“Garbage is gold”
(with just 1 carat, unfortunately)

Antonio Massarutto
DIES, University of Udine & IEFE, Bocconi University, Milano
antonio.massarutto@uniud.it

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Recycling of packaging waste: considering all the costs and the benefits

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WHY RECYCLE

The fundamental equation of waste management

$$V_M = \max \left\langle \left[P_R - \left(C_{SC} + C_{PR}\right)\right]; \left[-\left(C_{UC} + C_{TD}\right)\right]\right\rangle < 0$$

- For those who don’t like math:
  - The economic value of waste is the higher between:
    - The market price of recycled materials, less the cost of separate collection and preparation for recycling
    - The cost of dealing with unsorted waste (collection + treatment and disposal)
- If Vm > 0, it would not be a waste!
- The economic rationale for recycling lies in the fact that the net cost of recycling is lower than the cost of dealing with unsorted waste
- If disposal were cheap, very little recycling would pass the cost-benefit test!
- This also should warn us about the true “enemy”: the temptation of illegal disposal

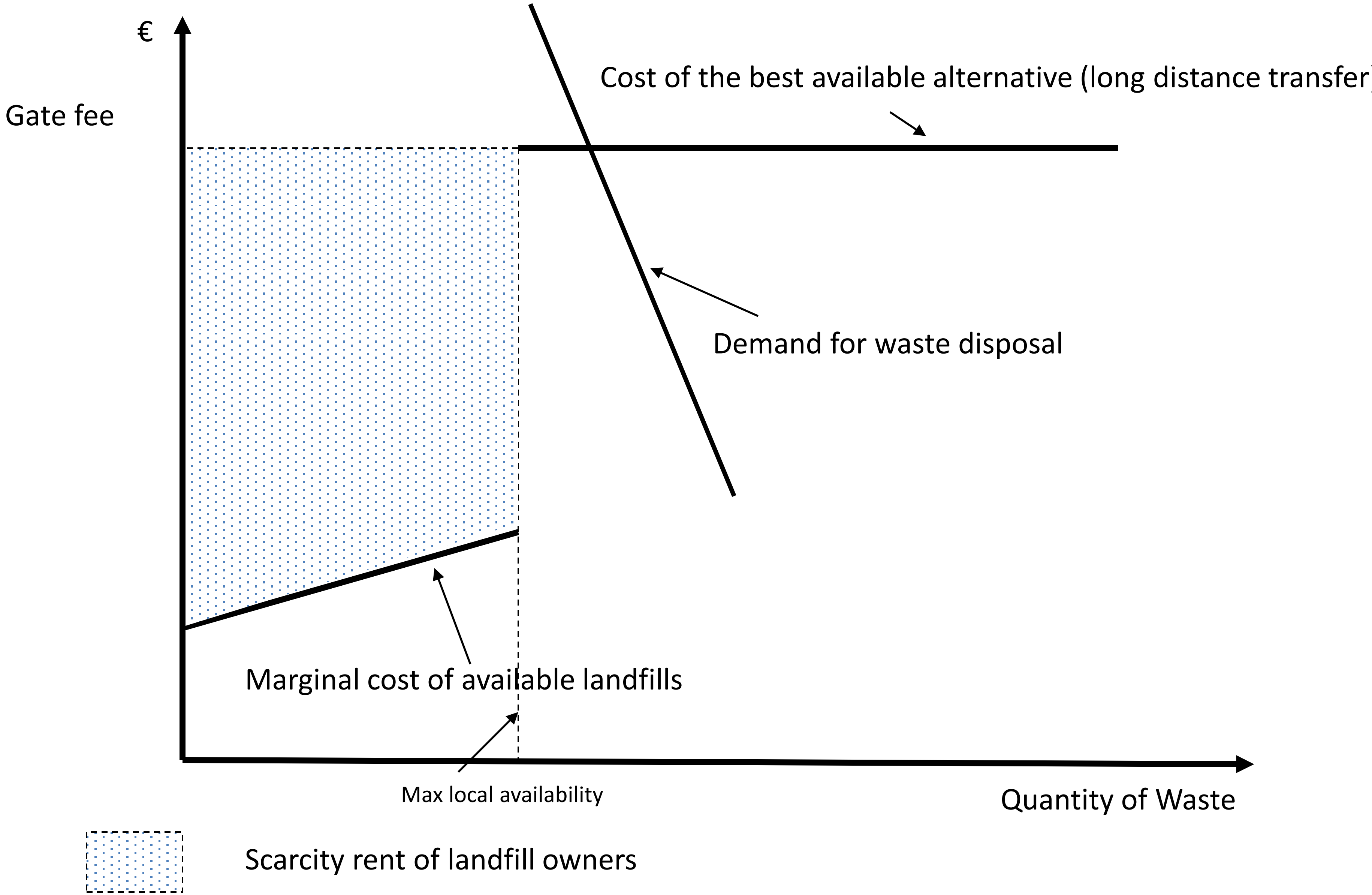
Why is recycling worthwhile? Wrong answers

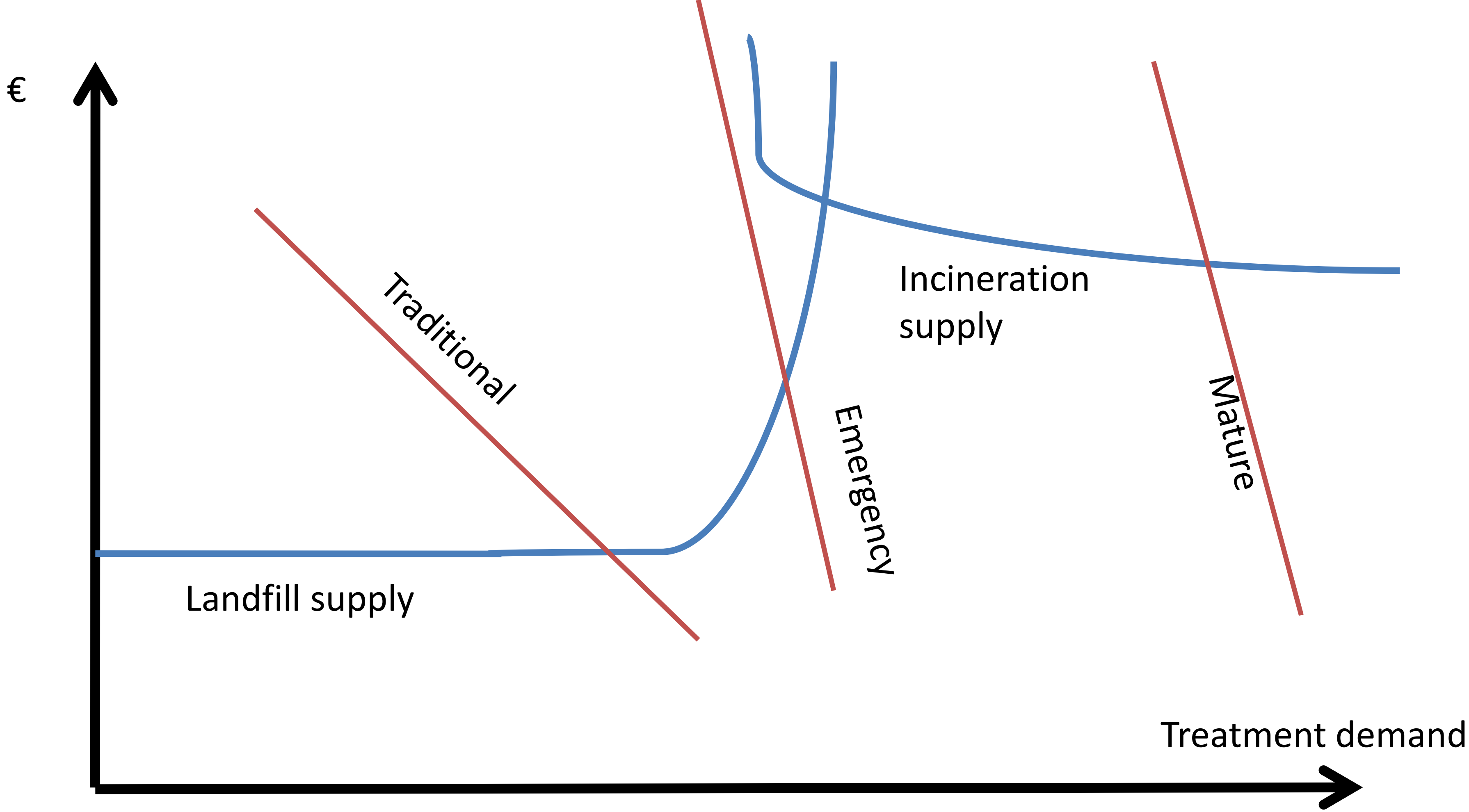
- Are raw materials really scarce?
  - As far as MSW is concerned, this is not the case (unless for very specific materials, e.g. metals in electronic equipment)
  - Most MW derives from renewable materials (organic, paper) or from rather abundant materials (metals, glass)
  - Plastics derives from oil, but only 0,5% of total oil consumption is due to plastic production
- Are raw materials really valuable?
  - Long-term trend do not show any tendency to grow
  - Short term fluctuations are very high and mainly due to market bottlenecks
- Why aren't any (more) waste pickers in Europe?
  - In developing countries, (CSC+CPR) positive given that salaries are lower
  - Cream-skimming vs. universal service: recycling is feasible and normally done on the market without incentives only for the fractions that are easiest to reach

The right answer: landfill scarcity

- Financial cost (opex + capex) of a properly run up-to-date landfill, complying with EU standards, can be estimated (roughly) in 50 €/t
- The gate fee can be three times higher
  - On average, observable gate fees are only slightly higher …
  - … but when landfill becomes scarce in absolute
  - Since prices are regulated and many sites are owned by public authorities, this may not be properly accounted for until landfills are available
  - Spot market gate fees in Italy are now stably > 120 – 150 €/t
- Is landfill availability a renewable resource?
  - Evidence it is not: after intensive use of territory, difficulty increases
  - Small landfills for sorted and not putrescible waste still possible, but ony for limited quantities
  - Opposition of locals (nimby)
- An example
  - Milano (early 90s): landfill price jumped from the equivalent of 10-15 to 150-200 €/t after the closure of the last available site
  - Napoli: despite the intervention of Civil Protection, no suitable site has been found within the concerned territory
  - Udine (the largest province in Italy): no site in the whole territory meets the legal requirements for siting (distance from houses, from water resources, from protected areas etc). In the 80s it received intensive flows from nearby regions

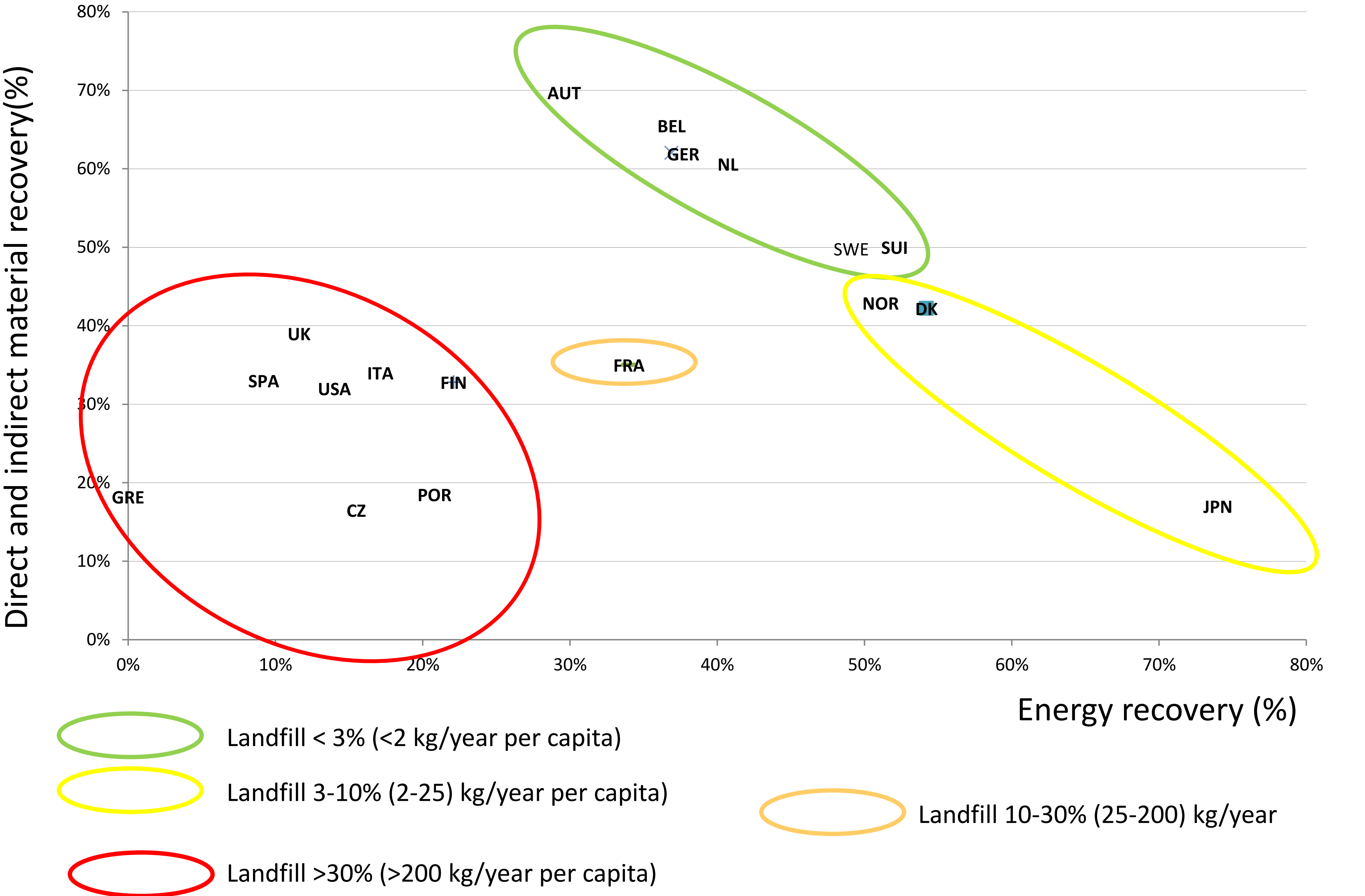
Good, old David Ricardo already taught this





The size and position of demand determines affects the kind of equilibrium: until waste generation is sufficiently low, market can supply disposal capacity:
In the transition phase, equilibrium is uncertain due to the strategic behavior of landfill owners, that can discourage investment in alternative solutions.
This is why planning is somewhat necessary, and prices should be corrected by a landfill tax

WtE and recycling are complementary and not alternative



Results from a LCC study

- From cradle to grave
  - Cradle: the moment when materials become waste (acquire negative value)
  - Grave: the moment when materials acquire positive value after treatement, or ar definitively disposed of
- Distinctive features
  - Address the totality of MW produced by a community (and not a specific waste flow)
  - Consider all flows regardless their belonging to MW or commercial waste
  - Social cost-benefit approach (including externalities, net of all subsidies and taxes)

Methodology

- Construction of alternative management scenarios based on different combinations of techniques
  - Separate collection: drop-off or curbside, with growing intensity in order to achieve source separation rates between 35% and 85%
  - Incineration of residual waste (unsorted waste + materials discarded from sorting); other options also tested (MBT, RDF, composting, downcycling)
- Application of scenarios to two fictitious regions, modeled on the typical features of Northern Italy
  - A metropolitan area
  - A small urban center + rural suburbs
  - Composition of waste coherent with field data
  - Material flows and energy recovery potential coherent with field data
- Interdisciplinary work
  - LCA (Consonni et al.) aimed at assessing the materials balance and the impact on the main environmental targets
  - LCC (Massarutto et al.) aimed at assessing social costs and benefits

Costs and benefits that should be accounted for

Costs

- Financial cost of SWM
  - Opex + Capex
  - Economic risk
  - Net of all incentives, subsidies etc!
- External costs
  - Pollution
  - Disamenity / landscape
- Scarcity cost (user cost)
  - associated with non-renewable resources
- (Household costs)
  - Utility loss
  - Private services handling waste before accessing the public service

Benefits

- Market value of materials
- External benefits from recovery and recycling
  - Spared emissions
  - ("Warm-glow" utility)

Assessment of costs and benefits

- Financial costs
  - Collection: optimized LP model based on input data from direct survey
  - Treatment: detailed meta-analysis of literature + desktop simulations based on engineering cost functions
  - Landfill: actual spot market price as proxy of scarcity cost
- Financial benefits
  - Market price of energy and recycled materials when available
  - Net-back analysis for some outputs (eg RDF, compost)
- External costs and benefits
  - Detailed meta-analysis of literature reporting the energy saving potential for each ton of recovered material for each material
  - For incineration: impact pathway analysis based on ExternE model
  - CO_2: 35 €/t (from the Stern report)

Steps of the analysis

- A cost per t of treated material is calculated per each technique (€/t)
- The standard ton (with the standard composition) is collected with a mix of techniques that are appropriate for each scenario
- The resulting total cost per each phase is divided for the total amount of waste generated (€/tMW)

Unitary cost of collection

Phase	Cost (€/t)	
	Drop-off	Kerbside
Collection of USW	70 - 85	150 – 187
Separate collection: glass	22 - 85	77 – 190
Separate collection: paper	22 - 29	62 – 101
Separate collection: plastics	245 - 249	307 – 372
Separate collection: mixed	75 - 103	94 - 123
Separate collection: Organic		82 – 138
Multimaterial (platform)	61	

Note: unitary costs vary because techniques are optimized according to the SSL targeted in each scenario

Unitary cost of treatment

Phase	Cost (€/t)
WtE (small area)	110 – 120
WtE (large area)	80 - 85
Sorting downstream of separate collection (paper)	110
Sorting downstream of separate collection (other materials)	43
Production of inerts for building industry (including refined sorting of URW)	100
Composting	45
Mechanical sorting of URW	39
Production of low quality RDF (from selected URW)	20,90
Production of high-quality RDF (including adaptation of the receiving plant)	40,90
Landfill (financial cost)	37 – 44
Landfill (scarcity cost)	100

Market prices of recovered materials and energy

Market prices considered	Unity of measure	Value	Reference year	Source
Electricity	€/MWh$_E$	75	2008	GME
Heat	€/MWh$_T$	35	2008	Massarutto and Kaulard, 1997 (net-back analysis)
Glass (mixed)	€/t	5,15	2002-2009	Chamber of Commerce (Milano)
Paper and cardboard (mixed)	€/t	30,32	2000-2009	Chamber of Commerce (Milano)
Plastics	€/t	294	1999-2009	Chamber of Commerce (Milano)
Aluminium (from separate coll.)	€/t	723,77	2000-2009	Chamber of Commerce (Milano)
Aluminium (from ashes)	€/t	1173,33	2000-2009	Chamber of Commerce (Milano)
Recovery of ashes in cement mills	€/t	20	2009	Direct survey
Iron	€/t	8	2008	Bianchi, 2008
Compost from separate collection	€/t	8		Ricci et al., 2003
Compost from mech. sorting	€/t	0	2008	Direct survey
RDF (for cement mills)	€/t	17,1	2008	Net-back analysis based on direct survey
Inert materials	€/t	0	2008	Net-back analysis based on direct survey

External costs

DATI SUI COSTI ESTERNI					BACINO PICCOLO					BACINO GRANDE									
				RABL	S35	S50	P50	P65	PC75	S35		S50		P50		P65		PC75	
										EL	COG	EL	COG	EL	COG	EL	COG	EL	COG
Incinerator	kWh/t	COG	EL	202	458	423	433	479	479	-	685	-	650	-	664	-	738	-	738
			Heat	607	2.230	2.214	2.262	2.519	2.519	-	1.498	-	1.449	-	1.479	-	1.647	-	1.647
		EL only	EL	270	-	-	-	-	-	770	-	732	-	749	-	832	-	832	-
	(€/t)	No energy recovery		21,2	21,2	21,2	21,2	21,2	21,2	21,2	21,2	21,2	21,2	21,2	21,2	21,2	21,2	21,2	21,2
		Electricity only		**15,9**	-	-	-	-	-	**6,1**	-	**6,8**	-	**6,5**	-	**4,9**	-	**4,9**	-
		Heat + Electricity		**13,1**	**-5,7**	**-5,2**	**-5,8**	**-8,8**	**-8,8**	-	**-0,7**	-	**0,2**	-	**-0,3**	-	**-2,7**	-	**-2,7**
	Saved eissions (€/t)	No energy recovery		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
		Electricity only		5	-	-	-	-	-	15,1	-	14,4	-	14,7	-	16,3	-	16,3	-
		Heat + Electricity		8,1	26,9	26,4	27,0	30,0	30,0	-	21,9	-	21,0	-	21,5	-	23,9	-	23,9
	Disamenity impacts (€/t)			**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**
Landfill	**Emissions(€/t)**	No energy recovery		**12,8**	**12,8**	**12,8**	**12,8**	**12,8**	**12,8**	**12,8**	**12,8**	**12,8**	**12,8**	**12,8**	**12,8**	**12,8**	**12,8**	**12,8**	**12,8**
	Disamenity impacts (€/t)			**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**
	Damage from leachate (€/t)			**1,5**	**1,5**	**1,5**	**1,5**	**1,5**	**1,5**	**1,5**	**1,5**	**1,5**	**1,5**	**1,5**	**1,5**	**1,5**	**1,5**	**1,5**	**1,5**

Materials balance of scenarios

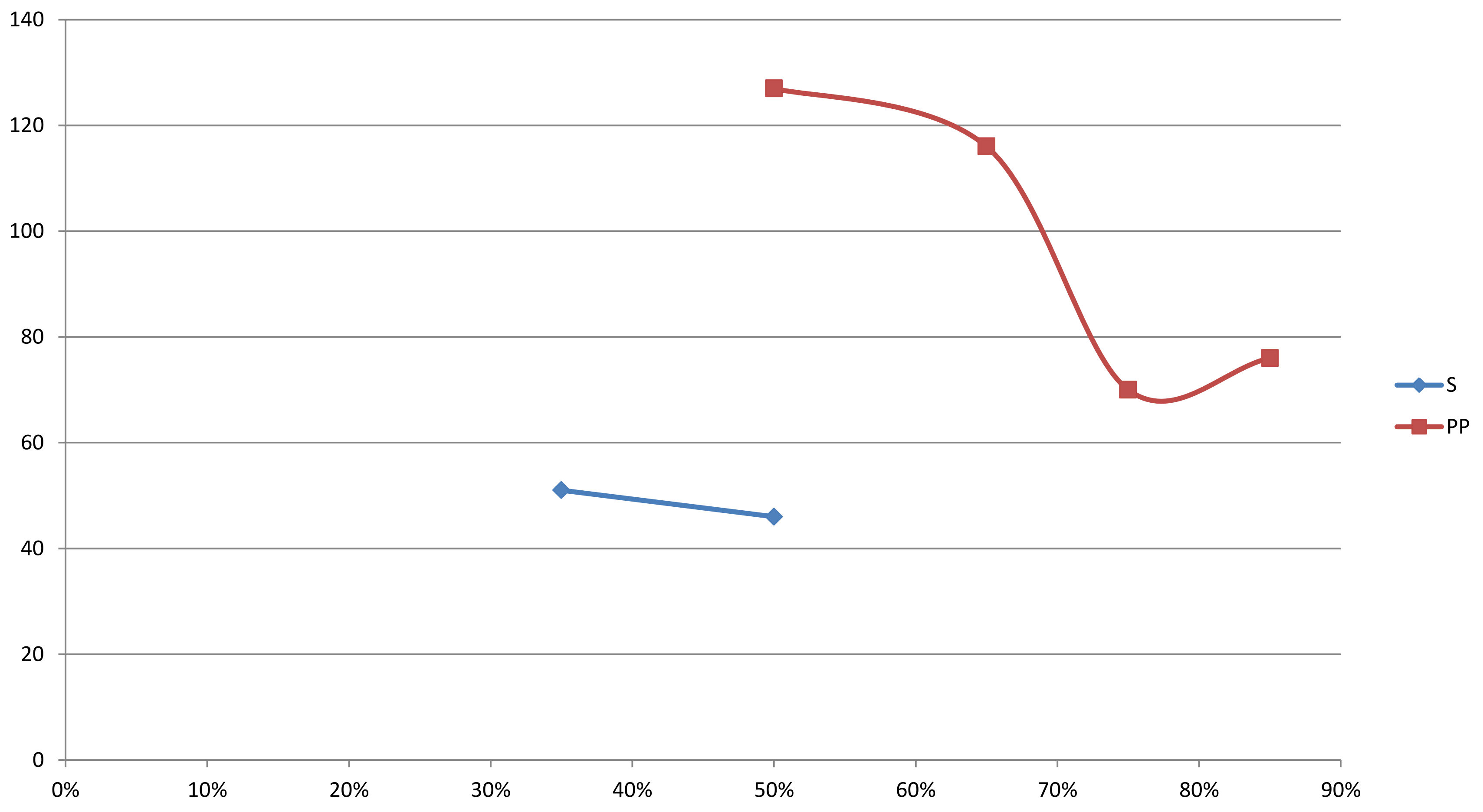
	SMALL BASIN						LARGE BASIN										
	D35	D50	K50	K65	K75	K85	D35		D50		K50		K65		K75		K85
							EL	COG	EL	COG	EL	COG	EL	COG	EL	COG	
MATERIAL BALANCE (kt/year)																	
Total waste flow	150	150	150	150	150	150	750	750	750	750	750	750	750	750	750	750	750
Recycling	32	45	33	40	47	57	159	159	226	226	165	165	202	202	236	236	283
Downcycling	15	10	14	11	6	33	76	76	52	52	68	68	53	53	39	39	164
High quality compost and domestic compost	3	4	10	12	39	39	14	14	19	19	48	48	60	60	115	115	197
Material recovery	50	59	56	63	93	129	250	250	297	297	280	280	315	315	390	390	645
Incineration	107	90	88	74	43	0	533	533	450	450	441	441	371	371	275	275	0
Landfill	6,9	5,7	5,4	6,3	4,5	0	22,9	22,9	16,9	16,9	16,3	16,3	20	20	13	13	0
ENERGY RECOVERED (MWh/year)																	
Electricity	202	458	423	433	479	479	770	685	732	650	749	664	832	738	832	738	270
Heat	607	2.230	2.214	2.262	2.519	2.519	-	1.498	-	1.449	-	1.479	-	1.647	-	1.647	607
OVERALL LCA RESULTS																	
Cumulative Energy Demand (TJ eq/y)	-1,6	-1,8	-1,5	-1,6			-7,7	-8.5	-8,9	-9,5	-7,1	-7,8	-7,8	-8,4			
Global Warming Potential (kt CO2 eq/y)	-15,8	-32,1	-21,2	-19,4			-82,1	-121,7	-163	-195	-107,8	-140,2	-99.1	-129,2			
Acidification Potential (kt SO2 eq/y)	-0,12	-0,23	-0,16	-0,18			-1,25	-1,22	-1,36	-1,33	-1,05	-1,02	-1,14	-1,12			
Human Toxicity Potential (kt 1,4-DHB-eq/y)	-25	-35	-22	-31			-128	-132	-176	-180	-112	-115	-156	-160			
Photochemical Ozone Production Potential (t C2H4-eq/y)	-24	-31	-18	-21			-118	-131	-156	-167	-92	-103	-104	-114			

Overall results

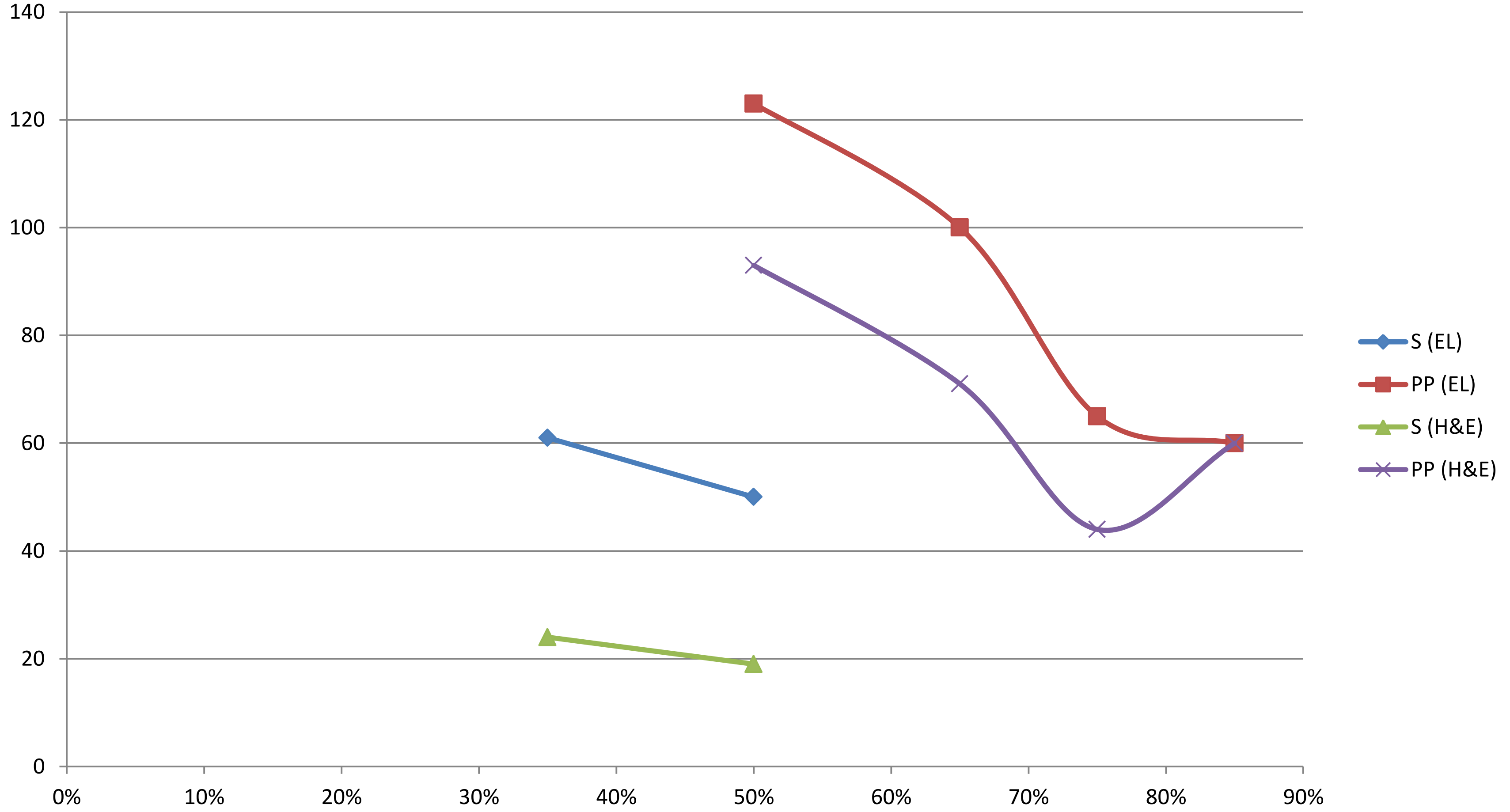
	SMALL AREA						LARGE AREA										
	BU35	BU50	K50	K65	K75	K85	BU35		BU50		K50		K65		K75		K85
							E	H&E	E	H&E	E	H&E	E	H&E	E	H&E	
Collection (+)	71	85	147	127	106	89	61	61	72	72	130	130	105	105	93	93	73
Treatment (+)	122	115	120	119	94	90	94	94	93	93	93	93	98	98	88	88	89
Financial costs	**193**	**200**	**267**	**246**	**200**	**179**	**156**	**156**	**165**	**165**	**223**	**223**	**203**	**203**	**181**	**181**	**163**
Revenues (-)	90	88	86	80	61	29	51	84	55	82	54	80	50	75	48	67	29
Net financial costs	**103**	**112**	**181**	**166**	**139**	**150**	**104**	**72**	**110**	**83**	**170**	**143**	**153**	**128**	**132**	**114**	**134**
External costs (+)	18	17	16	14	10	8	18	18	16	16	16	16	14	14	12	12	8
External benefits (-)	70	84	69	64	79	82	61	66	76	80	62	66	68	72	79	82	82
Net social cost	**51**	**46**	**127**	**116**	**70**	**76**	**61**	**24**	**50**	**19**	**123**	**93**	**100**	**71**	**65**	**44**	**60**
Cost increase for sub-scenarios (additional cost with respect to baseline)																	
MBT+ WtE	+60	+46	+44	+36	+25			+47		+44		+47		+37		+34	
MBT+ RDF	+71	+52	+48	+45	+26			+73		+73		+71		+62		+49	
MBT+ RDF-Q	+83	+70	+59	+59	+31												

All values in €/tMW, (referred to the initial standard ton of waste produced)

Net social cost – small city + rural suburbs



Net social cost – metropolitan area



Sensitivity analysis

Assumption	Variation tested	Result	
		Rank	Gap
Efficiency of energy recovery	Energy recovery as in average existing EU facilities (reduction of 30-50%)	K85 as best option S50 as second-best K75 as third-best option S35 as fourth-best	- -
Market value of recovered materials	Market prices doubled	No change	- -
	Market prices halved	S35 as the best option; otherwise no change	+
	Market price of ashes = 0 Market price of ashes = -200	No change	- - -
Efficient sizing of facilities	No buffer capacity assumed	No change	+
	Optimal achievement of economies of scale	No change	+ (small area)
Quality of source-separated materials	Residuals halved	No change	- (for K75-K85)
	Residuals doubled	S35 as best option No change otherwise	
Failure to achieve the targeted SSL	0 < SSL < 100% (K75) % of population equipped with home composting up to 100%	Increase of costs if SSL<70% No major change if SSL> 70% No break even	++ (if SSL <70%)
Alternative hypotheses for external costs and CO2	External costs doubled	No change	++
	External costs halved	S35 as the best option; otherwise no change	-

Key messages

- Landfill diversion can be maximized up to a “nearly zero landfill” target
- This target makes economic sense once the landfill price duly accounts for scarcity
- The target can be achieved at best with a balanced combination of WtE and material recovery
- Extreme recycling scenarios are cost effective only if very high source separation (> 75%) is achieved (feasible in small communities, not in large urban areas
- Incineration should be optimized (economies of scale + full use of capacity + full exploitation of energy recovery potential)
- Market signals are not enough for addressing the management system towards the optimal mix

WHY EPR

Why economists do no like EPR

- Criticism about EPR
  - EPR are normally associated with mandatory targets; criticism agains mandatory targets is extended to EPR (eg Pearce-Brisson; Dijkgraaf)
  - EPR are normally associated with monopolistic organizations having strong market power and able therefore to distort market functioning
  - EPR are focused on recycling and provide little incentives to waste prevention (Walls, 2006)
- Walls (2004) argues that
  - if the market works properly, EPR would be unnecessary;
  - a waste collection charge incorporating externalities (eg a landfill tax, tax on raw materials) would be equivalent
  - But are markets efficient? Probably not

Why should economists instead like EPR market failures in the reverse logistics system

- Transactions costs
  - Ensure coherency of product design with post-consumption phases
  - Identification of possible destinations of waste-derived materials
  - Sunk costs (eg research about potential reuse; treatment facilities; adaptation of plants that receive waste-derived materials
  - Risk of disruptive competition and wasteful double-investing in the early development of the recycling industry due to uncertainty
- Risk associated to secondary market price volatility
  - Volatile secondary prices and related risk (face to the PSO of dealing with all waste) ⇔ exposed to the market power of buyers
  - Thin market ⇔ bilateral transactions (especially for “poor” materials, for which transport costs are significant
- Increasing opportunities of trade btw household and commercial waste
  - Recycling opportunities are best achieved when flows of different origin are mixed; economies of scale and integration can hardly be achieved by local waste management operators
  - A neglected issue: preventing illegal destinations and illicit arbitrage; ensure fair trading with developing countries; minimize interregional spillovers

Market power and economic margins

- The pre-condition of market trades:
  - Someone is willing to pay X
  - Someone is willing to accept Y
  - X > Y
  - Y – X is the economic margin, and can be allocated to both according to the relative market power
  - In a competitive market, the economic margin, Y – X, tends to zero
- In the waste management industry, a similar mechanism operates, but there are some specific features
  - The economic margin, Y – X, is negative (unless alternative disposal costs are considered)
  - Municipalities are willing to pay X for getting rid of materials (X = CUC + CTD)
  - Recyclers are ready to pay Y = PR for receiving them
  - If (Y-X) > (CSC + CPR) recycling is socially convenient

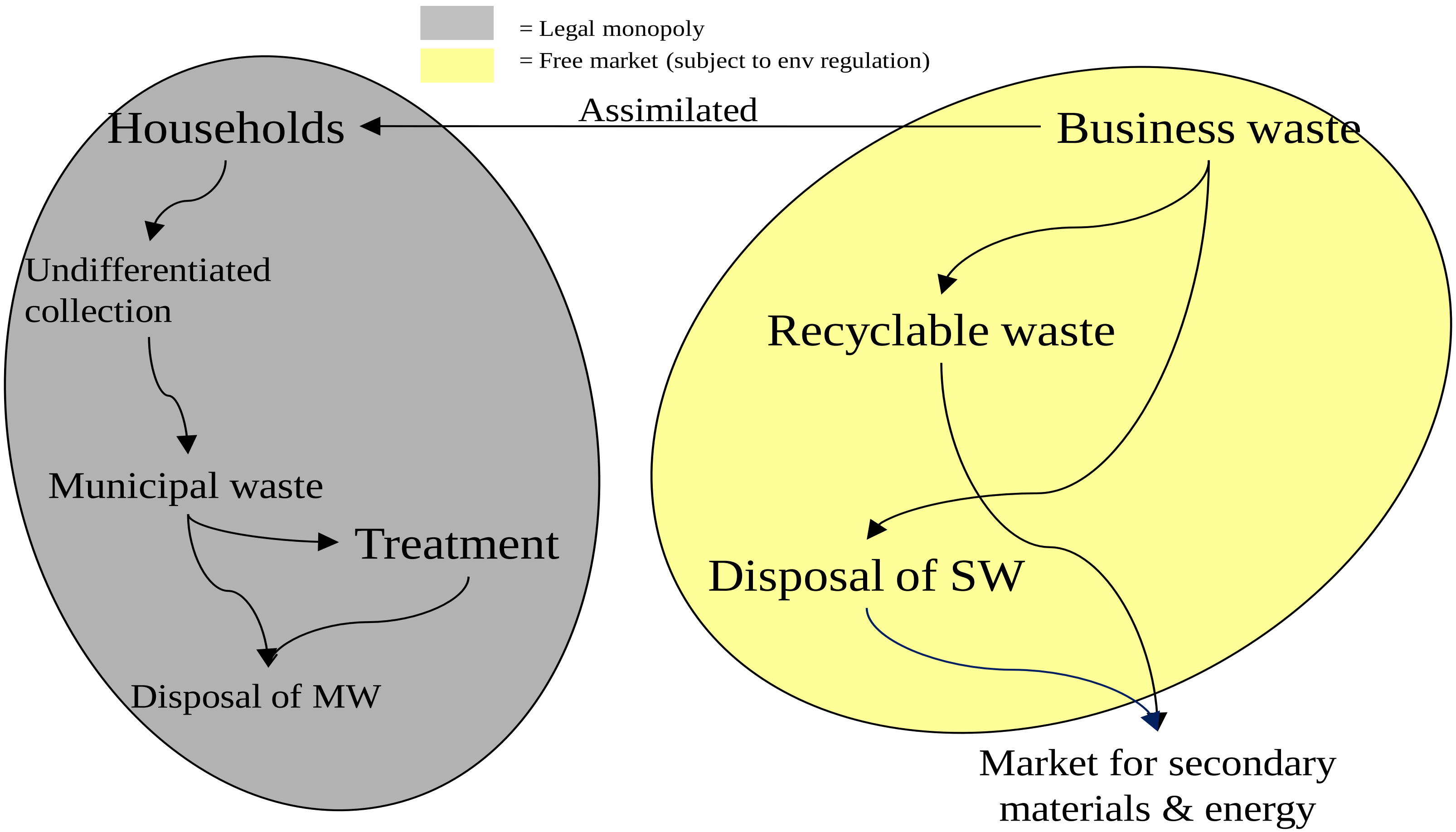
The Italian market for RDF as an example

- The promised advantages of converting combustible waste into RDF
  - Can be used as a substitute of traditional combustibles in already existing plants (cement mills, coal-fuelled power stations, ships)
  - Can be produced from undifferentiated waste
- Methodology of the study: net-back approach
  - Assessment of the net economic margin as the difference between the market value of electricity + incentives, less the cost of the WtE facility, less the cost of producing RDF
- Despite a sound positive margin, the market never developed
  - Only a minor fraction of sorted combustible waste is commercialized as RDF
  - The remaining part is burnt in dedicated plants (or landfilled as dry waste)
- The reason?
  - Achieving product standards that are satisfactory for users (in terms of caloric content) too costly for WM operators
  - If RDF has to be burnt in dedicated facilities, incineration of raw waste is more economic

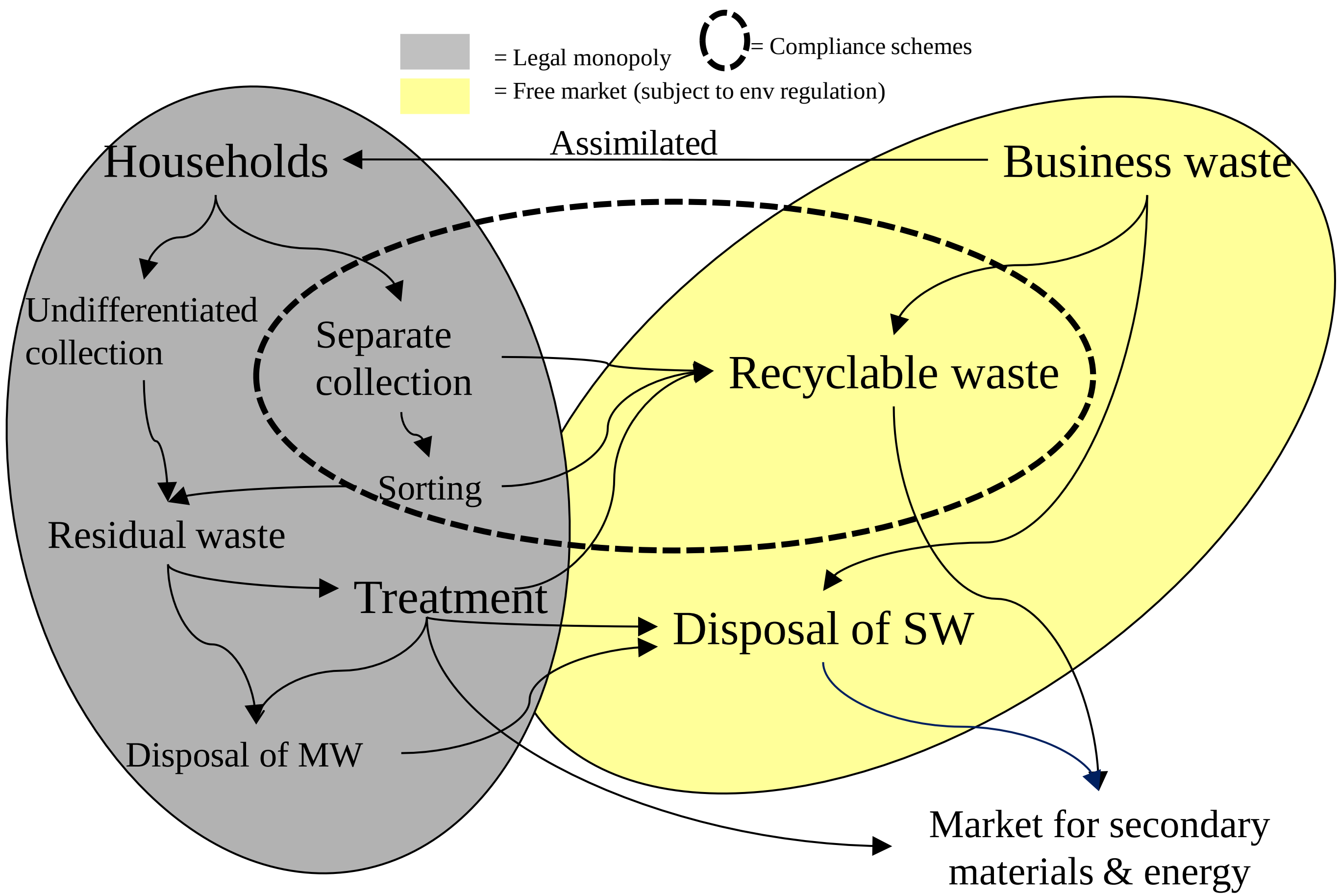
Household vs. commercial waste

- Recycling has diminishing returns
- Higher recycling rates imply long value chains, since opportunities for reuse are far from the original material, either in an industrial or geographical sense
- Recycling opportunities require industrial innovation
- Long value chains, however, also create the case for illicit arbitrage

Household and business waste: yesterday



Haousehold and business waste: today (and tomorrow)



SOME ISSUES ABOUT EPR THAT DESERVE FURTHER INVESTIGATION

EPR and competition

- Arrangements in the EU vary
  - Monopolistic scheme with mandatory adhesion and compulsory fee (Italy) + independent market operators
  - Competitive systems with little-no autonomy over contracting patterns with local authorities
  - Competitive systems with a public service obligation for a last-resort umbrella contract (France)
  - Competitive system (UK)
- Arguments in favour of monopoly
  - “Infant industry”
  - Risk of free riding
  - Achievement of recovery targets as “public service obligations”
- Trade-off: making public service obligation sustainable, without creating market distortions

Cross-subsidies and crowding out

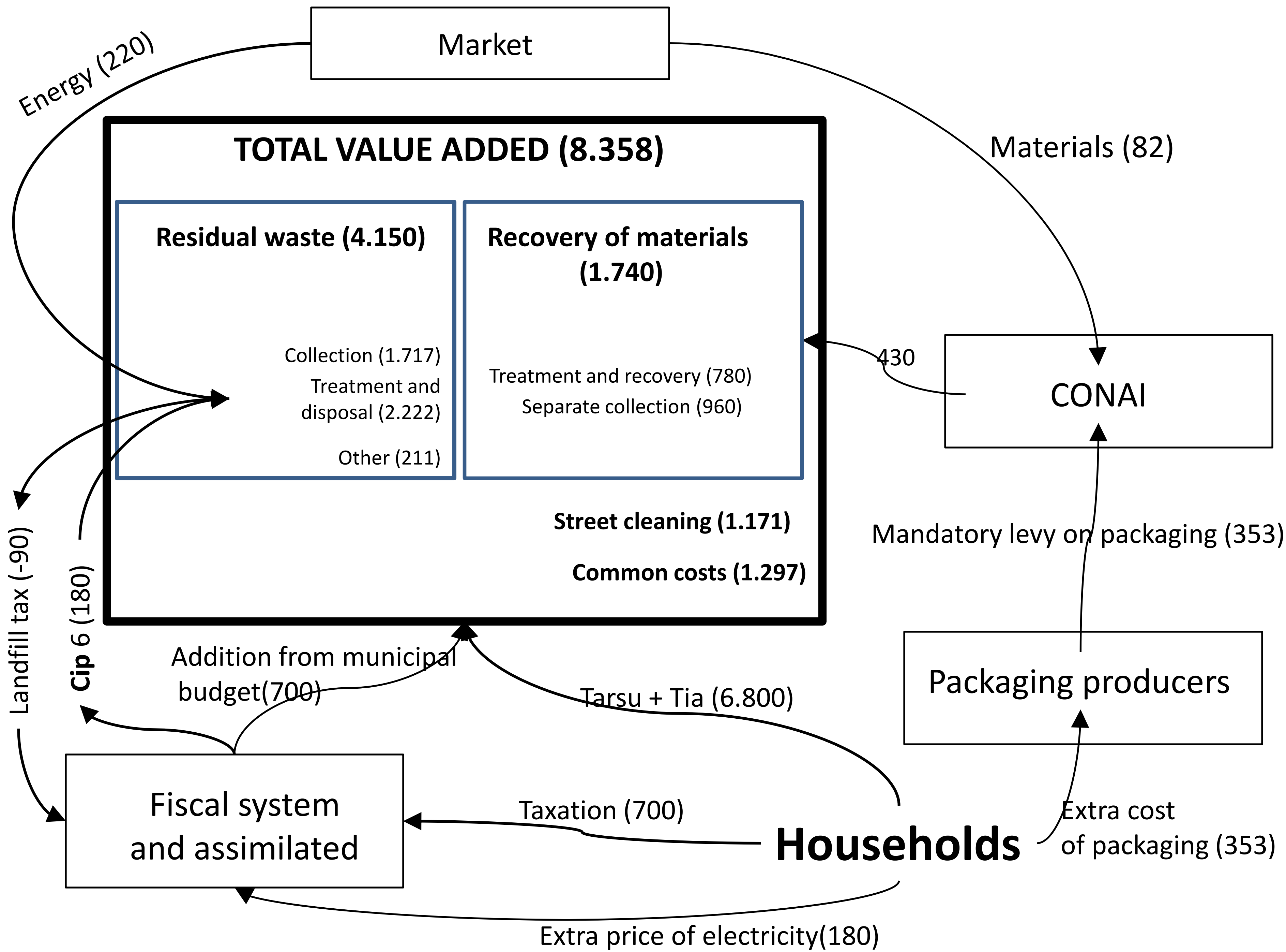
- The problem
  - EPR creates a subsidized market that may displace economic activities that would otherwise be carried out by private premises
- An example: the Italian market for paper recycling
  - Before EPR, the paper industry was paying for scrap paper (that was even imported from abroad)
  - Evidence that with EPR paper packaging is subsidizing paper mills, who are in the position of lowering prices
- Another example: wood in South Tyrol
  - Forest industry waste used to be a valueable input for industry producing wood panels, acquired at zero or below-zero price
  - The construction of a WtE- district heating by local cooperative has created a competition for the industrial waste, whose price has increased making the panel industry not viable
  - Subsidies paid to renewable energy are decisive for making the WtE plant economically viable

Household vs. commercial waste

- Conai: a success story
  - EU targets achieved one year in advance …
  - … for a rather low cost (591 million € in 2011, corresponding to approx. 68 €/ton on average)
- How has the target been achieved?
  - Underperformance om household PW
  - Overperformance on commercial PW (mostly managed directly by industry without Conai’s intermediation)

Allocation of costs

- Who pays for recycling?
  - If the cost is born by the waste collection entity, it ends up in the waste charge or in the municipal budget
  - If paid by EPR schemes, it ends up in the market price of
- Patterns of cost allocation between EPR systems and municipalities may vary (and hamper comparisons)
  - Full-cost base:
    - the EPR bears directly the cost of separate collection
    - Municipality saves entirely the cost of managing waste
  - Additional cost base:
    - the EPR pays the difference between the cost of separate collection and the alternative
    - The average municipality is indifferent whether to engage in separate collection or not
    - The relatively efficient municipality has the incentive to maximize efforts
- If EPR schemes and municipalities are free to negotiate the price, where will the equilibrium position?


Market
Energy (220)
Materials (82)
TOTAL VALUE ADDED (8.358)
Residual waste (4.150)
Collection (1.717)
Treatment and disposal (2.222)
Other (211)
Recovery of materials (1.740)
Treatment and recovery (780)
Separate collection (960)
Street cleaning (1.171)
Common costs (1.297)
430
CONAI
Mandatory levy on packaging (353)
Packaging producers
Landfill tax (-90)
Cip 6 (180)
Addition from municipal budget(700)
Tarsu + Tia (6.800)
Fiscal system and assimilated
Taxation (700)
Households
Extra cost of packaging (353)
Extra price of electricity(180)

Determinants of cost allocation

- Sources of contractual power for the municipality
  - The higher the target posed onto EPR
  - Competition among different EPR schemes
  - Relative efficiency in separate collection / sorting
- Sources of contractual power for the ECR
  - Possibility to achieve target from other waste flows (eg commercial waste)
  - Higher disposal price ⇔ higher WTP of municipalities for SC
  - Small municipalities