

Away with the national borders for waste incineration?

An analysis of the Dutch waste incineration plants in an European
market

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1 Introduction

Currently, the national borders for waste incineration in the European Union (EU) are closed for countries that wish no imports and exports. In the Netherlands, as in most other EU-countries, national self-sufficiency for waste incineration is a key issue of waste policy. This makes it possible to plan the national capacity of waste incineration plants. Furthermore, national instruments are used to steer waste streams. A landfill ban and a high tax on landfilling waste are examples of these instruments. As a result, it is possible to influence the way waste is handled. However, it is questionable whether this policy can be continued in the future. If for instance the EU decides to define incineration with energy recovery as a form of reuse a national ban to import and export waste is no longer allowed. The key question of this paper is what the financial consequences are for the Dutch waste incineration plants if national borders for incineration are opened.

To answer this question an economic model is used to simulate the possible effects of the opening of national borders. In the model waste suppliers choose the cheapest waste disposal option. In this decision not only the tariff to be paid to the waste company plays a role, but also the transport costs and the influence of waste steering instruments (landfill ban, landfill tax, incineration tax, fines for illegal dumping). The waste companies (landfilling sites, incineration plants and companies that can use waste as a fuel) differ with respect to location, capacity and costs. In the model a number of regions (parts of countries) are distinguished. Thus the model is able to reckon with international differences in waste supply, incineration capacity and steering instruments. Furthermore, transport costs from each region to each region can be modelled. Finally, the model has a short and long term version. The main difference between the two versions is the possibility of entry and exit.

The calibration of the model is based on real life data. With the calibrated model the effects of the opening of national borders on the waste markets are explored. Scenario analysis makes it possible to reckon with possible developments in the future (like harmonisation of steering instruments and changes in specific national circumstances) and uncertainty. The analyses show that opening borders for all waste will have a substantial (negative) effect on the financial position of Dutch waste incineration plants, but not on the amount of waste incinerated in the Netherlands. Thus, Dutch plants are still able to

attract enough waste to operate at full capacity, but at a price below average costs. Furthermore, it shows that the unlevel playing field between the Netherlands and surrounding countries (with respect to waste taxes and waste bans) is the most important factor that drives this result. The realisation of a level playing field has a price stimulating effect.

In the literature the effects of user fees on the generation of waste (see e.g. Jenkins, 1993 and Choe and Fraser, 1999) and the environmental effects of different treatment options (see e.g. Brisson, 1997 and Dijkgraaf and Volleberg, 1998) or a combination of both (see e.g. Beede and Bloom, 1995 and Kinnaman and Fullerton, 1999) get attention. With respect to the role of competition in waste markets nearly all papers focus on the waste collection market (see e.g. Bivand and Szymanski, 2000, Dijkgraaf et al., 1999, Dijkgraaf and Gradus, 1997 and Szymanski, 1996). An exemption is Tawil (1999) who analyse the effects of relaxing waste steering instruments in the US on the financial position of waste companies. However, on the effects of competition between international waste markets including the role of waste steering instruments is not much known. This paper tries to fill this gap.

The paper is organised as follows. Section 2 presents the waste model. The data which are necessary for simulation are presented in section 3. The main results of the simulations are given in section 4. Section 5 concludes.

2 A model for the European waste market

In this section a model for the European waste market (MEAM) is presented. The model makes it possible to analyse the effects on waste prices of different regulation regimes. Not only the effects of the opening of waste borders can be analysed, but also the possible impact of changes in landfill bans and landfill and incineration taxes.

First, we model the way waste suppliers in MEAM choose between the available waste treatment options. Second, we model the waste treatment firms (landfills, waste incineration plants, cement kilns, coal plants and separation plants). Third, we describe how MEAM handles waste regulation.

2.1 Waste supply

In MEAM waste suppliers (municipalities and companies) minimize treatment costs of their (not yet contracted) waste. These costs are the sum of the direct

cost of treatment (including taxes) and transport costs. In the model countries are split into different regions (the larger the country, the more regions). Within a region transport costs are constant, between regions these costs depend on the transport distance.

The model handles only not yet contracted waste. As part of the waste is contracted for a long term, changes in market circumstances have no influence on this amount of waste. However, the size of the contracted waste stream determines the free capacity of waste treatment plants.

The model discriminates between five different waste streams: very low caloric waste with an average caloric value of 8.9 GJ per ton, low caloric waste with an average caloric value of 10.3 GJ per ton, mid caloric waste and dirty mid caloric waste with an average caloric value of 14.1 GJ per ton and high caloric waste with an average caloric value of 17,9 GJ per ton. Very low caloric waste results when low caloric waste is separated. In this separation process a (relatively) small quantity of high caloric waste is produced. Mid caloric waste can also be separated in a low and a high caloric part. This is not the case for high and dirty mid caloric waste.

Suppliers of waste can choose between several treatment options: landfilling, incineration in a Waste Incineration Plant (WIP), incineration in a cement kiln or coal fired electricity plant or a waste separation plant. As landfilling in the European countries is seen as an option which should only be available for national waste streams, we assume no export or import of waste for this option. For the same reason separation of waste is also only possible in the country where the waste is collected.¹ As a consequence, landfilling via separation in an other country is not possible in the model.

Thus, the cost function of a waste supplier from region k is

¹Because the capacity of separation plants is currently very low and we assume equal costs for separation plants for the different countries, this assumption has no major influence on the results.

$$\begin{aligned}
\min_{Q_s} & (p_{landf}^{kk} + t^{kk})(q_{landf,l}^{kk} + q_{landf,m}^{kk} + q_{landf,md}^{kk} + q_{landf,h}^{kk}) \\
& + \sum_{j \in \mathcal{J}} (p_{incin,l}^{kj} + t^{kj})q_{WIP,l}^{kj} \\
& + \sum_{j \in \mathcal{J}} (p_{incin,m}^{kj} + t^{kj})q_{WIP,m}^{kj} \\
& + \sum_{j \in \mathcal{J}} (p_{incin,md}^{kj} + t^{kj})q_{WIP,md}^{kj} \\
& + \sum_{j \in \mathcal{J}} (p_{incin,h}^{kj} + t^{kj})q_{WIP,h}^{kj} \\
& + \sum_{r \in \mathcal{R}} (p_{incin,h}^{kr} + t^{kr})q_{cemcoa,h}^{kr} \\
& + p_{sep,l}^k q_{sep,l}^k + p_{sep,m}^k q_{sep,m}^k
\end{aligned} \tag{2.1}$$

with \mathcal{J} the set of all WIP's in the European Union (with index j) and \mathcal{R} the set of all cement kilns and coal fired electricity plants in the European Union (with index r). Furthermore, the following variables are used:

- p_{landf}^{kk} : the price of landfilling waste from region k in region k ,
- $p_{incin,l}^{kj}$: the price of incinerating low caloric waste from region k in WIP j ,
- $p_{incin,m}^{kj}$: the price of incinerating mid caloric waste from region k in WIP j ,
- $p_{incin,md}^{kj}$: the price of incinerating dirty mid caloric waste from region k in WIP j ,
- $p_{incin,h}^{kj}$: the price of incinerating high caloric waste from region k in WIP j ,
- $p_{incin,h}^{kr}$: the price of incinerating high caloric waste from region k in cement kilns or coal fired electricity plant r ,
- $p_{sep,l}^k$: the price of separating low caloric waste from region k ,
- $p_{sep,m}^k$: the price of separating mid caloric waste from region k ,
- t^{kk} : the transport costs per ton of waste from region k to a landfill in region k ,
- t^{kj} : the transport costs per ton of waste from region k to WIP j ,
- t^{kr} : the transport costs per ton of waste from region k to a cement kiln or coal fired electricity plant r ,
- $q_{landf,l}^{kk}$: the quantity low caloric waste landfilled in region k
- $q_{landf,m}^{kk}$: the quantity mid caloric waste landfilled in region k

- $q_{landf,md}^{kk}$: the quantity dirty mid caloric waste landfilled in region k
 $q_{landf,h}^{kk}$: the quantity high caloric waste landfilled in region k
 $q_{WIP,l}^{kj}$: the quantity low caloric waste incinerated in region k
 and WIP j,
 $q_{WIP,m}^{kj}$: the quantity mid caloric waste incinerated in region k
 and WIP j,
 $q_{WIP,md}^{kj}$: the quantity dirty mid caloric waste incinerated in region k
 and WIP j,
 $q_{WIP,h}^{kj}$: the quantity high caloric waste incinerated in region k
 and WIP j,
 $q_{cemcoa,h}^{kr}$: the quantity high caloric waste incinerated in region k
 in a cement kiln or coal fired electricity plant r,
 $q_{sep,l}^k$: the quantity low caloric waste separated in region k
 $q_{sep,m}^k$: the quantity mid caloric waste separated in region k
 Q_s : $\{q_{landf,l}^{kk}, q_{landf,m}^{kk}, q_{landf,md}^{kk}, q_{landf,h}^{kk}, q_{WIP,l}^{kj}, q_{WIP,m}^{kj}, q_{WIP,md}^{kj}, q_{WIP,h}^{kj},$
 $q_{cemcoa,h}^{kr}, q_{sep,l}^k, q_{sep,m}^k\}$.

As the total quantity of waste has to be treated somewhere (assuming no accumulation of waste outside the mentioned treatment options) a number of conditions is required. Low caloric waste has to be treated in a national landfill or separation plant or an (inter)national WIP. Incineration of low caloric waste in a cement kiln or coal fired electricity plant is not possible because the caloric value is not high enough. Mathematically

$$q_{landf,l}^{kk} + \sum_{j \in \mathcal{J}} q_{WIP,l}^{kj} + q_{sep,l}^k = \bar{Q}_l^k, \quad (2.2)$$

with \bar{Q}_l^k the supply of low caloric waste in region k.

Comparably, the formulae for mid caloric waste is

$$q_{landf,m}^{kk} + \sum_{j \in \mathcal{J}} q_{WIP,m}^{kj} + q_{sep,m}^k = \bar{Q}_m^k, \quad (2.3)$$

with \bar{Q}_m^k the supply of mid caloric waste in region k.

As separation of dirty mid caloric waste is not possible

$$q_{landf,md}^{kk} + \sum_{j \in \mathcal{J}} q_{WIP,md}^{kj} = \bar{Q}_{md}^k, \quad (2.4)$$

with \overline{Q}_{md}^k the supply of dirty mid caloric waste in region k.

As for high caloric waste all option are open

$$q_{landf,h}^{kk} + \sum_{j \in \mathcal{J}} q_{WIP,h}^{kj} + \sum_{r \in \mathcal{R}} q_{cemcoa,h}^{kr} = \overline{Q}_h^k, \quad (2.5)$$

with \overline{Q}_h^k the supply of high caloric waste in region k.

For different scenarios supplementary restraints can be imposed. For example, the scenario with open borders for mid and high caloric waste and closed borders for low caloric waste (which is a possibility currently discussed in the European Union) would suggest that incineration in a foreign WIP is not possible for this waste stream. Define

$$v(s, k) = \begin{cases} 1 & , \text{ if region k is in country s,} \\ 0 & , \text{ else,} \end{cases} \quad (2.6)$$

and

$$z(k, j) = \begin{cases} 1 & , \text{ if WIP j is in region k,} \\ 0 & , \text{ else.} \end{cases} \quad (2.7)$$

Thus

$$\forall k, j, s \text{ met } z(k, j) = 1 \text{ en } v(s, k) = 0 : q_{WIP,l}^{kj} = 0. \quad (2.8)$$

Other restriction such as landfill bans can be implemented in a comparable way.

2.2 Waste demand

In MEAM all WIP's which are currently operational in the European Union are included. It is assumed that these WIP's aim at maximising profits on free contractable waste. However, four technical restraints apply. First, the WIP's are constrained mechanically. Per hour a maximum quantity of waste can be handled. Second, the WIP's are constrained thermically. The caloric value of the incinerated waste may not exceed a certain limit. Third, the average caloric value of the incinerated waste has to be at least equal to the minimal caloric value the WIP is able to incinerate. Fourth, the average caloric value of the waste can not exceed the maximal caloric value the WIP is able to incinerate.

In the model, the boundaries on the quantity and type of waste a WIP is able to incinerate is given on short term. However, as some investments are already done, some WIP's are able to expand their capacity at low costs in the mid term. The model assumes that on the long term all WIP's can expand (at 'normal' costs) or new WIP's can enter the market. The profit equation of the WIP's is

$$\begin{aligned}
\max_{Q_d} \quad & \sum_{k \in \mathcal{K}} (p_{incin, ll}^{kj} - c_{WIP, ll}^j) q_{WIP, ll}^{kj} \\
& + \sum_{k \in \mathcal{K}} (p_{incin, l}^{kj} - c_{WIP, l}^j) (q_{WIP, l}^{kj} + q_{WIP, ml}^{kj}) \\
& + \sum_{k \in \mathcal{K}} (p_{incin, m}^{kj} - c_{WIP, m}^j) q_{WIP, m}^{kj} \\
& + \sum_{k \in \mathcal{K}} (p_{incin, md}^{kj} - c_{WIP, md}^j) q_{WIP, md}^{kj} \\
& + \sum_{k \in \mathcal{K}} (p_{incin, h}^{kj} - c_{WIP, h}^j) (q_{WIP, h}^{kj} + q_{WIP, lh}^{kj} + q_{WIP, mh}^{kj}),
\end{aligned} \tag{2.9}$$

with \mathcal{K} the set of all regions in the European Union and

- $c_{WIP, ll}^j$: the variable costs of incinerating very low caloric waste in WIP j,
- $c_{WIP, l}^j$: the variable costs of incinerating low caloric waste in WIP j,
- $c_{WIP, m}^j$: the variable costs of incinerating mid caloric waste in WIP j,
- $c_{WIP, md}^j$: the variable costs of incinerating dirty mid caloric waste in WIP j,
- $c_{WIP, h}^j$: the variable costs of incinerating high caloric waste in WIP j,
- $q_{WIP, ll}^{kj}$: the quantity of very low caloric waste from region k (out of the separation of low caloric waste) incinerated in WIP j
- $q_{WIP, ml}^{kj}$: the quantity of low caloric waste from region k (out of the separation of mid caloric waste) incinerated in WIP j
- $q_{WIP, lh}^{kj}$: the quantity of high caloric waste from region k (out of the separation of low caloric waste) incinerated in WIP j
- $q_{WIP, mh}^{kj}$: the quantity of high caloric waste from region k (out of the separation of mid caloric waste) incinerated in WIP j
- Q_d : $\{q_{WIP, ll}^{kj}, q_{WIP, l}^{kj}, q_{WIP, ml}^{kj}, q_{WIP, m}^{kj}, q_{WIP, md}^{kj}, q_{WIP, lh}^{kj}, q_{WIP, mh}^{kj}, q_{WIP, h}^{kj}\}$.

This formulae implies that the variable costs of the treatment options determine

the prices. For existing plants these costs are equal to the operational costs as fixed costs have no influence on the market price. However, in the long term scenario variable costs for new plants are equal to the total costs of treatment. As costs are included per ton we assume that all costs in the long term depend on the quantity of waste treated and that scale effects play no role. Although scale effects do play a role in practice, it is assumed that new plants enter at their optimal scale.

The actual mechanical quantity treated in WIP j is equal to

$$M^j = \sum_{k \in \mathcal{K}} (q_{WIP,l}^{kj} + q_{WIP,m}^{kj} + q_{WIP,md}^{kj} + q_{WIP,h}^{kj} + q_{WIP,ll}^{kj} + q_{WIP,ml}^{kj} + q_{WIP,lh}^{kj} + q_{WIP,mh}^{kj}), \quad (2.10)$$

while the actual thermic quantity treated is equal to

$$T^j = \sum_{k \in \mathcal{K}} (\epsilon_{ll} q_{WIP,ll}^{kj} + \epsilon_l (q_{WIP,l}^{kj} + q_{WIP,ml}^{kj}) + \epsilon_m q_{WIP,m}^{kj} + \epsilon_{md} q_{WIP,md}^{kj} + \epsilon_h (q_{WIP,h}^{kj} + q_{WIP,lh}^{kj} + q_{WIP,mh}^{kj})), \quad (2.11)$$

Thus, the mechanic constraint of WIP j is given by

$$M^j \leq K_j^{ton}, \quad (2.12)$$

with K_j^{ton} the capacity in kiloton (kton) of WIP j . The thermic constraint is given by

$$T^j \leq K_j^{therm}, \quad (2.13)$$

with K_j^{therm} the capacity in GigaJoule (GJ) per hour of WIP j . The minimal caloric value constraint is given by

$$\frac{T^j}{M^j} \geq \xi_{low}^j, \quad (2.14)$$

with ξ_{low}^j the minimal caloric value that WIP j is able to incinerate. The maximal caloric value constraint is given by

$$\frac{T^j}{M^j} \leq \xi_{high}^j, \quad (2.15)$$

with ξ_{high}^j the maximal caloric value that WIP j is able to incinerate.

In MEAM not only the WIP's are included, but also cement kilns and coal fired electricity plants with respect to their capacity to incinerate (high caloric) waste. The assumption is that these plants can substitute 'normal' fuel for waste with a maximum of a certain percentage of the total fuel use. It is assumed that cement kilns and coal fired electricity plants also maximise their profits. That is

$$\max \sum_{k \in \mathcal{K}} p_{incin,h}^{kr} (q_{cemcoa,h}^{kr} + q_{cemcoa,lh}^{kr} + q_{cemcoa,mh}^{kr}) - (c_{cemcoa,h}^r) (q_{cemcoa,h}^{kr} + q_{cemcoa,lh}^{kr} + q_{cemcoa,mh}^{kr}), \quad (2.16)$$

with

$c_{cemcoa,h}^r$: the variable costs of incinerating high caloric waste in a cement kiln or coal fired electricity plant r .

The capacity constraint of cement kilns and coal fired electricity plants is

$$\sum_{k \in \mathcal{K}} (q_{cemcoa,h}^{kr} + q_{cemcoa,lh}^{kr} + q_{cemcoa,mh}^{kr}) \leq \beta_{cemcoa} K_{cemcoa}^r, \quad (2.17)$$

with β_{cemcoa} the percentage of 'normal' fuels which can be substituted for high caloric waste and K_{cemcoa}^r the total fuel use of cement kiln or coal fired electricity plant r (converted to tons of high caloric waste using the average caloric values). The separation plants in MEAM separate waste streams in a low and high caloric fraction. After separation the low caloric waste can be incinerated in a WIP, while the high caloric fraction can be incinerated in a WIP, a cement kiln or a coal fired electricity plant. The profit maximising equation gives for the low caloric waste separation plant

$$\max_{q_{sep,l}^k} (p_{sep,l}^k - c_{sep,l}) q_{sep,l}^k - \sum_{j \in \mathcal{J}} (p_{incin,ul}^{kj} + t^{kj}) q_{WIP,ul}^{kj} - \sum_{j \in \mathcal{J}} (p_{incin,h}^{kj} + t^{kj}) q_{WIP,lh}^{kj} - \sum_{r \in \mathcal{R}} (p_{incin,h}^{kr} + t^{kr}) q_{cemcoa,h}^{kr} \quad (2.18)$$

$$\begin{aligned}
\text{z.d. } \sum_{j \in \mathcal{J}} q_{WIP, ll}^{kj} &= (1 - \theta_{lh}) q_{sep, l}^k \\
\sum_{j \in \mathcal{J}} q_{WIP, lh}^{kj} + \sum_{r \in \mathcal{R}} q_{cemcoa, lh}^{kr} &= \theta_{lh} q_{sep, l}^k.
\end{aligned} \tag{2.19}$$

Separation plants for mid caloric waste can be modelled in the same way. Used variables are

- θ_{lh} : the percentage of high caloric waste that can be separated from low caloric waste,
- θ_{mh} : the percentage of high caloric waste that can be separated from mid caloric waste,
- $c_{sep, l}$: costs of the separation of low caloric waste,
- $c_{sep, h}$: costs of the separation of high caloric waste.

Both for separation plants and landfills no capacity constraints are assumed.

2.3 Waste stream steering regulation

Countries differ with respect to the regulation with which they try to influence the way waste streams are treated. The main instruments are landfill taxes, incineration taxes and landfill bans. MEAM can handle these instruments. Landfill bans are included using the procedure described in equation 2.7 and 2.8. Taxes are included in the variable costs of landfill (landfill tax) and incineration (incineration tax).

2.4 Simulation

The most important variables calculated by the model are the market prices for the different waste streams and the allocation of waste to the different treatment plants. Given these prices and quantities a number of variables can be calculated: the utilisation rate per plant, the margin on a treated ton of waste, the quantity of exports and imports, the quantity of waste separated, the way waste is treated and the newly build capacity.

The model makes it possible to vary the institutional environment. Not only is it possible to include different regimes of waste regulation, but also the type of waste for which national borders are opened can vary. Furthermore, the model is simulated for the short, mid and long term.

Table 1: Overview exogenous variables

Variables
Transport costs
Number and area regions per country
Costs landfilling
Variable costs incineration WIP's: existing WIP's
Total costs incineration WIP's: new WIP's
Total costs incineration cement kilns and coal fired electricity plants
Capacity existing WIP's
Contracted capacity existing WIP's
Capacity cement kilns and coal fired electricity plants
Waste supply
Total costs separation
Waste regulation (landfill tax, incineration tax, landfill ban)

3 Data

Table 1 present the variables which are exogenous for the model. This section discuss the way these variables are quantified. As this section is based on Dijkgraaf et al. (2001), we only present the data in main lines.

Collection of the necessary data makes clear that availability of data is a serious problem in Europe. For almost every variable unambiguous, orderly and accessible sources are not available. Information from a lot of sources has to be combined to shed light on the actual situation. Thus, a number of assumptions have to be made to quantify the variables. As this increases the uncertainty of the model outcomes, we simulate the model for different values of the variables. Thus, not only a basic value is given for most variables but also a minimum and maximum value. In this paper we call the set of basic values the 'standard scenario', while the sets of minimum and maximum values are called the 'sensitivity analyses'.

3.1 Transport costs and regions

Transport costs included in the model are minimal costs given the available transport modes. We reckon with the way waste is collected (with a traditional system or a container system), different ways of main transport (bulk and container with lorries, train, inland and maritime shipping), costs of door-to-door

delivery and of transshipment. We assume that:

1. Transportation by train is no option given its high costs.
2. Maritime shipping is no alternative for waste that is not dried because the biological consequences of longer transports than 48 hours are not acceptable.
3. Inland shipping is an alternative for transport between the Netherlands, parts of Germany, Belgium, Austria and France given the availability of infrastructure.
4. Lorry transport is the main way of transport.

The main scenario assumes that all waste is transported by lorry. In the sensitivity analyses other transport modes are also analysed. Uncertainty in door-to-door delivery costs (especially regarding the distance between the place of collection and the start of the main transport as well as the distance between the end of the main transport and the place of treatment) are captured by simulating a cheap and an expansive case.

As it is not workable to calculate the transport costs between each possible place of collection and treatment in Europe we use regions. A specific municipality is chosen per region to represent the region. We distinguish more regions for large countries (four at most) than for small countries (one at least).

To calculate the transport costs between regions we used a route planner to calculate the distance between regions as well as the transport costs equation

$$C_T = 0.045D_L + 4.54 + 0.004D_F + 8.85N_F \quad (3.20)$$

The transport costs (C_T) from the place of collection to a treatment plant are equal to the sum of 4.5 eurocents times the distance travelled by lorry (D_L) plus 4.54 euro (door-to-door delivery and transshipment), 0.4 eurocents times the distance travelled by ferry (D_F) and 8.85 times the number of ferries used (N_F). Thus, within a region the costs of transport are 4.54 euro.

3.2 Costs landfilling

Table 2 gives a global overview of landfill tariffs in the European Union. Although the tariffs are not always consistent when two sources are combined, the minimum tariffs are the most interesting for our purpose as we have to include

Table 2: Landfill tariffs in the EU in euro per ton (excl. VAT and landfill taxes)

	Minimum tariff	Maximum tariff	Average tariff
Belgium	17	69	41
Denmark	3	161	27
Germany	25	50	53
Finland	6	24	13
France	40	99	53
Greece	6	13	9
Ireland	36	na	35
Italy	23	na	na
Netherlands	41	114	54
Austria	36	215	93
Portugal	6	14	na
Spain	14	14	na
UK	20	35	27
Sweden	4	200	30

Sources: Kossina (2000), EEA (2000) and own calculations.

the variable costs in the model. Big differences exist between countries. One reason could be that countries differ with respect to environmental regulation. However, as countries differ also with respect to population density and stability of the soil (especially regarding the leakage effect to groundwater) differences in facilities, and thus costs, need not lead to differences in environmental performance. For the model simulations we assume that the presented minimal tariffs mirror variable costs. Sensitivity analyses are carried out with variable costs 11 euro higher and lower per country.

3.3 Variable costs incineration WIP's: existing WIP's

For the Netherlands detailed information on the costs of WIP's is available (see AOO, 1997). However, for other countries this information is not available. Although various sources present information about the tariffs in EU-countries (see table 3), this information is rather unreliable (mostly based on expert opinions). Furthermore, results differ per source and the range in tariffs per country gives no basis to assume a sound relation between these tariffs and the variable costs of individual installations.

Table 3: Tariffs incineration in EU-WIP's in euro per ton (excl. VAT and incineration taxes)

	National	TIP	Senat	EEA
Belgium	53-110	74	94	44-97
Denmark	14-39	44	60	27
Germany	36-340	89-349	184	88
France	60-98	74-79	62	69-129
Italy		64-79		
Netherlands	69-125	109-140	96	64-119
Austria		99-180		103
Spain	16-52			34
UK		24-39		49
Sweden		29	38	35

Sources: TIP (1999), Senat (2000), EEA (2000) and national sources.

To estimate the variable costs of incineration in EU-WIP's a two step procedure is followed. First, cost information is collected for individual WIP's. We have send all EU-WIP's (with the exception of the French and Italian WIP's because individual figures or addresses where not available) a request for annual reports as well as an inquiry. Furthermore, for the Italian WIP's an useful study exists (Ecoistituto Veneto, 2000). Second, we estimated a statistical model with the data we obtained to extrapolate cost information for WIP's for which no cost data were available.

Table 4 presents the estimated cost model. Variable costs² are influence by the capacity of the plant. As the quadratic term is also significant, a U-shaped cost function applies (see figure 1). First, variable costs decrease when capacity is increased. However, after a certain optimal scale variable costs increase. It shows that for our sample an installation of about 600 kton has the lowest costs. The estimation shows clear cost differences between countries. Especially Danish, Italian, Spanish and Swedish installations have far lower costs than Dutch installations (the reference used in the estimation). Underlying data make clear that these cost differences have a clear reason. First, in Denmark, Italy and Sweden the revenues from electricity production are far higher than in the Netherlands. In Denmark and Sweden this is due to the utilisation

²Defined as total costs minus depreciation and costs of capital

Table 4: Estimated variable cost function EU-WIP's

Variable	Coefficient	Standard error	T-value
Q	-0.151	0.050	-3.03
Q ²	0.00012	0.00005	2.45
<i>D_{Bel}</i>	-9	15	-0.56
<i>D_{Dnk}</i>	-34	13	-2.50
<i>D_{Ger}</i>	29	10	2.67
<i>D_{UK}</i>	-7	13	-0.63
<i>D_{Ita}</i>	-47	13	-3.55
<i>D_{Spa}</i>	-26	11	-2.28
<i>D_{Swe}</i>	-58	17	-3.26
<i>D_{Swi}</i>	0	11	0.00
C	68	13	5.14
R ²	0,53		

of heat of the WIP's. Italy has lower costs because the price per unit electricity produced is more than twice the price in the Netherlands. The low costs of Spain are mainly caused by the lack of environmental facilities. Plants in Belgium, Germany, the UK and Switzerland have more comparable costs with the Netherlands.

As the capacity is available for all WIP's, the estimated cost function makes it possible to calculate the variable costs of all individual WIP's. For France and Austria it is assumed that the fixed part of the estimated equation is 10 and 6 euro higher than in the Netherlands, based on the average tariffs presented in Senat (2000) and EEA(2000).

Table 5 presents an overview of the maximum, minimum and average variable costs used in the model simulations.

The estimated and calculated variable costs apply to the incineration of low caloric waste. However, as the model distinguish waste streams of several caloric value, we have to estimate also the variable costs for other waste streams. We assume that the relation between energy revenue and caloric value is linear. Note that this does not mean that incineration of waste with a higher caloric value is always cheaper. The reason for this is that the total capacity of the WIP decreases when the average value of the caloric value of incinerated waste increases (see the model description).

For the Spanish installations we mentioned that less equipment for emissions

Figure 1: Variable costs WIP per ton waste

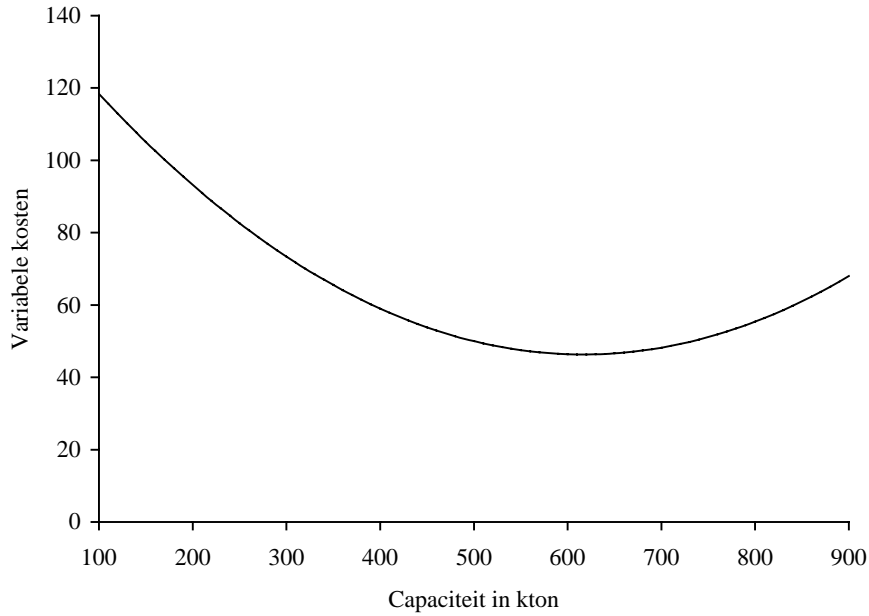


Table 5: Estimated variable costs of WIP's in euro per ton

	Maximum	Minimum	Average (unweighted)
Belgium	118	51	96
Denmark	68	-20	47
Germany	204	110	146
France	109	26	83
Italy	42	-36	24
Netherlands	96	46	68
Austria	138	88	110
Spain	79	-6	39
UK	122	27	76
Sweden	20	-66	-5

resulted in lower costs. As it is not clear whether the existing installations comply with the EU-directive, this could also apply to other countries. Therefore, we simulate also a sensitivity analysis for the case that installations in some countries have to improve their plant. Based on EC (1996) and information from the inquiry we simulate a scenario with higher variable costs for installations that possibly do not comply with the EU-directive.³ As we only for Germany and the Netherlands know for sure that all installations comply, this scenario reckons with higher costs for installations in all other countries.

Furthermore, uncertainty in the estimated variable costs is handled by simulating scenario's with higher or lower variable costs (11 euro) per country.

3.4 Total costs incineration: new WIP's

In the long term scenario new plants can enter the market. The crucial variable for this is the total costs of a new entrant. When these costs are below market price, new plants will enter the market. Unfortunately no data are available on the costs of new plants. Therefore, we build on the experience we have with Dutch installations and count for the differences between countries.

Table 6 summarizes the assumptions we made for the costs of a new Dutch WIP. As a reference we used the figures of a recent build Dutch WIP. In the Netherlands this WIP is seen as an example of newest technology, complying with the new EU-directive.

As the reference WIP is build in a market environment that can be classified as a protected monopoly and as the plant is rather luxury, we assume a possible efficiency improvement of 15%.⁴ Based on a yearly constant annuity the costs of a new entrant per ton are 77 euro.⁵ As uncertainty exist about the used assumptions we also calculated the total costs with other assumptions. This results in minimum entrants costs of 63 euro⁶ and maximum costs of 94 euro.⁷

³EC(1996) gives information on the renovation costs of installations that do not comply. As these costs are dependent on the scale of the plant, we estimated a renovation cost equation that counts for this property and calculate the costs for each individual installation using data on their capacity.

⁴See Megginson and Netter (2001) for a recent overview of effects of privatisation.

⁵Although the reference plant is a low caloric waste incineration plant, calculations show that costs for mid of high caloric incineration in a WIP are comparable.

⁶Availability is 90%, company capital 30%, interest outside capital 6%, depreciation term 25 years, energy revenue 20% higher

⁷Availability is 85%, net return on company capital 13%, interest outside capital 8%, efficiency improvement 10%, energy revenue 20% lower

Table 6: Assumptions costs new Dutch WIP

Assumption	Standard scenario
1. Investment (in mln euro)	436
2. Mechanic capacity (kton at 100% availability)	648
3. Availability (as % of total capacity)	87.5
4. Company capital (as % of total capital)	40
5. Net return on company capital (%)	12
6. Interest outside capital (%)	7
7. Tax on profits (%)	32
8. Inflation (%)	2
9. Efficiency improvement (as % of total costs)	15
10. Economic life span (in year)	25
11. Depreciation term (in years)	15
12. Reinvestment costs (in euro per ton)	4
13. Variable costs (in euro per ton)	39
14. Energy revenue (in euro per ton)	26

For the entrants costs of other countries we use as a reference the Dutch costs, but correct for country specific circumstances. The following corrections are made:

1. Capital costs are calculated taking into account the national effective tax rate on profits.
2. Variable costs are calculated taking into account the national average wage rate.
3. Total costs are calculated taking into account the differences with respect to environmental facilities. In practice this means that total costs for most countries are about 4 euro less than in the Netherlands because the Netherlands has stricter environmental requirements for NO_x .
4. Energy revenues are calculated assuming no difference between countries. As described above especially Italy, Denmark and Sweden differ from other countries. However, it is not reasonable to assume the same conditions for new plants as the infrastructure to take advantage of the produced heat is often not available for new plants. Furthermore, the high

energy price of Italy is not sustainable in the future because this can lead to very large imports.

Table 7 present the total costs of new WIP-plants in the European countries. The second column give the figures for our standard scenario. The columns three, four and five represent figures for sensitivity analysis scenarios. In these scenarios we vary with the degree of harmonisation of the costs of landfilling the incineration residue and the energy revenue. Furthermore, the low and high cost scenario are given in the last two columns.

Table 7: Total costs new WIP-plants in the European Union in euro per ton

	Standard ^a	A ^b	B ^c	C ^d	D ^e	E ^f
Belgium	74	74	75	75	91	60
Denmark	73	43	45	76	91	59
Germany	81	81	81	81	98	66
Finland	71	71	74	74	88	57
France	77	77	78	78	95	63
Greece	61	61	65	65	78	47
Ireland	67	67	68	68	83	53
Italy	73	33	35	76	90	58
Luxembourg	88	88	79	79	107	74
Netherlands	76	76	76	76	93	62
Austria	76	76	73	73	93	62
Portugal	60	60	63	63	76	46
Spain	66	66	70	70	83	52
UK	72	72	74	74	88	58
Sweden	73	43	44	75	90	59

^a Standard: different landfill costs incineration residue, equal energy revenues.

^b Analysis: different landfill costs incineration residue, equal energy revenues.

^c Analysis: equal landfill costs incineration residue, different energy revenues.

^d Analysis: equal landfill costs incineration residue, energy revenues.

^e Analysis: high costs for new plants.

^f Analysis: low costs for new plants.

3.5 Total costs incineration: other options

For incineration of waste in a cement kiln or coal fired electricity plant waste has to be pretreated which leads to additional costs. Separation, drying, shredding and compressing amounts to a minimal cost of 18 euro per ton. Furthermore, dependent on the available facilities, extra investments can be necessary to comply with environmental regulation. On the other side the ‘normal’ fuel costs are avoided. We assume that minimal costs for incineration in a cement kiln or coal fired electricity plants amounts to 18 euro per ton. In a sensitivity analysis we reckon with 36 euro per ton.

3.6 Capacity incineration

MEAM reckons with the individual WIP's.⁸ Thus we need the individual WIP capacity data. Partly based on BM (2000) we made a complete list of the mechanical capacity of all EU plants (including plants to be build).

Data on the thermic capacity and the other caloric constraints are not available for individual installations outside the Netherlands. Therefore, we use the average numbers of the Dutch plants for all EU plants. The assumption is that the average thermic capacity is 9.35 GJ per ton. The minimal caloric value is 6.4 GJ per ton and the maximum value is 12.9 GJ per ton. In sensitivity analyses we reckon with 10% higher and lower values.

Comparing the utilisation rates of different WIP's in countries with not much incentives to incinerate, assuming an average contract rate of 70% seems reasonable. In sensitivity analyses we reckon with 10%-point lower and higher values.

The potential capacity of coal fired electricity plants is calculated based on the amount of actual used coal in 1997 (based on OECD, 2000). The assumption is that 10% of the total energy use can be substituted for waste. This is in line with a study in the US (EPA, 2000). In the same way the potential capacity of cement kilns is estimated. These figures are based on Global (2000). Following Vanderborght (2000) and AOO (1996) fossil fuels can be substituted for waste at a maximum percentage of 30% in the cement process.

⁸To make the model workable individual WIP's are sometimes combined when their costs are comparable.

Table 8: Capacity WIP's, coal fired electricity plants and cement kilns in the EU in mton

Country	Coal	Cement	WIP's	Total
Belgium	0.9	0.5	1.7	3.1
Denmark	1.5	0.6	3.0	5.1
Germany	18.0	9.8	20.7	48.5
Finland	1.3	0.6	0.1	2.0
France	1.5	1.8	11.8	15.1
Greece	1.8	0.8	0.0	2.6
Ireland	0.5	0.1	0.0	0.6
Italy	1.2	1.1	3.9	6.2
Luxembourg	0.0	0.0	0.2	0.2
Netherlands	1.5	0.6	5.4	7.5
Austria	0.3	0.3	0.5	1.1
Portugal	0.7	0.3	0.0	1.0
Spain	3.5	1.9	1.8	7.2
UK	6.5	4.5	5.6	16.6
Sweden	0.2	0.1	2.0	2.3
EU	39.4	23.0	56.8	119.2

Table 8 presents the total capacity in mton per year of WIP's (assuming a 87.5% availability rate), cement kilns and coal fired electricity plants. Especially in the UK and Germany the capacity of coal fired electricity plants and cement kilns is very big in absolute terms and even more than the capacity of WIP's. Only Luxembourg and Sweden have a cement kiln and coal fired electricity plant capacity that is relatively low. Only Germany, France and the UK have more WIP capacity than the Netherlands, while four countries have no WIP-capacity at all.

3.7 Waste supply

In MEAM the quantity of waste available for incineration is an important variable. However, as public sources do not present enough data to determine this quantity directly, we follow an indirect approach. First, we collect the necessary data for the Netherlands. Second, we extrapolate these data to other countries. The quantity of waste is based on 'standard' figures for household and com-

mercial waste. As the model is forward looking a projection for the future is necessary. The short term simulations are based on actual figures (2001). As reference for the mid term 2004 is chosen, while we choose 2011 as reference for the long term. The Dutch Waste Management Council made projections for us for these years (see AOO, 2000), using a standard waste model.

MEAM distinguishes between low, (dirty) mid and high caloric waste. Based on the average caloric value of the different waste streams and the potential to separate the waste we calculated the quantities for these waste streams. The following assumptions are made:

- Municipal waste (MW) is low caloric waste (10.3 MJ per kilo). Separation in a high (plastics, wood) and very low caloric part (8.9 MJ per kilo) is possible for 15% of the total waste stream.
- Commercial waste (CW) can be split in a mid caloric (14.1 MJ per kilo), dirty mid caloric (also 14.1 MJ per kilo) and high caloric part (17.9 MJ per kilo). Sources of commercial waste are industrial waste (IW), demolition waste (DW) and sludge waste (SW).
- High caloric waste, 50% of total commercial waste, can be incinerated in cement kilns and coal fired electricity plants without major pre-handling.
- Mid caloric waste, 30% of total commercial waste, can be separated in a low (50%) and high caloric part. The high caloric part can be incinerated in cement kilns and coal fired electricity plants.
- Dirty mid caloric waste, 20% of total commercial waste, can not be separated due to major contamination making incineration in cement kilns and coal fired electricity plants not possible.
- Waste available is total waste generated minus recycling.

For the other countries the quantity of household waste is extrapolated from the Dutch figures using the quantity of waste per inhabitant, where commercial waste is extrapolated using the quantity of waste per unit of national income. Table 9 presents the waste supply figures for 2001. Compared with the total EU-capacity of incineration, a very large amount of waste is generated. Especially France, Italy, Spain and the United Kingdom have an enormous shortage of incineration capacity. In eleven countries the quantity of household waste

exceeds the total incineration capacity. Only Denmark shows a balance between capacity and supply.

Table 9: Waste supply 2001 in the European countries (Mton per year)

	MW	IW	DW	SW	Total	Cap-WIP	Cap-tot
Belgium	3.1	1.9	0.3	1.1	6.4	1.7	3.1
Denmark	3.0	1.3	0.2	0.7	5.2	3.0	5.1
Germany	25.0	15.7	2.3	9.0	52.0	18.1	45.9
Finland	2.1	3.2	0.1	0.6	6.0	0.1	2.0
France	23.8	34.2	1.6	6.2	65.8	11.8	15.1
Greece	5.3	4.9	0.1	0.5	10.8	0.0	2.6
Ireland	1.9	4.0	0.1	0.4	6.4	0.0	0.6
Italy	28.8	44.5	1.2	4.8	79.3	3.6	5.9
Luxembourg	0.1	0.1	0.0	0.1	0.3	0.2	0.2
Netherlands	4.8	3.0	0.4	1.7	9.9	5.4	7.5
Austria	2.5	1.6	0.2	0.9	5.2	0.5	1.1
Portugal	5.0	4.4	0.1	0.5	10.0	0.0	1.0
Spain	19.8	23.6	0.7	2.6	46.7	1.8	6.4
UK	29.7	54.0	1.5	5.8	91.0	1.6	12.6
Sweden	3.6	5.6	0.3	1.0	10.5	2.0	2.4
Total	157.1	202.0	9.1	35.9	404.1	49.8	111.5

Because we followed a necessary but rough estimation process for the standard scenario, a number of sensitivity analyses are simulated. In different scenarios we work with other figures for national recycling rates, the split in low, (dirty) mid and high caloric waste and the quantity of total waste generation. Not only the uncertainty about the figures used is captured but also the possible indirect effects of the incineration and landfilling market on recycling and prevention.

3.8 Waste regulation

Table 10 presents the waste stream steering regulation in the different countries. Eleven countries do have a landfill tax, but the level of this tax shows a high deviation. For Wallonia, Italy and Luxembourg it is assumed that the landfill tax is zero or equal tot the presented minimum. An incineration tax is less common. Only Flanders and Denmark have an incineration tax. Flanders, Denmark and the Netherlands have a landfill ban. However, the Dutch expe-

rience show that a landfill ban is a very difficult instrument to implement. As long as the total waste supply is more than capacity, exemptions have to be given to waste suppliers not able to incinerate their waste. If landfill taxes are not high enough, each waste supplier has incentives to ask for an exemption. Thus, suppliers can profit from the lower landfill tariff. For this reason we assume in the standard scenario that a landfill ban has no effect on the quantity of waste going to WIP's. In sensitivity analysis it is shown what the effects are if a landfill ban has positive effects. In the mid and long term scenarios a landfill ban is also simulated for Sweden, Austria, Finland, Germany and France. For these countries a landfill ban is expected to come in practice before 2005.

Table 10: Waste regulation in the EU (tariffs in euro per ton)

	Landfill tax	Incineration tax	Landfill ban
Belgium (Flanders)	45 ^a	25	Yes
Belgium (Wallonia)	Yes	No	No
Denmark	60	28	Yes
Germany	No	No	Yes (2005)
Finland	15	No	Yes (2005)
France	6	No	Yes (2002)
Greece	No	No	No
Ireland	No	No	No
Italy	5-26 ^b	No	No
Luxembourg	>23	NB	NB
Netherlands	64	0	Yes
Austria	15	No	Yes (2004)
Portugal	No	No	No
Spain	No	No	No
UK	20 ^c	No	No
Sweden	30	No ^d	Yes (2002)

Sources: 54 different sources

^a Tariff for municipal waste.

^b Tariffs differ per region. Commercial waste: min. 5 and max. 10 euro per ton. Municipal waste: min. 10 and max. 26 euro per ton.

^c Tariff in 2000. Per year an one pound increase is agreed.

^d A discussion is going on about an incineration tax.

4 Results

We simulated MEAM for three different regimes. First, a scenario is simulated in which national borders are closed for all types of combustible waste. This is the reference scenario as currently national borders for waste treatment in WIP's are closed. Second, a scenario is simulated with open borders for mid and high caloric waste. Third, a scenario is simulated with open borders for all types of waste. Before the results are presented for these scenarios a short remark is given about the relevant waste market.

4.1 Relevant market

Simulation of all scenarios, including the sensitivity analyses, would result in an estimated 12 months of computer time. Therefore, the results presented in this section are simulated with data for the Netherlands and some nearby countries (Germany, Belgium, France, the UK, Austria, Italy and Denmark). Starting with the full model (all EU-members) we compared simulation results excluding countries with relatively high transport costs to the Netherlands. It showed that restricting the model to the countries mentioned did not alter the results. Thus, we can state that from a Dutch perspective the relevant market is restricted to these countries. Apparently, transport costs are an important factor in the waste market.⁹

4.2 Closed national borders

With closed national borders for combustible waste, the simulated market price for low caloric waste in the Netherlands is 105 euro per ton (see table 11). WIP's can charge this price because waste suppliers have no cheaper alternative than landfilling. In the Netherlands the minimal tariff for landfilling is 105 euro per ton (41 euro for landfill costs and 64 euro for the landfill tax). As the supply of waste exceeds the available WIP-capacity, WIP's can set the price at this level. The same is true for mid and high caloric waste. Supply exceeds capacity and treatment plants can ask a relatively high price (more than 100 euro per ton).

⁹Of course this conclusion depends on the level of transport costs. Remember that the standard scenarios reckon with transport costs based on the costs of lorry transport. For some types of waste the relevant market will be larger because shipping is possible for these streams.

Table 11: Model results closed borders

	KT	MT	LT
Price low caloric (euro per ton)	105	105	77
Price mid caloric (euro per ton)	105	105	77
Price high caloric (euro per ton)	105	105	77
Thermic utilisation NL in % cap.	100	100	100
Mechanical utilisation NL in % cap.	92	93	96
Landfilled combustible waste (in kton)	3152	3023	0
Exports (in kton)	0	0	0
Imports (in kton)	0	0	0
Separation low caloric (in kton)	0	0	0
Separation mid caloric (in kton)	0	0	0
Expansion existing capacity (in kton)	0	374	374
Entry low (in kton)	0	0	681
Entry mid (in kton)	0	0	2567
Entry high (in kton) ‘	0	0	344

As investments are already partly done, in the mid term cheap expansion of existing WIP-capacity is possible in the Netherlands. Indeed, the model predicts that this expansion is attractive for the WIP’s. Although in the long term the results indicate that the expansion is still profitable, the market prices decrease vast. Given the high landfill costs and closed borders, entry of new plants takes place, resulting in market prices equal to the costs of an entrant. As a consequence, the market prices decrease to 77 euro per ton. Even though existing WIP’s are still active in the long term simulation (their variable costs are below 77 euro per ton), nearly all WIP’s operate at financial losses (average total cost is 90 euro per ton). In other words, Dutch WIP’s can cover costs only in the short and mid term.

Sensitivity analysis makes clear that these conclusions are robust. Only other levels of the landfill costs in the short and mid term and the entry cost in the long term scenario have a significant effect on the conclusions.

4.3 Open national borders for mid en high caloric waste

With open national borders for mid en high caloric waste, the Dutch market price for low caloric waste remains at a level of 105 euro per ton (see table 12).

Table 12: Model results closed borders low caloric waste

	KT	MT	LT
Price low caloric (euro per ton)	105	104	77
Price mid caloric (euro per ton)	No	No	68
Price high caloric (euro per ton)	29	29	29
Thermic utilisation NL in % cap.	100	100	100
Mechanical utilisation NL in % cap.	93	94	94
Landfilled combustible waste (in kton)	135	0	0
Export low caloric (in kton)	0	0	0
Export mid caloric (in kton)	2147	2144	2050
Export high caloric (in kton)	862	868	798
Imports (in kton)	0	0	0
Separation low caloric (in kton)	57	63	0
Separation mid caloric (in kton)	954	958	1068
Expansion existing capacity (in kton)	0	374	374
Entry low (in kton)	0	0	743
Entry mid and high (in kton)	0	0	0

Although large amounts of mid and high caloric waste are exported, enough low caloric waste is available to give the WIP's a good bargaining position. However, minor changes in capacity or supply of low caloric value result in major changes in the market price of low caloric waste. Thus, the match between WIP-capacity and supply of low caloric waste is very tight.

Prices for mid and high caloric waste are very much below the level in the closed border scenario. This results from the combination of a relatively cheap and high international capacity to incinerated this waste (cement kilns and coal fired electricity plants) and a bad bargaining position of international plants due to the cheap available landfilling alternative. The price for incinerating mid caloric waste is 59 euro and the price for incinerating high caloric waste is even lower and equals 29 euro. The low price for high caloric waste is lower than for mid caloric waste because no separation costs have to be made.

Because expansion of existing WIP's is still profitable and this growth in capacity exceeds the extra waste supply, the match between the supply of low caloric waste and WIP-capacity is even more tight in the mid term. As a consequence, prices are more sensitive to this match compared with the short term.

In the long term again entry occurs for low caloric WIP's leading to a market

price of 77 euro per ton. However, entry is not profitable for mid and high caloric WIP's in the Netherlands as enough cheap capacity is available abroad. As the financial position of the Dutch WIP's strongly depends on the market price of low caloric waste, the effects of opening national borders for mid and high caloric waste are not large as long as more supply of low caloric waste than capacity is guaranteed. However, recycling and prevention are now discouraged as prices for mid and high caloric waste decrease dramatically.

Table 13 presents the sensitivity analyses for the scenario with open borders for mid and high caloric waste that have influence on the financial position of Dutch WIP's compared with the standard scenario (in total 92 sensitivity analyses are simulated, but 82 had no effect on the financial position compared with the standard scenario). As the table makes clear, the mentioned effects of an increase of the capacity of WIP's or a decrease of low caloric waste supply are big, while the other effects are small. This shows that the results are robust with the exception of the match between capacity and waste supply.

Table 13: Sensitivity analyses: effect on price low caloric waste, closed borders low caloric waste

Definition	Country	Effect	KT	MT	LT
Landf. price lower (euro per ton)	Net.	-11	-12	-11	0
Landf. price higher (euro per ton)	Net.	+11	3	0	0
Supply low caloric waste lower	Net.	-5%	-28	-24	0
More separation municipal waste	All	+15%	-29	-26	-1
Availability rate WIP's lower	All	-2,5%	0	8	0
Availability rate WIP's higher	All	+2,5%	0	-24	0
Cap. cement and elect. higher	All	+50%	0	-5	0
Therm. cap. higher (mech. same)	All	+10%	-28	-21	0
Entry: low costs	All	Sev. ^a	0	0	-14
Entry: high costs	All	Sev. ^a	0	0	16
Price incineration low caloric waste standard scenario			105	104	77

^a See table 7 column D and E.

4.4 Open national borders for all waste

With open borders for all waste, the price for low caloric waste decreases to 71 euro per ton (see table 14). The total supply of low caloric waste in Europe is

less than the total WIP-capacity. Thus, the absence of (high enough) landfill taxes result in a fierce competition between the European WIP's. The Dutch WIP's has to lower their tariffs in order to be able to fill their capacity. In this scenario not only mid and high caloric waste is exported, but also low caloric waste is now transported to foreign plants. Actually, in this scenario waste is exported from the Netherlands to Germany, France, Belgium and the UK. On mid and long term the picture doesn't change. The market price is not high enough to provoke entry. The low price for low caloric waste results in a financial loss for all Dutch WIP's. Furthermore, prevention and recycling are further discouraged.

Table 14: Model results all borders open

	KT	MT	LT
Price low caloric (euro per ton)	71	71	71
Price mid caloric (euro per ton)	67	68	64
Price high caloric (euro per ton)	29	29	29
Thermic utilisation NL in % cap.	100	100	100
Mechanical utilisation NL in % cap.	92	93	93
Landfilled combustible waste (in kton)	0	0	0
Export low caloric (in kton)	552	571	1001
Export mid caloric (in kton)	1735	1581	1812
Export high caloric (in kton)	866	873	779
Imports (in kton)	0	0	0
Separation low caloric (in kton)	0	0	0
Separation mid caloric (in kton)	864	874	1086
Expansion existing capacity (in kton)	0	374	374
Entry (in kton)	0	0	0

Table 15 present the significant sensitivity analyses. Only two cases result in a price lower than the one resulting from the standard scenario. This is the case when the thermal capacity is larger or the costs of the entrant are lower than assumed. In general the model results are rather robust. Not only because the most sensitivity analyses have no significant effect at all compared with the standard scenario (in total only 14 out of 114 scenarios do result in a significant different financial position of the Dutch WIP's), but also because the effects of the significant sensitivity analyses are modest.

Table 15: Sensitivity analyses: effect on price low caloric waste, all borders open

Scenario	Country	Effect	KT	MT	LT
Landf. price higher (euro per ton)	Vla.	+11	6	4	4
Landf. price higher (euro per ton)	Fra.	+11	5	0	0
Landf. price higher (euro per ton)	UK	+11	0	0	3
Supply commercial waste higher	Net.	+25%	2	0	0
Contracted cap. WIPs higher	All	+7%	0	2	0
Contracted cap. WIPs higher	Fra.	+30%	3	0	0
Therm. cap. higher (mech. same)	All	+10%	-1	-3	-2
Therm. cap. lower (mech. same)	Abr.	-10%	8	6	4
Var. costs WIP low cal.	Ger.	+11	4	2	0
Var. costs WIP low cal.	Fra.	+11	3	0	0
Level playing field environment	All	Sev. ^a	2	2	0
Costs cement and elect. higher	All	+54	4	3	3
Caloric value waste higher	All	Sev. ^b	n.a.	n.a.	5
Entry: low costs	All	Sev. ^c	n.a.	n.a.	-9
Price incineration low caloric waste standard scenario			71	71	71

^a According to estimated model, see section 3.3.

^b Plus 5%-point plastics.

^c See table 7 column E.

5 Conclusions

The model simulations show that opening borders for all types of waste results in fierce competition between Dutch and foreign waste disposal firms. As waste stream steering instruments are not harmonised between the European countries, there is an incentive to transport the waste to places with a lack of (effective) waste instruments. Simulation of the introduction (or an increase of) landfill taxes in the different member states shows that from the Dutch perspective only France and Germany have a major influence on the financial position of Dutch WIP's. As a consequence, harmonisation of waste steering instruments between these three countries prevents the sharp price decrease

when national borders are opened.

Although the opening of borders for all waste is attractive from a competition point of view, it results in less incentives for prevention and recycling. Dramatic price decreases occur not only for low caloric waste if no harmonisation of waste policy takes place, but also mid and high caloric waste. If the environmental welfare effect is larger than the competition effect on the costs of waste treatment, national borders should not be opened from a welfare point of view.

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