ANNEX V - MONETISATION OF COSTS AND BENEFITS

1. MONETISATION METHODS

Rossi et al. (2004) provide a good overview of different methods used to monetise costs and benefits (in Thompson, 1980). The least controversial methods are **direct money measurements and market evaluations**. The former directly estimates monetary cost and benefits; the latter evaluates them at market price. For example, it is possible to measure the benefit of a reduction in MSW disposed by multiplying the quantities of waste reduced by the price of disposal. Of course, in order to do this, markets must exist for the costs and benefits to be measured.

Although **econometric and other statistical estimations** are more controversial, they have been widely used in previous literature to estimate the effect of PAYT schemes (e.g., Dijgraaf & Gradus, 2003; Hallas & Healstead, 2004; Huang et al, 2011). **Hypothetical questions** are another method used to value non-monetary costs and benefits, for example, by asking households about their willingness to pay (WTP) for a better environment, for a better-looking city or, in this case, for a reduction of the time allocated for waste-related activities. Although WTP's main criticism is that it overestimates the real value of things in the research, the amount of money paid for a reduction of ten minutes of waste-related activities was very low and the majority of people were not willing to pay anything. Therefore it is possible to assume that, in this particular case, there was no overestimation but actually a possible underestimation of the value of time. Another approach can be the **observation of political choices**; it is possible to quantify costs and benefits by looking at the expenditure of public authorities on specific programs or on the prevention of specific problems. This approach can be very risky, since political will is often complex, inconsistent and changes quickly.

Lastly, the (potential) **Pareto criterion** is used to measure **distributive issues** in the form of welfare distributions within the society.

Other methods are used to circumvent the problem of monetising effects that do not have a market price:

- **Shadow prices:** proxies or derived prices for goods and services that should reflect precisely their costs and benefits when market prices do not exist. It is often defined as 'what an individual must give up in order to obtain an additional unit of the good or service considered'. Sometimes, shadow prices are considered to be more realistic than market prices, for example in the presence of market failures. Shadow prices are often estimated - especially in the assessment of a program impact - through stated and revealed preferences;
- **Opportunity costs**: this concept is based on the fact that resources are limited and individuals must choose how to allocate them. By choosing one activity, the possibility of performing other activities is precluded. Therefore the cost of engaging yourself in an activity can be measured in terms of the next best activity that is given up. Although this method is often used, it is considered to be complex and controversial (Rossi et al, 2004).

It is important to specify that these methods are not always valid and reliable, and they may lead to errors (over- or underestimation of costs, benefits and social efficiency). Therefore, it is important to recognise when the effects can be reasonably valued and when not (Rossi et al, 2004).

In the case of redistributive issues or non-tradable goods that cannot be precisely monetised, as suggested by Eijgenraam et al. (2000, p. 17), these effects should be *"…indicated (quantitatively as far as possible) in a social cost-benefit analysis, but are not expressed in monetary terms"*. These effects will be therefore indicated as **PM-items**.

2. MONETISATION OF COSTS AND BENEFITS

Here, each one of the effects is translated into costs and benefits that may influence the social efficiency of the cases selected. A detailed explanation and description of the method used to recognise and monetise costs and benefits is given.

Table 1 summarises different costs and benefits as seen in the different cases. A detailed explanation of each cost and benefit, and how these are monetised, will follow.

COSTS	BENEFITS
MSW collection costs: - Residual - Recyclables - Bulky	Waste to Energy (WTE)
MSW disposal costs: - Residual - Recyclables - Bulky	Profits from recyclable materials
Administrative and equipment costs	Equity in paying for the service (Alt 1 and 2) (PM+)
Environmental costs: - From collection - From disposal (incineration)	
Illegal dumping and waste tourism: - Enforcement costs - Environmental costs	
Households time and costs'	
Distributive issues: Families with babies and low-income (Alt 1 and 2) (PM-)	
Discounting and other costs	

TABLE 1: OVERVIEW OF COSTS AND BENEFITS

It is important to consider that the scarcity of benefits presented in table 1 is mainly due to two factors. Firstly, some of the benefits have been accounted as a reduction in costs. For example, the introduction of a PAYT scheme may have the benefit of decreasing the total costs for MSW management. This benefit is not shown in the benefit column, but is reflected in lower costs for collection and disposal of residual waste. Moreover, since less waste is collected and disposed with a PAYT scheme, the environmental quality increases. This benefit is not stated as an environmental benefit, but as a reduction of environmental costs. Secondly, this problem is also related to the program's nature. The collection and disposal of MSW is a public service, which usually presents more costs than benefits and rarely has a positive balance. Moreover, the main source of income in all municipalities is the taxes paid (either on waste or on general income). These are not taken into account, since they constitute a redistribution and not a net increase in welfare.

2.1 COSTS

Collection costs for residual, recyclable, organic and bulky waste include, for example, costs of employees and vehicles (depreciation, fuel, and maintenance). These costs, among others, depend on the collection system in use (centralised or kerbside) and on the frequency of collection. Some differences in the collection of these three types of waste can be recognised: residual waste is collected only from kerbside or centralised containers and cannot be disposed in Ecocentres; recyclables are collected both from centralised containers[1] and Ecocentres open to every citizen of the municipality; organic waste is only collected in Ecocentres. Finally, for bulky waste, two possibilities exist: they can be delivered to Ecocentres by the households themselves, or specific days can be set for kerbside collections by the municipality. Of course, if recyclables and bulky waste are disposed by households in Ecocentres and not in centralised bins or kerbside on specific days, this may decrease the collection costs for the municipality but increase cost and time for the households.

Since the municipality is responsible for the collection and transportation of waste, these costs can be directly measured by asking the different municipalities about their expenses (to ascertain a direct money measurement). A very practical alternative is to retrieve these costs from the annual waste census (see Repubblica e Canton Ticino, 2011). This census already presents separate data on quantities and costs for collection of different types of waste. Both methods are used and the results compared, in order to reduce data collection errors.

[1] Usually these differentiate residual waste from, glass, paper and aluminum. The degree of availability of glass, paper of aluminum vary among and within municipalities

In terms of **disposal costs** for residual, recyclable, organic and bulky waste, the easiest to measure are the costs for disposing residual and bulky waste - they only involve payments to the incinerator company. It is important to point out that, from the beginning of 2010, the Azienda Cantonale dei Rifiuti (ACR)[2] was assigned to manage the new incinerator at Giubiasco. In this way, the MSW that was previously disposed in another canton is now disposed directly in Ticino. This permitted an important reduction in the price fixed for the disposal of waste - from 258.70 CHF/t (without VAT) in 2009, to 175 CHF/t (without VAT) in 2010 (DFE, 2010)[3]. As stated by the Dipartimento Federale dell'Economia (DFE), this has had a positive impact on the income statement of the municipalities - in total, 9 million Swiss Francs can be saved (DFE, 2010, p. 1). Some municipalities corrected their taxes on MSW according to the lower price applied by the ACR, while others kept them constant[4]. This is an important factor to take into account, since the reduction in the price for disposing waste may result in an increase in MSW produced by households if the price change is reflected in lower taxes for households.

Organic waste is usually disposed in specific composting areas where it is transformed into fertiliser. These specific areas are managed by municipal/regional public authorities (e.g., forestry department), or by private companies (ACR, 2012). These costs may therefore vary a lot among municipalities.

Disposal costs for recycling materials are the most challenging to measure because of the diversity of the materials. For example, recyclable materials such as aluminium, metals, paper and glass are sold for a profit; the costs of plastic P.E.T. disposal are not influential for the municipality, since they are supported by private companies who sell them. Treated wood is disposed at the expense of the municipality (Ing. Di Gianfrancesco, 2013a).

To measure the disposal costs of all types of waste, it is possible to use several techniques. Firstly, it is possible to measure directly these costs within the municipalities through specific questions. Secondly - at least for residual and bulky waste - the weight in tons produced can be multiplied by the price set by public authorities (175 CHF/ton) (market evaluation). Again the cantonal waste census provides ready-to-use data, thus saving time.

Administrative and equipment costs: these include all remaining costs related to the functioning of the WMS, for example costs to purchase bags, to pay for employees responsible to sell bags, to maintain equipment (e.g., scale systems or containers), to pay for accounting and secretary works, etc. These costs can be measured directly by specific questions to the municipalities. The limitation here is that, very often, these costs are included into the collection and disposal costs and are not accounted for in a separated manner. For example, within the data about costs for collection and disposal from the census, depreciation and personnel costs are already included. This has also been confirmed by one of those responsible for the cantonal census (Zulliger, 2013), who stated that the costs of the employees and the amortization of vehicles and equipment are included in the general costs of collection and disposal. Therefore, they are not accounted separately within the CBA, but are included within collection and disposal costs. When possible, some qualitative indication of the extent of these administrative costs - or if they have increased or decreased after the introduction of a PAYT scheme (alternative 1 and 2) - is also given.

Environmental costs: although in recent years many studies have monetised environmental costs and benefits, especially involving CO_2 emissions[5], this practice is still largely debated. It is, for example, possible to easily measure and quantify the impact of CO_2 emitted by the incineration of non-recyclable waste on the environment. Consider that 1 ton of waste burned results in 0.7 to 1.2 tons of CO_2 emitted (IPCC, 2000); if we apply the price of £65 per ton of CO_2[6], it is easy to understand that the impact on the environment can be monetised as between £45.5 and £78 per ton of waste. This estimate has been found to be very different from the actual measure (Chen & Lin, 2010). Moreover, it is very challenging to understand the quantities, the impact on the environment of other substances emitted, and their monetary value. In order to measure these quantities, taking into account that quantities of substances emitted may depend a lot on the technology adopted in the incinerator, specific questions for the ACR that manage the incinerator of Giubiasco have been developed. These questions aim to understand the quantities of pollutants emitted by a ton of non-recyclable waste, as well as the electricity and heat produced (see section 2.2). In order to monetise the impact of different substances, shadow prices are used. In the literature, several studies at a

[2] Independent entity founded by public authorities that is responsible of managing the MSW collection and disposal as well as the regional incinerator.
[3] A maximum price of 185CHF/t has been fixed by law (art. 24 LACR).
[4] 14 on 29 modify the taxes on a study of the DFE (2010).
[5] See for an example Hogg et al. (2006a, b).
[6] See Watkiss et al. (2005), in Hogg (2006b).

European level have measured the impact of incinerator emissions in terms of abatement or damage costs. Dijgraaf & Vollebergh (2003) took into account both direct and indirect, private and environmental costs, and estimated social costs of incineration as 79 Euros per ton for net private costs and 17.57 Euros for net environmental costs. Despite this study providing a good overview of environmental costs of incineration, these are not used since it was not possible to exactly identify the costs and quantities of the different substances emitted, but only the total cost into air or water. Moreover, incinerators built nowadays have much lower emissions than those built 10 years ago, because of technological progress. Therefore, using data from the study of Dijgraaf & Vollebergh (2003) based on data from 2000 may lead to an overestimation of the quantities emitted, and therefore of costs. Assumptions about energy and material functions are also very time- and place-specific; therefore they may not reflect the local reality. Last but not least, the shadow prices on which environmental costs are calculated are based on abatement costs. In order to reflect (at least partially) the impact on human health, it was important to use shadow prices based on damage costs and not on abatement costs.

De Bruyn et al. (2010) estimated emission costs, both abatement and damage, in different European countries. Figure 1 summarises the impact for average emissions based on the damage costs for EU-27 countries. These damage costs are time- and place-specific, and must be adjusted. The EU countries in which damage costs have been estimated (including Switzerland, and therefore Ticino) have different population densities, income levels and costs of living. For this reason, these estimated costs must be adjusted for income differences.

The adjusted values can be calculated by the following equation:

$$Xp = X_E\ (Yp / Y_E)ß$$

where X_E is the original value, Y_E *is* the income level of the country or region selected in the research and *Yp* is the income level of the country from which the values are transferred. In case the income levels are not available, then per capita GDP at parity purchase power (PPP) level can be used. Lastly *ß* is the income elasticity of X for the environmental goods in question. This is always less than 1; usually an income elasticity of 0.85 is used for environmental quality (de Bruyn et al, 2010).

Taking into account all the parameters, the equation will be as follows[7]:

$$X_p = X_E\ (29.324 / 32.761)^{0.85} \quad {}^{8}$$

This formula is used to calculate the value transfer of each of the relevant emissions from incineration. The emissions included are: dioxins, furan, CO_2, N_2O, SO_2, CH_4, NO_x, NH_3, and other heavy metals (see IPCC, 2000).

[7] For more information about value transfers see NEEDS, 2007.

[8] Data in dollars year 2008, retrieved from World Bank, 2012 (Y_p= 42.915 Y_E=47.946 have been exchanged in euro at the average exchange rate of 2008 (USD/EUR: 0.6833, retrieved from: fxtop.com)

	Human health	Ecosystems	Crops and buildings	Total
CO_2	0.00487	0.0201		0.0250
CH_4	0.122	0.503		0.625
N_2O	1.45	6.00		7.45
CFC-11	62.4	95.6	1.25	159
CFC-12	103	219	1.31	324
CFC-113	67.8	123	1.34	192
CFC-114	84.3	201	1.25	287
CFC-115	52.6	148	0.75	202
HCFC-22	12.8	36.4	0.05	49.2
Halon-1211	350	38.0	3.17	391
NO_x	7.87	1.30	0.480	9.64
SO_2	8.73	0.254	0.263	9.25
NH_3	13.0	4.69	-0.220	17.5
NMVOC	1.29	-0.097	0.227	1.42
P (manure)		0.0890		0.0890
P (fertiliser)		0.0947		0.0947
P (from STP)		1.78		1.78
PM_{10} (particulates)	22.6			22.6
$PM_{2.5}$ (particulates	33.8			33.8
Dioxins	5.09E07			5.09E07
As (arsenic)	728			728
Cd (cadmium)	115			115
Cr (chromium)	18.2			18.2
Ni (nickel)	3.16			3.16
Pb (lead)	383			383
CH_{20}	0.275			0.275
Uranium-235 (air)[48]	1.16E09			1.16E09
Uranium-235 (water)	1.27E08			1.27E08

FIGURE 1: SHADOW PRICES OF EMISSIONS IN THE EU-27 IN 2008 BASED ON DAMAGE COSTS (EURO PER KG)[9] (SOURCE: DE BRUYN ET AL, 2010)

Considering what is stated above and the answers from the ACR, **environmental costs of disposal** have been calculated as follows. Firstly, it needs to be considered that the incinerator of Giubiasco emits pollutant materials of three forms:

- Gaseous emissions, emitted into the atmosphere by two flues of 55m and include particulate matter (PM), sulphur dioxide (SO_2), carbon monoxide (CO), Nitrogen oxides (NO_x), hydrochloric acid (HCl), Ammonia (NH_3), hydrogen fluoride (HF), Lead (Pb), Zinc (Zn), Mercury (Hg), Cadmium (Cd), Dioxins and furans;
- Liquid residues from the treatment of smoke and ashes;
- Solid residues, including waste (which go to landfill), washed ashes (which go to landfill), and sewage hydroxides (residues resulting from the treatment of liquid waste).

As stated by the ACR, one ton of waste burned in the incinerator at Giubiasco produces 6,000m^3 of gases, and 63 litres of water (ACR, 2012 and 2013). Therefore with the waste burned in 2011 amounting to 154,924 tons, the emissions generated by the incinerator were 929,544,000 m^3 of gases and 9,760,212 litres of waste water.

In order to measure the pollution for which each municipality was responsible, the amount of non-recyclable waste produced by the municipality is multiplied by 6,000 (m^3), in order to obtain emissions into the air and by 63 litres, in order to obtain emissions of water. Lastly, the shadow prices are used in order to monetise the total

[9] A more comprehensive list of substances and their damage impact can be found on Annex J of de Bruyn et al. 2010.

emissions for each pollutant. Table 2 shows the measured emissions of pollutants into the air from both flues, and table 3 shows the pollutants released into the water.

Pollutant (mg/ m^3)	**Flue 1**	**Flue 2**	**Total**	**Adjusted Shadow Price (CHF/kg)** [10]
Total Particulate (PM)	0.0001	0.012	0.0121	31.67
Sulphur oxides (as SO2)	3.48	2.58	6.06	12.96
Oxides of nitrogen (as NOx, NO2)	24.30	24.30	48.6	14.85
Gaseous inorganic chlorine compounds (as HCl)	0.11	0.14	0.25	6.04
Ammonia and ammonium compounds (NH3)	0.10	0.03	0.13	24.52
Substances org. gaseous (as total carbon, C)	0.01	0.04	0.05	3.55
Carbon monoxide (CO)	7.11	6.28	13.39	0.03
Mercury (Hg)	0.0006	0.0005	0.0011	1,5416.98
Cadmium (Cd)	0.0006	0.0007	0.0013	177.99
Zinc (Zn) + Lead (Pb)	0.09	0.108	0.198	571.83
Dioxins + Furans	0.014	0.008	0.022	71,338,611.97
Fluorine Composites (HF) [11]	0.07	0.02	0.09	43.05

TABLE 2: POLLUTANTS' COMPOSITION OF GASEOUS EMISSIONS (SOURCE: ACR, 2012)

Water is used to clean the ashes, and smokes are treated before released into the river. The amount of water released into the river is on working days $5m^3/h$. Considering 246[12] working days and 8 hours of activity a day, the total amount of water in one year is 9,840 m^3. Dividing the annual quantity of water by the annual waste disposed it is possible to obtain the total m^3 of water needed to treat 1 ton of waste, and therefore quantify the municipality contribution. 0.063 m^3 (or 63 litres) of water are used for each ton of waste burned in the incinerator.

Pollutant (mg/l)	**Total emissions**	**Adjusted Shadow Price (CHF/kg)** [13]
DOC	2.2	-
Cadmium (Cd)	0.01	6.95
Chromium (Cr)	0.02	0.03
Mercury (Hg)	0.0001	1,342.67
Nickel (Ni)	0.02	4.72
Lead (Pb)	0.03	11.81
Copper (Cu)	0.02	0.0059
Zinc (Zn)	0.1	2.25
Ammonia nitrogen (NH4-N)	5.8	38.96
Nitrous oxide (NO2-N)	0.152	14.85

TABLE 3: POLLUTANTS' COMPOSITION INTO WATER (SOURCE: ACR, 2012)

[10] This value has been adjusted for income and the 2013 average euro/CHF exchange rate of 1.22835 has been applied in order to translate the values.

[11] Average of different fluorine composites' damage costs

[12] 365 days in one year minus 104 weekends and 15 holidays (Dipartimento Federale dell'Economia, 2013).

[13] This value has been adjusted for income and the 2008 average euro/CHF exchange rate of 1.54 has been applied in order to translate the values since these are already expressed in the literature as euros, 2008.

It is known that the ashes from the incinerator of Giubiasco are brought to a specially built landfill in Lostallo (Canton Graübunden) for disposal (sorting and depositing). Unfortunately, data - both on quantities of ashes produced and quantities of pollutants in the ashes - were not available. Proxies from the literature were not available or not detailed enough. Therefore the environmental impact from ashes cannot be estimated and is not taken into account.

Moreover, since some of the pollutants of the same class have been accounted together, the highest shadow price is applied to the entire group in order to monetise the environmental costs (i.e., NOx and NO2).

We do not consider the emissions created when materials are recycled for several reasons: 1) since different materials are recycled with different methods it is practically impossible, especially taking into account the time and resources given, to have a representative estimation of such emissions; 2) if we considered that the same product would have been produced with virgin materials and as a consequence the emissions will be higher, we should calculate the difference in order to understand the effect - either negative or positive - of recycling against producing from virgin materials.

In order to account for **environmental costs from MSW's collection,** both questions in interviews and previous literature are used. It is important to know from the municipality which and how many trucks are used, how many litres of gasoline have been consumed, and how many kilometres have been travelled in one year. Most of the municipalities had complete data - except for Caslano, which outsourced its collection system to a private company. The next step was to be able to measure the emissions of pollutants per litre or kilometre of each truck.

Emissions of heavy duty vehicles, also within the normative EURO, are calculated using g/Kwh. Since the municipalities were not able to provide exact measures of emissions or consumption in g/Kwh, but only total litres of diesel consumed and kilometres travelled, these need to be translated in order to address the impact of waste collection on the environment. Unfortunately, it is not possible to convert Kwh into kilometre or litres of consumption; there are many variables (the exact weight of the truck, the times that the truck stopped and the type of streets, etc). Therefore, to calculate the impact of trucks' emissions on the environment, table 4 (provided by Volvo trucks) is used since it is already translated into g/litres and provides a good overview of all the EURO-standard emissions for heavy duty vehicles. The emissions are calculated according to the emission standard on a fully loaded truck (i.e., 40 tons). The table provides a good proxy for the calculation of emissions - even for other brands and types of truck, since they all need to comply with the EURO normative and therefore will have very similar emissions.

Typical values, based on certification measurements, for the more common Volvo engines, with EU certification diesel fuel						[g/litre fuel]
	Law from	Volvo from	NO_x g/litre	PM g/litre	HC g/litre	CO g/litre
Typical	1980		58±5	4±2	6±2	8±3
Euro 0	1990	1987	41-44	1.5-1.7	1.5-1.8	3-6
Euro 1	1993	1991	28-32	0.2-0.6	0.5-1.2	2-8
Euro 2	1996	1993	25-28	0.2-0.5	0.4-1.0	1-7
Euro 3, D6, 180-220	2001	2000	18	0.35	1.3	2.6
Euro 3, D6, 250	2001	2000	18	0.25	1.3	2.6
Euro 3, D7, 250	2001	2000	18	0.25	0.4	2.3
Euro 3, D7, 290-310	2001	2000	18	0.30	0.4	2.3
Euro 3, D9, 260	2001	2001	18	0.30	0.8	2.3
Euro 3, D9, 300	2001	2001	18	0.35	0.8	2.3
Euro 3, D9, 340-380	2001	2001	19	0.30	0.8	2.4
Euro 3, D12, 340-420	2001	2000	19	0.25	0.8	2.4
Euro 3, D12, 460	2001	2001	20	0.35	0.4	2.5
Euro 3, D12, 500	2001	2001	20	0.30	0.4	2.5
Euro 3, D16, 550	2001	2003	17	0,25	0,8	2,7
Euro 3, D16, 610	2001	2003	17	0,25	0,8	3,9
Euro 4	2006	2005	13	0,10	0,04	1,0
Euro 5	2009	2005	7	0,10	0,00	1,2

TABLE 41: EMISSIONS OF TRUCKS ACCORDING TO DIFFERENT STANDARDS (SOURCE VOLVO TRUCKS, 2013)

Grams of emissions per litre are then multiplied by the total litres used by each truck. Once the total grams per litres of each pollutant are obtained, these are multiplied by the shadow prices - as for the emissions for incinerator (de Bruyn et al, 2010). Shadow prices of damage cost are taken from figure 1, and are as follows:

- NOx: 10.6 euros/kg
- PM: 22.6 euros/kg
- HC: 0.278 euros/kg
- CO: 0.026 euros/kg

Since data about litres consumed and kilometres travelled were generally available only aggregated - not for each truck - these have been divided equally among the number of trucks. Moreover, in the case of Caslano and Bellinzona, only kilometres and not litres were available; in this case, the average consumption of a truck is used. Despite the fact that usually the average consumption of an heavy duty truck is considered to be around 40 litres for 100 kilometres (see figure 2), in the research, an average consumption of 70l/100km is used in order to convert kilometres travelled into litres consumed. The reasons are several: firstly, the average of 40l/100km is calculated on highway trips and thus the diesel consumption is significantly lower than on an urban trip; secondly and most importantly, by dividing the stated litres consumed by the stated kilometres travelled of the other municipalities (Lugano and Locarno), the ratio of 70l/100 kilometres was obtained in both cases.

The last consideration is that costs - both economic and environmental - for collection depend widely on the geographical characteristics of the municipality, as well as on the type and number of vehicles used to provide the collection service.

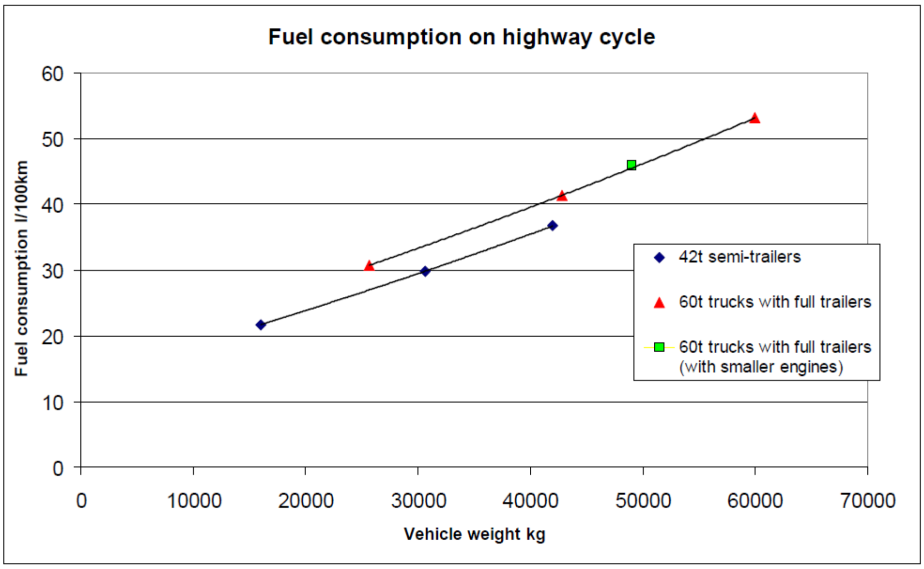

FIGURE 21: AVERAGE CONSUMPTION OF HEAVY-DUTY TRUCKS ON HIGHWAY (SOURCE: NYLUND, N & ERKKILA, K., 2005)

Illegal dumping includes illegal burning (e.g., in private fireplaces, gardens, etc.), illegal disposal (in the forest, parking lots or other public spaces) and littering (Bischof et al, 2003, p. 23). Despite some publications recognising illegal dumping as a problem only in PAYT schemes' municipalities, as stated by Bischof et al (2003), illegal dumping in Switzerland concerns both municipalities with and without causal taxes. This is true especially if littering is considered. This is also confirmed by the interviews with different municipalities. In fact, it was not possible to recognise clear differences between PAYT and non-PAYT municipalities regarding quantities or costs for illegal dumping. Waste illegally dumped is often organic or bulky, and no episodes of garbage bags dumped in woods or burned in fireplaces have been recorded in the municipalities selected in recent years. On the contrary, bulky and organic waste is often dumped next to Ecopoints or Ecocentres - or in the wood in the case of organic waste. These episodes have been recorded in Lugano and Locarno, as well as Caslano and Bellinzona. The reasons for illegal dumping are often more related to scarcity of Ecopoints or Ecocentres, the inability to transport them or simple laziness - that is to say, it is not merely down to the high price for disposal due to the PAYT scheme.

Environmental costs from illegal dumping are very difficult to estimate and monetise. As stated by Fullerton and Kinnaman (1996), *"we could not provide direct measures of such behaviour, and we could not trust answers to direct survey questions about it either"* (p. 978). Moreover, the authors recognised that the social costs linked to illegal dumping vary with the method used (e.g., dumped, burned, littering). It was also not possible to use other costs as proxies, such as clean-up costs, since these were not accounted for or included within collection and disposal costs. Despite this, the literature provided good proxies for the estimation of illegal dumping.

Bischof et al. (2003) recognise that illegal dumping is present in both PAYT and non-PAYT municipalities, but is more incentivised in the former, at least to begin with. The authors estimated that the quantities of waste illegally dumped constitutes between 1% and 2% of the total MSW. Moreover, in canton Ticino, the Dipartimento del Terriotrio estimated that the amount of waste illegally burned was around 2,500 tons (Zulliger, 2008). Considering the 170,033 tons of waste produced in Ticino in 2008, the waste illegally burned is around 1.5%. Lastly, as estimated by the "clean-up" organisation, "*Let's do it*"[14], the total amount of waste illegally dumped in 2010 in Switzerland was 26,033 tons. If this amount is divided by the total Swiss population in 2010, 7,826,153[15], the total illegally dumped waste per capita is estimated at 3.3kg of residual waste per year. Considering the population and the total waste produced by the municipalities, the estimated[16] waste illegally dumped is between 0.5% and 1% depending on the municipality.

Taking into account the above, in order to monetise the environmental costs of illegal dumping in the research, a percentage of between 0.5% and 2% is applied to the total quantity of MSW of the municipality under analysis. In order to decide on the extent of illegal dumping, and therefore to apply these percentages, specific qualitative questions were asked during municipalities' interviews, households' surveys and questions to employees. Moreover, first-hand explorations of the territory were made to verify the qualitative data collected.

Other proxies, such as clean-up costs, could not be used, mainly because of the lack of detailed data. These data were collected separately by the municipalities only when special events occurred (e.g., illegal deposit of pneumatics in Locarno). The costs of everyday illegal dumping are either integrated within collection costs or general maintenance costs.

In order to monetise the cost of illegal dumping, emissions from the incinerator are applied on the estimated quantity of MSW illegally dumped and shadow prices are applied, as showed above for environmental costs. Despite the fact that environmental damage from waste illegally dumped may not be the same as the environmental impact from the incinerator, no better proxies were available. This is mainly due to the different methods and locations of illegal dumping (e.g., burning, disposal in woods, along rivers, etc.) and the unavailability of data to exactly describe the environmental impact for each method and location. For example, according to Svizzera Energia, waste burned in fireplaces emits one thousand times (for dioxins and furans) more pollutants than those burned in incinerators, since there are no filters. Data on the impact of the other pollutants are not available; therefore it is difficult to estimate the real environmental impact. Moreover, it was not possible to know the exact amount of waste burned within the total quantity of MSW illegally dumped and, as stated by all the municipalities and by the UFAM (2012), waste burned in private facilities has been largely reduced since the 1980s and is almost non-existent. For this reason it is assumed that waste burned constitutes a very small part of the already small tendency of illegally dump waste and therefore its environmental costs are calculated on a normal emission level.

Other costs related to illegal dumping, such as surveillance or awareness campaigns, are also take into account under the label of enforcement costs.

Waste tourism is the action performed by households of transferring waste from a municipality (usually with a PAYT or higher casual tax) to another (without PAYT or lower casual tax). Waste tourism is considered to be at least partially responsible for the reduction of MSW's quantities (Fullerton & Kinnaman, 1996; Linderhof et al, 2001) and has been recognised as the main concern for municipalities wishing to introduce a PAYT scheme, or for non-PAYT municipalities which have neighbouring municipalities with PAYT schemes (Allers and Hoeben, 2010).

[14] http://www.letsdoitworld.org/
[15] World Bank (2012)
[16] Calculated by multiplying 0.0033 tons by the population. The result is multiplied by 100 and divided by the total amount of MSW collected in order to have the percentage of MSW illegally dumped in the municipality.

It is assumed that this transfer of waste does not create particular environmental damage[17], at least in canton Ticino, since garbage is dumped near to underground containers. Instead, this reflects in the form of higher (or lower) collection and disposal costs for municipalities without (or with) a PAYT scheme. Therefore waste tourism is in fact a redistribution of economic costs among municipalities. Nevertheless, it is essential to account for the impact of waste tourism, since the municipality boundaries are taken as boundaries within the research (see section 3.2).

Two types of cost related to waste tourism are recognised: enforcement, and collection/disposal costs. Enforcement costs, such as surveillance, can be directly measured in interviews. Direct measures of higher or lower collection and disposal costs were not available.

In order to overcome the lack of direct measures, literature on waste tourism is investigated. Studies that directly estimated waste tourism are very scarce. The most useful input comes from the study of Linderhof et al. (2001), who investigated the effect of a weight-based system in the municipality of Oostzaan (The Netherlands). They estimated that in the case study, around 4-5% of the total MSW was diverted through waste tourism. This corresponds to approximately 13-17% of the total reduction of MSW (Dijkgraaf and Gradus, 2003). A similar result (5%) is presented by Harry Clarke (2006) in his blog, focusing on the United States.

Other studies did not directly estimate the amount of waste transferred to neighbouring municipalities, and found waste tourism to be statistically insignificant (Bucciol et al, 2011; De Jaeger and Eyckmans, 2012; Dijkgraaf and Gradus, 2003), or only significant for specific types of waste (Allers and Hoeben, 2010). These studies were useful though, since they showed the importance of considering specific characteristics of neighbouring municipalities: the schemes applied (PAYT or non.-PAYT), the prices, distances and sizes.

In order to estimate the impact of waste tourism, the characteristics of neighbouring municipalities are first considered, in order to explore the potential extent of waste tourism in a qualitative way[18]. If relevant differences are found, the percentage estimated by Linderhof et al (2001) is applied, according to the qualitative assessment[19].

For PAYT municipalities (Bellinzona and Caslano), the highest and lowest reduction in MSW from the introduction of the PAYT scheme is considered. The highest reduction usually corresponds to the year(s) immediately after the introduction of the PAYT scheme, since households are more prone to waste tourism and illegal dumping in the first years (Bischof et al, 2003). The highest and lowest reductions are considered in order to have an estimation of the potential range of waste tourism's impact. The average reduction from the year of introduction until today was not a reliable measure; after the first few years, MSW may have actually increased or reduced only slightly. Therefore the average measure will show a really small average reduction, which in turn will result in an underestimation of the potential impact of waste tourism.

The percentage chosen is then applied on the highest reduction, and the total amount of MSW diverted to waste tourism is calculated. Lastly, in order to monetise this cost, the average[20] cost per ton of MSW is considered and multiplied by the quantity previously calculated.

For non-PAYT municipalities, the lowest and highest decrease in MSW is calculated for each neighbouring PAYT municipality. It is assumed that the decrease in MSW due to waste tourism is spread across all municipalities without PAYT, proportionally according to their size (in terms of population). For simplicity and because of the lack of detailed data, this proportion is calculated on the configuration of municipalities' schemes in 2011[21].

The costs are added in the case of a PAYT municipality exporting its waste, and reduced in the case of a non-PAYT municipality importing waste. This adjustment is important to allow for a better representation of the social efficiency of the different schemes. In fact, since with waste tourism, costs are transferred among municipalities, this can be seen as an efficiency transfer and therefore must be adjusted.

[17] Excluding higher emissions, due to the higher frequency of collection and therefore higher emissions from collection vehicles.
[18] Additional qualitative data is collected through municipalities' interviews.
[19] 13% if small differences in characteristics between the municipality considered and neighbouring municipalities, or 17% if the characteristics are very different.
[20] The period from the introduction of the PAYT scheme until 2011 is taken to calculate the average.
[21] Not all the municipalities introduced the PAYT scheme in the same year. Therefore it is possible that in the past waste tourism was spread by fewer municipalities to more of them. This may also be the reason for the fact that, in the past, municipalities without PAYT schemes were less concerned by waste tourism.

Data about total quantities of MSW, total costs and population are taken from the cantonal census on waste (Repubblica e Cantone Ticino, 2011)[22].

Households' time and costs for separating and transporting recyclable materials to Ecopoints. In this section, two main costs are accounted for: separation and disposal costs. In order to be able to monetise the costs incurred by the households in the different municipalities, four variables need to be measured: distance, time, frequency and delivery costs.

Data about distance and time have been collected both by direct calculation and through households' statements. Frequency and delivery costs have only been measured through household questionnaires. This double measure is adopted in order to give more validity to the data used.

Disposal costs. Distances and time are calculated only for those places where households dispose only separate waste, therefore if both containers for recyclable waste and residuals are available in an Ecopoint, this is not taken into account since it is assumed that a household would travel in any case - either if waste was separated (in different bags) or not (in only one bag) - to dispose residual waste. Therefore this does not constitute any extra travel cost or extra time. Distance and time to Ecopoints are given but in general only distances and time to Ecocentres are used in order to calculate households' costs. In order to increase the validity two different methods for measuring distances and time are used.

First data about the exact location of the Ecopoints and Ecocentres are collected through municipalities' interviews. These data are then used to calculate, on an electronic map (Google Maps), the maximum distances between two Ecopoints (all the combinations), or between Ecopoints/Ecocentres and the furthest points in the city. In this way data about the maximum and minimum distance in meters, and time in minutes, are collected. An interval between the maximum and minimum measure is built in a spread sheet with gaps of 50-100 meters and half-minutes. The mean value within the max/min interval is calculated in order to have a measure of the average distance and time that a household in the municipality needs to travel to dispose its separated waste. The mean value is then multiplied by two in order to have a round-trip measure.

The same variables were also measured through direct questions to households. The aim was to understand the distance of each household from the place where they bring separated waste and the time spent on travelling, disposing separated waste and returning home. Therefore, while the calculated time only accounts for the trip, the measured time also accounts for the time which households spent on actually disposing their waste. Moreover, households were also asked to express their opinion about the costs to deliver the waste according to their frequency, distance, fuel consumption, reasons of the trip, etc. If households do not travel with the specific purpose of disposing their waste (for example, if they already travel to go to work or for other activities) it is assumed that the costs of delivery are zero. In order to monetise the time, a question measured their WTP in order to reduce waste-related activities of ten minutes (and therefore have ten minutes of extra free time).

Separation costs are measured by the monetisation of the time spent by each household on separating their waste. In order to measure this, the only possibility was direct questions to households. The time spent is then multiplied by the average WTP. In order to have homogeneous and precise measures - and therefore to be able to calculate yearly costs - the frequency with which households travel to Ecocentres in order to dispose their separated waste is measured through households' questionnaire.

Total costs are first presented per household in one day; these are then multiplied by the number of days and the number of households in the municipality, to reach a total social cost in one year.

Due to the fact that data from households were more complete (see time for disposal), and that calculated and measured distances and time were very similar, the data from households' questionnaires are used to calculate costs. The calculated data are used only to have an idea of the accuracy of households' statements.

Since the questionnaire included mostly answers with a range of time or space (see Annexes I and II), the measures and the results about time and costs are presented in a range of maximum and minimum. A complete overview of descriptive statistics and graphs for every variable measured within the survey is available for all four cases in Annex III.

[22] For more information see Annex III.

Discounting. In order to account for the investment's risk, a discounting rate of between 4% and 5% is applied to investment costs within the two PAYT municipalities. A complete explanation and comprehensive justification for the choice of the percentages can be seen in section 3.3 of the main research text.

Investment costs are directly measured through municipalities' interviews and municipal publications (messaggi municipali). There is no need to monetise these costs, since they are already expressed in monetary terms.

Other costs include the costs of parallel programs, costs for awareness initiatives, costs for informing households about days of kerbside collection, or any other costs related to the WMS not recorded in one of the categories presented above. These are directly measured within the different municipalities.

2.2 Benefits

Energy produced through waste: since the MSW disposed is transformed into energy through combustion in the incinerator, some benefits arise from the energy created (**waste-to-energy**). This benefit can be measured through market evaluation. In order to do this, the total quantity of waste sent to the incinerator (in tons) is considered and multiplied by the quantity of Kw/h of electricity and/or Kj of heat produced by one ton of waste. In a second step, the total Kw/h and/or Kj produced is multiplied by the average selling price of one Kw/h or Kj. The total costs are then subtracted from the gross profits to obtain the net profits. In order to collect data on the production of electricity and heat, specific questions will be posed to the ACR and incinerator of Giubiasco.

In one year, the Giubiasco's incinerator is able to produce 100,000-120,000 MWh of electricity. 20,000 MWh are used to satisfy internal energetic needs, and the rest is put into the grid and sold at market price. Since in 2011 the total amount of waste disposed in Giubiasco was 154,924 tons, the electricity produced for each ton was around 0.78Mwh/ton or 780Kwh/ton. Therefore the contribution of each municipality to the production of electricity is calculated simply by multiplying 780Kwh by the amount of waste (tons) that the municipality produced. The result is then multiplied by the electricity's average selling price to households - 20cts/Kwh in 2012 (DATEC, 2013). In this way it is possible to obtain the gross income. To have an exact measure of the net profits that can be attributed to the municipality, the operating cost per ton must be subtracted. Since data about operating costs of the incinerator of Giubiasco were not available due to confidentiality, literature is used as a proxy. Within the literature, operating costs of incinerators vary greatly according to the size and the technology adopted. Table 5 shows a summary of the results found in the literature:

Source	**Operating costs per ton of incinerator (original value)**	**Operating costs per ton of incinerator (CHF)**[23]
Durham Environmental Watch (Gasser, L, 2011)	115$ - 139$	109 - 131
Pembina Institute (2007)	102$ - 168$	96 - 158
Carroll County Times (Bruce Holstein, 2011)	60$	57
The World Bank (1999)	86$ (with 150,000 tons/year capacity)	81
Daniel Rolph Schneider, Dražen Lončar and Željko Bogdan (2010)	53, 52 euro - 64,27 euro (100,000 tons/year capacity)	65.3 - 78.4
Agence de l'Environnement et de la Maitrise de l'Energie (ADEME, 2011)	88 euro - 94 euro (with depreciation) 71 euro - 76 euro (without depreciation)	107 - 115
Le courrier des maires (1998)		150 - 250
Autorità regionale per la vigilanza dei servizi idrici e di gestione dei rifiuti urbani Regione Emilia Romagna (2004)	80 euro (with 150,000 tons/year capacity)	98

TABLE 5: LITERATURE REVIEW OF OPERATING COSTS OF DIFFERENT INICNERATORS

The average operating costs per ton of an incinerator found in the literature is 153.5 CHF/ton. The average cost is calculated within the interval between the minimum value found (57 CHF) and the highest (250 CHF). This can be considered a realistic measure of the cost of the incinerator of Giubiasco, since cutting-edge technologies and

[23] In order to translate the original value, the exchange rates at the date 25.03.2011 have been used. These are 0.944 for US dollars and 1.22 for euros.

high capacity may lead to above-average cost.

Profits for recyclable materials sold. The recyclable materials collected by the municipalities do not only generate costs, but are often sold to third-party companies - for a profit - which will eventually treat and reuse them. Clearly municipalities with higher rates of recycling will obtain higher profits and thus higher social efficiency (at least in respect of this variable). This benefit can be directly measured, since it is presented in the municipality balance sheet. As already stated above, it is important to recognise the materials, since different materials produce different benefits. Usually metals and aluminium have the highest profitability (on average 150 CHF/ton). In second place in order of profitability is glass. The municipalities actually have to pay to dispose glass, but since a proactive tax is refunded by VetroSuisse[24], the net profits are roughly 50 CHF/ton. Paper is also profitable when disposed, and produces from 30 to 60 CHF/ton of profits depending on the level of separation. In fact, if paper is separated from carton, the price paid is higher. Finally plastic P.E.T. disposal does not produce any profits (or costs) since it is responsibility of the seller (i.e., convenience stores) to dispose, treat and recycle it[25].

2.3 PM-ITEMS

As mentioned above it is possible that some of the effects are influential for social efficiency, but cannot be monetised or quantified in a reliable manner. These effects are not excluded from the CBA but instead are quantified as far as possible and taken into account in a qualitative way. In order to account for these costs, specific questions will be posed during interviews and questionnaires.

Increased equity in paying for the service (PM+). After the implementation of a PAYT scheme, equity in paying for the MSW management service is enhanced. This in turn will lead to a better situation for one part of the society (those who were paying a lump sum that was more costly than the actual service used) but worse for other individuals (those who were paying a lump sum and using more of the collection and disposal service). In this situation, the costs of those people producing more MSW than what they were paying for are partially sustained by those who produced less MSW and thus used less of the service they paid for. This equity effect is, in fact, a distributional effect within the society. The problem is deciding how to account for this effect. The potential Pareto criterion can be very difficult to apply and hypothetical questions may result in a positive response from those people who would see an improvement from the introduction of PAYT schemes, and a negative response from those losing out. Monetising the effect by asking directly the WTP of households to increase the equity in paying the service may lead to the same results; those who produce less waste are WTP more than those who produce more waste. A specific question aimed to understand the importance of equity among the household is introduced in the questionnaire. This does not give an exact monetary measure of the value of equity, but just an indirect measure of its importance.

Because of all these issues the fact that the introduction of a PAYT scheme enhances equity is accounted as an established fact in prior scientific literature[26], and therefore only qualitative considerations are made. Enhanced equity is therefore a qualitative element, accounted as a positive PM-item into the SCBA.

Distributional issues (PM-) (families with babies, low income and elders). Here, again, equity and fairness are the focal points. Is it fair to introduce a PAYT scheme? Surely it is, if we consider that PAYT schemes may enhance equity in paying for the service; but it is not, if we consider the adverse effect on large families with babies or those with a low income. How can the distribution of fairness be measured and monetised? Firstly, it is very challenging to measure the actual shares of society that will gain and lose in equity. Moreover, the monetisation of equity and fairness is an ethical issue and as such it is always subject to a lot of scepticism (see, for example, valuing human lives). For these reasons this distributional issue is taken into account only as a qualitative measure. For example, the extent to which municipalities recognise, and attempt to solve, the problem is asked (i.e., the number of families that experienced the problem and those that received help). The municipality's expenses for ad-hoc solutions given to low-income families, or families with babies, such as free bags or lifetime discounts, can also be used as secondary measures of the extent of the problem. Moreover, other data from literature will serve as a proxy to identify and weight this effect.

[24] http://www.vetroswiss.ch/.

[25] These data have been collected during a preliminary interview with Ing. Di Gianfrancesco from the Dicastero servizi tecnici of the city of Lugano and may vary within the other municipalities.

[26] See section 3.6.

2.4 Excluded Effects

It is necessary to make clear that, since a social perspective is used, many costs and benefits are excluded which could have counted if a program sponsor or individual target perspective were used. Take, for example, the taxes (either PAYT or lump sum) on MSW paid by households to the municipality. These would result in a net increase in welfare if the program sponsor perspective is adopted, but a net decrease if the individual target perspective is taken. On the contrary, if the social accounting perspective is used, these taxes do not represent a net welfare increase or decrease for the society, but only a redistribution of welfare.

Losses for companies in the waste management sector (collection and disposal) are considered a redistribution within the society. In fact, the reduction in profit of the incinerator of Giubiasco - a consequence of the reduction of MSW disposed - is reflected in lower costs for the municipalities and in turn fewer taxes from households are used for this purpose. Losses for companies that perform a collection service are present only where municipalities outsourced the collection service. In both cases, the redistribution is between the households and the private company, or between the households and the municipality.

Virgin materials[27]. In the same way, the effects of increased recycling rates on virgin materials and related externalities are also not included in the CBA. Most of the benefits cross the geographical boundaries of the study.

Ad-hoc solutions for families with babies and low incomes (direct transfer)[28]. Although issues related to potential negative effects of PAYT schemes on families with babies and low-income families have been recognised and accounted for as a PM-item, the costs of providing ad-hoc solutions, such as free bags, or other types of incentives are not included in the SCBA. They constitute a redistribution of welfare between municipality and households, and not a net change in welfare. Moreover some of the costs for formulating and administrating this ad-hoc solution are taken into account when measuring the total administrative costs.

The following tables summarise the costs and benefits, and the methods used for their monetisation.

Costs	Measure	Monetisation	Data source
MSW collection costs: residual, bulky and recyclable waste	Direct money measurement	Monetised by the municipality (market prices)	Municipalities' interviews + Repubblica e Cantone Ticino (2011)
MSW disposal costs: residual, bulky and recyclable waste	Direct money measurement	Monetised by the municipality (market prices) (price of disposal per ton depending on the material)	Municipalities' interviews + Repubblica e Cantone Ticino (2011)
Administrative, management and equipment costs	Direct money measurement	Monetised by the municipality (market prices)	Municipalities' interviews + Repubblica e Cantone Ticino (2011)
Environmental costs: from collection	Shadow prices (emissions damage impact)	Total emissions from collection vehicles X shadow prices	Municipalities' interviews + Volvo Trucks (2013) + de Bruyn et al. (2010)
Environmental costs: from disposal (incineration)	Shadow prices (emissions damage impact)	Total emissions from waste sent to incinerator X shadow prices	Municipality interview + ACR interview + de Bruyn et al. (2010)
Illegal dumping	Proxies from literature + shadow prices for emissions damage impact (environmental costs) Direct money measurement (enforcement costs)	(0.5-2% X total MSW) X emissions per ton X shadow prices + enforcement costs (market prices)	Municipalities' interviews + literature[47]+ de Bruyn et al. (2010)
Waste tourism	Proxy from literature Direct money measurement	4-5% of total MSW (13-17% of total reduction) + enforcement costs (market prices)	Linderhof et al. (2001) + Municipalities' interviews

[27] See for example Sauer et al. (2008) and Taylor (2000).
[28] See Rudin (2010); Hogg et al. (2006a,b); Skumatz (2002, 2008); Rapporto Mozione Stojanovic NO.3442

	(enforcement)		
Households time and cost for recyclable separation, delivery and disposal	Hypothetical questions	Average stated costs for recyclable deliver + (time for separation and delivery of recyclable waste X WTP)	Households' interviews
Distributive issues: families with babies, low-income and elderly (Alt 1 e 2) (PM-)	PM-item	PM-item	Municipalities' and households' interviews
Discounting	Direct money measurement + proxies from literature	4% (PBV) and 5% (PBW) of risk and time discounting applied on investment costs (Market Prices) (see section 3.3)	Eijgenraam et al. (2000) + municipalities' interviews + local publications
Other costs	Direct money measurement	Market prices for parallel programs, awareness rising, information to households about the WMS, etc.	Municipalities' interviews

TABLE 6: OVERVIEW OF COSTS' MONETISATION METHODS AND SOURCES

Benefits	**Measure**	**Monetisation**	**Data source**
Waste-to-energy (WTE)	Market value	Net profits from electricity produced [(quantities of Kw/h produced X selling prices) - costs of production)]	Municipalities' interviews + ACR interview + literature review
Profits from recyclable waste	Direct monetary measure	Quantity of material X selling price	Municipalities' interviews
Increased equity (Alt 1 e 2) (PM+)	PM-Item	PM-item	Municipalities' and households' interviews

TABLE 7: OVERVIEW OF BENEFITS' MONETISATION METHODS AND SOURCES