The estimated rates of these are: 5% formal way – recycling, 60% formal way- landfill, 35% illegal waste dumping.

The same theory was applied in case of the LCD TV as in case of all other products considered. While 30% of the whole transported amount gets into waste, the other 70% will be reused.

This scenario doesn't contain WCC and transfer station.

Table 2.95: Data inventory on informal scenario – used LCD TV

Name of the process	**Informal – used LCD TV**
Process description	Used LCD TV are collected at the households and transported by informal collectors to be sold as re-used product, the unsalable parts turn into waste (30% of all). The missing (30%) amount of the reusable product is replaced with new product in as many amounts.
Reference unit	piece
Area of application	Production and collection of LCD televisions in Austria/Germany, transportation to Hungary/Slovakia/Poland, selling them at the flea market to the customers.
Completeness of the process	Production of the base materials of the LCD TV is included. LCD television assembly is excluded. Production of infrastructure (works) is also excluded. Transportation (small lorry (7,5t), 300 km) to the market and from the market to the recycling centre (diesel car, 2 km) included
EoL Credits	We counted with the formal EoL, and the illegal waste dumping. The illegal waste dumping was modelled based on the base material of the TV.
Comments on the choice of used processes	
Other comments	We neglected the product and the reusable product transport from the market to the using place. And some parts of the TV set (PCB other parts and the lights of the display)

2.4.13.4 Results

The two scenarios in consideration are comparable only if the formal scenario is duplicated in values (as matters of fact, two life cycles are calculated). 30% waste arose in the second life cycle stage in the informal scenario.

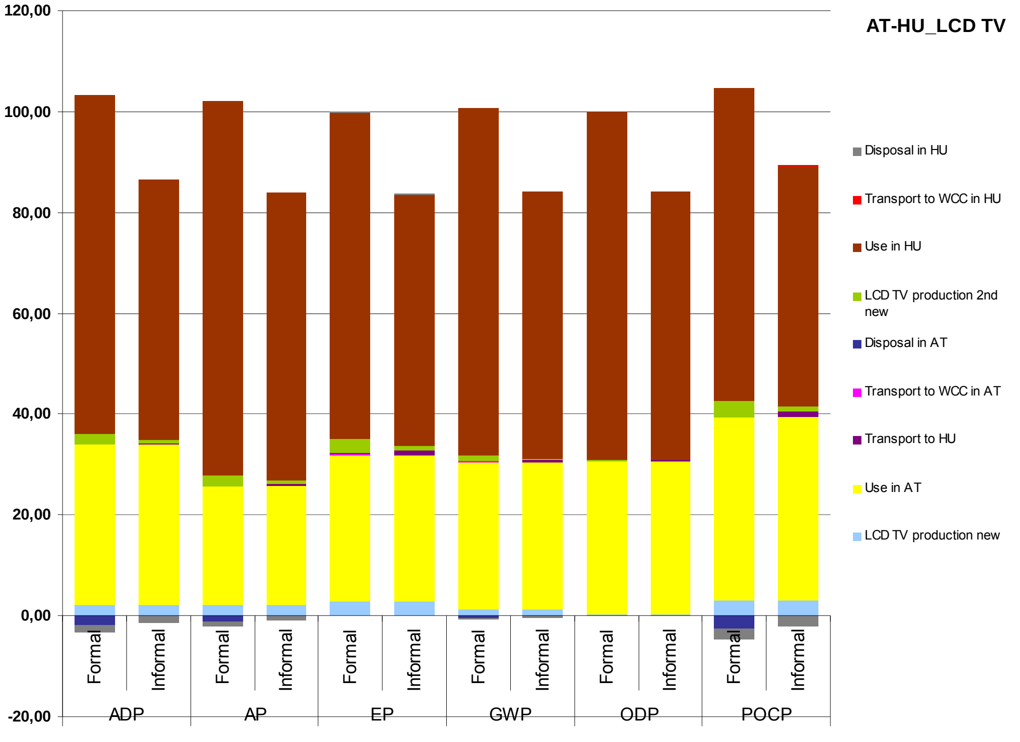

Figure 2.81: Relative results of the formal-informal scenarios with involvement of Austria and Hungary by environmental indicators (LCD-TV)

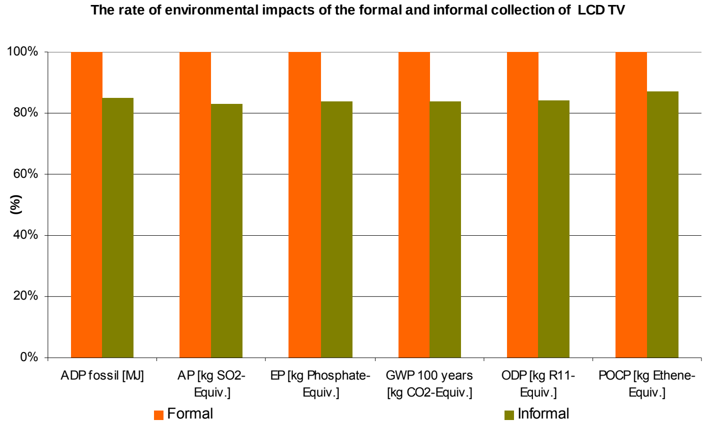

Figure 2.82: The ratio of the formal-informal scenarios (Austria and Hungary) by environmental indicators (LCD-TV)

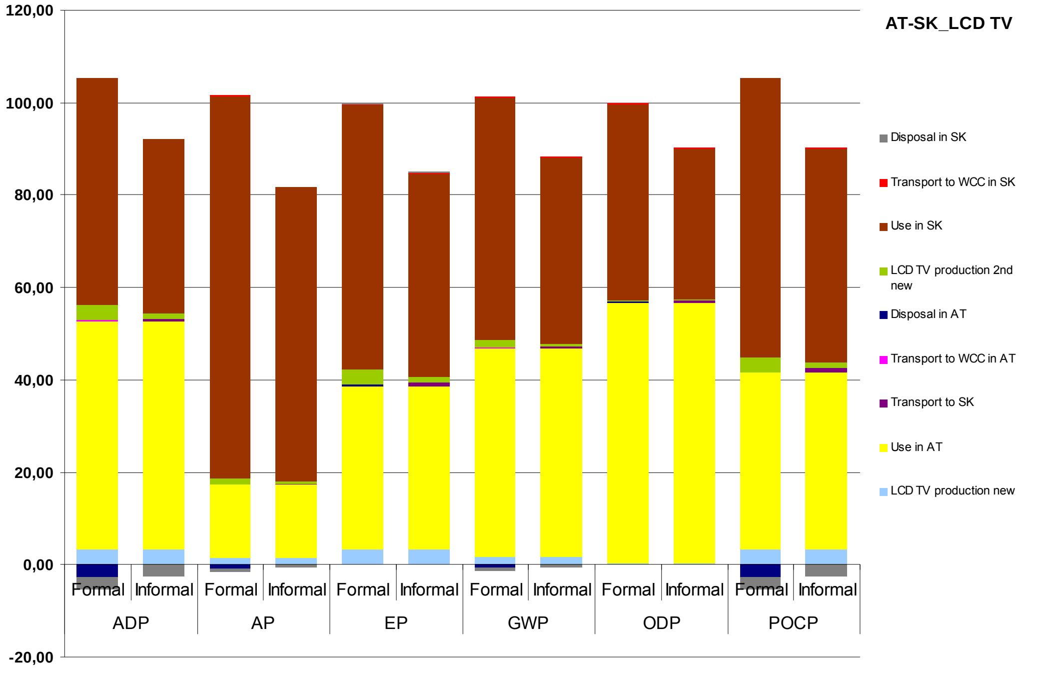

Figure 2.83: Relative results of the formal-informal scenarios with involvement of Austria and Slovakia by environmental indicators (LCD-TV)

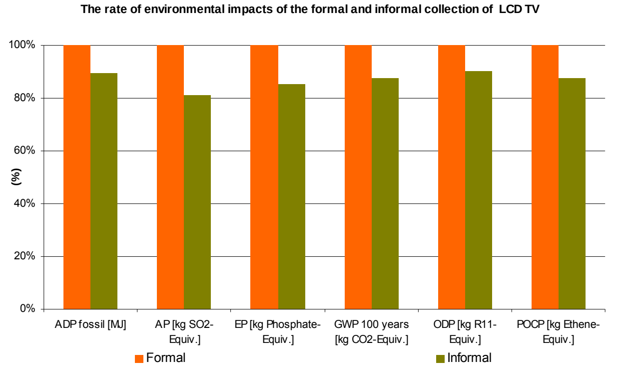

Figure 2.84: The ratio of the formal-informal scenarios (Austria and Slovakia) by environmental indicators (LCD-TV)

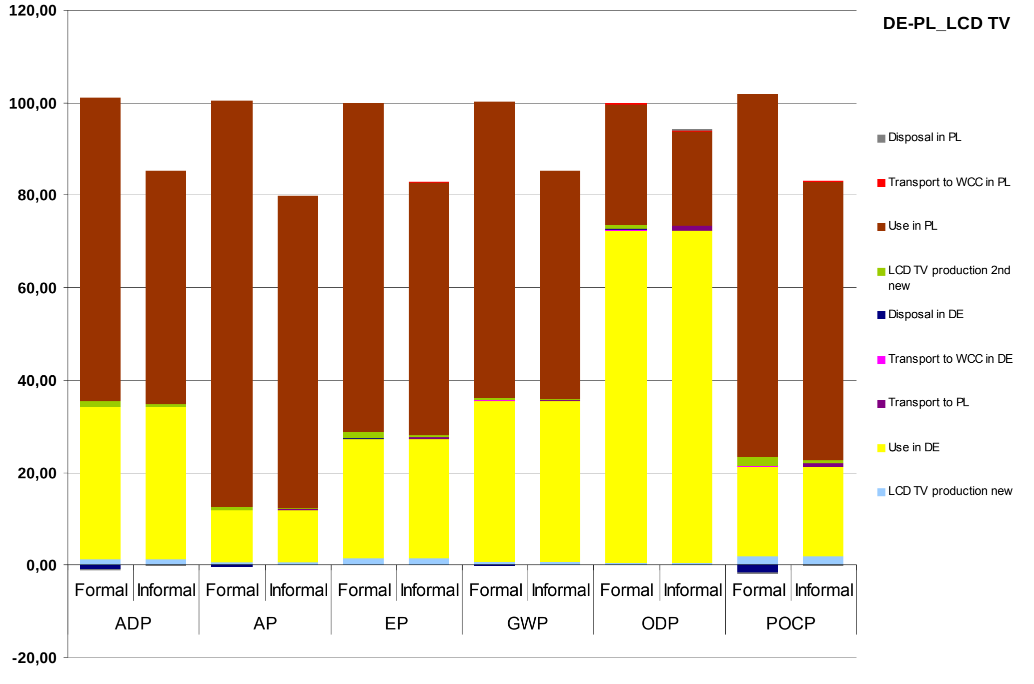

Figure 2.85: Relative results of the formal-informal scenarios with involvement of Germany and Poland by environmental indicators (LCD-TV)

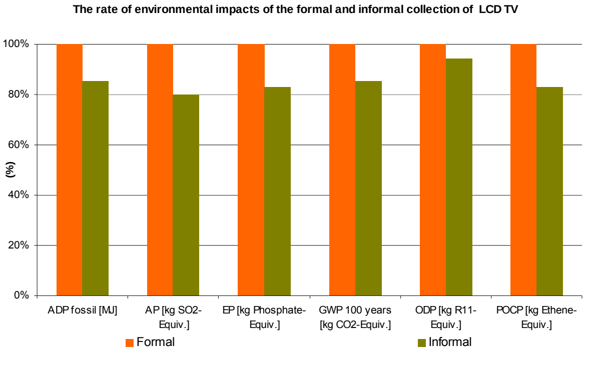

Figure 2.86: The ratio of the formal-informal scenarios (Germany and Poland) by environmental indicators (LCD-TV)

Inside the examined environmental impact categories, the power utilisation rises in the course of the use phase with normalized values as impact increaser. Of course, the use phase – in the formal scenario -, the reuse phase – in the informal scenario- rises from the total impacts. It has to be emphasized that the using of the televisions are more than 95% of the whole amount. The rise in energy consumption values (forecasted 10% rising) due to the old equipment is counted here. In all cases the reuse phase shows higher values in the environmental impact categories of the informal case due to the country specific power grid mix of the model. The environmental load of the

Hungarian energy mix is more than the Austrian mix due to the lignite utilization of the power stations.

While material composition and amounts were considered during the modelling of the production stage, energy flows were neglected. This stage doesn't show significant impact compared to other stages. Only in two impact categories – GWP and EP – the impacts of the disassembly and recycling have a 5% part of the whole impact.

In all categories, the values of the informal scenario are lower than the formal scenario.

The tables show three scenarios. The first is the formal collection; the second is the informal collection – with illegal waste incineration and illegal waste dumping. The third case is the formalised one, where 95% of the used products are reused and the only 5% goes to waste. This case doesn't contain illegal acts. In case of every transportation routes (every scenario), the values of the formalized case are higher than the other scenarios. This comes from the higher electricity consumption in the use and reuse stages. The differences are only 2-3% compared to the formal scenario.

Table 2.96: Absolute results of each scenario by environmental indicators (AT-HU)

Environment Category (CML2001-nov.09.)	Unit	Formal	Informal (30/70)	Formalized (5/95)
Abiotic Deplation Potential (ADP)	[MJ]	1,37E+04	1,17E+04	1,41E+04
Acidification Potential (AP)	[kg SO2-Equiv.]	2,42E+00	2,01E+00	2,49E+00
Eutrophication Potential (EP)	[kg Phosphate-Equiv.]	2,38E-01	1,99E-01	2,40E-01
Global Warming Potential (GWP 100 years)	[kg CO2-Equiv.]	1,06E+03	8,89E+02	1,09E+03
Ozone Layer Depletion Potential (ODP)	[kg R11-Equiv.]	1,33E-04	1,12E-04	1,37E-04
Photochem. Ozone Creation Potential (POCP)	[kg Ethene-Equiv.]	2,89E-01	2,52E-01	2,99E-01
Human Toxicity Potential (HTP)	[kg DCB-Equiv.]	3,43E+02	2,56E+02	2,99E+02

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Table 2.97: Absolute results of each scenario by environmental indicators (AT-HU)

Environment Category (CML2001-nov.09.)	Unit	Formal	Informal (30/70)	Formalized (5/95)
Abiotic Deplation Potential (ADP)	[MJ]	8,81E+03	7,89E+03	8,94E+03
Acidification Potential (AP)	[kg SO2-Equiv.]	3,63E+00	2,94E+00	3,74E+00
Eutrophication Potential (EP)	[kg Phosphate-Equiv.]	1,97E-01	1,68E-01	1,97E-01
Global Warming Potential (GWP 100 years)	[kg CO2-Equiv.]	6,90E+02	6,05E+02	7,00E+02
Ozone Layer Depletion Potential (ODP)	[kg R11-Equiv.]	7,19E-05	6,50E-05	7,34E-05
Photochem. Ozone Creation Potential (POCP)	[kg Ethene-Equiv.]	2,75E-01	2,41E-01	2,82E-01
Human Toxicity Potential (HTP)	[kg DCB-Equiv.]	3,59E+02	2,70E+02	3,27E+02

Table 2.98: Absolute results of each scenario by environmental indicators (DE-PL)

Environment Category (CML2001-nov.09.)	Unit	Formal	Informal (30/70)	Formalized (5/95)
Abiotic Deplation Potential (ADP)	[MJ]	2,64E+04	2,25E+04	2,71E+04
Acidification Potential (AP)	[kg SO2-Equiv.]	8,40E+00	6,70E+00	8,72E+00
Eutrophication Potential (EP)	[kg Phosphate-Equiv.]	4,33E-01	3,59E-01	4,42E-01
Global Warming Potential (GWP 100 years)	[kg CO2-Equiv.]	1,87E+03	1,59E+03	1,92E+03
Ozone Layer Depletion Potential (ODP)	[kg R11-Equiv.]	3,85E-05	3,63E-05	3,90E-05
Photochem. Ozone Creation Potential (POCP)	[kg Ethene-Equiv.]	4,64E-01	3,84E-01	4,82E-01
Human Toxicity Potential (HTP)	[kg DCB-Equiv.]	5,31E+02	3,99E+02	4,97E+02

The relative value of the informal scenario is about 80% of the formal in all categories.

In case of the analysing of the LCD TV production, the frame production gives the high values due to the plastic (polypropylene) production in all but ODP category. In this category, the display production shows the biggest impact due to the plastic, too.

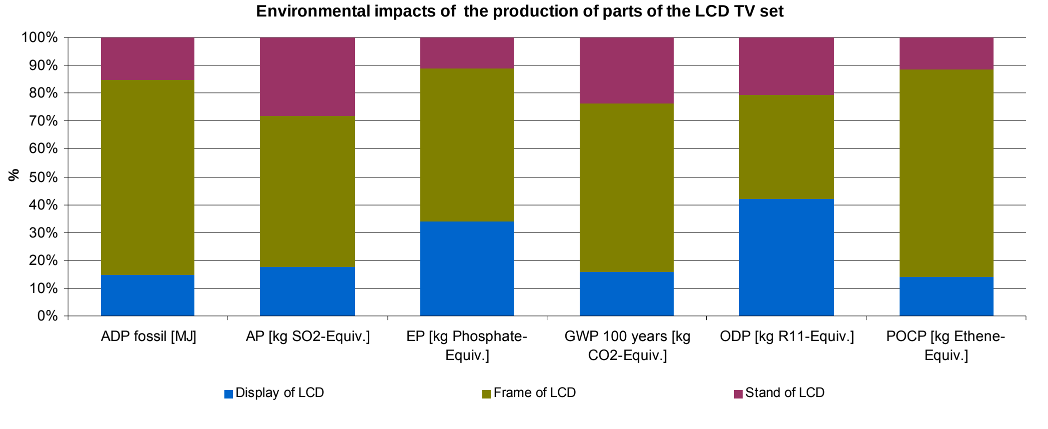

Figure 2.87: Environmental impacts of the production of the parts of the TV set

Analysing the TV production in components, the used two plastics (PP and PE) give higher values in all categories. Beside this, the copper utilisation –in the AP; and the glass utilisation – in the ODP show up.

Summarized the assessment, the actuation of the informal scenario proves it to be better result, but in this case the amount of the used electricity is growing along with the environmental impacts.

2.5 Case study

2.5.1 Functional unit

The aim of the life-cycle assessment of the Transwaste project is demonstration of the environmental impacts of the informal act. The LCA was carried out as an environmental comparative assessment. It reveals the burdens and benefits of the processe compared to a baseline. In the case of the project, environmental impact of the informal scenario is in the focus of the assessment, compared to the impacts of the formal scenario as a baseline. Based on the analysis, the international part of the informal used item collection act is done in three different transport ways inside Europe. Specification of the several countries were considered such as waste management technology, country specific energy-mix, etc. It has to act on the main steps and points of the ISO 14000 standard in every case of LCA. Accordingly the aim of the analysis and the functional unit, with the referenced values has to be determined.

Functional unit: a full van with used items (with the determined rates and amounts) in a year

The conditions of the transport were defined by questionnaires (see D 3.1.1), border counting (see D 3.1.2) and literature data.

Table 2.99: Parameters used for the comparison

Prevalence of the collection (occassion/year)	**75**
Transport distance (km/trip)	**300**
loading capacity (%)	69,5

Prevalence of the collection is 75 occasions per year. The big part of the lomis of the East-Central-European countries runs only short transport distance (for example from a settlement of West-Hungary to settlements of East-Austria). Some collectors travel several hundred kilometres in the hope of higher quality goods and bigger amounts (for example to the Netherlands or to North of Germany.) As an average 300 km travel distance were determined. An average of filling percentage for a normal van of 71% and for a large van as 68% stated in the Deliverable 3.1.2 - Table 3.13. The average is 69.5%. A consideration of several scenarios for filling percentage was abandoned, because 100% loading capacity cannot be reached due to rate of the weight and bay and due to the “imperfection” of the collection (in the formal and informal scenarios, too).

The most frequent car type is the van for the collectors, therefore data of 20 different van types was calculated for average by Bay-Logi:

Table 2.100: Data of an average van

Loadability of the van	*payload (kg)*	*cargo bay (m3)*
average data	1 315	9,85

The next data – based on the functional unit – came from the average data and the rate values:

Table 2.101: Collected amount per year and per van

	kg	m3
Effectively collected amount in a year	68544,38	513,43

2.5.2 Composition based on formal collection amounts

The following data sources were used for the determination of the composition of the indicator products in one van:

- Hungarian formal bulky waste collection (source: questionnaire survey of public waste management companies in Hungary (2009-Bay-Logi),
- Rates of the Hungarian formal WEEE collections (because the questionnaire didn't contain such division),
- Data on the traffic counting (in HU-AT, SK-AT and PL-DE borders).

To compare the different scenarios, the values used for the formal and informal scenarios are identical. The next chart shows the rates (Table 2.102).

Table 2.102: Rates of the collection in products (%)

	Scenarios	
products	**Formal (mass%)**	**Informal (mass%)**
EEE	30,45%	30,45%
monitor	4,83%	4,83%
computer	4,58%	4,58%
refrigerator	8,56%	8,56%
LCD TV	4,58%	4,58%
electric lawnmower	7,89%	7,89%
Furniture	33,85%	33,85%
couch	11,61%	11,61%
plastic garden chair	4,64%	4,64%
wood (shelf)	16,83%	16,83%
clothes	3,48%	3,48%
bicycle	13,33%	13,33%
tyre	5,73%	5,73%
steel	13,16%	13,16%

The next chart shows the values for weight of different products, based on the fixed functional unit:

Table 2.103: Rates of the collection in products (kg)

	Scenarios	
products	**Formal (kg)**	**Informal (kg)**
EEE	20873,45	20873,45
monitor	3313,34	3313,34
computer	3140,77	3140,77
refrigerator	5867,38	5867,38
LCD TV	3140,77	3140,77
electric lawnmower	5411,19	5411,19
Furniture	23203,49	23203,49
couch	7955,48	7955,48
plastic garden chair	3182,19	3182,19
wood (shelf)	11535,45	11535,45
clothes	2386,58	2386,58
bicycle	9138,44	9138,44
tyre	3925,13	3925,13
steel	9017,30	9017,30

According to the data above, a van can transport for example 9138 kg bicycle per year at the present situation. The next table shows the values of the several products in pieces (except for 3 products: wood, clothes, steel as indicated).

Table 2.104: Rates of the collection in products (piece)

	Scenarios			
products	**Formal (piece)**		**Informal (piece)**	
	per year	per occassion	per year	per occassion
monitor	166,8	2,2	166,8	2,2
computer	277,9	3,7	277,9	3,7
refrigerator	154,0	2,1	154,0	2,1
LCD TV	523,5	7,0	523,5	7,0
electric lawnmower	200,4	2,7	200,4	2,7
couch	73,3	1,0	73,3	1,0
plastic garden chair	1591,1	21,2	1591,1	21,2
wood (shelf) (kg)	11535,4	153,8	11535,4	153,8
clothes (kg)	2386,6	31,8	2386,6	31,8
bicycle	657,4	8,8	657,4	8,8
tyre	490,6	6,5	490,6	6,5
steel (kg)	9017,3	120,2	9017,3	120,2

2.5.3 Results based on formal collection amounts

The normalized diagrams give scope for examination of the different predetermined impact categories. In this case, the environmental scenario with the highest impact value gives the 100% in the category. Due to the indicated product distribution in every scenario, the product with the most environmental impact in the category can be easily identified.

In the first concept – where the used items are transported from Austria to Hungary, - three products rise on the diagram: monitor, computer and the fridge. The fridge has the highest impact on the Ozone Depletion Potential, while the monitor and computer on the other examined environmental impacts.

The formal case gives higher values in most categories compared to the informal scenario (Figure 2.2: Formal, informal and formalized scenarios on the example of AT-HU

). The values of the informal scenario are only 92-99% of the formal. The Ozone depletion potential category shows another result. Here the burdens of the informal scenario are multiple than the formal case. The ODP is dominated by the assessment of the fridge. The high ODP in the indicator product fridge is due to the CFCs release in the illegal disposal phase. It influences therefore the total results considerably.

If the environmental impacts are investigated in detail, individual LCAs of products have to be considered. Based on those chapters of the study, the impacts of production of the EEE products and the used item transport give lower values than the impact of the electricity intake at the use stage. These values are changing in case of non EEE, the production or transportation has higher environmental impact values.

The electricity intake of the electronic and electric equipment is responsible for the high environmental impacts. The difference between the two concepts are not as big if we consider that 70% of the used item are re-used and 30% goes to waste in the destination country. The values of the informal scenario are raised by the plus 10% energy utilization of the old EEE and energy-mix of the destination countries are worse than the source countries in every case (for example: while the energy-mix of Austria consist of mostly renewable energy, Hungary has rather fossil and nuclear – that highly influences the environmental impacts of the used products.)

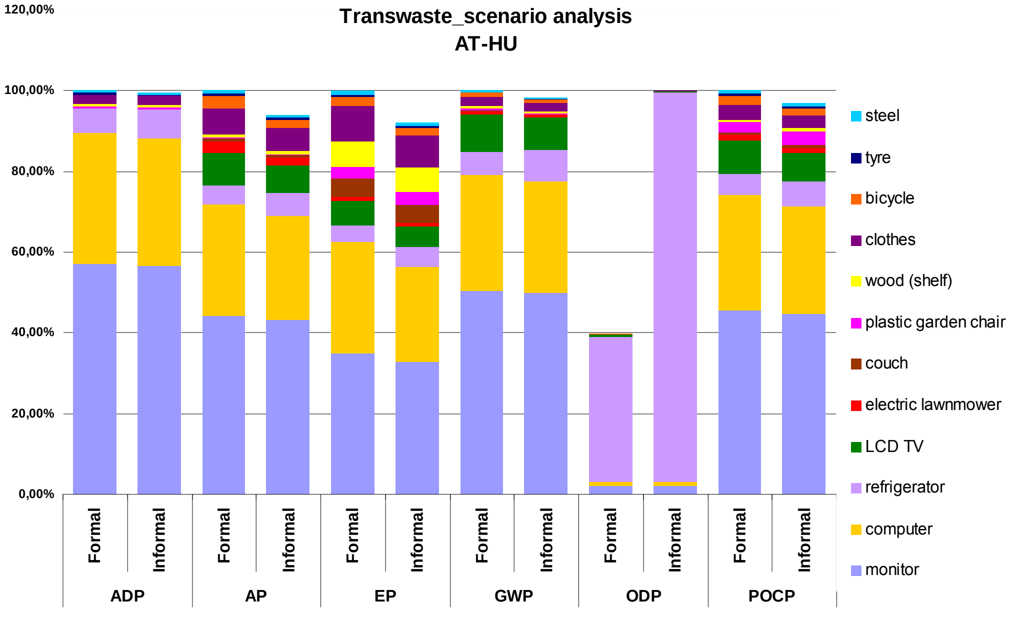

Figure 2.88: Comparative analysis of the formal and informal scenarios (AT-HU)

In case of the second route (where the used items are transported from Austria to Slovakia) similar results are obtained. The rate of the ODP scenario is different in some percentage, which is explained by the fact that the big part of the Slovakian energy-mix consists of mainly nuclear and water energy, and less fossil energy.

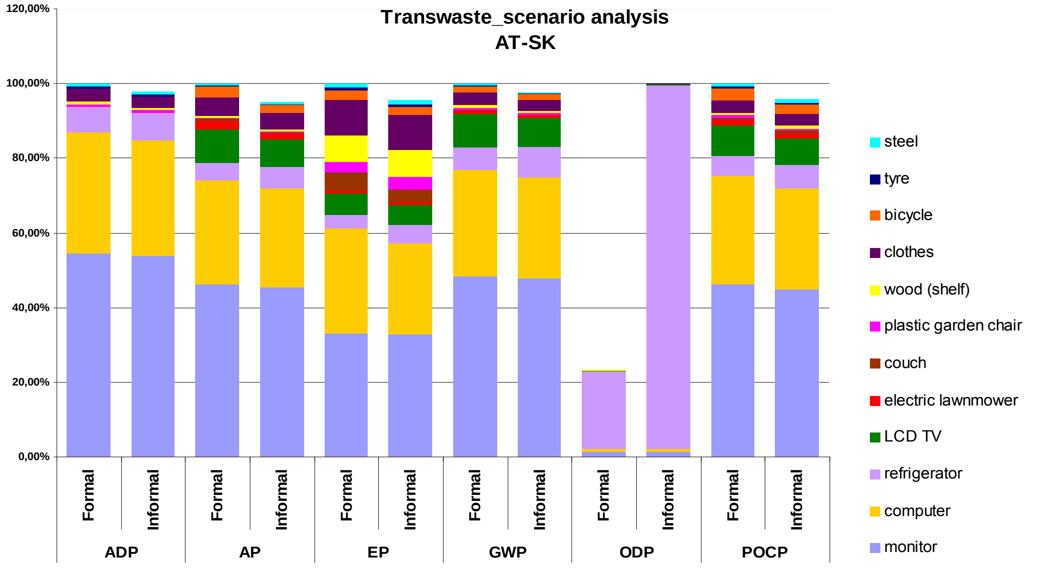

Figure 2.89: Comparative analysis of the formal and informal scenarios (AT-SK)

In case of the third route, - where the used items are transported from Germany to Poland, - the different values need some explanations. Energy production consists of mainly fossil (coal) power stations in both countries. These raise the environmental impacts. Hence there is the same rate between the two scenarios as previous two routes.

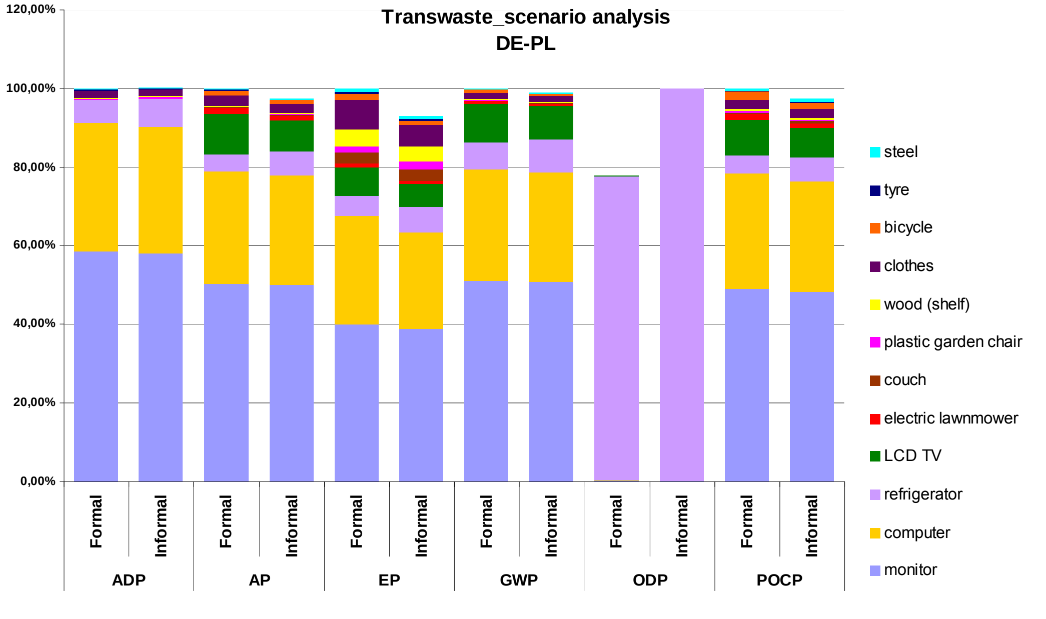

Figure 2.90: Comparative analysis of the formal and informal scenarios (DE-PL)

The next diagram was made to compare the three proposed routes (Figure 2.91). This shows the difference in environmental load between the routes in the informal scenario. The highest values arise at the informal acts of the DE-PL countries in every analysed impact categories. Between the other two possibilities, the AT-SK case is the best in all but one categories (Abiotic depletion potential, eutrophication potential, global warming potential, ozone depletion potential and photochemical ozone creation potential) and the AT-HU in one (acidification potential).

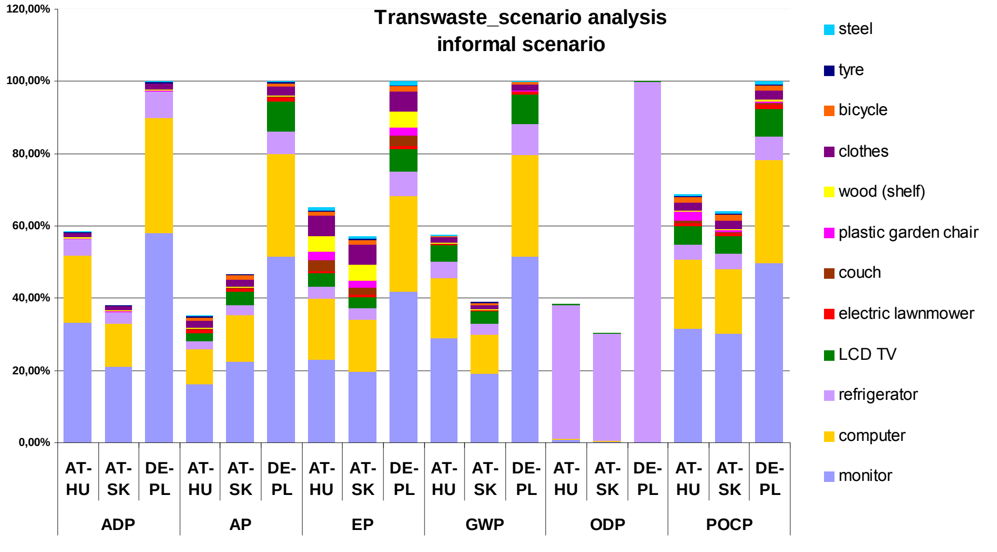

Figure 2.91: Comparative analysis of the informal scenarios

This is a good example for that the county for re-using is less important than the products for reuse themselves. The country specific energy-mix (in case of determined and fixed product composition) used in the use phase of EEE has bigger impact on the environment than the other factor: product manufacturing, waste dismantling and product transport. This is the reason why the electric and electronic equipment (monitor, computer and fridge) have significant impacts in every scenario. Thus the environmental advantages of the re-use could be demonstrated at the LCA of individual products. In case of EEE, reusability is determined by the individual characteristics of an appliance for energy, water, etc. use. This is indicated in the environmental category (C, B, A, A+, etc.) of the product and should be analysed for every product.

The results are dominated by the use phase of EEE. The use phase is influences by the electricity mix of the different countries. As the electricity mix of Poland has the most environmental burdens compared to other countries, the total emissions are in the DE-PL scenario higher than AT-HU or AT-SK

At the defining of the usefulness of reuse, we have to do product-specific life cycle assessments. As it turned out from the study, products such as clothes, couch, shelves etc. clearly give environmental savings with their reuse as they are dominated by the production phase which is avoided in the reuse while EEE are dominated by the use phase. The use phase is the same in formal and informal scenario in the assumed scope and boundary of the assessment, therefore the differences between formal and informal are not that significant. Clear analysis has to be done to see the environmental gains and burdens of reuse in the case of product; for example: it is not enough to examine a monitor, but their different subtypes have to be analysed as well. Modernization of some EEE is so fast, that the reuse of such products has become senseless from environmental point of view. This is the case for example the refrigerator. There is counter-example also, those devices, which energy consumption hasn't been changed drastically for years. Overall it can be said - based on the study- the present informal scenario provided more favourable scenarios with some percentages in all analysed environmental impact categories. This is explained by the fact that the majority of the products get into reuse; there is no need for production again for this amount.

3 Conclusion

Waste picking, collecting recyclable materials from the waste stream in order to make a living from it by processing or reselling secondary raw materials or goods is well known in developing countries

The waste pickers, in most cases but not solely poor people belonging to ethnic groups as Roma, are collecting electronic scrap, scrap metals and bulky waste mainly as their only income source without any statutory permits like authorisation for waste collection or labour permits. The waste products often picked up in front of waste collection centres or at households, are collected in countries with high developed waste management structures and are transported into countries whose waste management is in the process of being established. This actual state causes problems in the environmental, social and economic field:

Ecological problems arise when parts of waste which are not usable anymore are treated and recycled at inadequate places in their target countries. Due to the transboundary shipment of waste, the amount of bad treated waste increases immensely in these regions. Because of informal activities the waste cannot be tracked and no proper waste processing can be guaranteed. Both improper waste handling and disposal (especially littering) may contribute to serious environmental impacts

The aim of this task is to analyse environmental, social and financial problems due to the informal waste collection and the transboundary shipment of wastes by investigating the actual scale of informal waste activities.

The results of the environmental assessment show that the informal scenario has in most cases less environmental burdens than the formal scenario. The reason for it is the avoided production of reused items in the informal scenario. Also the different and often more environmental burdened end of life phase in some countries where reused items are brought to, are not influencing this result. This avoidance of the production phase can therefore compensate the given higher burdens in the end of life phase. Even the illegal disposal, which is considered in the informal scenario for 30%, it doesn’t influence the total results. One significant exception is the fridge. The fridge show high environmental emissions in case of the ODP when disposed illegally. This is due to the CFCs release of old appliances. Furthermore the high energy consumption of old fridges is the reason why the informal scenario has more emissions than the formal scenario. All other indicator products show environmental benefits when reusing them in the informal scenario.

Scenarios on the different origin and receiving countries show that DE-PL processes have more environmental burdens than AT-SK or AT-HU. This is mainly due to the electricity mix used in those countries. As the use phase is the most dominant in the EEE products, it influences the total results considerably.

This project is implemented through the CENTRAL EUROPE Programme co-financed by the ERDF

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5 Glossary

Administrative offence	a minor offence, not a criminal one, usually punishable with a fine.
Bring system	Waste collection by producer. Collective term for method of household waste separation at the point of generation involving the consumer taking separated materials to waste collection centres.
Bulky waste	Wastes from households, which can't be collected in normal sized household waste bins, because of their size and form (BMLFUW, 2006).
District Administrative Authority	General administrative body of first instance of a political district

Junk	Second-hand goods
Junk traders	People who deal with second-hand goods
Kerbside collection	Waste collection at source. Waste collection system: waste is collected in standardised containers and collected directly at the waste producer.
Non authorised collector	See informal collector
Illegality	an activity or situation, that is violating existing legal norms
Informal collection	without formal assignment, not official; some activities are related to the so called "black" or "hidden economy".
Informal collector or non authorised collector (also referred to collector or waste picker in this document)	A person or a group of person collecting useable goods from waste collection centres or directly from households in a non-authorised (informal) way. Also called waste collector, bulky collector, Lomi, waste picker, waste reclaimer, scavenger (mostly in developing countries and in terms of collections at landfills "scavenging")
"Lomis"	Hungarian expression for bulky waste collector without licence
"Lomi"	Hungarian expression for the collecting act of Lomis
Secondary materials	Materials which can be recycled and used for to produce other products. They can be used several times. Secondary fuel is a special from of secondary materials, which means that the materials are thermally treated. Secondary materials comprises among others mainly packaging materials like glass, plastic, metals but also paper, wood and textiles.
Waste collection centre (WCC)	A public waste collection facility for the purpose of collecting bulky waste and other waste fractions from households as well as from small businesses and transfer to disposal units. The concept is part of the bring system. Also called civic amenity cite (CAC), household waste recycling centre (HWRC), recycling

	centre, recycling point
Waste management associations (WMA)	An association which overtakes the waste management organisation for municipalities and cities
PC	Personal computer
CRTs	Cathode ray tubes
LCD	Liquid Cristal Display
Ecoinvent database	The applied database in the model building by the life cycle assessment software
GaBi	The environmental assessment was made by this software
GWP	Impact category – CML 2001 method – Global warming Potential
ADP	Impact category – CML 2001 method – Abiotic Depletion Potential
EP	Impact category – CML 2001 method – Eutrophication Potential
AP	Impact category – CML 2001 method – Acidification Potential
POCP	Impact category – CML 2001 method – Photocemical Ozone Creation Potential
HTP	Impact category – CML 2001 method – Human Toxicity Potential
ODP	Impact category – CML 2001 method – Ozone Deplation Potential
Informal	The present situation, where the used item collectors do their act without licence, but this act isn't forbidden.
Formal	The official process of the waste collection
Formalized	The future situation, where the used item collectors can do their activity in official way.
EoL	End-of-Life: The stage of the going to waste of the product

Normalized values	Percentage values
EEE	Electric and electronic equipment
WEEE	Waste of Electric and electronic equipment

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