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THE ENVIRONMENTAL COMPATIBILITY OF THE POTENTIAL GROWTH OF ALUMINIUM USE IN THE TRANSPORT SECTOR

A STUDY CARRIED OUT BY "AMICI DELLA TERRA" FOR EUROPEAN ALUMINIUM ASSOCIATION

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Synthesis report

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1. TRANSPORT AND SUSTAINABILITY

Since the last decades, the need of scrutinising the impact of human activities on natural resources (that is material availability and carrying capacity) has turned to be a central theme of the international debate on the compatibility of economic growth with the environment.

Even if the resource use efficiency of the production/consumption system has substantially increased since the late '70s, the transport sector still retains a trend of growth, which today seems unsustainable.

Therefore, in this decade the environmental impact of the transport sector has become a crucial and unsolved issue, despite the fact that climate change prevention (Kyoto protocol) and material resource uptake and throughput reduction (Factor 4, Factor 10) have become priority policies world-wide and particularly in the European Union.

To achieve such goals requires a reduction of materials' use, while providing an increasingly higher standard of services. Thus, while modal split adjustment is considered the main long-term policy, it is worth to evaluate technological changes, which might contribute to the reduction of the growing environmental impact of terrestrial transports.

2. LIGHTER VEHICLES IMPLY REDUCED IMPACTS?

Reducing vehicles weight is a way to reduce their fuel consumption and, consequently, their environmental impact. Therefore, the use of a lighter metal, like aluminium, in substitution of steel and iron, might appear environmentally convenient, especially if the share of primary aluminium remains low. Indeed, primary aluminium production has a very consistent environmental impact (mainly due to its high energy requirement) and it is uncertain whether a disadvantage in the production may be adequately compensated during the use phase (table 1).

table 1: Ferrous metals, primary and recycled aluminium functional unit - 2 kg of ferrous metals, 1 kg of aluminium – production's environmental impacts (mg)

Externality	*Ferrous metals*	*Primary aluminium*	*Recycled aluminium*
CO_2	2,917.30	7,644.61	401.48
SO_2	0.32	0.12	0.00
NO_X	2.30	15.98	0.90
PM_{10}	1.09	21.23	0.22
CO	3.21	61.46	0.15
COVNM	-	10.69	0.29

Source: worked out by Amici della Terra

In order to deal comprehensively with the different impacts it has been adopted the method of evaluating them over the entire vehicle life cycle and to translate them in monetary terms: the so called externalities and the related "external costs" that do not affect the direct cost of transport but are shared by the entire society. However, it is recognised that cost externalisation has enormously increased the competitiveness of cars production and use over other transport modes. Besides, the externalities produce economic disadvantages that may undermine the economic system growth. In this field, Amici della Terra (Friends of the Earth Italy) have recently been involved in the development and use of external costs. The methodology adopted is based on the work carried out by the ExternE project (1991-1997) of the European Commission Research Directorate.

These studies have highlighted that, within the vehicles' life cycle, the impact of the phase of use is more relevant then the other ones. Therefore, a previous study (1999) commissioned to Amici della Terra by European Aluminium Association (EAA) and focused on the Italian transport scenario, has evaluated the environmental performance of aluminium versus steel and the potential savings deriving from Al utilisation, though high energy demand for primary aluminium production.

The results of this study showed that *vehicle weight reduction, through the substitution of iron with aluminium determines a reduction of the overall external costs,* and that this advantage is proportional to the share of recycled aluminium.

3. ALUMINIUM FOR LIGHTER VEHICLES

Therefore, EAA has supported the present study on *Environmental compatibility of a potential growth of aluminium use in the transport sector* that covers all kinds of road and rail transport vehicles in a Europe-wide scenario (EU15 plus Norway and Switzerland – EU17) over a time frame of twenty-three years (reference period covered by forecast studies developed for EU Commission by INFRAS/IWW and Auto Oil Program).

In order target this aspect, the study has identified two comparative scenarios.

- IRON SCENARIO (IS) – vehicles production at the present metal share;
- ALUMINIUM SCENARIO (AS) – vehicles production with increasing share of aluminium in substitution of iron.

The simulation has involved two different areas:

- Externalities evaluation in the vehicle production and use phases (related to the yearly EU17 registered fleets, starting from 1997). The EU17 fleets for years after 1997 have been simulated on the basis of the official fleet development forecasts (table 2);
- Growing aluminium use in the different transport vehicles, directly linked to the availability of recycled aluminium.

table 2: Percent increase assumptions for registered fleets in EU17in the period 1997 - 2020 (%)

	Vehicles category	1997 - 2010	2011 - 2020
ROAD	Cars	17.63	11.54
	Mopeds and Motorcycles	17.06	11.19
	Buses and Coaches	11.07	7.64
	Light duty vehicles (< 3,5 ton)	28.27	16.99
	Heavy duty vehicles (> 3,5 ton)	25.27	15.50
RAIL	Electric locomotives	39.53	5.00
	Diesel locomotives	44.30	7.02
	Passenger coaches	68.30	9.64
	Freight wagons	0.00	0.00

Source: worked out by Amici della Terra from INFRAS/IWW 1997 and Auto Oil 2000 Programme data.

In order to highlight the effect of this simulation, all other parameters, like mileage, occupation coefficient, average life (table 3), significant material breakdown, average weight, have been kept unchanged. So that vehicle weight in the IS remains unchanged, while in the AS, it decreases only in consequence of the increasing of aluminium share.

table 3: Average life of vehicles registered in EU17 in 1997 (years)

	Vehicles category	Average life
ROAD	Cars	12
	Mopeds and Motorcycles	9
	Buses and Coaches	8
	Light duty vehicles (< 3,5 ton)	12
	Heavy duty vehicles (> 3,5 ton)	8
RAIL	Electric locomotives	25
	Diesel locomotives	25
	Passenger coaches	25
	Freight wagons	25

Source: worked out by Amici della Terra ACEA 2000 and UIC 1999 data

Following EAA indications, the aluminium yearly growth rate has been taken as 5% for cars and 2.5% for all the other vehicles (with the exception of electric locomotives which have weight requirements for their dynamic performance).

Other significant assumptions are: recycled aluminium is available at 95% efficiency only from scrap vehicles (a sort of closed loop material use), road vehicles fuel consumption decreases by 6% every 10% of weight reduction, rail vehicles consumption decreases proportionally to their respective weight reduction.

Vehicles production impacts have been evaluated by means of the SimaPro4 and the vehicles use impacts have been quantified applying the ExternE methodology to the yearly registered fleets. Emission factors have been adopted varying according to EURO Directives enforcement schedule (worked out from COPERT model of European Environmental Agency and Italian Environmental Protection Agency – ANPA - data).

For the production phase, monetary values of the industrial stack emissions have been adopted; for the use phase these values have been adopted only for electric trains, while for all the other vehicles monetary values of the exhaust emissions in extra-urban drive have been adopted (table 4).

table 4: External costs – Unit monetary values adopted (euro97/ton)

	SO_2	NO_X	*COVNM*	*CO*	*PM*	CO_2
Industrial stack emissions	10,410	9,447	1,005	3	12,333	71
Vehicle exhaust emissions (extra-urban)	12,110	12,504	1,351	3	341,546	71

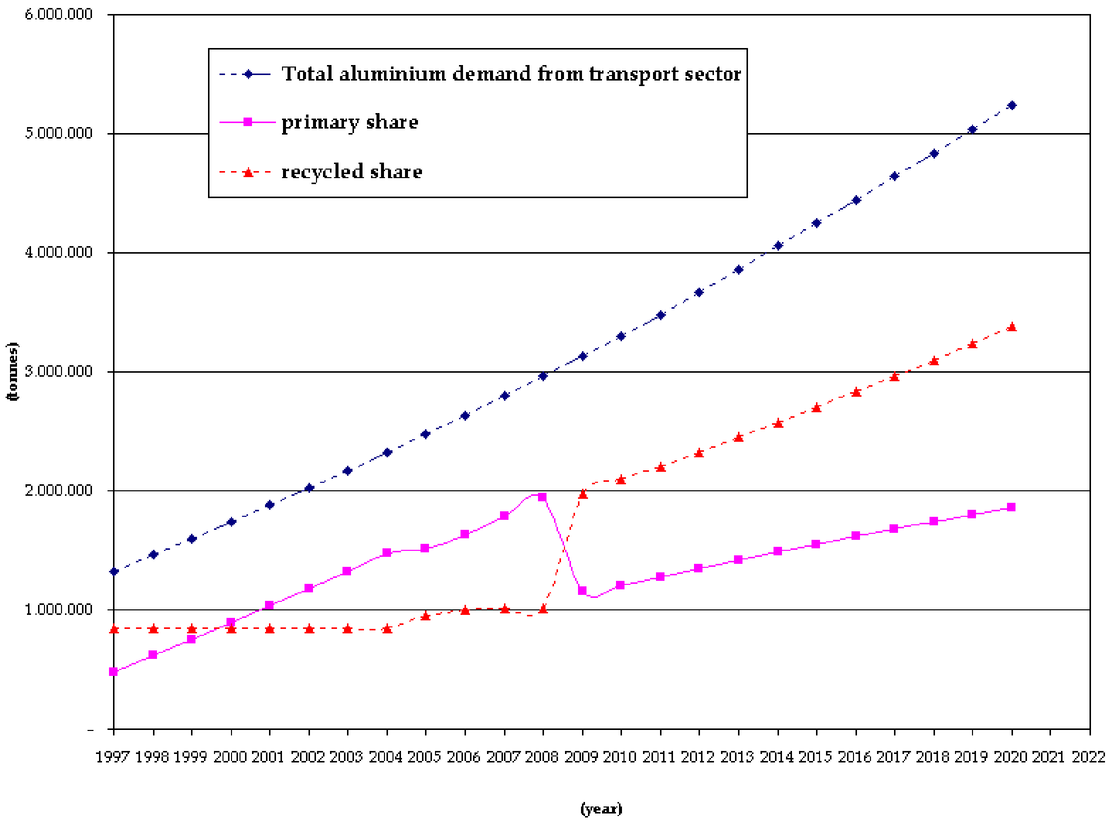
Source: worked out by Amici della Terra

4. Increase of aluminium demand

The results of the AS for what concerns aluminium demand trend (figure 1) shows an increase of primary aluminium demand, starting from reference year 1997 (aluminium input in the vehicle production industry is 36% primary, 64% recycled) up to 2008. From 2009 the recycled aluminium availability increases sharply with the increasing contribution from scrapping of cars registered since 1997. A first small drop is evident in the year 2005, connected with the end of life of Buses and Heavy Duty Vehicles registered since 1997. Between 1997 and 2000 recycled aluminium share is relevant but decreasing, while, in the 2001-2008 period, primary aluminium covers the highest share of the demand.

Besides, it has to be stressed that the total aluminium growth in the whole time range is due not only to the increase of its use in the vehicles production, but also to the steady increase of the registered fleets. However, in a long time perspective, it seems reasonable to infer that the circulating fleets will reach their limit and also that aluminium in vehicles will reach a maximum, so that aluminium demand will stabilise and recycled aluminium will tend to satisfy the whole demand.

figure 1: Aluminium Scenario – Aluminium demand from transport sector in the period 1997 – 2020 in EU17 countries (tonnes)



Source: worked out by Amici della Terra

5. VEHICLE LIGHTENING AND CONSUMPTION REDUCTION

The absolute vehicles lightening of the registered vehicles fleets in the period 1997-2020 for AS is given in table 5.

The time patterns of CO_2 emissions and of one of the five atmospheric pollutants considered, due to production and use of all vehicles categories registered between 1997 and 2020 in EU17, are given respectively in figure 2 and in figure 3. Beside the increase of CO_2 emissions, due to the assumption of a steady increase of the fleets, the AS shows a definite reduction of the emissions in comparison with the IS figure, starting from 2009 and connected to the sharp increase of recycled aluminium share.

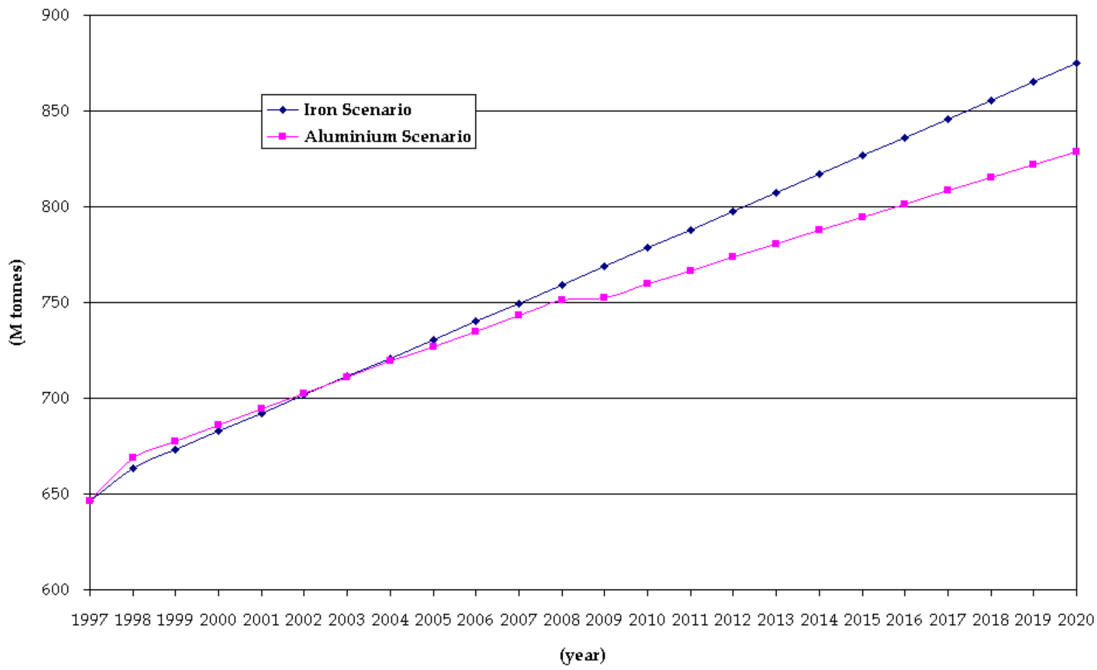
For what concerns atmospheric pollutants, the pattern shows the influence of EURO Directives implementation on the reduction of polluting emissions. As they set progressively lower limits to these effluents, but not to fuel consumption, they have no effect on CO_2 emissions.

table 5: Aluminium Scenario - Transport vehicles unit weight patterns in the period 1997- 2020 (kg)

Registered vehicles weight	*Cars*	*Mopeds and motorcycles*	*Buses and coaches*	*LDV*	*HDV*	*Electric locomotives*	*Diesel locomotives*	*Passenger coaches*	*Freight wagons*
1997	1,088	114	8,631	1,513	6,579	82,800	58,800	50,000	16,500
2020	922	101	7,634	1,478	6,346	82,800	58,800	48,624	15,743
ΔP	165	13	997	35	233	-	-	1,376	757

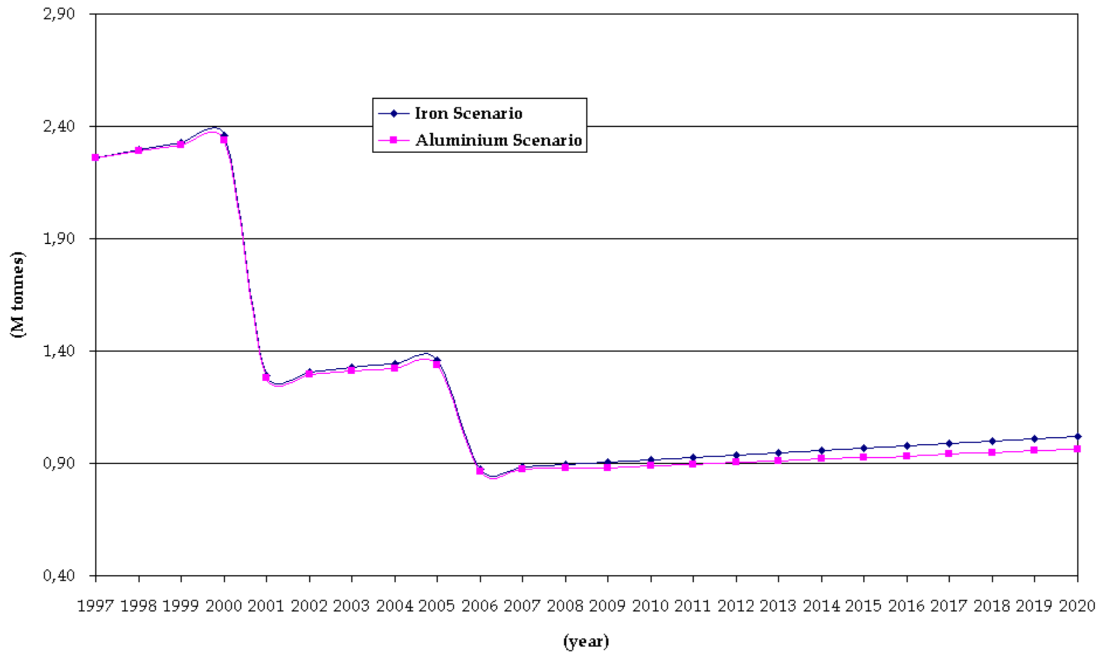
Source: worked out by Amici della Terra

figure 2: Life cycle CO_2 emissions trend of the registered road and rail fleets in the period 1997-2020 in EU17 countries (M tonnes)



Source: worked out by Amici della Terra

figure 3: Life cycle COVNM emissions trend of the registered road and rail fleets in the period 1997-2020 in EU17 countries (M tonnes)



Source: worked out by Amici della Terra

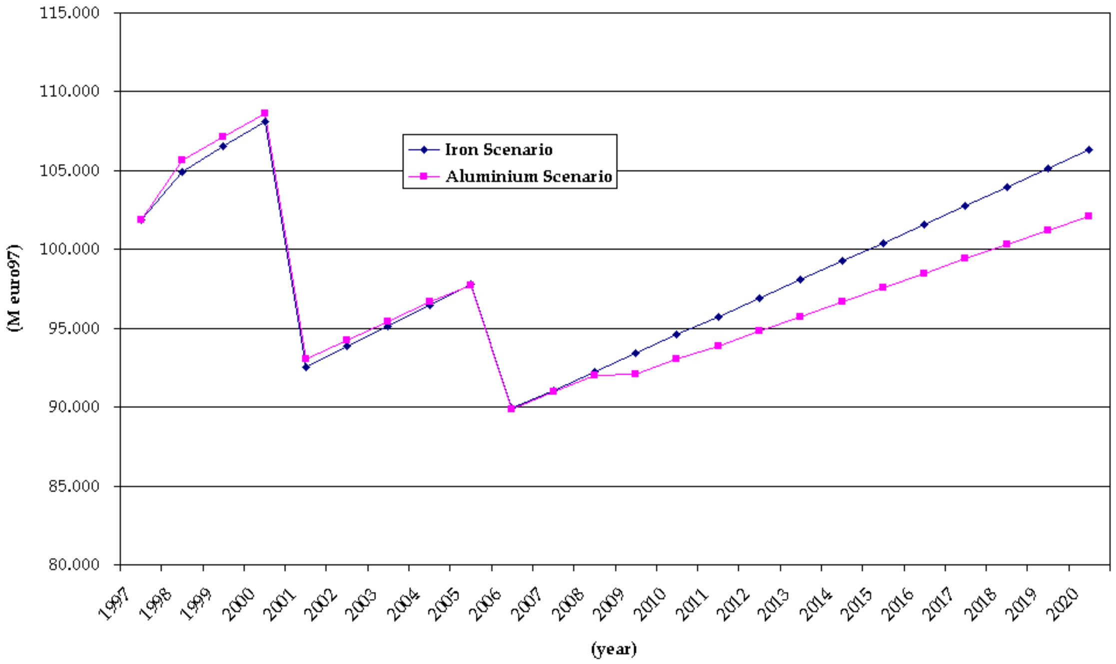
6. External cost trends

The results in terms of total external costs are presented in figure 4 and show that AS implies their reduction relatively to IS. Even if initially (1997-2008) AS total external costs are slightly higher than those of IS, after 2008 the two curves diverge increasingly as the recycled aluminium share increases.

These results can be broken down for each vehicle category, in order to analyse the respective specificity. In fact, in some cases, like cars, AS is systematically advantageous with respect to IS, while in other cases the opposite is true, like in the case of heavy duty vehicles. This is the consequence of the different average life and of the initial amount of aluminium used for that type of vehicle in 1997, which has been assumed to be low (4,6%) for heavy duty vehicles and to increase at a lower yearly rate (2,5%).

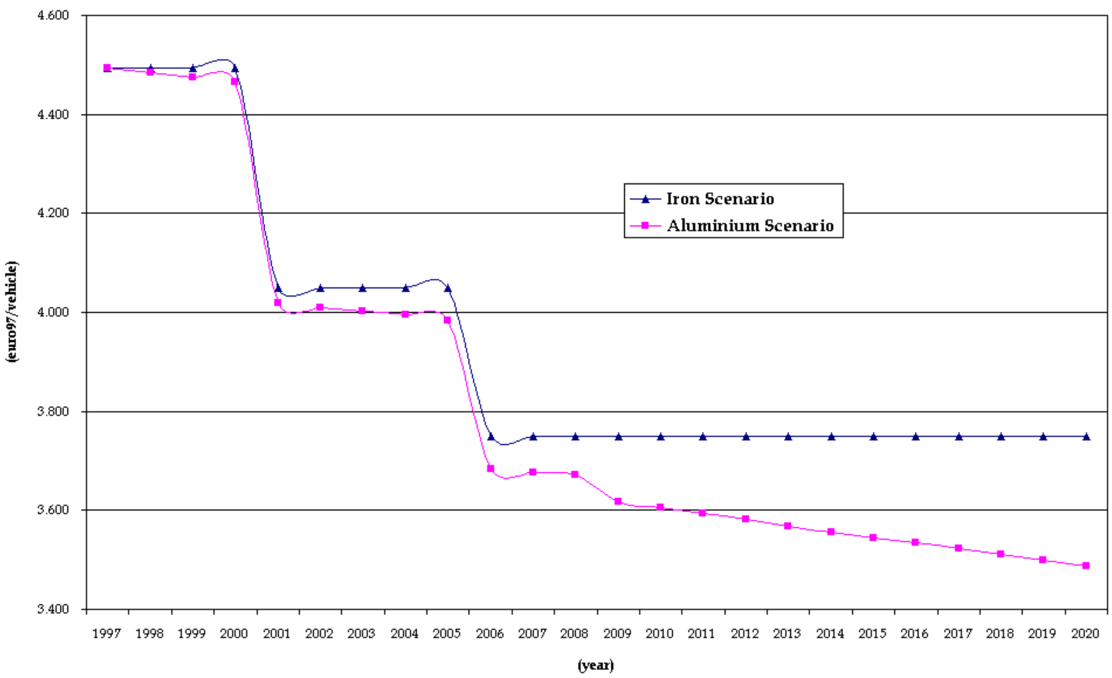
Unit external costs of production and use of cars are presented in figure 5; as they do not depend on the fleets increasing trend, they show clearly the trends due to the entry into force of the EURO Directives and to the substitution of iron whit aluminium.

figure 4: Total external costs of production and use of all vehicles categories in the period 1997-2020 in EU17 countries (M euro97)



Source: worked out by Amici della Terra

figure 5: Unit external costs of production and use of cars registered in the period 1997-2020 in EU17 countries (euro97/car)



Source: worked out by Amici della Terra

7. Aluminium in the transport vehicles and sustainability

Even if EU Commission has declared in various documents the need to reduce environmental impacts (especially through the evaluation of the external costs) of the transport sector, in the perspective of the enforcement of the Kyoto protocol and of improving urban environment quality, no specific targets, no time limits, no indication for instruments, have been developed. Therefore, CO_2 emissions from transport sector are foreseen to grow steadily in the time interval covered by the study.

The study indicates that, even in absence of any other provision, an increase of aluminium in road and rail vehicles can ensure a reduction of CO_2 emissions after 2004, of about 3% in 2012 and 10% in 2020 (overall reduction average on all vehicle categories), while the initial disadvantage (between 1997 and 2004) is largely compensated by the subsequent reduction (figure 2).

Aluminium use in road and rail transport vehicles, in substitution of iron, provides also some contribution to sustainability in terms of material uptake and throughput reduction. It has been estimated that, at EU17 level, AS in 2020 implies a cut of 7,000,000 tones of iron and a net reduction of Total Material Requirement (TMR) of 3.500.000 tonnes. Note that TMR has been selected as *Headline Indicator* by EEA since 2000 and it is in the course of being adopted by the EU Commission also.

8. Aluminium and dissent

The potential advantages of a growing recourse to aluminium for road and rail transport vehicles have been examined with respect to the environmental and social impacts of primary aluminium production. An accurate analysis of dissent in the countries that host mining, refining and primary smelting activities has been carried out through a literature research and NGOs consultation, which has included Friends of the Earth groups in 63 countries, Sierra Club, International Rivers Network, Moles.

It has been ascertained that, even if improvements have been gained mostly in Europe and in OECD countries (in the last fifteen years the emissions have been reduced to 10 - 25% of original values; in the last five years many plants have developed or are developing an Environmental Management System), in various developing and ex-URSS countries there is still dissent.

Main impacts from the production cycle come from the land alteration of mining activities and inadequate ecosystem rehabilitation, production and disposal/recycle of red mud produced in the alumina production, fluorinate emissions and energy consumption in the electrolysis for aluminium production.

Land rehabilitation is carried out efficiently, for what concerns biodiversity protection, in a growing number of mining sites, as documented by the Survey carried out every ten years by the International Primary Aluminium Institute (IPAI). However, from some countries (like India, Indonesia, Russia and other ex URSS countries) very scanty information is available inferring that the environmental impact is severe. Huge land modifications are also due to damming, particularly in developing countries, so to provide cheap electric energy for refining and smelting.

Red mud are produced in the alumina refining from bauxite ore. They are highly basic and need to be handled cautiously and disposed of in basins, least they don't damage the underlining water table, the surrounding ecosystem and the population living close to the site. As their characteristics may vary substantially in relation with the ore quality (aluminium content), producers will have to consider the different solutions outlined in some studies: neutralisation through recovery of sodium hydroxide and subsequent use as filler in the mined pits, compounding with binding materials for producing construction materials to be used in substitution of quarry products.

The importance of these problems has prompted the United Nation Environmental Program (UNEP) to produce a guide for governments and industries in the activities of impact reduction from bauxite mining and alumina production. It represents a valid, even if generic, standard that can be applied widely but requires specific commitment in order to make it appropriate for local characteristics.

Fluorinated emissions (PFC: CF_4 and C_3F_6) are of particular concern, not only for their impact on workers and local population health, but also for their contribution to green-house effect (Global Warming Potential: 6,500-9,200). Even if in the last decade these emission have been largely reduced (from 0.61 to 0.34 kg PFC/ton of Al), there is a further potential for bringing them, in most efficient plants, to as low as 0.1- 0.05 kg PFC/ton of Al.

Energy consumption of primary aluminium production through alumina electrolysis is still very high. It ranges from 17 to 13 kWh/kg Al and indicates that some consistent reduction of overall emission of the sector could be achieved by applying the best available standards. Besides, a further extreme reduction to 12.5 kWh/kg Al could be possibly envisaged with technological excellence. It has also to be considered that about 40% of the electric power used for primary production is derived from fossil fuelled plants, whose efficiency could be largely improved from the current 35% up to 50% if fed with coal, and to 60% if fed with gas; not considering that the combined production of electricity and process heath can boost efficiency to 80%, and consequently reduce the emissions by a correspondent amount.

Large scale damming may be reduced by locating in proper sites wind generators, which are technologically reliable and financially convenient. In this case the problem of tuning electricity production to demand can be solved by integrating the wind farm with a small scale dam.

Workers of aluminium industries are exposed to the various impacts: alkaline red mud in the alumina refining, aromatic polinuclear hydrocarbons in the electrolytic production. These last substances are of particular concern for the respiratory system and some of them may induce cancer. Therefore, in many plants have been installed system for abating these effluents and prevent workers exposure, also with the aid of personal protection clothing. Such means are enforced with different standards in different countries, while a common protection level should be adopted by all industries.

It is still controversial that aluminium uptake from human body may induce Alzheimer syndrome, as all the studies carried out have considered relatively small population groups and their significance is therefore limited.

It has also to be considered that populations located close to mining, refining and smelting sites are affected by deprivation of land utilisation without an adequate compensation, by an increase of heavy duty traffic, by air pollution from red mud dust diffusion, PFC, polinuclear aromatic hydrocarbons and power plant emissions.

The whole of these considerations show that if the companies will strive to comply with the best above mentioned standards, the aluminium system will have opportunities to become more attractive to the stakeholders and more competitive vs. other materials in the transport applications.