ICARUS-4

A database of energy reduction options for the Netherlands, 1995-2020

Sector study for the Non-Ferrous Metals Industry

Revision 1

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Abstract

In this report we describe the energy consumption in 1995 and the energy saving options that exist within the non-ferro base metal industry (SBI/NACE 27.4-5) in the Netherlands. The data will be included in the ICARUS-4 database which gives an inventory of the technological options for energy savings for all economic sectors in the Netherlands. For all described measures the report provides data on the achievable energy savings up to the year 2020, investment and O&M costs and actual penetration data in the base year of 1995.

Acknowledgement

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Contents

1. Introduction

1.1. General

The non-ferrous basic metals sector (SBI/NACE 27.4-5) in the Netherlands comprises the following activities:

- production of primary aluminium from alumina (SBI 27.42a);
- production of secondary aluminium from scrap (SBI 27.42b);
- production of primary zinc from ore (SBI 27.43);
- non-ferrous metal casting (foundries; SBI 27.53-54)
- non-ferrous metal forming (extrusion, rolling; SBI 27.42c, 27.44-45)

Unfortunately our list of activities do not have a one-to-one correspondence with the SBI subsector divisions. SBI sector 27.42 includes almost all aluminium production activities: primary and secondary production as well as aluminium rolling/extrusion. For our analysis it is useful to discern the above-mentioned activities, therefore we have subdivided SBI code 27.42 into three subcategories a, b and c.

1.2. Energy consumption 1995

The primary aluminium industry is by far the largest energy consumer within the non-ferrous (NF) sector, as shown in table 1-1. We will therefore concentrate our discussions on this activity.

The primary zinc production is much less energy-intensive, while non-ferrous foundries have only a limited activity in the Netherlands. Secondary aluminium production is a fast growing activity, with a fairly low energy intensity. The same goes for the production of non-ferrous semi-fabricates where processes like rolling and extrusion take place. A rest category comprises secondary lead production but also energy use that we could not allocate.

	Main process	Production (kton)	Fuel cons. (PJ)	Electr. cons. (PJ_e)	Primary[a)] en. cons. (PJ)	SEC[c)] (GJ/t)
Primary Al	electrolysis	216	4.1[c]	11.9	33.7	157
Primary Zn	electrolysis	210	0.5	3.1	8.2	39
Secondary Al	melting	190	1.0	0.1	1.4	7
NF metal casting	melting	20	0.3	0.2	0.8	40
NF metal forming	extrusion/rolling	150	0.9	0.4	1.8	13
Other NF			0.3	1.0	2.8	
Total			**7.0**	**16.7**	**48.5**	

Table 1-1: Overview of energy use in the non-ferrous basic metals sector in 1995 [AEA Technology, 2000, Aluminium Delfzijl, 1999, CBS, 1996, Energetics, 1997, Frijlink, 2000, Gielen and van Dril, 1997, Lijftogt, Kuijk, 1998, Metallgesellschaft and World Bureau of Statistics, 1997, Quinkerz and Rombach, 1999, Van den Elsen, 2000]

a) To obtain primary energy consumption 1 PJ of electricity is taken equivalent to 2.5 PJ primary energy.
b) Specific Energy Consumption = (Primary energy consumption) / (Yearly production).
c) Includes anode production and consumption within the primary aluminium industry (see text).

Regarding the fuel consumption we can remark that 42% of this is non-energetic use of oil products for anodes, while the energetic use is composed of 95% natural gas and 5% fermentation gas. Energetic use of oil and coal is negligible.

In addition to the fuel and electricity consumption in table 1.1 there was also 1.5 PJ of steam or hot water consumption, but we could not find out in which subsector of the non-ferrous metals this was used[1]. Therefore we will allocate it to the subsector “Other Non-ferro”; the same was done for the small consumption of fermentation gas (0.2 PJ). No savings measures will be given for this sector.

[1] All that we do know is that was not used by the primary aluminium or primary zinc smelters.

1.3. Energy functions

We can discern the following energy functions within the non-ferrous subsectors

- electrolysis to produce primary metal
- anode production (for Al electrolysis)
- melting/holding of metal
- scrap pretreatment
- heat treatment
- extrusion
- rolling

Furthermore there are the general facilities among which ventilation and flue gas removal, compressed air supply and space heating are probably the most important within this sector.

1.4. Energy reduction options

Available data, assumptions and literature references regarding the identified energy reduction options will be discussed by subsector in the following sections. Detailed information about the options can be found in *Appendix B* in a tabular format. *Appendix A* gives an explanation of the variables and codes used in these tables

2. Primary aluminium production

2.1. Sector description

Primary aluminium production takes place in two plants in the Netherlands: Aluminium Delfzijl (Aldel) with a production capacity of 100 kt/y and Pechiney Vlissingen with a capacity of 180 kt/y. The Aldel plant was built in 1966 and the Pechiney plant in 1972, so both plants are relatively old. However, several renovations have been implemented at the plants. Due to market conditions in 1995 there was only a 77% utilisation of the production capacity resulting in a primary Al production of 216 kt.

The production of primary aluminium is performed by electrolytic reduction of alumina (Al_2O_3) in the Hall-Heroult process:

$$2\ Al_2O_3\ (dissolved) + 3C\ (solid) \rightarrow 4\ Al\ (molten) + 3\ CO_2\ (gaseous)$$

The alumina is dissolved in an electrolyte consisting of cryolite $(NaF)_3AlF_3$ and aluminium fluoride (AlF_3), which is kept at a temperature of 950 ^oC. The alumina reacts with the carbon anodes which are thus consumed during the process at a rate of 0.45 kg per kg Al.

In 1995 the specific electricity consumption for the electrolysis process, which is usually expressed in kWh of DC electricity per kg aluminium, was 15 kWh (DC) at Aldel, while the Pechiney plant used 13.5 kWh/kg [2]. As this is DC electricity one has to take into account 1–1.5% losses for ac-to-dc conversion. Moreover some 6% additional electricity is used by the flue gas cleaning equipment (3%) and by other general facilities (3%).
The theoretical minimum energy consumption for alumina reduction is 6.3 kWh/kg [ICF Consulting, 2000]. The two best plants currently operating around the world have a specific electricity consumption of 13.0 kWh/kg (DC). Other modern plants achieve about 13.4 kWh/kg [Frijlink, 2000]. From the energy input about 45% is lost as heat, both through the pot shell and through the anodes.
In the CBS energy statistics and in the Long Term Agreements on Energy Efficiency [Novem, 1996] the electricity consumption for electrolysis is labelled as non-energetic use.

Gas consumption in the primary aluminium smelters is relatively low, around 1.1 PJ, and it is mainly used for the casthouses, where produced aluminium is cast in slabs, and for the anode production.
The "prebaked" anodes are made by baking a mixture of petroleum coke, recycled anode butts and petroleum or coal tar at 1150 ^oC in a furnace. So the anodes have an embodied energy from the coke and tar and they require a certain amount of energy for processing. The anode *embodied* energy is found in the energy statistics as non-energetic use of coal and oil products, to a total amount of 2.95 PJ for 1995 [CBS, 1996]. The *processing* energy for the anodes is about 3.9 GJ of fuel[3] (mainly gas) and 0.4 GJe of electricity per ton of anode [Frijlink, 2000]. In the energy statistics this processing energy is only allocated to the non-ferrous sector in so far as the anodes are produced within the sector itself.
Regarding the Dutch plants it is known that Pechiney Vlissingen has an anode production capacity of 120 kt/y [Gielen and van Dril, 1997] for its own use but also for others, while Aldel purchases its anodes from other suppliers, like Aluchemie in Rotterdam (300 kt capacity). Process energy for anode production outside the non-ferrous sector (e.g.

[2] Because of the production in 1995 was limited to 75-80% of the nominal capacity, the specific electricity consumption – at least in the Pechiney plant – was relatively low. Under normal conditions the Pechiney plant operates at 13.6-13.8 kWh/kg **Frijlink, A (2000)**, *Energy use data Pechiney NL*, Manager Energy and Environment, Pechiney Nederland, Vlissingen, March 2000..
[3] This is considerably higher than the 2.2 GJ of fuel per ton of anode estimated for the US aluminium industry **Energetics, Inc (1997)**, *Energy and Environmental Profile of the U.S. Aluminum Industry*, DOE, Washington..

Aluchemie) is not included in the sector's energy data in tables 1 and 2, but may be found within the sector of chemical industry.

Function	Fuel cons. (PJ)	Electr. cons. (PJ_e)
electrolysis	0	11.1
anode production	3.3[a]	0.03
melting/holding	0.7	0.06
general facilities	0.1	0.70
Total	**4.1**	**11.9**

Table 2-1: Overview of energy use by function in primary aluminium production (1995)
a) Includes 2.95 PJ non-energetic use (anode consumption), energetic use is only 0.3 PJ.

2.2. Energy reduction options

Because the cost of energy in primary aluminium production are a substantial part of the total production costs there has always been a strong driving force for energy efficiency. Therefore there are relatively little "cheap" options with a large savings potential. However on the longer term there are some interesting technologies with a good savings potential.
We will first focus on the largest energy consumer, the electrolysis process.
One obvious measure is the modernisation of the electrolysis pots and implementation of *continuous point-feeding* of alumina [ICF Consulting, 2000, IDEE, 1999a]. In 1995 both aluminium plants used the older technology in which alumina is added a few times per day. The implementation of this measure also involves a more sophisticated computer control of the electrolysis process. The major advantage of continuous point-feeding is that it reduces the occurrence of the anode effect and thereby the emission of Per Fluoro Carbons (PFC's) from the pots. A secondary effect is the reduction of electricity consumption by 0.2-0.4 kWh/kg. Aldel introduced continuous feeding in 1998 as part of the "Retrofit" project for all of its 304 electrolysis pots. The company aims to achieve a reduction of the electricity consumption from the 15.0 kWh/kg figure for 1995 to 14.6-14.7 kWh/kg in the year 2000 when the new production equipment is fully optimised. Pechiney has performed a pilot scale project (on 8 out of the 504 pots) with continuous point-feeding in 1996-1997. This measure reduced the energy consumption with 0.2 kWh/kg in the involved pots. The pilot project has not yet been followed up by a renovation of all electrolysis pots. Together with additional savings on the ventilation the total energy savings for a full plant renovation is estimated at 1.0 GJe per ton Al, with a projected cost of 80 Mfl, or € 200 per ton of production capacity[4] [Frijlink, 2000, IDEE, 1999a].

Another measure which have might been considered in 1995 is a complete *renovation of the Aldel plant* bringing it to the state-of –the-art production technology Pechiney has available, with specific energy consumption of 13.3-13.4 kWh/kg. The energy savings would thus be 6 GJe/t and the measure would entail an estimated investment cost of 600-700 Mfl [Jacobs, 2000], or around 3000 € per ton production capacity. However, in view of the "Retrofit" operation at Aldel in 1998 actual implementation of this measure has now become unlikely. Therefore we will not include it as a measure within ICARUS.

A third measure is the *energetic optimisation of the electrolysis process*, i.e. optimisation to achieve lower energy consumption. In plants where this is done the energy use is reduced by about 0.3 kWh/kg, be it at the cost of reduced productivity. This approach is followed in some energy supply-constrained plants around the world. If we assume that the productivity loss is

[4] Note that these costs data are much higher than the estimate of $ 40/ton in an IEA study **ICF Consulting (2000)**, *Greenhouse Gas Emissions from the Aluminium Industry*, Report nr. PH3/23, IEA Greenhouse Gas R&D Programme, Washington.. We cannot explain this difference.

limited to 10% and assuming an aluminium price of 1500 €/t, the financial penalty would be around 150 €/t.

An option more on the longer term is the *lowering of the electrolyte temperature* by optimisation of the electrolyte composition. In the current practice electrolysis is performed at temperatures of 1220 K which is far above the melting point of aluminium (933 K). It has been estimated theoretically that a temperature reduction of 373 ^{o}C might save 1-1.5 kWh/kg, from the reduced heat loss alone [Sen, 1996]. Several approaches for temperature reduction are being investigated, with promising results from new additives for the electrolyte [Sen, 1996]. We will assume that this option becomes available in 2010, saves 0.7 kWh/kg and involves only extra operational costs of 75 €/t (=5% of the aluminium price).

A promising future technology on which much effort is now spent, is *inert anode* technology. With inert, dimensionally stable non-carbon anodes that are not consumed in the electrolytic process energy efficiency increases of 10-25% are expected [Aluminum Association, 1997, Aluminum Association and DOE/OIT, 1998, ICF Consulting, 2000]. The higher efficiencies will be achieved when the anode is combined with stable, wettable cathode. Fuel consumption would also be reduced as the anode baking facility is no longer required. Finally, non-carbon anodes would remove the source of carbon for PFC generation. Commercially viable inert anode designs are expected by 2020. We will assume no extra costs for inert anodes. *Wettable cathodes* alone also have the potential to increase energy efficiency because it allows the anode cathode distance to be reduced. The potential energy savings are estimated to be as high as 15-20 %, and introduction can be expected within the next 10 to 20 years [Anonymous, 1994, ICF Consulting, 2000]. We will assume that no extra costs are involved.

In the production of anodes the application of *enhanced furnace designs*, with recuperative or regenerative burners, may realise fuel savings of 30-50% at investment costs of 4-10 €/GJ/yr and O&M costs of 0.2 €/GJ [Caddet, 2000a, Flanagan, 1993, Worrell, Bode, 1997].

3. Primary zinc production

3.1. Sector description

Primary zinc production takes place at one location in the Netherlands (Budel), using an electrolysis process. In 1995 the energy requirement for electrolysis was about 3.6 kWh per kg zinc. Other facilities required 0.40 PJe of electricity and 0.46 PJ of natural gas. In the period 1995-1999 the energy requirement for electrolysis decreased by about 6%, an improvement which was partly due to optimisation of the electrolysis process. Furthermore a 20% reduction on gas consumption was achieved by process optimisation, waste heat utilisation and good housekeeping measures. The industry believes that they are close to the world top regarding their energy efficiency [Van den Elsen, 2000].
Apart from 210 kt of primary zinc the same factory also produces a small amount of cadmium (about 500 ton./yr). The energy use for this latter operation is included in the overall energy data. Furthermore there is an installation to clean up polluted groundwater[5]. This biological cleaning installation consumes some energy (for heating the groundwater to 25-30 ^{o}C), but it also provides opportunities to utilize low-temperature waste heat.
In the near future the zinc producer will switch over to a different type of ore in order to reduce the jarosite waste problem. It is not known what effects this operation will have on the energy efficiency.

Function	Fuel cons. (PJ)	Electr. cons. (PJ_e)
electrolysis	0	2.7
general facilities	0.5	0.4
Total	**0.5**	**3.1**

Table 3-1: Overview of energy use by function in primary zinc production (1995)

3.2. Energy reduction options

Between 1995 and 1999 a reduction of 6% was achieved on electrolysis energy consumption and about 25% on gas consumption. These savings are reflected in the measures *improved processs control '95-'99* and *Other measures '95-'99* defined below.

In the literature not much attention is given to efficiency improvements in primary zinc production. Work on improved anodes in Germany which was reported in previous ICARUS studies [Beer, Wees, 1994], was stopped due to lack of funding. The industry itself does not see any breakthrough technologies that could significantly improve the energy efficiency of the electrolysis process. The current efficiency is already around 93%, but some improvements may be achieved in reducing overvoltages by enhanced process monitoring and control, enhanced electrodes and by new additives [Van den Elsen, 2000].

We will assume that *improved process control* in the electrolysis can save 8% upto 2010 (6% in the period '95-'99 and 2% between 2000 and 2010) and another 3% after 2010. Probably no extra investment or O&M costs are required for this measure.
Optimisation of the compressed air supply can save some 28 TJp, or 3% of the electricity consumption for general facilities [Van den Elsen, 2000]. We estimate the cost of these measures at 5 €/(GJ/yr), which gives a simple Pay-Back Time of about 2 yr[6]. Other good

[5] At the production site there exists a soil pollution problem from zinc smelting operations in the past.
[6] For the primary non-ferro metal industry we assume a gas price of 3 €/GJ (f 0.22 /m^3) and an electricity price of 2.5 €/GJ_p (f 0.05 /kWh) for the base year 1995 **CBS (1996)**, *Nederlandse Energie Huishouding: jaarcijfers 1995*, CBS, Voorburg..

house keeping measures, mainly with regard to the steam supply, can save some 10 TJ of gas or 2% of the fuel consumption, at low costs, which we estimate at 2 €/(GJ/yr).

Various *measures to reduce heat losses* (extra insulation of process baths, optimisation of cooling water supply) can save 85 TJ of gas (18%). Another 20 TJ (4.5%) can be saved on gas consumption by *continuous dry zinc feeding*. Significant gas savings of 120 TJ (25%) can further be achieved by *utilisation of waste heat for the groundwater treatment plant* [Van den Elsen, 2000]. We estimate the pay back time of all these measures at 3 years, so that the investments cost would be about 9 €/(GJ/yr).
Also there is a possibility for installation of a gas engine for cogeneration. This unit might supply 6 TJ of heat and 13 TJe of electricity.

Finally we assume that *optimization of electric drives* (e.g. application of high efficiency motors or ASD's in pumps and fans, cf. section 2.2) can save 3% on the electricity consumption for general facilities at investment costs of 5 €/(GJ/yr). The pay-back time of this measure would be 2 yrs.

4. Secondary aluminium production

4.1. Sector description

Secondary aluminium production is a fast growing activity which in 1995 almost equalled primary aluminium production with a production of 190 ton secondary aluminium. The energy consumption is only 5-10% of that for the primary metal since it involves remelting of the metal instead of electrochemical reduction. Distinction has to be made between post-consumer scrap, e.g. used beverage cans, and industrial scrap. Post consumer scrap needs pretreatment (delacquering, sorting) before it can be remelted. U.S. data indicate that pretreatment requires about 0.1 MJ/kg of electricity and 1.3 MJ/kg of fuel [Energetics, 1997]. The same source estimates secondary melting and refining energy requirements at 0.5 MJe/kg of electricity and 4.4 MJ/kg of fuel.

In the Netherlands about 30% of secondary smelter capacity is capable of processing very lightly polluted scrap [Gielen and van Dril, 1997]. Part of this capacity is located at the primary aluminium plants which remelted some 40 kt of industrial aluminium scrap in 1995. We assume that the average fuel consumption (gas) in the sector is 5 GJ/ton of which 80% is used for melting, 10% for scrap pretreatment and 10% for space heating and other general facilities.

4.2. Energy reduction options

In secondary aluminium production *new decoating equipment* (IDEX) has been demonstrated which employs a indirect-fired kiln and uses the heating value of released VOC's and which preheats the scrap to 480 ^{o}C before it goes into the melting furnace. This equipment can save up to 100% on fuel consumption for scrap pretreatment and probably about 50% on furnace energy consumption [Caddet, 2000a]. We estimate the extra investment cost at € 40 per ton of aluminium processing capacity. The extra revenues from increased productivity are also about € 40/ton.

We will assume that sector-wide this kind of technology can save 50% on fuel costs for scrap pretreatment at € 30/ton. Furthermore we will assume that one can realise 10% savings on melting energy by using waste heat for *scrap preheating* at a cost of € 10 /GJ/yr.

Other important improvements concern the application of *enhanced furnace designs*, with recuperative or regenerative burners, realising fuel savings of 30-50% at investment costs of 4-10 €/GJ/yr and O&M costs of 0.2 €/GJ [Caddet, 2000a, Flanagan, 1993, Worrell, Bode, 1997].

5. Non-ferrous metals casting

5.1. Sector description

Apart from the foundries found at primary metal producers, there is about 20 kt of non-ferrous foundry capacity at other locations in the Netherlands. These are usually smaller plants, the largest having a 4 kt/y capacity. The main consumer of cast aluminium is probably the automobile industry. We estimate the specific electricity consumption in this sector at 10 MJe/kg and the fuel consumption at 16 MJ/kg. We estimate furthermore that 50% of the electricity and 75% of the fuel is used for melting and holding the metals [ETSU and EVE, 1994].
Notable is that in non-ferrous casting the yield, that is the weight ratio of saleable castings to the melted metal, is relatively low, around 50%.

5.2. Energy reduction options

In the non-ferrous foundry sector most energy is consumed in the melting of the metal and also in holding the metal in a liquid state. *Improved process scheduling* can therefore reduce holding losses. Savings up to 15% at costs around € 10 /GJ/yr have been estimated [ETSU, 1994]. Other important improvements concern the application of *enhanced furnace designs*, with recuperative or regenerative burners, realising fuel savings of 30-50% at investment costs of 4-10 €/GJ/yr and O&M costs of 0.2 €/GJ [Flanagan, 1993, Worrell, Bode, 1997].
A final interesting option is the *use of liquid aluminium* instead of solid ingots. In a Dutch demonstration project the liquid aluminium was transported from the primary metal producer to the foundry in special containers which minimise heat losses. As a result the consumption of natural gas for the melting furnace was reduced to zero. Total savings of 60-70% of the current energy consumption were realised [IDEE, 1999c].

6. Non-ferrous metal forming

6.1. Sector description

Apart from casting, metals may be formed into semifabricates by extrusion, yielding metal pipes, bars and rods, or by rolling, producing metal sheets and foils. In 1993 about 100 kt was extruded and 50 kt was rolled in the Netherlands [Gielen and van Dril, 1997]. Both type of processes can be done with either cold or hot metal resulting in different material properties. Based on US data [Energetics, 1997] we estimate the average specific energy requirement for extrusion at 2.2 MJe/kg and 4.8 MJ/kg fuel, while for rolling it is somewhat lower: 1.4 MJe/kg and 2.5 MJ/kg fuel. We will assume that 80% of the fuel use is for heating the metals prior to extruding or rolling or for other heat treatments.

6.2. Energy reduction options

Two near-term reduction options can be discerned: improved furnaces and charge preheating, often in combination with each other [IDEE, 1999b]. An improved furnace has shown a 65% energy saving in one aluminium extrusion company. Charge preheating with waste heat may save another 20%.
On the longer term the adoption of continuous strip casting instead of the current preheat/rolling route may save up to 35% [ETSU, 1994]. In extrusion the Conform and Castex Conform processes, which allows continuous production of extruded product without preheating, seem promising. Estimated energy savings are 20% and also savings on O&M costs are expected.

7. Sector-wide energy reduction options

We think that for the whole sector, with the exception of the primary metals production, a fair efficiency improvement can be realised at low costs by *monitoring and targeting* of energy consumption and material yields. We will assume that 5% improvement can be achieved up to 2010 and an additional 3% in the period 2010-2020.

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Appendix A: Presentation of energy saving measures

Energy saving measures are presented in this report using a standard format, shown in **Error! Reference source not found.**. The first column gives the name of the information item. The second column specifies the value of this information item. The third column is for comments.

Table A-0-1 Standard format for presenting energy saving measures

Name of measure	reduced temperature of electrolyte	
(sub)sector code	SBI 27.42a Primary aluminium production	
Energy function	Electrolysis	
Savings electricity	2.5 GJe/t Aluminium	Uncertainty: [1.3-3.0] Reliability: medium Source: 1,5,3,4
Savings fuel/heat		Uncertainty: Reliability: Source:
Type of measure	Retrofit	
Measure category	2	
First year of implementation	2010	
Current penetration (1995)	0%	Uncertainty: - Reliability: high Source: 6,1,10,4
Penetration 1999	0%	
Technical maximum penetration	100%	
Additional investments	€ 0 /t Al	Uncertainty: [0-25] Reliability: low Source: 6,8,10,4
Additional O&M costs	€ 75 /t Al	Uncertainty: [0-150] Reliability: low Source: 6,8,10,4
Other costs/benefits		
Economic lifetime	-	
Implementation characteristics	1,0,P,0,H,M	

Explanation to some of the items in this table:

NUSAP notes
NUSAP (Numeral, Unit, Spread, Assessment, Pedigree) is a notation system developed by Functovitz and Ravetz [Funtowitz and Ravetz, 1990] for presenting the quality of data. Not only the number and unit of the number given but also information on uncertainty, reliability and the pedigree of the data is given. For some of the data in the table NUSAP information is given (where possible). The following conventions are used:
Uncertainty is represented by ± x% or by [lower bound, upper bound]. The real value should be in this interval with 90% certainty.
Reliability is represented by L (=Low), M (= Medium) or H (= High)
Source is given with 4 numbers (Origin, Type, Method, Verification), as shown in the following table.

Origin	**Type**
1. from reviewed literature 2. other public source 3. non-public source 4. written personal information from expert 5. oral personal information from expert 6. own estimate	1. data for many companies/installations 2. data from one realised demonstration project 3. data from one project, not a demonstration project 4. data from design-study 5. data from R&D results 6. data from good comparable situations 7. data from possibly comparable situations 8. target data
Method:	**Verification:**
1. theoretical deduction 2. directly taken from source, without calculations 3. directly taken from source, only unit conversion 4. taken from source, minor adjustment 5. taken from source, major adjustment 6. generalisation based on specific situation 7. own calculation based on statistical data 8. own calculation based on other data 9. expert estimate 10. own estimate	1. verified by (other) expert 2. internally verified 3. compared with other studies/situations 4. unverified.

(sub)sector code
Here the Dutch three-digit SBI-93 (SBI = Standaard Bedrijfs Indeling) sector code is specified. This code is equivalent with the NACE Rev. 1 code (NACE=Nomenclature générale des Activité économiques dans les Communautés Européennes).

Savings electricity/fuel/heat
Savings presented are savings on the energy used for the energy function mentioned. A negative sign means that an extra amount of this energy carrier is needed in order to achieve saving of the other energy carrier.

Type of measure
Three values are possible here: *New*, *retrofit* or *good housekeeping*.
New means that the measure will only be applied when production capacity is expanded or replaced at the end of the economic lifetime
Retrofit means that changes are made to existing installations
Good housekeeping means that procedures are in effect that prevent unnecessary losses of energy (e.g., reduction of uncontrolled ventilation in buildings). In theory this type of measure is considered reversible, which means that during low energy prices less attention is payed to good housekeeping.
Closure means that the plant or installation will be closed down.

Measure category
One of the following values, based upon a taxonomy of energy efficiency measures by De Beer et al. (1996):

1. Good housekeeping
2. Process control and management
3. Reduction of heat losses through surfaces

4. Heat recovery
5. Process integration
6. Energy recovery other than heat
7. Improved lighting
8. Reduction of friction losses during movement
9. More efficient conversion of electricity in movement
10. New process technologies
11. More efficient kilns and burners
12. More efficient conversion of fuel to work

Additional investments/O&M costs
These can be expressed either in Euro (€) per gigajoule (GJ) primary energy saved per year or in € per ton throughput. Actually an approximation is used when these items are expressed in terms of primary energy savings: electricity saved is converted to primary energy saved using an electric power generation efficiency of 40%[7]. No conversion factors are used for fuels and heat. Subsidies will not be considered.

Economic lifetime
The economic lifetime is the time during which the capital goods involved with the measure is actually used. Usually the economic lifetime is shorter than the technical lifetime (e.g., because O&M costs increase above an acceptable level or new developments make it attractive to replace existing equipment). The economic lifetime can be longer than the fiscal depreciation period.

Implementation characteristics
Seven values with the following meaning:
1. Core production process. The measure affects the core production process (1=yes, 0=no)
2. Standard or customised technology (1=standard, 0 = customised)
3. Technical implementation (P = during production, M = during maintenance, S = during production stop)
4. Side effects (+=positive, 0=neutral, - = negative)
5. Cost uncertainty (H = High, M = Medium, L = Low)
6. Energy savings uncertainty (H = High, M = Medium, L = Low)
7. Production uncertainty (H = High, M = Medium, L= Low)

[7] This efficiency is used for the calculation of additional investments and O&M costs only. It does not mean that the actual efficiency for any year is set to this value.

Appendix B: Tables with energy saving measures

Primary Aluminium

Table B- 1: Point feeding of electrolysis pots at Aldel

Name of measure	Point feeding of electrolysis pots at Aldel	
(sub)sector code	SBI 2742a Primary Aluminium	
Energy function	Electrolysis	
Savings electricity	1.4 GJ/ton Al	Uncertainty: 15 % Reliability: H Source: (2,4,3,1)
Savings fuel	0 GJ/ton Al	Uncertainty: Reliability: Source:
Savings heat	0 GJ/ton Al	Uncertainty: Reliability: Source:
Type of measure	New	
Measure category	2. Process control and management	
First year of implementation	1998	
Penetration base year (1995)	0 %	Uncertainty: Reliability: Source:
Current penetration (1999)	20 %	
Technical maximum penetration	40 %	Only for Aldel facility
Additional investments	€ 200 /ton Al	Uncertainty: 20 % Reliability: M Source: (4,7,3,4)
Additional O&M costs	€ 0 /ton Al	Uncertainty: Reliability: Source:
Economic lifetime	20 year	
Implementation Char	1/0/P/+/L/L/M	

Table B- 2: Point feeding of electrolysis pots at Pechiney

Name of measure	Point feeding of electrolysis pots at Pechiney	
(sub)sector code	SBI 2742a Primary Aluminium	
Energy function	Electrolysis	
Savings electricity	0.7 GJ/ton Al	Uncertainty: 15 % Reliability: H Source: (2,2,3,1)
Savings fuel	0 GJ/ton Al	Uncertainty: Reliability: Source:
Savings heat	0 GJ/ton Al	Uncertainty: Reliability: Source:
Type of measure	New	
Measure category	2. Process control and management	
First year of implementation	2000	
Penetration base year (1995)	0 %	Uncertainty: 0 % Reliability: H Source: (2,0,0,0)
Current penetration (1999)	1 %	
Technical maximum penetration	60 %	Only for Pechiney facility
Additional investments	€ 200 /ton Al	Uncertainty: 10 % Reliability: H Source: (4,4,3,4)
Additional O&M costs	€ 0 /ton Al	Uncertainty: Reliability: Source:
Economic lifetime	20 year	
Implementation Char	1/0/P/+/L/L/M	

Table B- 3: Energetic optimization of electrolysis process

Name of measure	Energetic optimization of electrolysis process	
(sub)sector code	SBI 2742a Primary Aluminium	
Energy function	Electrolysis	
Savings electricity	1 GJ/ton Al	Uncertainty: 25 % Reliability: H Source: (5,1,3,4)
Savings fuel	0 GJ/ton Al	Uncertainty: Reliability: Source:
Savings heat	0 GJ/ton Al	Uncertainty: Reliability:

		Source:
Type of measure	Good housekeeping	
Measure category	2. Process control and management	
First year of implementation	1995	
Penetration base year (1995)	0 %	Uncertainty: 0 % Reliability: H Source: (6,1,10,4)
Current penetration (1999)	0 %	
Technical maximum penetration	100 %	
Additional investments	€ 150 /ton Al	10% prod. loss @ € 1500/ton Uncertainty: 30% Reliability: M Source: (6,0,0,4)
Additional O&M costs	€ 0 /ton Al	Uncertainty: Reliability: Source:
Economic lifetime	20 year	
Implementation Char	1/0/P/-/M/L/M	

Table B- 4: Reduced temperature of electrolyte

Name of measure	Reduced temperature of electrolyte	
(sub)sector code	SBI 2742a Primary Aluminium	
Energy function	Electrolysis	
Savings electricity	2.5 GJ/ton Al	Uncertainty: 50 % Reliability: M Source: (1,5,3,1)
Savings fuel	0 GJ/ton Al	Uncertainty: Reliability: Source:
Savings heat	0 GJ/ton Al	Uncertainty: Reliability: Source:
Type of measure	Retrofit	
Measure category	2. Process control and management	
First year of implementation	2010	
Penetration base year (1995)	0 %	Uncertainty: 0 % Reliability: H Source: (0,0,0,0)
Current penetration (1999)		
Technical maximum penetration	100 %	
Additional investments	€ 0 /ton Al	Uncertainty: [0 ,25] Reliability: L Source: (6,8,10,4)
Additional O&M costs	€ 75 /ton Al	Uncertainty: [0 ,150] Reliability: L Source: (6,8,10,4)

Economic lifetime	10 year	
Implementation Char	1/0/P/0/H/M/M	

Table B- 5: Wettable cathodes

Name of measure	Wettable cathodes	
(sub)sector code	SBI 2742a Primary Aluminium	
Energy function	Electrolysis	
Savings electricity	10 %	Uncertainty: 50 % Reliability: M Source: (2,5,2,1)
Savings fuel	0 %	Uncertainty: Reliability: Source:
Savings heat	0 %	Uncertainty: Reliability: Source:
Type of measure	Retrofit	
Measure category	10. New process technologies	
First year of implementation	2010	
Penetration base year (1995)	0 %	Uncertainty: 0 % Reliability: H Source: (0,0,0,0)
Current penetration (1999)	0 %	
Technical maximum penetration	100 %	
Additional investments	€ 0 /ton Al	Uncertainty: [0 ,25] Reliability: M Source: (6,8,10,4)
Additional O&M costs	€ 0 /ton Al	Uncertainty: [0 ,5] Reliability: H Source: (6,8,10,4)
Economic lifetime	2 year	
Implementation Char	1/ /S/+/H/M/M	

Table B- 6: Inert anodes and wettable cathodes

Name of measure	Inert anodes and wettable cathodes	
(sub)sector code	SBI 2742a Primary Aluminium	
Energy function	Electrolysis	
Incompatible measures	Energetic optimization of electrolysis process Reduced temperature of electrolyte Wettable cathodes	
Savings electricity	25 %	Uncertainty: 50 % Reliability: M Source: (1,8,2,1)

Savings fuel	0 %	Uncertainty: Reliability: Source:
Savings heat	0 %	Uncertainty: Reliability: Source:
Type of measure	New	
Measure category	10. New process technologies	
First year of implementation	2020	
Penetration base year (1995)	0 %	Uncertainty: Reliability: Source:
Current penetration (1999)	0 %	
Technical maximum penetration	100 %	
Additional investments	€ 0 /ton Al	Uncertainty: [0 ,10] Reliability: M Source: (6,8,10,4)
Additional O&M costs	€ 0 /ton Al	Uncertainty: [0 ,5] Reliability: M Source: (6,8,10,4)
Economic lifetime	20 year	
Implementation Char	1/0/S/+/H/H/M	

Table B- 7: Inert anodes (stopping of anode prod.)

Name of measure	Inert anodes (stopping of anode prod.)	Conventional anode baking facility can be closed down
(sub)sector code	SBI 2742a Primary Aluminium	
Energy function	Anode production	
Incompatible measures	Enhanced furnaces 1995 Enhanced furnaces 2010	
Savings electricity	100 %	Uncertainty: 0 % Reliability: H Source: (6,8,10,4)
Savings fuel	100 %	Uncertainty: 0 % Reliability: H Source: (6,8,10,4)
Savings heat	0 %	Uncertainty: Reliability: Source:
Type of measure	Closure	
Measure category	10. New process technologies	
First year of implementation	2020	
Penetration base year (1995)	0 %	Uncertainty: Reliability: Source:
Current penetration (1999)	0 %	
Technical maximum penetration	100 %	including non-energetic cons. (anode material)

Additional investments	€ 0 /ton anodes	Uncertainty: 0 % Reliability: H Source: (6,8,10,4)
Additional O&M costs	€ 0 /ton anodes	Uncertainty: 0 % Reliability: H Source: (6,8,10,4)
Economic lifetime	20 year	
Implementation Char	1/1/S/+/L/L/L	

Table B- 8: Enhanced furnaces 1995

Name of measure	Enhanced furnaces 1995	
(sub)sector code	SBI 2742a Primary Aluminium	
Energy function	Anode production	
Savings electricity	0 %	Uncertainty: Reliability: Source:
Savings fuel	30 %	Uncertainty: 30 % Reliability: M Source: (2,1,2,3)
Savings heat	0 %	Uncertainty: Reliability: Source:
Type of measure	New	
Measure category	11. More efficient furnaces and burners	
First year of implementation	1995	
Penetration base year (1995)	0 %	Uncertainty: [0 ,20] Reliability: M Source: (6,0,10,4)
Current penetration (1999)	0 %	
Technical maximum penetration	10 %	Not for anode material (non-energetic consumption)
Additional investments	€ 10 /(GJ/yr)	Uncertainty: 30 % Reliability: M Source: (2,1,3,4)
Additional O&M costs	€ 0.2 /GJ	Uncertainty: 20 % Reliability: M Source: (2,1,3,4)
Economic lifetime	20 year	
Implementation Char	1/0/S/0/L/M/L	

Table B- 9: Enhanced furnaces 2010

Name of measure	Enhanced furnaces 2010	
(sub)sector code	SBI 2742a Primary Aluminium	
Energy function	Anode production	
Savings electricity	0 %	Uncertainty: Reliability: Source:

Savings fuel	50 %	Uncertainty: 30 % Reliability: M Source: (2,1,2,3)
Savings heat	0 %	Uncertainty: Reliability: Source:
Type of measure	New	
Measure category	11. More efficient furnaces and burners	
First year of implementation	2010	
Penetration base year (1995)	0 %	Uncertainty: 0 % Reliability: H Source: (6,0,10,4)
Current penetration (1999)	0 %	
Technical maximum penetration	10 %	Not for anode material (non-energetic consumption)
Additional investments	€ 4 /(GJ/yr)	Uncertainty: 30 % Reliability: M Source: (2,1,3,4)
Additional O&M costs	€ 0.1 /GJ	Uncertainty: 20 % Reliability: M Source: (2,1,3,4)
Economic lifetime	20 year	
Implementation Char	1/0/S/0/L/M/L	

Primary zinc

Table B- 10: Improved process control '95-'99

Name of measure	Improved process control '95-'99	
(sub)sector code	SBI 2743 Primary Zinc	
Energy function	Electrolysis	
Savings electricity	6 %	Uncertainty: 0 % Reliability: H Source: (4,2,3,4)
Savings fuel	0 %	Uncertainty: Reliability: Source:
Savings heat	0 %	Uncertainty: Reliability: Source:
Type of measure	Good housekeeping	
Measure category	2. Process control and management	
First year of implementation	1995	
Penetration base year (1995)	0 %	Uncertainty: Reliability: Source:
Current penetration (1999)	100 %	
Technical maximum penetration	100 %	
Additional investments	€ 0 /ton zinc	Uncertainty: Reliability: Source:
Additional O&M costs	€ 0 /ton zinc	Uncertainty: 50 % Reliability: M Source: (6,8,10,4)
Economic lifetime	10 year	
Implementation Char	1/0/P/0/L/M/L	

Table B- 11: Other measures '95-'99

Name of measure	Other measures '95-'99	
(sub)sector code	SBI 2743 Primary Zinc	
Energy function	Facilities	
Savings electricity	0 %	Uncertainty: Reliability: Source:
Savings fuel	25 %	Uncertainty: 0 % Reliability: H Source: (4,2,2,4)
Savings heat	0 %	Uncertainty: Reliability: Source:
Type of measure	Good housekeeping	
Measure category	2. Process control and	

	management	
First year of implementation	1995	
Penetration base year (1995)	0 %	Uncertainty: Reliability: Source:
Current penetration (1999)	100 %	
Technical maximum penetration	100 %	
Additional investments	€ 2 /(GJ/yr)	Uncertainty: Reliability: Source:
Additional O&M costs	€ 0 /GJ	Uncertainty: Reliability: Source:
Economic lifetime	10 year	
Implementation Char	0/ /P/0/M/M/L	

Table B- 12: Improved process control 2000-2010

Name of measure	Improved process control 2000-2010	
(sub)sector code	SBI 2743 Primary Zinc	
Energy function	Electrolysis	
Savings electricity	2 %	Uncertainty: [0 ,6] Reliability: H Source: (6,8,10,4)
Savings fuel	0 %	Uncertainty: Reliability: Source:
Savings heat	0 %	Uncertainty: Reliability: Source:
Type of measure	Good housekeeping	
Measure category	2. Process control and management	
First year of implementation	2000	
Penetration base year (1995)	0 %	Uncertainty: Reliability: Source:
Current penetration (1999)	0 %	
Technical maximum penetration	100 %	
Additional investments	€ 0 /ton zinc	Uncertainty: Reliability: Source:
Additional O&M costs	€ 0 /ton zinc	Uncertainty: Reliability: Source:
Economic lifetime	10 year	
Implementation Char	1/0/P/0/M/M/L	

Table B- 13: Improved process control 2010-2020

Name of measure	Improved process control 2010-2020	
(sub)sector code	SBI 2743 Primary Zinc	
Energy function	Electrolysis	
Savings electricity	3 %	Uncertainty: [0 ,6] Reliability: H Source: (6,8,10,4)
Savings fuel	0 %	Uncertainty: Reliability: Source:
Savings heat	0 %	Uncertainty: Reliability: Source:
Type of measure	Good housekeeping	
Measure category	2. Process control and management	
First year of implementation	2010	
Penetration base year (1995)	0 %	Uncertainty: Reliability: Source:
Current penetration (1999)	0 %	
Technical maximum penetration	100 %	
Additional investments	€ 0 /ton zinc	Uncertainty: Reliability: Source:
Additional O&M costs	€ 0 /ton zinc	Uncertainty: Reliability: Source:
Economic lifetime	10 year	
Implementation Char	1/0/P/0/M/M/L	

Table B- 14: Optimisation of compressed air supply

Name of measure	Optimisation of compressed air supply	
(sub)sector code	SBI 2743 Primary Zinc	
Energy function	Facilities	
Savings electricity	3 %	Uncertainty: 20 % Reliability: H Source: (4,8,9,4)
Savings fuel	0 %	Uncertainty: Reliability: Source:
Savings heat	0 %	Uncertainty: Reliability: Source:
Type of measure	Good housekeeping	
Measure category	1. Good Housekeeping	
First year of implementation	2000	
Penetration base year (1995)	0 %	Uncertainty:

		Reliability: Source:
Current penetration (1999)	0 %	
Technical maximum penetration	100 %	
Additional investments	€ 5 /(GJ/yr)	Uncertainty: 30 % Reliability: M Source: (6,6,10,4)
Additional O&M costs	€ 0 /GJ	Uncertainty: Reliability: Source:
Economic lifetime	10 year	
Implementation Char	0/0/P/0/L/M/L	

Table B- 15: Optimisation of steam supply

Name of measure	Optimisation of steam supply	
(sub)sector code	SBI 2743 Primary Zinc	
Energy function	Facilities	
Savings electricity	0 %	Uncertainty: Reliability: Source: (0,0,0,0)
Savings fuel	2 %	Uncertainty: 20 % Reliability: H Source: (5,8,4,4)
Savings heat	0 %	Uncertainty: Reliability: Source:
Type of measure	Good housekeeping	
Measure category	1. Good Housekeeping	
First year of implementation	2000	
Penetration base year (1995)	0 %	Uncertainty: Reliability: Source:
Current penetration (1999)	0 %	
Technical maximum penetration	100 %	
Additional investments	€ 2 /(GJ/yr)	Uncertainty: Reliability: M Source: (4,8,5,4)
Additional O&M costs	€ 0 /GJ	Uncertainty: Reliability: Source:
Economic lifetime	20 year	
Implementation Char	0/0/P/0/L/L/L	

Table B- 16: Reduction of heat losses

Name of measure	Reduction of heat losses	
(sub)sector code	SBI 2743 Primary Zinc	
Energy function	Facilities	
Savings electricity	0 %	Uncertainty:

		Reliability: Source:
Savings fuel	18 %	Uncertainty: 20 % Reliability: H Source: (5,8,4,4)
Savings heat	0 %	Uncertainty: Reliability: Source:
Type of measure	Retrofit	
Measure category	3. Reduction of heat losses through surfaces	
First year of implementation	2000	
Penetration base year (1995)	0 %	Uncertainty: Reliability: Source:
Current penetration (1999)	0 %	
Technical maximum penetration	100 %	
Additional investments	€ 9 /(GJ/yr)	Uncertainty: 30 % Reliability: M Source: (5,8,5,4)
Additional O&M costs	€ 0 /GJ	Uncertainty: Reliability: Source:
Economic lifetime	20 year	
Implementation Char	1/ /M/0/M/L/L	

Table B- 17: Continuous dry zinc feeding

Name of measure	Continuous dry zinc feeding	
(sub)sector code	SBI 2743 Primary Zinc	
Energy function	Facilities	
Savings electricity	0 %	Uncertainty: Reliability: Source:
Savings fuel	4.5 %	Uncertainty: 20 % Reliability: H Source: (5,8,4,4)
Savings heat	0 %	Uncertainty: Reliability: Source:
Type of measure	Retrofit	
Measure category	2. Process control and management	
First year of implementation	2000	
Penetration base year (1995)	0 %	Uncertainty: Reliability: Source:
Current penetration (1999)	0 %	
Technical maximum penetration	100 %	
Additional investments	€ 9 /(GJ/yr)	Uncertainty: 30 % Reliability: M

		Source: (5,7,5,3)
Additional O&M costs	€ 0 /GJ	Uncertainty: Reliability: Source:
Economic lifetime	20 year	
Implementation Char	1/ /S/0/L/L/M	

Table B- 18: Waste heat utilisation for ground water treatment

Name of measure	Waste heat utilisation for ground water treatment	
(sub)sector code	SBI 2743 Primary Zinc	
Energy function	Facilities	
Savings electricity	0 %	Uncertainty: Reliability: Source:
Savings fuel	25 %	Uncertainty: 10 % Reliability: H Source: (5,4,4,4)
Savings heat	0 %	Uncertainty: Reliability: Source:
Type of measure	Retrofit	
Measure category	4. Heat recovery	
First year of implementation	2000	
Penetration base year (1995)	0 %	Uncertainty: Reliability: Source:
Current penetration (1999)	0 %	
Technical maximum penetration	100 %	
Additional investments	€ 9 /(GJ/yr)	Uncertainty: 20 % Reliability: M Source: (5,4,5,4)
Additional O&M costs	€ 0 /GJ	Uncertainty: Reliability: Source:
Economic lifetime	20 year	
Implementation Char	0/0/P/0/L/L/L	

Table B- 19: Optimisation of electric drives

Name of measure	Optimisation of electric drives	
(sub)sector code	SBI 2743 Primary Zinc	
Energy function	Facilities	
Savings electricity	3 %	Uncertainty: 50 % Reliability: L Source: (6,8,10,4)
Savings fuel	0 %	Uncertainty: Reliability: Source:

Savings heat	0 %	Uncertainty: Reliability: Source:
Type of measure	Retrofit	
Measure category		
First year of implementation	2000	
Penetration base year (1995)	0 %	Uncertainty: Reliability: Source:
Current penetration (1999)	0 %	
Technical maximum penetration	100 %	
Additional investments	€ 5 /(GJ/yr)	Uncertainty: 30 % Reliability: M Source: (2,6,5,4)
Additional O&M costs	€ 0 /GJ	Uncertainty: Reliability: Source:
Economic lifetime	10 year	
Implementation Char	0/ /P/0/M/L/L	

Secondary aluminium

Table B- 20: Enhanced decoating equipment

Name of measure	Enhanced decoating equipment	
(sub)sector code	SBI 2742b Secondary Aluminium	
Energy function	Scrap pretreatment	
Savings electricity	0 %	Uncertainty: Reliability: Source:
Savings fuel	50 %	Uncertainty: 30 % Reliability: M Source: (6,2,4,4)
Savings heat	0 %	Uncertainty: Reliability: Source:
Type of measure	New	
Measure category	6. Energy recovery other than heat	
First year of implementation	2000	
Penetration base year (1995)	0 %	Uncertainty: Reliability: Source:
Current penetration (1999)		
Technical maximum penetration	30 %	
Additional investments	€ 40 /ton Al	Uncertainty: 20 % Reliability: M Source: (2,2,5,4)
Additional O&M costs	€ 0 /ton Al	Uncertainty: Reliability: Source:
Other benefits	€ 40 /ton Al	increased productivity
Economic lifetime	20 year	
Implementation Char	1/ /S/+/M/M/L	

Table B- 21: Scrap preheating with waste heat

Name of measure	Scrap preheating with waste heat	
(sub)sector code	SBI 2742b Secondary Aluminium	
Energy function	Melting	
Savings electricity	0 %	Uncertainty: Reliability: Source:
Savings fuel	10 %	Uncertainty: 50 % Reliability: M Source: (2,2,6,4)
Savings heat	0 %	Uncertainty:

		Reliability: Source:
Type of measure	Retrofit	
Measure category	4. Heat recovery	
First year of implementation	1995	
Penetration base year (1995)	0 %	Uncertainty: [0 ,10] Reliability: H Source: (0,0,0,0)
Current penetration (1999)		
Technical maximum penetration	50 %	
Additional investments	€ 10 /(GJ/yr)	Uncertainty: 70 % Reliability: L Source: (6,0,0,4)
Additional O&M costs	€ 0 /GJ	Uncertainty: Reliability: Source:
Economic lifetime	20 year	
Implementation Char	/ /S/0/H/M/L	

Table B- 22: Enhanced furnaces 1995

Name of measure	Enhanced furnaces 1995	
(sub)sector code	SBI 2742b Secondary Aluminium	
Energy function	Melting	
Savings electricity	0 %	Uncertainty: Reliability: Source:
Savings fuel	30 %	Uncertainty: 30 % Reliability: M Source: (2,1,2,3)
Savings heat	0 %	Uncertainty: Reliability: Source:
Type of measure	New	
Measure category	11. More efficient furnaces and burners	
First year of implementation	1995	
Penetration base year (1995)	0 %	Uncertainty: [0 ,20] Reliability: M Source: (6,0,10,4)
Current penetration (1999)		
Technical maximum penetration	100 %	
Additional investments	€ 10 /(GJ/yr)	Uncertainty: 30 % Reliability: M Source: (2,1,3,4)
Additional O&M costs	€ 0.2 /GJ	Uncertainty: 20 % Reliability: M Source: (2,1,3,4)
Economic lifetime	20 year	
Implementation Char	1/0/S/0/L/M/L	

Table B- 23: Enhanced furnaces 2010

Name of measure	Enhanced furnaces 2010	
(sub)sector code	SBI 2742b Secondary Aluminium	
Energy function	Melting	
Savings electricity	0 %	Uncertainty: Reliability: Source:
Savings fuel	50 %	Uncertainty: 30 % Reliability: M Source: (2,1,2,3)
Savings heat	0 %	Uncertainty: Reliability: Source:
Type of measure	New	
Measure category	11. More efficient furnaces and burners	
First year of implementation	2010	
Penetration base year (1995)	0 %	Uncertainty: 0 % Reliability: H Source: (6,0,10,4)
Current penetration (1999)		
Technical maximum penetration	100 %	
Additional investments	€ 4 /(GJ/yr)	Uncertainty: 30 % Reliability: M Source: (2,1,3,4)
Additional O&M costs	€ 0.1 /GJ	Uncertainty: 20 % Reliability: M Source: (2,1,3,4)
Economic lifetime	20 year	
Implementation Char	1/0/S/0/L/M/L	

Table B- 24: monitoring and targeting

Name of measure	monitoring and targeting	
(sub)sector code	SBI 2742b Secondary Aluminium	
Energy function	All	
Savings electricity	5 %	Uncertainty: [3 ,8] Reliability: M Source: (6,0,0,4)
Savings fuel	5 %	Uncertainty: [3 ,8] Reliability: M Source: (6,0,0,4)
Savings heat	0 %	Uncertainty: Reliability: Source:
Type of measure	Good housekeeping	
Measure category	1. Good Housekeeping	

First year of implementation	1995	
Penetration base year (1995)	0 %	Uncertainty: Reliability: Source:
Current penetration (1999)		
Technical maximum penetration	100 %	
Additional investments	€ 1 /(GJ/yr)	Uncertainty: [0 ,3] Reliability: M Source: (6,0,0,4)
Additional O&M costs	€ 0 /GJ	Uncertainty: Reliability: Source:
Economic lifetime	10 year	
Implementation Char	0/1/P/0/L/M/L	

Table B- 25: monitoring and targeting 2010

Name of measure	monitoring and targeting 2010	
(sub)sector code	SBI 2742b Secondary Aluminium	
Energy function	All	
Savings electricity	8 %	Uncertainty: [5 ,11] Reliability: M Source: (6,0,0,4)
Savings fuel	8 %	Uncertainty: [5 ,11] Reliability: M Source: (6,0,0,4)
Savings heat	0 %	Uncertainty: Reliability: Source:
Type of measure	Good housekeeping	
Measure category	1. Good Housekeeping	
First year of implementation	2010	
Penetration base year (1995)	0 %	Uncertainty: Reliability: Source:
Current penetration (1999)	0 %	
Technical maximum penetration	100 %	
Additional investments	€ 1 /(GJ/yr)	Uncertainty: [0 ,3] Reliability: M Source: (6,0,0,4)
Additional O&M costs	€ 0 /GJ	Uncertainty: Reliability: Source:
Economic lifetime	10 year	
Implementation Char	0/1/P/0/L/M/L	

Non-ferrous metal casting

Table B- 26: Liquid aluminium as feedstock

Name of measure	Liquid aluminium as feedstock	
(sub)sector code	SBI 2753-4 NF metal casting	
Energy function	Melting/holding	
Savings electricity	0 %	Uncertainty: Reliability: Source:
Savings fuel	30 %	Uncertainty: [20 ,50] Reliability: M Source: (2,2,3,4)
Savings heat	0 %	Uncertainty: Reliability: Source:
Type of measure	New	
Measure category	4. Heat recovery	
First year of implementation	2000	
Penetration base year (1995)	0 %	Uncertainty: Reliability: Source:
Current penetration (1999)	5 %	
Technical maximum penetration	50 %	
Additional investments	€ 5 /(GJ/yr)	Uncertainty: Reliability: M Source: (2,2,3,4)
Additional O&M costs	€ 0 /GJ	Uncertainty: Reliability: Source:
Economic lifetime	20 year	
Implementation Char	1/ /S/0/M/L/M	

Table B- 27: Enhanced furnaces 1995

Name of measure	Enhanced furnaces 1995	
(sub)sector code	SBI 2753-4 NF metal casting	
Energy function	Melting/holding	
Savings electricity	0 %	Uncertainty: Reliability: Source:
Savings fuel	30 %	Uncertainty: 30 % Reliability: M Source: (2,1,2,3)
Savings heat	0 %	Uncertainty: Reliability: Source:
Type of measure	New	
Measure category	11. More efficient furnaces and burners	
First year of implementation	1995	

Penetration base year (1995)	0 %	Uncertainty: [0 ,20] Reliability: M Source: (6,0,10,4)
Current penetration (1999)		
Technical maximum penetration	100 %	
Additional investments	€ 10 /(GJ/yr)	Uncertainty: 30 % Reliability: M Source: (2,1,3,4)
Additional O&M costs	€ 0.2 /GJ	Uncertainty: 20 % Reliability: M Source: (2,1,3,4)
Economic lifetime	20 year	
Implementation Char	1/0/S/0/L/M/L	

Table B- 28: Enhanced furnaces 2010

Name of measure	Enhanced furnaces 2010	
(sub)sector code	SBI 2753-4 NF metal casting	
Energy function	Melting/holding	
Savings electricity	0 %	Uncertainty: Reliability: Source:
Savings fuel	50 %	Uncertainty: 30 % Reliability: M Source: (2,1,2,3)
Savings heat	0 %	Uncertainty: Reliability: Source:
Type of measure	New	
Measure category	11. More efficient furnaces and burners	
First year of implementation	2010	
Penetration base year (1995)	0 %	Uncertainty: 0 % Reliability: H Source: (6,0,10,4)
Current penetration (1999)		
Technical maximum penetration	100 %	
Additional investments	€ 4 /(GJ/yr)	Uncertainty: 30 % Reliability: M Source: (2,1,3,4)
Additional O&M costs	€ 0.1 /GJ	Uncertainty: 20 % Reliability: M Source: (2,1,3,4)
Economic lifetime	20 year	
Implementation Char	1/0/S/0/L/M/L	

Table B- 29: monitoring and targeting

Name of measure	monitoring and targeting	
(sub)sector code	SBI 2753-4 NF metal casting	

Energy function	All	
Savings electricity	5 %	Uncertainty: [3 ,8] Reliability: M Source: (6,0,0,4)
Savings fuel	5 %	Uncertainty: [3 ,8] Reliability: M Source: (6,0,0,4)
Savings heat	0 %	Uncertainty: Reliability: Source:
Type of measure	Good housekeeping	
Measure category	1. Good Housekeeping	
First year of implementation	1995	
Penetration base year (1995)	0 %	Uncertainty: Reliability: Source:
Current penetration (1999)		
Technical maximum penetration	100 %	
Additional investments	€ 1 /(GJ/yr)	Uncertainty: [0 ,3] Reliability: M Source: (6,0,0,4)
Additional O&M costs	€ 0 /GJ	Uncertainty: Reliability: Source:
Economic lifetime	10 year	
Implementation Char	0/1/P/0/L/M/L	

Table B- 30: monitoring and targeting 2010

Name of measure	monitoring and targeting 2010	
(sub)sector code	SBI 2753-4 NF metal casting	
Energy function	All	
Savings electricity	8 %	Uncertainty: [5 ,11] Reliability: M Source: (6,0,0,4)
Savings fuel	8 %	Uncertainty: [5 ,11] Reliability: M Source: (6,0,0,4)
Savings heat	0 %	Uncertainty: Reliability: Source:
Type of measure	Good housekeeping	
Measure category	1. Good Housekeeping	
First year of implementation	2010	
Penetration base year (1995)	0 %	Uncertainty: Reliability: Source:
Current penetration (1999)	0 %	
Technical maximum penetration	100 %	
Additional investments	€ 1 /(GJ/yr)	Uncertainty: [0 ,3]

		Reliability: M Source: (6,0,0,4)
Additional O&M costs	€ 0 /GJ	Uncertainty: Reliability: Source:
Economic lifetime	10 year	
Implementation Char	0/1/P/0/L/M/L	

Non-ferrous metal forming

Table B- 31: Improved furnaces

Name of measure	Improved furnaces	
(sub)sector code	SBI 2742c,2744-5 NF metal forming	
Energy function	Heating metals	
Savings electricity	0 %	Uncertainty: Reliability: Source:
Savings fuel	50 %	Uncertainty: [40 ,60] Reliability: H Source: (2,2,4,4)
Savings heat	0 %	Uncertainty: Reliability: Source:
Type of measure	New	
Measure category	11. More efficient furnaces and burners	
First year of implementation	1995	
Penetration base year (1995)	10 %	Uncertainty: [5 ,15] Reliability: H Source: (6,0,0,3)
Current penetration (1999)	20 %	
Technical maximum penetration	100 %	
Additional investments	€ 2 /(GJ/yr)	Uncertainty: [0.5 ,4] Reliability: M Source: (2,2,4,4)
Additional O&M costs	€ 0 /GJ	Uncertainty: Reliability: Source:
Economic lifetime	20 year	
Implementation Char	1/ /S/0/M/L/L	

Table B- 32: charge preheating

Name of measure	charge preheating	
(sub)sector code	SBI 2742c,2744-5 NF metal forming	
Energy function	Heating metals	
Savings electricity	0 %	Uncertainty: Reliability: Source:
Savings fuel	15 %	Uncertainty: [10 ,20] Reliability: H Source: (2,2,4,4)
Savings heat	0 %	Uncertainty: Reliability: Source:
Type of measure	New	

Measure category	4. Heat recovery	
First year of implementation	1995	
Penetration base year (1995)	10 %	Uncertainty: [5 ,15] Reliability: M Source: (6,0,0,4)
Current penetration (1999)		
Technical maximum penetration	100 %	
Additional investments	€ 15 /(GJ/yr)	Uncertainty: [5 ,25] Reliability: M Source: (2,2,5,4)
Additional O&M costs	€ 0 /GJ	Uncertainty: Reliability: Source:
Economic lifetime	20 year	
Implementation Char	0/0/P/0/M/L/L	

Table B- 33: strip casting

Name of measure	strip casting	
(sub)sector code	SBI 2742c,2744-5 NF metal forming	
Energy function	Heating metals	
Savings electricity	0 %	Uncertainty: Reliability: Source:
Savings fuel	30 %	Uncertainty: [10 ,40] Reliability: L Source: (2,5,4,4)
Savings heat	0 %	Uncertainty: Reliability: Source:
Type of measure	New	
Measure category	10. New process technologies	
First year of implementation	2010	
Penetration base year (1995)	0 %	Uncertainty: Reliability: Source:
Current penetration (1999)	0 %	
Technical maximum penetration	0 %	
Additional investments	€ 0 /(GJ/yr)	Uncertainty: Reliability: Source:
Additional O&M costs	€ 0 /GJ	Uncertainty: Reliability: Source:
Economic lifetime	20 year	
Implementation Char	1/ /S/0/H/M/H	

Table B- 34: Continuous extrusion (Conform)

Name of measure	Continuous extrusion (Conform)	
(sub)sector code	SBI 2742c,2744-5 NF metal forming	
Energy function	Heating metals	
Incompatible measures	Improved furnaces	
Savings electricity	0 %	Uncertainty: Reliability: Source:
Savings fuel	15 %	Uncertainty: [5 ,20] Reliability: M Source: (2,0,4,4)
Savings heat	0 %	Uncertainty: Reliability: Source:
Type of measure	New	
Measure category	10. New process technologies	
First year of implementation	1995	
Penetration base year (1995)	0 %	Uncertainty: Reliability: Source:
Current penetration (1999)	0 %	
Technical maximum penetration	0 %	
Additional investments	€ 15 /(GJ/yr)	Uncertainty: [5 ,25] Reliability: L Source: (6,0,0,4)
Additional O&M costs	€ 0 /GJ	Uncertainty: Reliability: Source:
Economic lifetime	20 year	
Implementation Char	1/ /S/0/M/M/M	

Table B- 35: monitoring and targeting

Name of measure	monitoring and targeting	
(sub)sector code	SBI 2742c,2744-5 NF metal forming	
Energy function	All	
Savings electricity	5 %	Uncertainty: [3 ,8] Reliability: M Source: (6,0,0,4)
Savings fuel	5 %	Uncertainty: [3 ,8] Reliability: M Source: (6,0,0,4)
Savings heat	0 %	Uncertainty: Reliability: Source:
Type of measure	Good housekeeping	
Measure category	1. Good Housekeeping	

First year of implementation	1995	
Penetration base year (1995)	0 %	Uncertainty: Reliability: Source:
Current penetration (1999)		
Technical maximum penetration	100 %	
Additional investments	€ 1 /(GJ/yr)	Uncertainty: [0 ,3] Reliability: M Source: (6,0,0,4)
Additional O&M costs	€ 0 /GJ	Uncertainty: Reliability: Source:
Economic lifetime	10 year	
Implementation Char	0/1/P/0/L/M/L	

Table B- 36: monitoring and targeting 2010

Name of measure	monitoring and targeting 2010	
(sub)sector code	SBI 2742c,2744-5 NF metal forming	
Energy function	All	
Savings electricity	8 %	Uncertainty: [5 ,11] Reliability: M Source: (6,0,0,4)
Savings fuel	8 %	Uncertainty: [5 ,11] Reliability: M Source: (6,0,0,4)
Savings heat	0 %	Uncertainty: Reliability: Source:
Type of measure	Good housekeeping	
Measure category	1. Good Housekeeping	
First year of implementation	2010	
Penetration base year (1995)	0 %	Uncertainty: Reliability: Source:
Current penetration (1999)	0 %	
Technical maximum penetration	100 %	
Additional investments	€ 1 /(GJ/yr)	Uncertainty: [0 ,3] Reliability: M Source: (6,0,0,4)
Additional O&M costs	€ 0 /GJ	Uncertainty: Reliability: Source:
Economic lifetime	10 year	
Implementation Char	0/1/P/0/L/M/L	

Other Non-ferro

Table B 37: monitoring and targeting

Name of measure	monitoring and targeting	
(sub)sector code	SBI 2741,2743-5 Other Non-Ferro	
Energy function	All	
Savings electricity	5 %	Uncertainty: [3 ,8] Reliability: M Source: (6,0,0,4)
Savings fuel	5 %	Uncertainty: [3 ,8] Reliability: M Source: (6,0,0,4)
Savings heat	5 %	Uncertainty: [3 ,8] Reliability: M Source: (6,0,0,4)
Type of measure	Good housekeeping	
Measure category	1. Good Housekeeping	
First year of implementation	1995	
Penetration base year (1995)	0 %	Uncertainty: Reliability: Source:
Current penetration (1999)		
Technical maximum penetration	100 %	
Additional investments	€ 1 /(GJ/yr)	Uncertainty: [0 ,3] Reliability: M Source: (6,0,0,4)
Additional O&M costs	€ 0 /GJ	Uncertainty: Reliability: Source:
Economic lifetime	10 year	
Implementation Char	0/1/P/0/L/M/L	

Table B 38: monitoring and targeting 2010

Name of measure	monitoring and targeting 2010	
(sub)sector code	SBI 2741,2743-5 Other Non-Ferro	
Energy function	All	
Savings electricity	8 %	Uncertainty: [5 ,11] Reliability: M Source: (6,0,0,4)
Savings fuel	8 %	Uncertainty: [5 ,11] Reliability: M Source: (6,0,0,4)
Savings heat	8 %	Uncertainty: [5 ,11] Reliability: M Source: (6,0,0,4)
Type of measure	Good housekeeping	

Measure category	1. Good Housekeeping	
First year of implementation	2010	
Penetration base year (1995)	0 %	Uncertainty: Reliability: Source:
Current penetration (1999)	0 %	
Technical maximum penetration	100 %	
Additional investments	€ 1 /(GJ/yr)	Uncertainty: [0 ,3] Reliability: M Source: (6,0,0,4)
Additional O&M costs	€ 0 /GJ	Uncertainty: Reliability: Source:
Economic lifetime	10 year	
Implementation Char	0/1/P/0/L/M/L	