

INETI

CENDES

**Comparative Analysis of the Life Cycle of
AT Fibre-cement and NT Fibre-cement**

- Final Report -

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1. Introduction

Cimianto, Sociedade Técnica de Hidráulica, S.A. commissioned CENDES to study the life cycle of two different fibre-cement products:

- AT Fibre-cement: Fibre-cement containing chrysotile asbestos fibres;
- NT Fibre-cement: Fibre-cement containing PVA (poly vinyl alcohol) fibres.

The study's aim is to provide, for internal use, well-founded information within the framework of the recent evolution in Community legislation regarding the use of chrysotile asbestos fibre.

Accordingly, two products that are presently manufactured by Cimianto were selected for study – roofing sheets.

The eco-efficiency profile of these products was compared using, to the extent permitted by data availability, the Life Cycle Assessment (LCA) methodology.

This methodology allows the environmental impacts of the products to be assessed over life cycle. It also allows the respective life cycle costs to be analysed.

It should be stressed that Life Cycle Assessment is internationally standardised under the ISO 14040 Standard. The computer programme used for the LCA was “SimaPro 5.1” and the “Eco-Indicator 99” method was used to assess the impacts of the fibre-cement sheets' life cycle.

2. Objective and Scope

2.1 Objective

The study's objective is to compare, in terms of eco-efficiency, the life cycle of two different types of roofing sheets manufactured by Cimianto - AT fibre-cement sheets and NT fibre-cement sheets.

This shall be carried out through a comparative LCA and an analysis of the life cycle costs of each type of sheet.

Cimianto has commissioned the study for its internal use, namely to be used as a basis for the decision-making process.

2.2 Definition of Scope

2.2.1 Products under analysis

Two types of fibre-cement sheets were studied and compared with each other:

- 177 AT – 2.00 m profile sheets, containing chrysotile asbestos fibres;
- 177 NT FS – 2.00 m profile sheets, containing PVA (poly vinyl alcohol) fibres.

Both types have the same length and width, and each sheet of both types provides 1.89 m² of roof coverage for buildings.

2.2.2 Function

AT and NT fibre-cement sheets serve the same purpose – that of protecting the interior of buildings from the weather. They are used as roofing for buildings. They do not have the function of providing thermal insulation.

2.2.3 Functional Unit

The functional unit used was **1 packaged palette of unpainted sheets.**

Each palette contains sixty sheets.

In practice, it is known that AT fibre-cement sheets have a **service life time** of around fifty years. However, the service life time of NT sheets had to be estimated given that they only started to be used during the nineteen eighties.

The ageing tests carried out by the National Civil Engineering Laboratory indicate that NT sheets, under normal use, may likewise have a service life of fifty years. Conversely, Cimianto believes that criteria such as the variation in the material's dimensions brought about by temperature variations indicate a service life time that may not be as long as that estimated.

For the purpose of this study and in that vein, two alternative scenarios were also considered:

- Scenario A: a fifty year service life for NT sheets;
- Scenario B: a thirty year service life for NT sheets.

2.2.4 System under analysis

The system under analysis consists of a set of different processes that constitute the life cycle of fibre-cement sheets.

For AT sheets, the following processes were taken as forming part of the system:

- The extraction and processing of chrysotile asbestos;
- The manufacture of Portland cement;
- The attainment of fly ash;
- The recycling of filler (sheets that are crushed and reincorporated into production);
- The production of cellulose fibres;
- The production of wood for packaging;
- The manufacture of plastic ties for packaging;
- The transport of the above-mentioned components to Cimianto's manufacturing facility;
- The manufacture of sheets at Cimianto's manufacturing facility;
- The packaging of sheets;
- The distribution/ transport of sheets;
- The end of the sheets' service life.

And for NT sheets:

- The production of PVA fibres;
- The manufacture of Portland cement;
- The attainment of fly ash;
- The production of cellulose fibres;
- The processing of amorphous silica;
- The production of calcium carbonate;
- The manufacture of safety tape;
- The production of wood for packaging;
- The manufacture of plastic ties for packaging;
- The manufacture of plastic wrap for packaging;
- The transport of the above-mentioned components to Cimianto's manufacturing facility;
- The manufacture of sheets at Cimianto's manufacturing facility;
- The packaging of sheets;
- The distribution/ transport of sheets;
- The end of the sheets' service life.

This study does not aim to tackle the specific toxicity problem of the asbestos fibres and PVA fibres that the fibre-cement contains, an issue on which, despite the large number of studies, no consensus exists.

The material used to fix the sheets in place was deemed negligible, given that it is similar for both sheet types.

2.2.5 Allocation procedures

The calculation of the allocation of material flows, based on their mass, was carried out when deemed necessary.

2.2.6 Information requirements

The baseline information (e.g. types of transport, most common constituent material of fibre-cement, end of service life scenarios) was obtained, in general, from international databases specifically compiled for LCA studies. Reference books and experts were consulted, whenever necessary.

Detailed information, such as asbestos and PVA processing data, was obtained from the respective suppliers.

2.2.7 Assumptions

- Service life time of AT sheets – fifty years;
- Service life time of NT sheets – fifty years (scenario A) or, alternatively, thirty years (scenario B);
- No material, water or electricity was spent in the time during which the sheets were in use;
- End of the service life time of the fibre-cement sheets – disposal in landfill.

3. Analysis of the Life Cycle Inventory

3.1 Life Cycle Diagrams

The following figure shows the diagrams of the individual processes considered for the study:

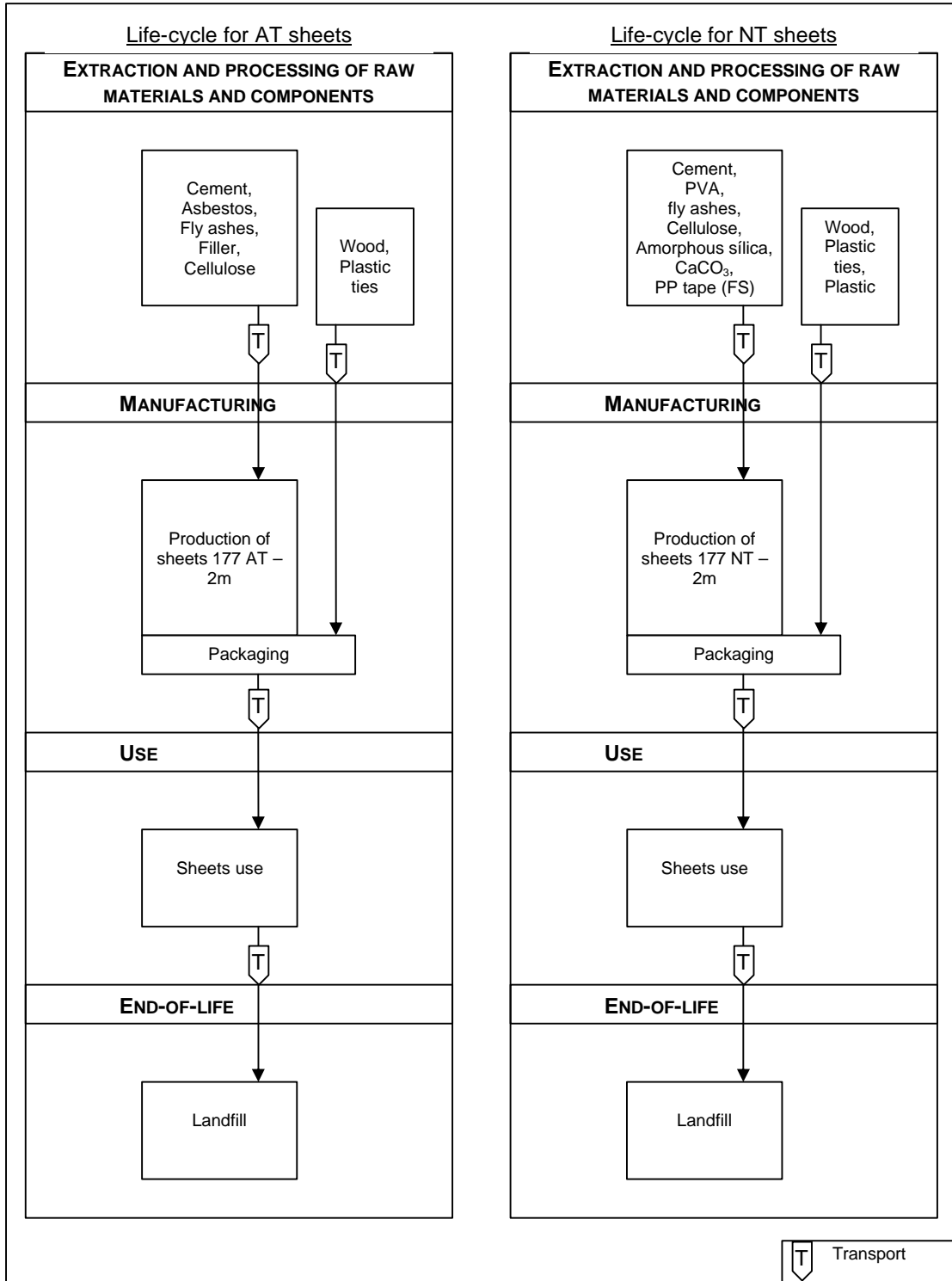


Figure 1 - Diagram of the life cycles of AT and NT sheets

3.2 AT sheets – Details of life cycle phases

The data extracted from the database used by the SimaPro program are listed in the appendix, whereas the field data that we collected is listed in the following tables.

3.2.1 Extraction and processing of raw material and other constituent material

The data relative to the raw material and other constituent materials of one palette of AT fibre-cement sheets and respective packaging is listed in the following tables:

Palette of AT sheets

Constituent material	Kg	Euro (€)	Source	Km	Transport type
(Portland) cement	1,015	92.37	Cimpor, Alhandra	3	40 t truck
Chrysotile asbestos fibre	160	86.45	LAB Chrysotile, Quebec, Canada	5,465	Container ship
Cellulose	5	2.15	Portucel, V. Velha Ródão	200	28 t Truck
Fly ash	47	1.41	Sines Thermoelectric Power Station	160	40 t Truck
Filler	33	1.09	Cimianto	0	-

Packaging

Constituent material	Kg	Euro (€)	Source	Km	Transport type
Wood (palette)	29	5.53	Seixal / Barreiro	65	28 t truck
Plastic ties (PP)	0.027		Wohlen, Switzerland	2,098 45	40 t truck 28 t truck

Relative to the extraction and processing of chrysotile asbestos fibres, the following data sent by LAB Chrysotile, corresponding to the extraction and processing of 1 tonne of fibres, are deemed valid for the purposes of the study:

Item	Component	Quantity
Energy consumption	(Hydro) electricity	1,775 MJ
	No. 6 Fuel bunker	1,941 MJ
	Diesel	3,171 MJ
	Petrol	57 MJ
Air emissions	Asbestos fibre	0.0062 kg

3.2.2 Manufacture

The following table contains data referring to the manufacture of one palette of AT fibre-cement sheets by Cimianto.

Activity	Quantity	Euro (€)
Electricity consumption	0.439 GJ	7.26
Propane gas consumption	0.039 GJ	0.51
Fibre emission	0.011 kg	-
Production of fibre-cement waste	10.848 kg	0.81 ¹

¹ The price of disposal at a landfill site.

3.2.3 Distribution

The data for the market distribution of one palette of AT fibre-cement sheets and respective packaging is as follows:

Transport	Euro (€)	Km	Transport type
Road transport to mainland Portugal (96.1%)	20	(average) 300	40 t truck (80%) 28 t truck (10%) 16 t truck (10%)
Sea transport to the Azores (2.6%)	Not available	1,590	Cargo ship
Sea transport to Madeira (0.6%)	Not available	1,020	Cargo ship
Sea transport to Cape Verde and Sao Tomé (0.7%)	Not available	4,620	Cargo ship

3.2.4 Application

The material used to fix the roofing sheets in place was deemed negligible, given that it is similar in type and quality for both types.

3.2.5 End of life

Given that demolition waste in Portugal is still disposed of at a landfill site, this was deemed to be the most probable end of service life scenario for fibre-cement sheets.

Waste	Kg	Euro (€)
1 palette of AT fibre-cement sheets	1,650	142.83

3.3 NT sheets – Details of life cycle phases

3.3.1 Extraction and processing of raw material and other constituent material

The data relative to the raw material and other constituent material of one palette of NT fibre-cement sheets and respective packaging is listed in the following table:

Palette of NT sheets

Constituent material	Kg	Euro (€)	Source	Km	Transport type
(Portland) cement	1,115	105.11	Cimpor, Alhandra	3	40 t truck
PVA fibre (80% K2 + 20% U30)	28	92.67	K2: Kuraray Co., Japan U30: Unitika Ltd., Japan	18,760	Container ship
Cellulose	35	15.89	Portucel, V. Velha Ródão	200	28 t Truck
Fly ash	3.5	0.11	Sines Thermolectric Power Station	160	40 t Truck
Amorphous silica	73.5	21.98	Norway	2,945	Container ship
Calcium carbonate ²	14.9	0.20	CMP Maceira – Liz	125	28 t truck
Safety tape (PP)	2.6	4.66	Bexco Fibres, Belgium	2,100	40 t truck
Flocculante ²	0.299	0.86	Rivaz Química, Maia	290	28 t truck
Anti-foam agent	0.404	1.27	Schill + Seilacher, Hamburg	2,600	28 t truck

²In the time available for the study it was not possible incorporate information relative to the calcium carbonate and flocculant. Nevertheless, taking into account the quantities involved and their harmless nature, these two substances shall have no significant influence on the final result. Their transport, however, from the supplier to Cimianto was included in the study.

Packaging

Constituent material	Kg	Euro (€)	Source	Km	Transport type
Wood (palette)	29	8.42	Seixal / Barreiro	65	28 t truck
Plastic ties (PP)	0.027		Wohlen, Switzerland	2,098	40 t truck
Plastic wrap (PE)	0.88		Leiria	45	28 t truck
				120	28 t truck

Relative to the manufacture of PVA fibres, the data sent by the respective suppliers, corresponding to the manufacture of 1 tonne of fibres, are deemed valid for the purposes of the study:

Kuralon K2 PVA Fibre

Item	Component	Quantity
Energy consumption	Heavy oil	50,200 MJ
	Coke	48,192 MJ
	LPG	2,008 MJ
Air emissions	SO _x	13.9 kg
	NO _x	57.4 kg
	CO ₂	3,427 kg
Liquid effluent	BOD	8.1 kg
	COD	6.1 kg
	Suspended solids	0.3 kg

Mewlon U30 PVA Fibre

Item	Component	Quantity
Energy consumption	Crude oil	103,600 MJ
Air emissions	SO _x	21.1 kg
	NO _x	9.3 kg
	CO ₂	2,977 kg
Liquid effluent	BOD	5.2 kg
	COD	4.0 kg
	Boric acid	7.3 kg
	Sodium sulphate	47.3 kg
	Suspended solids	1.4 kg

3.3.2 Manufacture

The following table contains data referring to the manufacture of one palette of NT fibre-cement sheets by Cimianto.

Activity	Quantity	Euro (€)
Electricity consumption	0.614 GJ	10.15
Propane gas consumption	0.042 GJ	0.56
Fibre discharge	0.011 kg	-
Fibre-cement waste production	45.688 kg	3.01 ³

³The price of disposal at a landfill site.

3.3.3 Distribution

The market data relative to the distribution of one palette of NT fibre-cement sheets and respective packaging is as follows:

Transport	Euro (€)	Km	Transport type
Road transport to mainland Portugal (96.1%)	22	(average) 300	40 t truck (80%) 28 t truck (10%) 16 t truck (10%)
Sea transport to the Azores (2.6%)	Not available	1,590	Cargo ship
Sea transport to Madeira (0.6%)	Not available	1,020	Cargo ship
Sea transport to Cape Verde and Sao Tome (0.7%)	Not available	4,620	Cargo ship

3.3.4 Application

The material used to fix the roofing sheets in place was deemed negligible, given that it is similar in type and quality for both types.

3.3.5 End of life

Given that demolition waste in Portugal is still disposed of at a landfill site, this was deemed to be the most probable end of service life scenario for fibre-cement sheets.

Waste	Kg	Euro (€)
1 palette of NT fibre-cement sheets	1,750	122.85

3.4 Analysis of the Life Cycle Inventory

The material, energy and transport figures per functional unit for the two types of sheet were compared, as well as the respective costs.

Material Figures

The weight of one palette of NT sheets is 100 kg greater than that of a palette of AT sheets. This difference in weight is due to the greater thickness of the NT sheets, needed to provide them with the same rigidity as AT sheets.

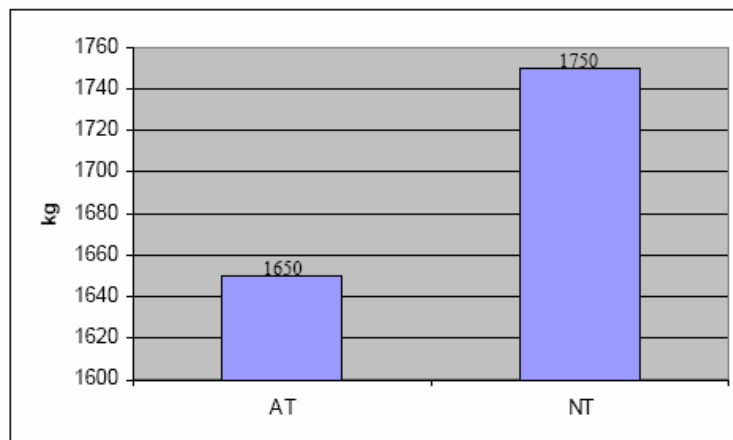


Figure 2 – Weight of one AT-NT palette

Energy consumption

The consumption of energy in the pre-manufacture and manufacture phases of NT sheets is significantly greater, more than thirteen times greater than that of AT sheets (see figure 3). Conversely, the amount of energy consumed in the pre-manufacture phase is very much greater than the amount consumed during the manufacture phase, more than one hundred times greater.

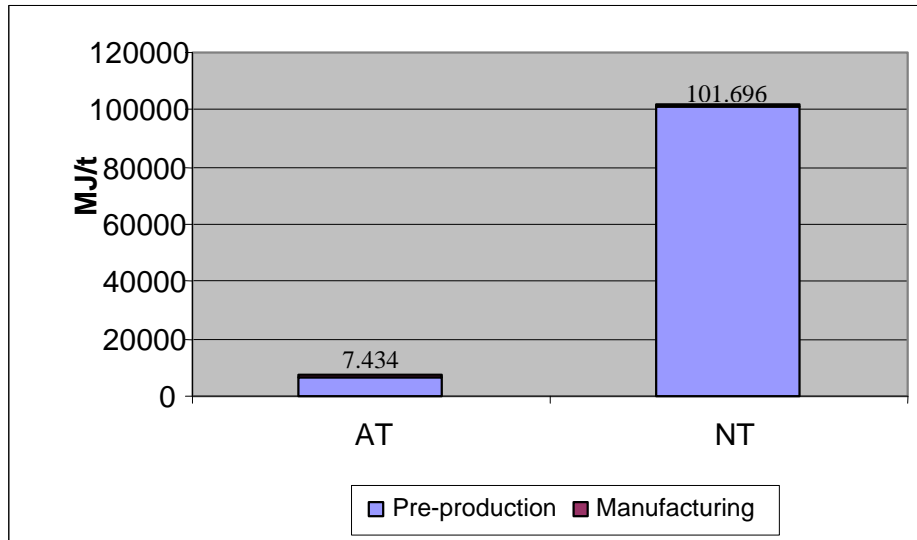


Figure 3 – AT-NT Energy Consumption

Transport Figures

Figure 4 indicates that the distance travelled to deliver the constituent materials to Cimianto's manufacturing facility are greater for NT sheets, more than twice as great. This fact is due to the greater range of constituent material that is required to manufacture NT sheets. The distances related to market distribution are equal for both sheet types.

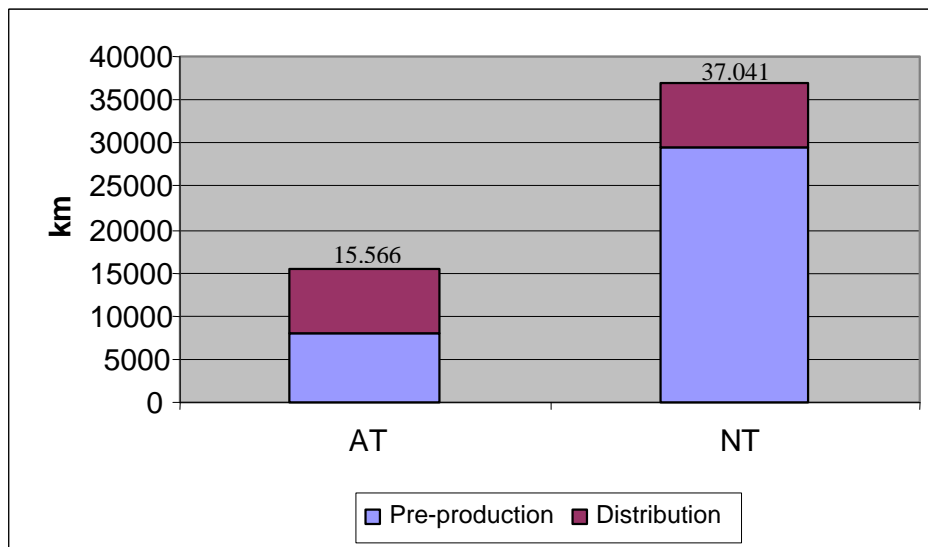


Figure 4 - AT-NT Transport intensity

Costs

Figure 5 displays the costs supplied by the Company, which include the cost of the manufacturing material in Cimianto and the distribution of the fibre-cement sheets. It can be observed that the costs associated with NT sheets are close to 45% higher than the costs related to AT sheets.

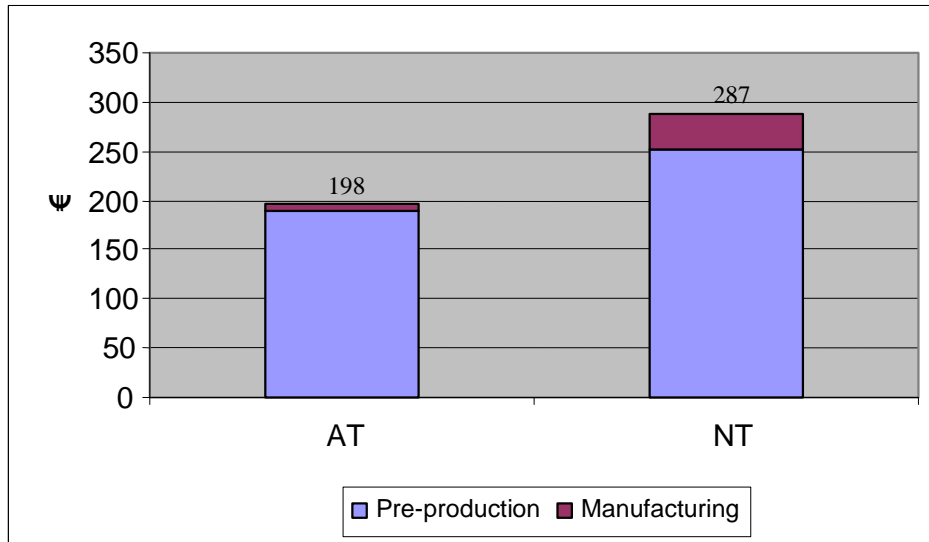


Figure 5 – AT-NT Costs

3.5 Information sources

The data used in the study were obtained from a number of different sources, in particular:

- Cimianto, Soc. Técnica de Hidráulica, S.A., Alhandra, Portugal – for the AT and NT fibre-cement sheets' manufacture phase;
- LAB Chrysotile Inc., Quebec, Canada – supplier of asbestos fibres to Cimianto for the asbestos fibre extraction and pre-processing phase;
- Kuraray Co., Ltd., Japan – supplier of PVA (K2) fibres to Cimianto for the PVA fibre production phase;
- Unitika Ltd., Japan. - supplier of PVA (U30) fibres to Cimianto for the PVA fibre production phase;
- Databases linked to the "SimaPro 5.1" program, in particular Buwal250, Idemat 2001, ETH-ESU 96 System Processes, Franklin USA 98 and Data archive – for the provision of general data;
- AIPA, Association of Industries Manufacturing Chrysotile Asbestos Products, Lisbon, Portugal.

The following bibliography was also consulted:

- The ISO 14040 series of standards;
- Commission Directive 1999/77/EC of 26 July 1999, which modifies Appendix I of Council Directive 76/769/EEC for the sixth time, concerning the convergence of administrative, regulatory and legal provisions of Member States regarding the restriction of the market placement and use of certain dangerous substances and products (asbestos);
- Risk to human health from chrysotile asbestos and organic substitutes. Scientific Committee on Toxicity, Ecotoxicity and the Environment (CSTEE). Brussels, 17 December 2002.

- LCA of Fibre-Cement Products and other Products having the same function – Executive summary, Final version. Asbestos International Association. November 1996;
- WorkCover, New South Wales, March 2003. Your guide working with asbestos;
- Gross energy content of selected materials in the fields of roofing and water piping. Batelle Europe. Geneva, August 1993.
- Chrysotile and its substitutes: a critical evaluation. IEH Web Report W4. Institute for Environment and Health. December, 2000;
- Ecodesign in product development. INETI – ITA, 1995;
- Adopting the life cycle view – Encouraging the sustainable competitiveness of companies. INETI – CENDES, 2003.

The following bodies were contacted:

- The Asbestos Institute (<http://www.chrysotile.com/en/main.asp>);
- SAMA – Mineração de Amianto, Ltda., Brazil;
- Internet group of users of the Eco-Indicator 99 LCA method.

4. Assessment of Life Cycle Impacts

The standard edition of the Eco-Indicator 99 H/A method was used to assess the life cycle impacts of the fibre-cement sheets. The method was adjusted to permit damage assessment. The method contains eleven impact categories divided into three damage categories:

- Human health:
 - Carcinogenic effects;
 - Respiratory effects caused by organic substances;
 - Respiratory effects caused by inorganic substances;
 - Damage caused by climate change;
 - Effects caused by ionizing radiation;
 - Effects caused by depletion of the ozone layer;

- Ecosystem quality:
 - Damage caused by eco-toxic discharge;
 - Damage caused by the combined effect of acidification and eutrophication;
 - Damage caused by the occupation of land and the alteration of land use;

- Associated to the removal of resources:
 - Damage caused by mineral extraction;
 - Damage caused by fossil fuel extraction.

A brief description of the method used and its principal shortcomings is attached to this document. For a more detailed description, the following reports, available on the internet at <http://www.pre.nl/eco-indicator99/ei99-reports.htm>, are recommended: “Eco-indicator 99 Methodology report” and “Eco-indicator 99 Manual for Designers”.

Results

The results obtained for the two different scenarios tested are displayed in the graphs contained in figures 6 to 9. The appendix contains the original graphs, produced by the “SimaPro 5.1” program, in English.

Figures 6 and 8 display the environmental impact distribution of AT and NT fibre-cement amongst the impact categories incorporated into the test. Figures 7 and 9 display the environmental impact distribution of AT and NT fibre-cement at the main phases of the respective life cycles – pre-production and manufacture, market distribution and end of life. In addition, these graphs display the environmental impacts related to the life cycle of the packaging of AT and NT sheets.

Scenario A: NT fibre-cement sheets with a fifty-year service life

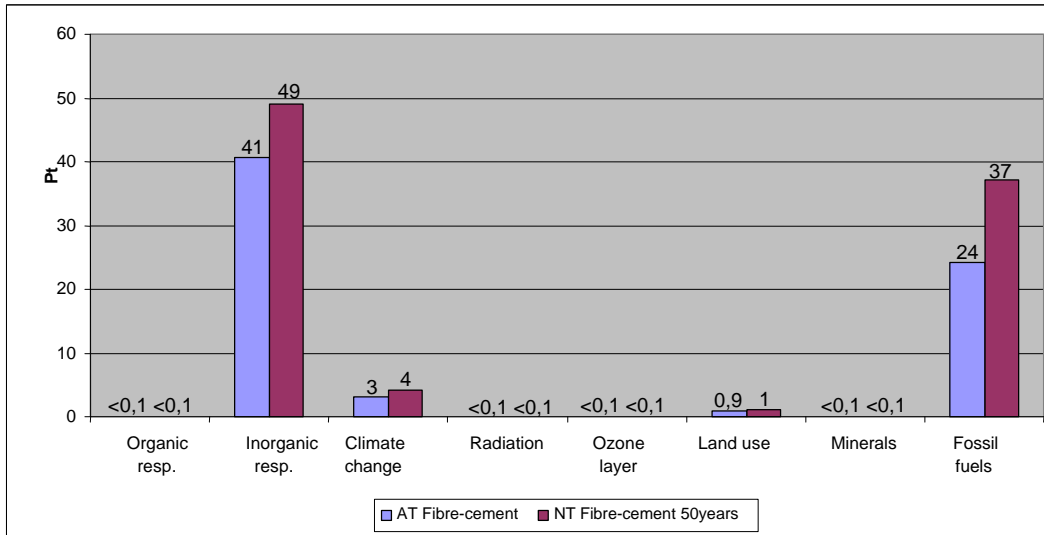


Figure 6 – Comparison of AT and NT sheets per environmental impact category

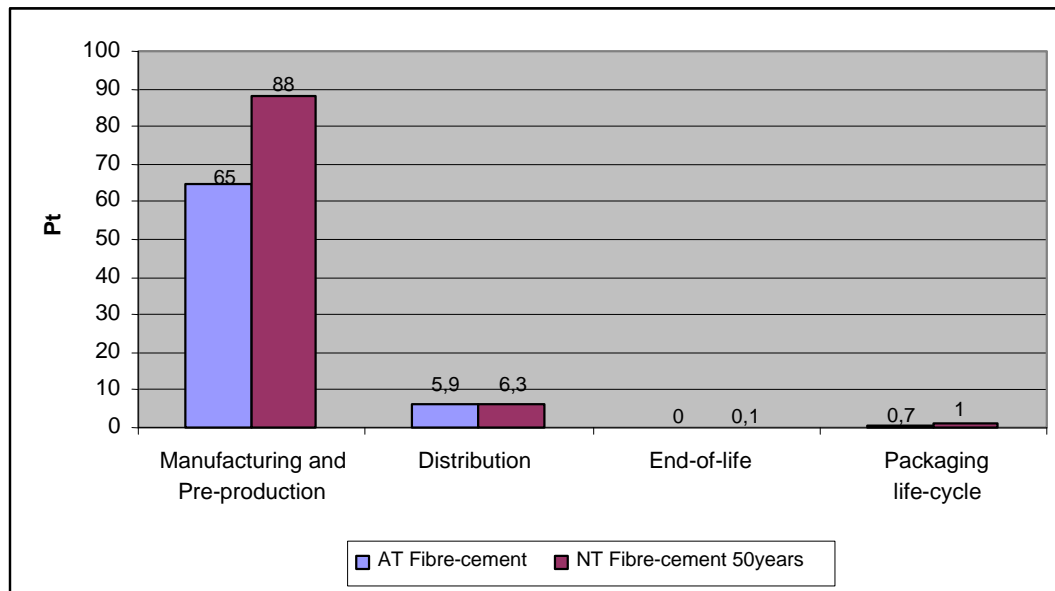


Figure 7 – Comparison of AT and NT sheets per life-cycle stage

Scenario B: NT fibre-cement sheets with a thirty-year service life

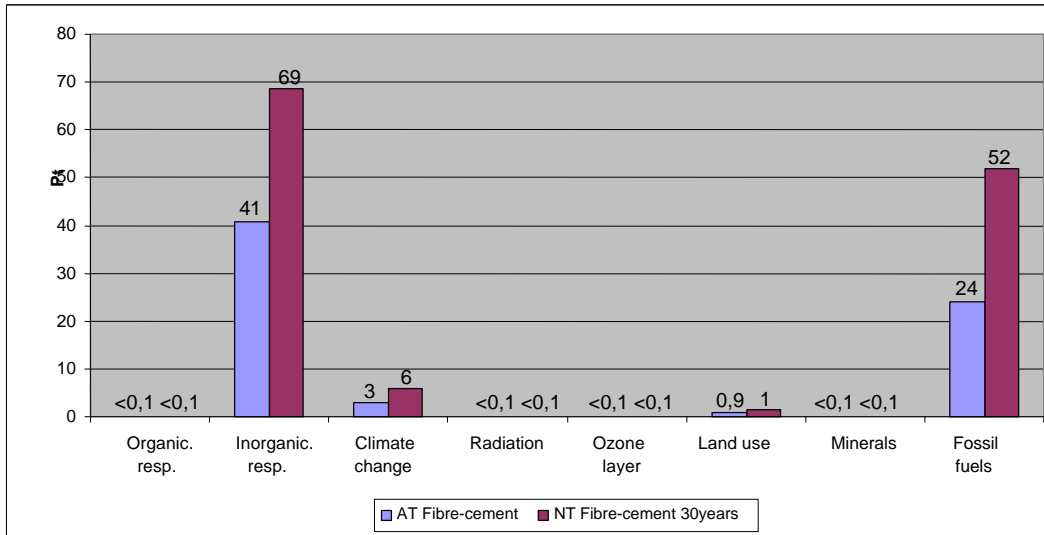


Figure 8 – Comparison of AT and NT sheets (30 years) per environmental impact category

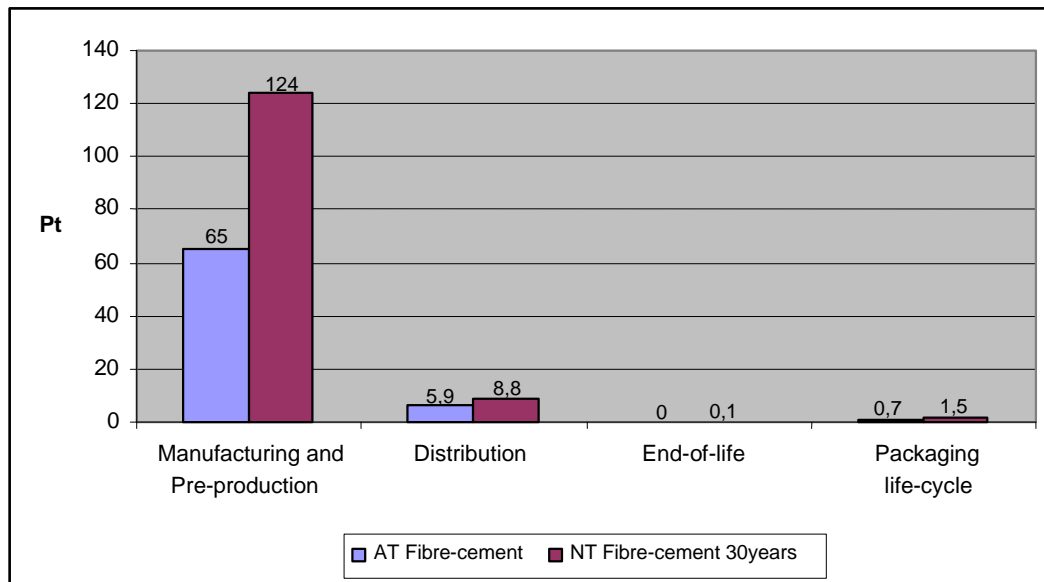


Figure 9 – Comparison of AT and NT sheets (30 years) per life-cycle stage

5. Interpretation of Life Cycle

5.1 Interpretation of Results

As referred to in the study's scope, this work shall not concern itself with issues related to the specific toxicity of the fibres used in fibre-cement (chrysotile asbestos, PVA and cellulose). Accordingly, these were not taken into account in the appraisal of the environmental impact. The analysis of the graphs provided is complemented by information, attached as Appendix III, that identifies the constituent material and/or substances that determine the score assigned to each environmental category.

Scenario A: NT fibre-cement sheets with a fifty year service life

A rapid analysis of figures 6 and 7 allows the immediate conclusion to be drawn that NT fibre-cement has a greater environmental impact than AT fibre-cement in practically all of the categories and all of the life cycle phases.

It can further be concluded that the environmental category on which both types of sheet have the most significant impact throughout their life cycles is clearly the discharge of breathable inorganic particles and the consumption of fossil fuels (figure 6).

The impact due to the discharge of breathable inorganic particles principally results from:

- cement production (AT: 80% and NT: 75%);
- fibre production and its transport to Cimianto's manufacturing facility (AT: 8% and NT: 11%);
- the market distribution of fibre-cement sheets (AT: 6% and NT: 5%).

In both cases the production of cement is principally responsible for the discharge of these types of particles. The production of fibres during the manufacture of NT sheets has a slightly higher discharge percentage than that of AT sheets.

On the other hand, the impact of the consumption of fossil fuels for both types of sheets is principally due to:

- cement production (AT: 62% and NT: 45%);
- fibre production and transport (AT: 15% and NT: 32%);
- electricity consumption during the manufacture of the sheets in Cimianto's manufacturing facility (AT: 10% and NT: 9%);
- the market distribution of fibre-cement sheets (AT: 11% and NT: 7%).

Of note is the fact that the relative importance of cement production in the overall impact total for the consumption of fossil fuels is much greater for the manufacture of AT sheets, whereas, with NT sheets, the production and transport of fibres has a clearly greater impact.

On the basis of figure 7 it can be concluded that the principal environmental impacts of both types of fibre-cement sheet occur in the pre-manufacturing and manufacturing phases, although the impact caused by the distribution phase, resulting from the fact that the transport of the sheets is primarily carried out by road, should not be overlooked.

The processes that range from the extraction of the raw material up to the finished product ready for market distribution are those that most contribute to the overall environmental impact of the life cycle of fibre-cement.

Scenario B: NT Fibre-cement sheets with a thirty year service life

Figures 8 and 9 show that a reduction in the longevity of NT fibre-cement sheets, from fifty to thirty years, causes a proportional increase in the environmental impact in all categories over the life cycle. This increase in the in the environmental impacts of NT fibre-cement sheets only serves to further accentuate the difference in relation to AT fibre-cement.

It can be concluded from the economic data collected (see figure 5), and given the cost difference between the two types under study (AT: EUR 315.00; NT: EUR 440.00), that NT fibre-cement sheets have a greater production cost, whereas AT sheets possess a greater end of service life cost in scenario A.

	Palette AT sheets	Palette NT sheets (scenario A)	Palette NT sheets (scenario B)
Manufacture			
Constituent materials	€183.47	€242.76	€339.86
Packaging	€5.53	€8.42	€11.79
Energy	€7.77	€10.71	€14.99
Waste	€0.81	€3.01	€4.21
TOTAL	€197.58	€264.90	€370.86
End of life	€142.83	€122.85	€171.99

In brief:

If the objective of the study were to compare the environmental impact associated with the life cycle of the types of fibre-cement and, from this, extract information that would be used as a basis for future decision-making processes in the Company, then the results obtained allow the following conclusion to be drawn: AT sheets are economically and ecologically more favourable, in other words, they are more eco-efficient.

Appendices

Appendix I – Life cycle inventory tables used by the “SimaPro 5.1” program

Appendix II – Brief description of the “Eco-Indicator 99 H/A” impact assessment method

Appendix III – Information provided by “SimaPro 5.1”

Appendix IV – Comparison of NT sheets with and without safety tape.

APPENDIX I

Life cycle inventory tables used by the "SimaPro 5.1" program

- AT fibre-cement LCI tables
- NT fibre-cement (50 years) LCI tables

APPENDIX II

Brief description of the “Eco-Indicator 99 H/A” impact assessment method

The “Eco-Indicator 99 H / Europe EI 99 H/A” assessment method used by the “SimaPro 5.1” computer programme is a method that carries out a life cycle assessment. This method consists of eleven impact categories divided into three damage categories:

- Damage to human health, expressed in the number of life years lost and the number of disability-related life years. These two values are combined in an indicator used by the World Bank and the World Health Organisation – DALY (Disability Adjusted Life Years). Damage to human health is caused by:

- carcinogenic substances

The damage to human health caused by the discharge of carcinogenic substances is calculated by means of an estimate of the concentration of those substances in the environment and their effect on human health. The hazard unit concept is used. The hazard unit factor for inhalation, for example, is an estimate of the probability that an average person has of developing cancer when exposed to a polluting compound at a concentration of 1 microgram per cubic metre during that person’s lifetime (70 years).

- respiratory effects from organic compounds
- respiratory effects from inorganic compounds

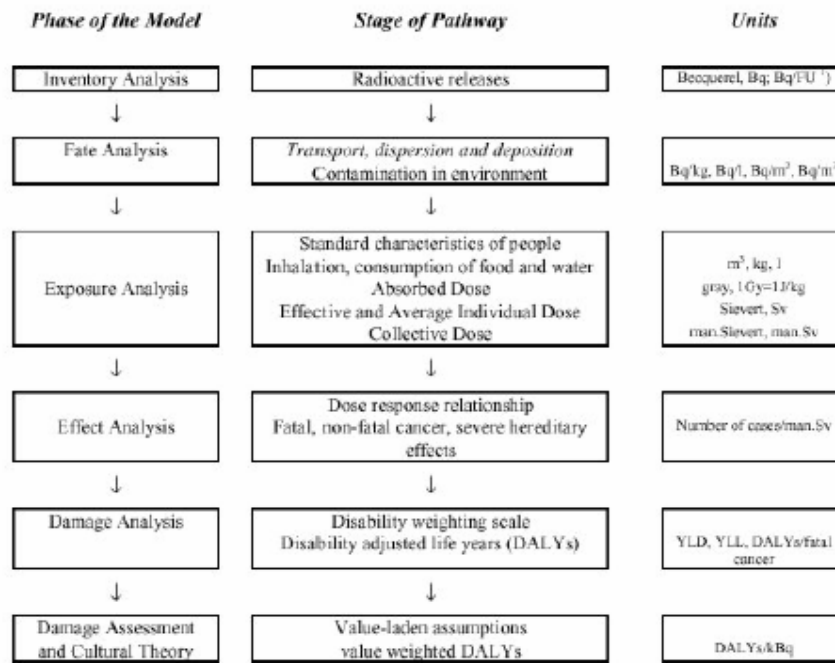
The damage to human health caused by the inhalation of organic and inorganic compounds is calculated by means of a dose-response model. The substances considered in this study are: particles (PM₁₀ and PM_{2.5}), nitrates (NO_x), sulphates (SO_x), ozone (O₃), carbon monoxide (CO), volatile organic compounds (VOC) and ammonia (NH₃).

- climate change

The damage to human health caused by climate change is quite difficult to calculate. Only the following effects, of the many effects that occur, are modelled: exposure to extreme temperatures, changes to the range and activity of infectious vectors and parasites, and a rise in sea-level, with the consequent population movements and destruction of infrastructures.

- radiation

The damage to human health caused by the discharge of ionising radiation is calculated using the following model:



- depletion of the ozone layer

The damage to human health caused by the depletion of the ozone layer is divided into two categories. The first is the prevalence of skin cancer and the second is the prevalence of eye cataracts. The modelling of these effects follows the sequence, Fate – Exposure – Effect – Damage.

- The damage to ecosystem quality, expressed in species lost in a specified area over a specified period of time, is caused by:
 -
 - eco-toxic substances

The assessment of the fate of these substances is calculated using the EUSES model, based on the following equation:

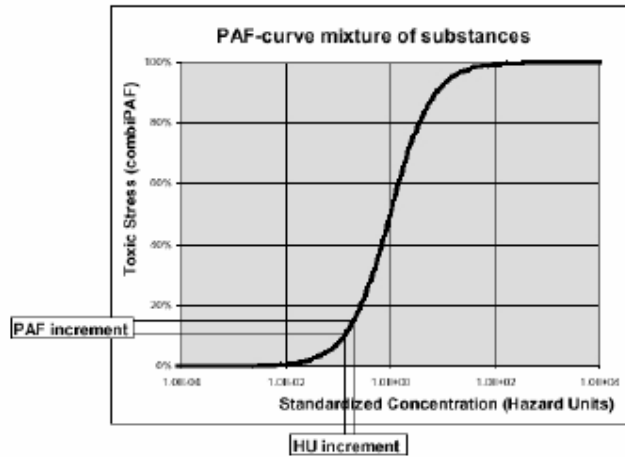
$$PAF(c) = \frac{1}{1 + e^{(\alpha - \log c) / \beta}}$$

C: concentration of the substance

a: parameter calculated from the average NOEC for a single substance for all species

b: coefficient derived from the standard deviation of the NOECs for the substance

The calculation of the damage caused is based on the following graph:



Damage to Ecosystem Quality is indicated by the Potentially Affected Fraction (PAF) of species. The dose-response relationship of the ambient mixture of substances follows a logistic curve. Concentrations of single substances are standardised to Hazard Unit (HU), representing the background mixture of substances.

- acidification and eutrophication

The calculation of this type of damage is carried out by means of the “Nature Planner” modelling system, which is presently only validated for Dutch data. Therefore, the results obtained in this category cannot be applied in Portugal.

- land use

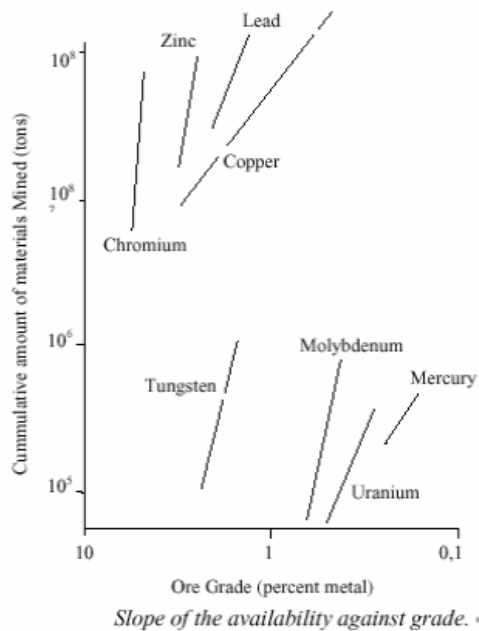
The calculation of the damage in this category is based on the PDF concept (Potentially Disappeared Fraction) and on the values displayed in the following table:

	PDF Occupations		Local and regional PDF of conversion from column to row												
	Only local	regional plus local	Continuous urban	Conventional arable	Integrated arable	Intensive meadow	Organic arable	Less intensive meadow	Organic meadow	Discontinuous urban	Industrial area	Rail area	Green urban	Broad-leaved forest	Swiss Lowlands
Continuous urban	0.95	1.15	0	0	0.01	0.05	0.11	0.11	0.16	0.26	0.26	0.26	0.26	1.04	1.15
Conventional arable	0.95	1.15	0	0	0.01	0.05	0.10	0.10	0.16	0.26	0.26	0.26	0.26	1.03	1.15
Integrated arable	0.95	1.15	0	0	0.01	0.05	0.10	0.10	0.16	0.26	0.26	0.26	0.26	1.03	1.15
Intensive meadow	0.94	1.13	-0.01	-0.01	-0.01	0	0.04	0.09	0.09	0.15	0.25	0.25	0.25	1.02	1.13
Organic arable	0.94	1.09	-0.05	-0.05	-0.05	-0.04	0	0.05	0.06	0.11	0.21	0.21	0.21	0.98	1.09
Less intensive meadow	0.85	1.02	-0.11	-0.10	-0.10	-0.09	-0.06	0	0.05	0.13	0.15	0.15	0.15	0.91	1.02
Organic meadow	0.85	1.02	-0.11	-0.10	-0.10	-0.09	-0.06	0	0.05	0.15	0.15	0.15	0.15	0.91	1.02
Discontinuous urban	0.89	0.96	-0.16	-0.16	-0.16	-0.15	-0.11	-0.05	-0.05	0	0.10	0.10	0.10	0.84	0.96
Industrial area	0.79	0.84	-0.26	-0.26	-0.26	-0.25	-0.21	-0.15	-0.15	-0.10	0	0	0	0.72	0.84
Rail area	0.79	0.84	-0.26	-0.26	-0.26	-0.25	-0.21	-0.15	-0.15	-0.10	0	0	0	0.72	0.84
Green urban	0.79	0.84	-0.26	-0.26	-0.26	-0.25	-0.21	-0.15	-0.15	-0.10	0	0	0	0.72	0.84
Broad-leaved forest	0.70	0.11	-1.04	-1.03	-1.03	-1.02	-0.98	-0.91	-0.91	-0.84	-0.72	-0.72	-0.72	0.11	0.11
Swiss Lowlands	0.00	0.00	-1.15	-1.15	-1.15	-1.13	-1.09	-1.02	-1.02	-0.96	-0.84	-0.84	-0.84	-0.11	0.00

Values for the relative species change for local and the local plus regional occupation in the first two columns. The matrix in the other columns can be used to calculate the effect of conversions. The damage to Ecosystem Quality can be found by multiplying the proper PDF value in this table with the area and the occupation or restoration time.

- The damage to resources, expressed in the surplus energy necessary for the future extraction of minerals and fossil fuels, is caused by:
 - - mineral depletion
 - fossil fuel depletion

These damages are calculated using the surplus energy concept, in other words, the difference between the energy needed now to extract a resource and the energy needed in the future. In relation to minerals, this concept can be represented by means of the slope of the lines plotted on the graph that follows. In relation to fossil fuels, the calculations are made based on estimates of existing reserves and possible replacement fuels.



The contribution of the inputs and outputs of the different individual processes throughout the life cycle of the product are assessed using the Eco-Indicator points unit (Pt). These points are dimensionless units.

The absolute value of these points is not really relevant, given that the main objective is to compare the relative differences between products or types of constituent material. The scale is selected so that one point represents one thousandth of the annual environmental load of one average European inhabitant.

Uncertainties of the method

In any reading of the results it is important to bear in mind the uncertainties associated with the method. Two main types can be highlighted:

- data-related uncertainties,
- uncertainties regarding the precision of the models used.

The uncertainties related to data are specified for the majority of the damage factors as a "squared geometric standard deviation" in the original reports, but not as such in the computer program. Expressing the model's uncertainties as a distribution is not constructive. The uncertainties that exist in relation to the model are related to the subjective choices made in the model. Three different versions of the method were developed to deal with these uncertainties. These three versions use the archetypes specified in:

- the egalitarian perspective,
- the hierarchist perspective,
- the individualist perspective.

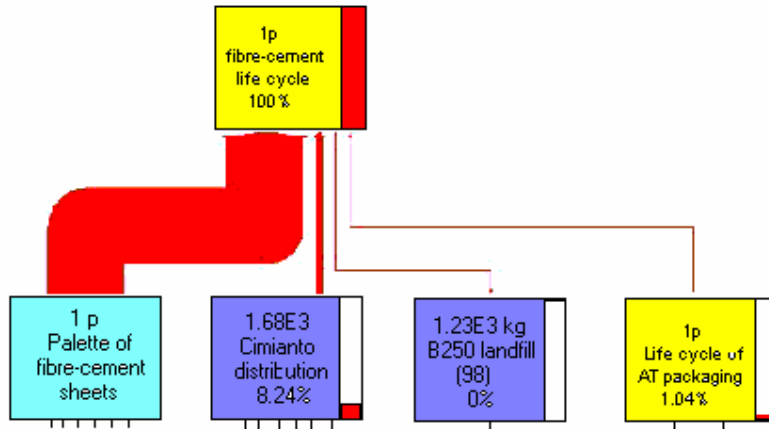
In the perspective used by this study, the hierarchist one, the chosen time perspective is "long term" and the substances are included if there is consensus regarding their effect. For example, all of the carcinogenic substances in class 1, 2a and 2b of the IARC are included, whereas those of class 3 are deliberately excluded.

The hierarchist perspective assumes that damage is avoidable through good management. For example, the danger of people being forced to flee from rising water levels is not included. With regards to fossil fuels, it is assumed that they cannot be easily replaced. The weighting of age is not included in the DALY calculations.

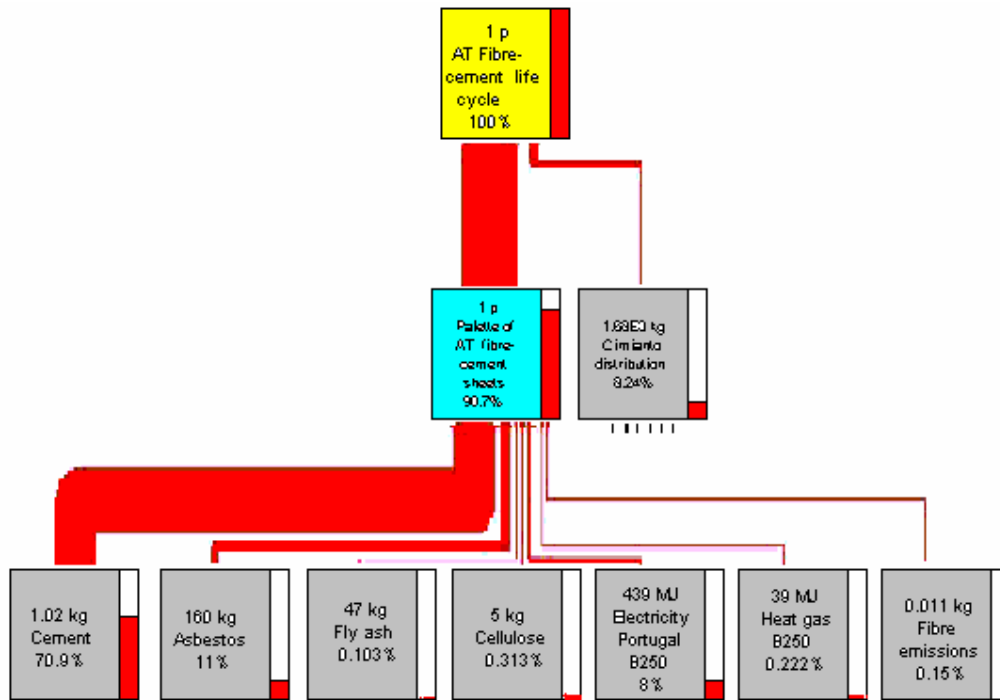
APPENDIX III

Results of the "SimaPro 5.1" Program

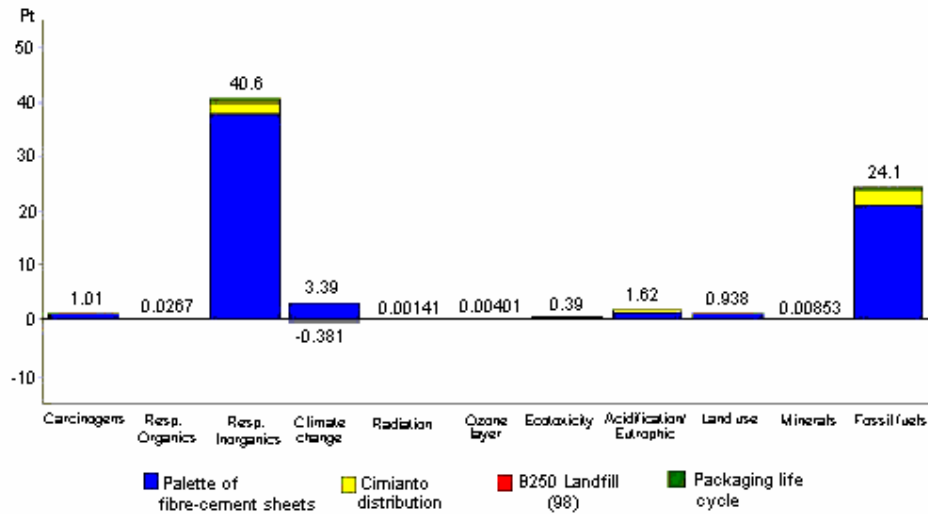
Principal results of the impact assessment of the life cycle of AT fibre-cement sheets



Tree diagram of the general factors contributing to the overall environmental impact of AT sheets

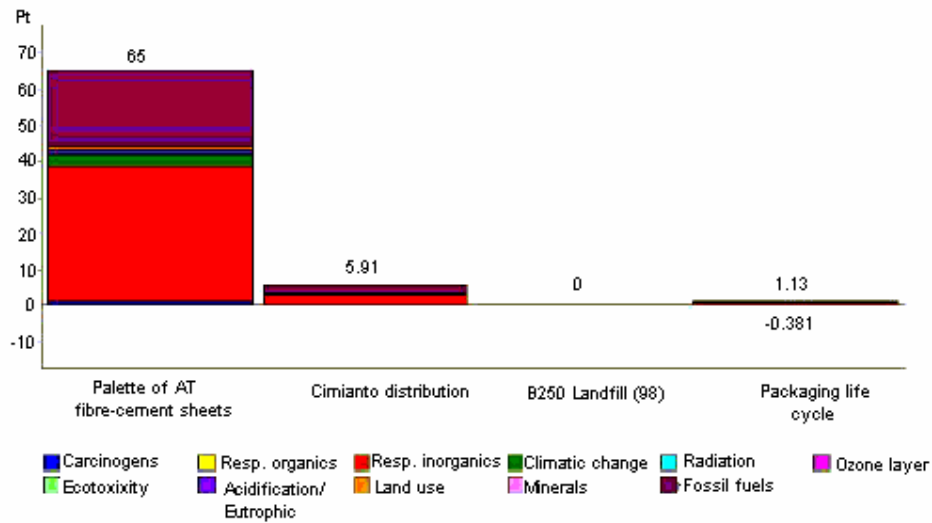


Tree diagram of the principal factors contributing to the overall environmental impact of AT sheets



Analysing 1 p life cycle of 'AT fibre-cement life cycle'
 Method: Eco-Indicator 99 (H) / Europe EI 99 H/A / weighting

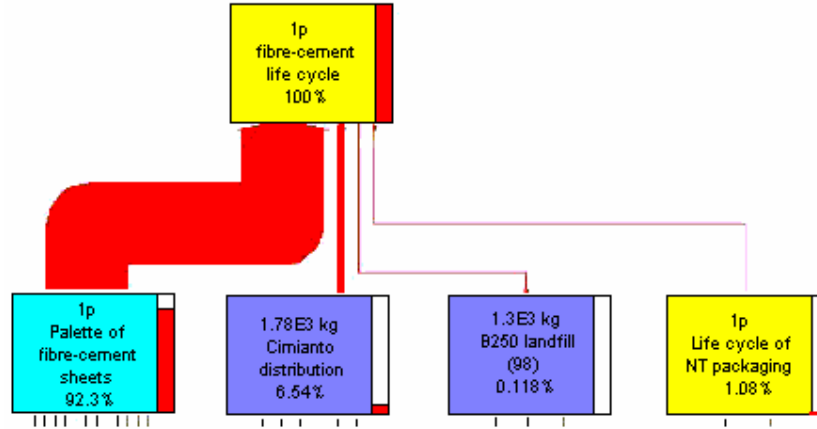
Assessment of AT sheets - environmental impact categories



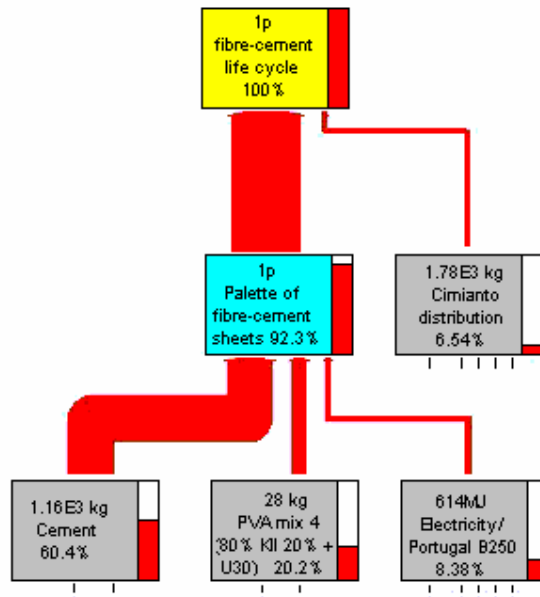
Analysing 1 p life cycle of 'AT fibre-cement life cycle'
 Method: Eco-Indicator 99 (H) / Europe EI 99 H/A / single scoring

Assessment of AT sheets – life cycle phases

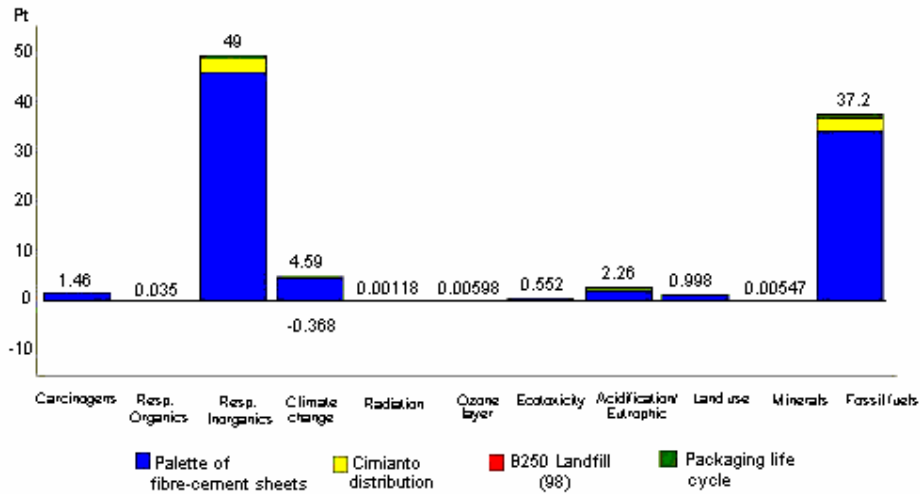
Principal results of the impact assessment of the life cycle of NT fibre-cement sheets (50 years)



Tree diagram of the general factors contributing to the overall environmental impact of NT sheets

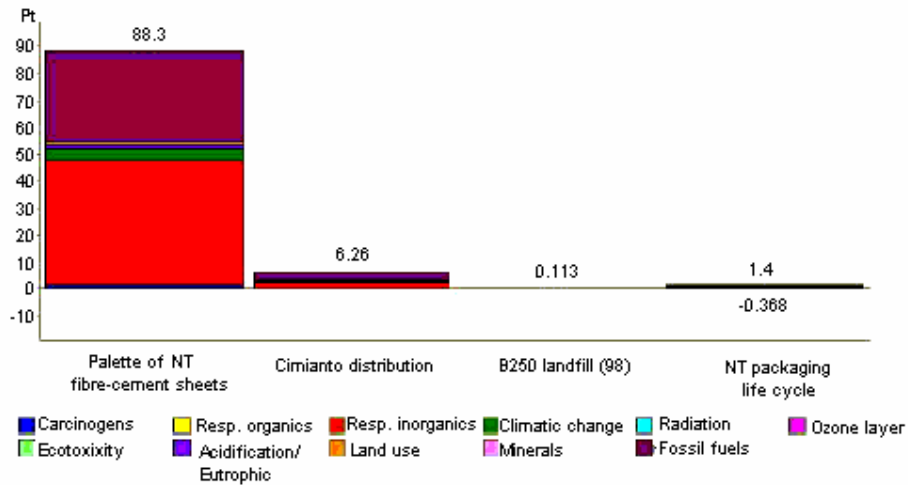


Tree diagram of the principal factors contributing to the overall environmental impact of NT sheets



Analysing 1 p life cycle of 'NT fibre-cement life cycle (50 years)
Method: Eco-Indicator 99 (H) / Europe EI 99 H/A / weighting.

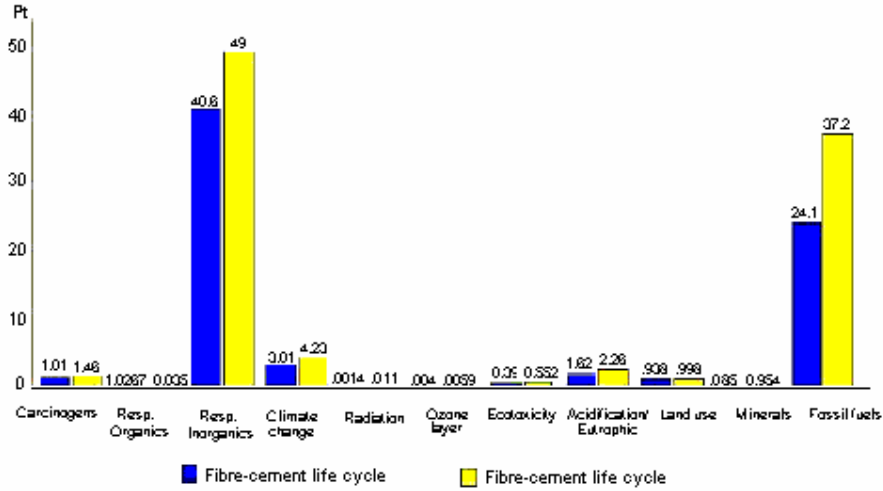
Assessment of NT sheets - environmental impact categories



Analysing 1 p life cycle of 'NT fibre-cement life cycle (50 years)
Method: Eco-Indicator 99 (H) / Europe EI 99 H/A / single scoring

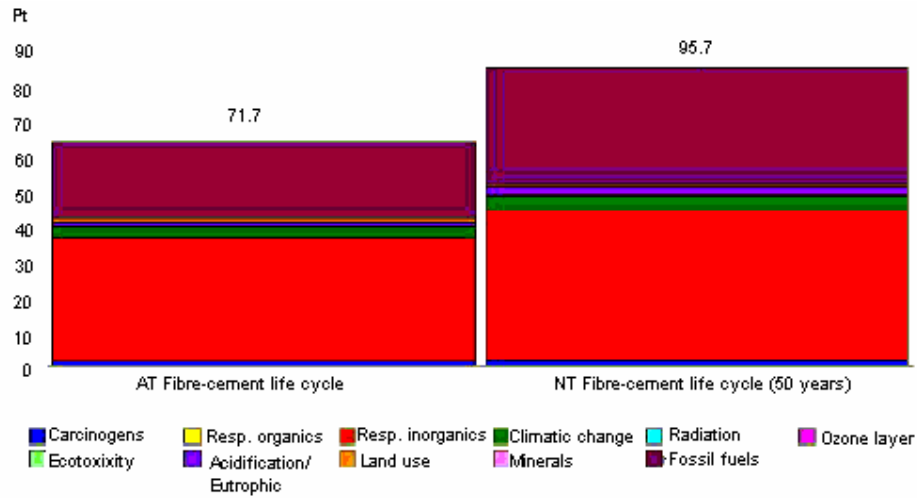
Assessment of NT sheets – life cycle phases

Comparison of the impact assessment results of the life cycles of AT and NT fibre-cement sheets



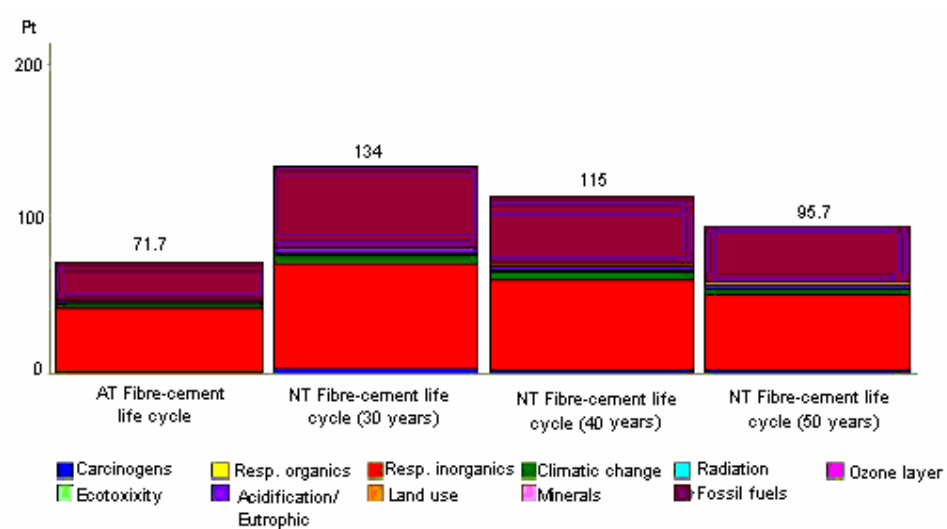
Comparing 1 p life cycle of 'AT fibre-cement life cycle' with 'NT fibre-cement life cycle (50 years)
Method: Eco-Indicator 99 (H) / Europe EI 99.

Environmental impact comparison



Comparing 1 p life cycle of 'AT fibre-cement life cycle' with 'NT fibre-cement life cycle (50 years)
Method: Eco-Indicator 99 (H) / Europe EI 99

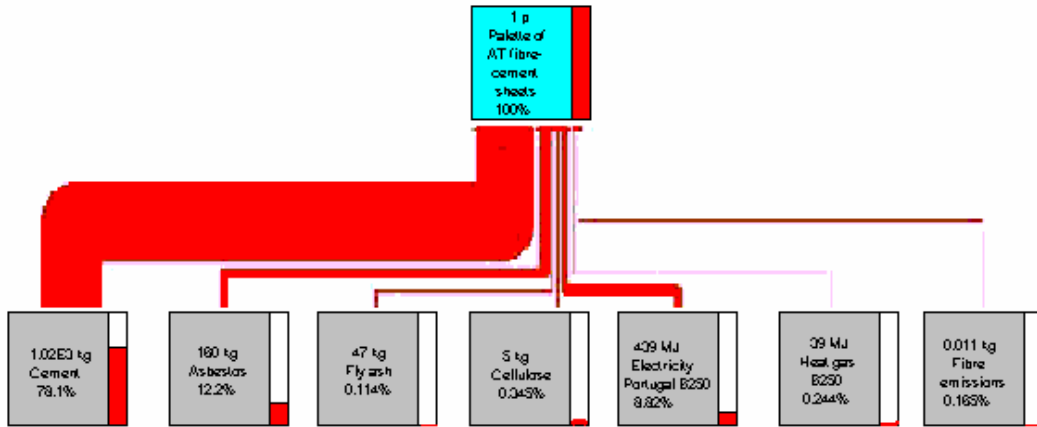
Comparison of the total impact values of the life cycles



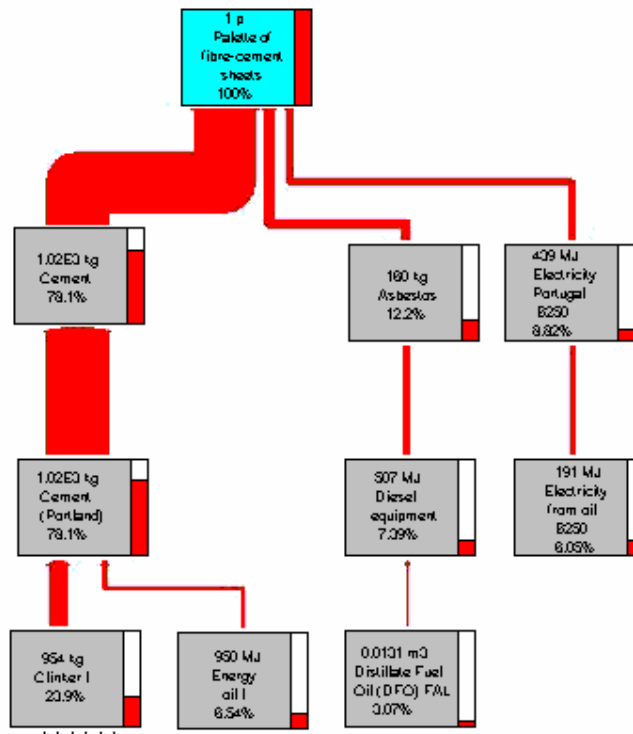
Comparing product phases; Method: Eco-Indicator 99 (H) / Europe EI 99 H/A / single scoring

Comparison of the total impact values for the life cycles of AT sheets and NT sheets with 30, 40 and 50 years durability.

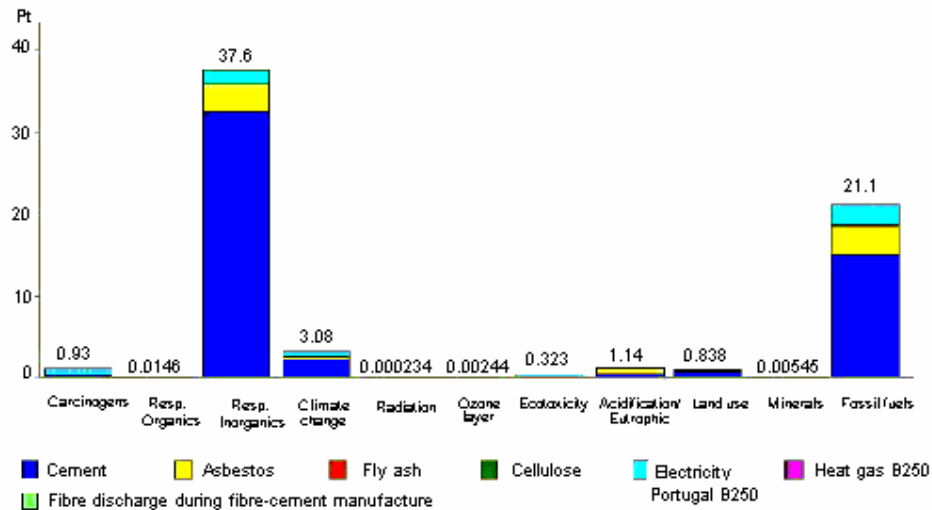
Principal results of the impact assessment of the assembly (pre-production and manufacture) of AT fibre-cement sheets



Tree diagram of the general factors contributing to the environmental impact of the assembly of AT sheets

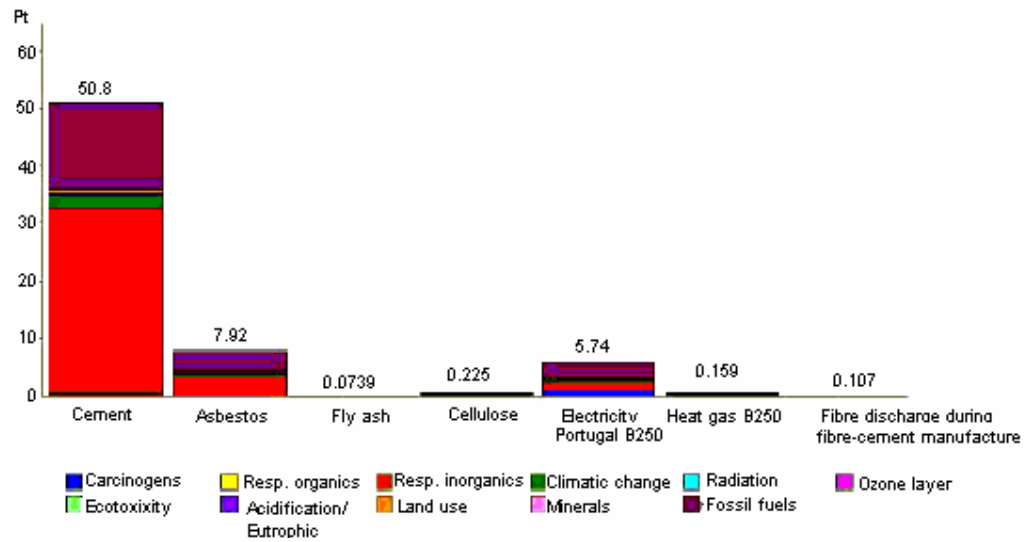


Tree diagram of the principal factors contributing to the environmental impact of the production of AT sheets



Analysing 1 p assembly of 'Palette of AT fibre-cement sheets
 Method: Eco-Indicator 99 (H) / Europe EI 99 H/A / weighting.

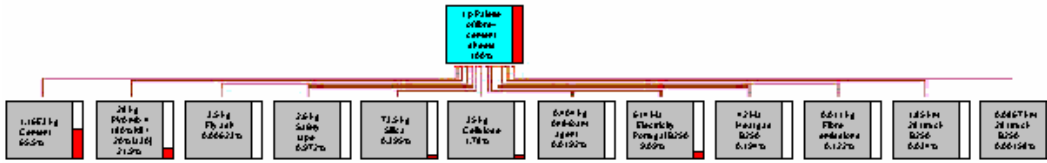
Assessment of the production of AT sheets - environmental impact categories



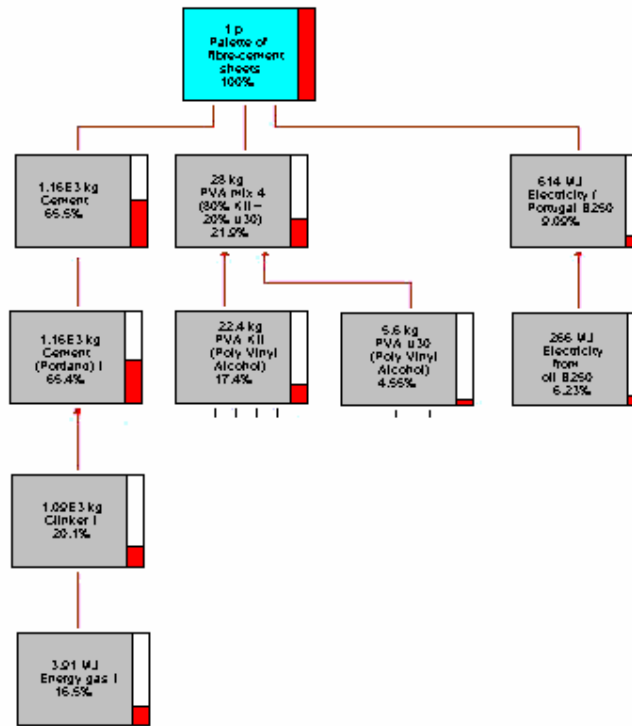
Analysing 1 p assembly of 'Palette of AT fibre-cement sheets
 Method: Eco-Indicator 99 (H) / Europe EI 99 H/A / single scoring.

Assessment of the production of AT sheets – components

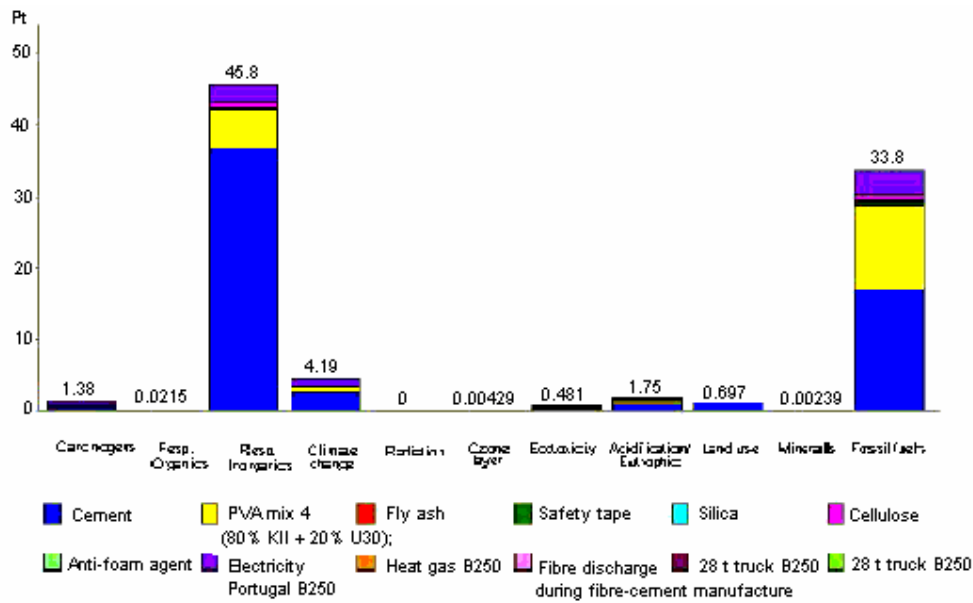
Principal results of the impact assessment of the assembly (pre-production and manufacture) of NT fibre-cement sheets (50 years)



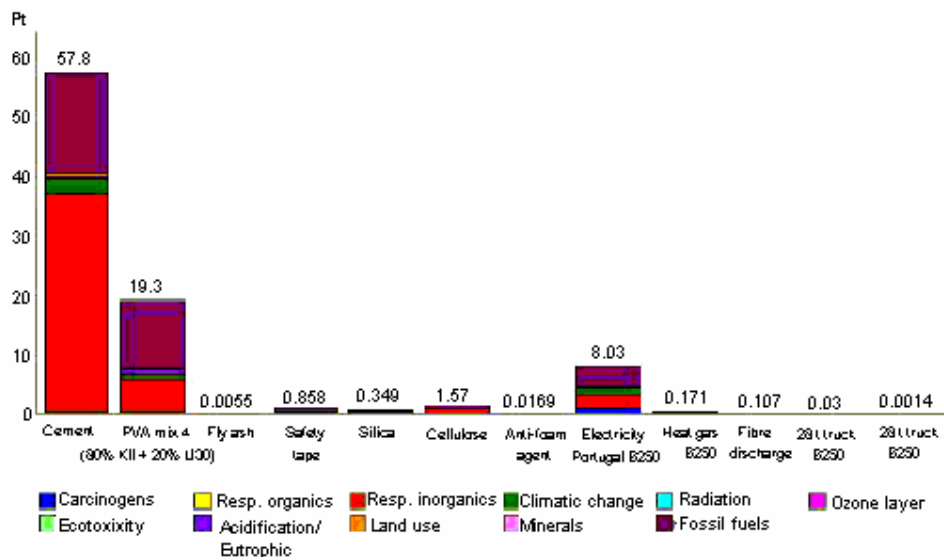
Tree diagram of the general factors contributing to the environmental impact of the assembly of NT sheets



Tree diagram of the principal factors contributing to the environmental impact of the assembly of NT sheets

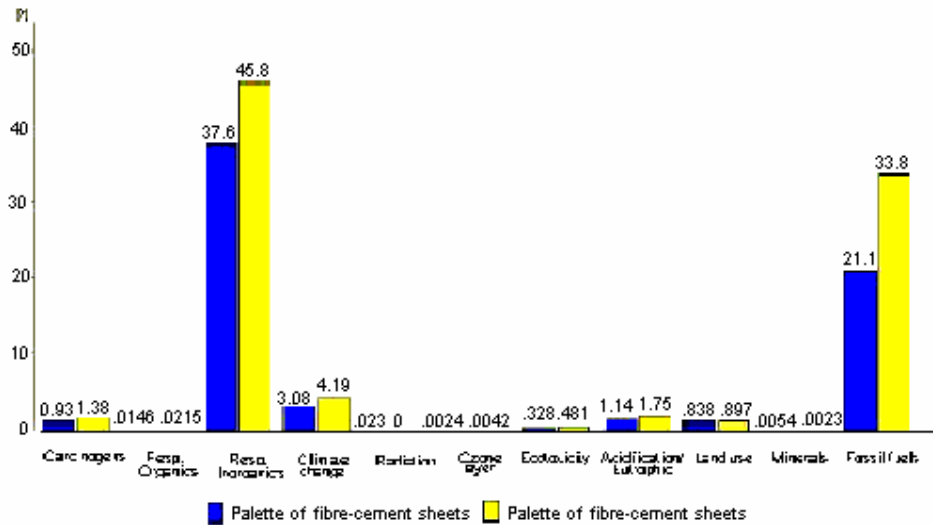


Assessment of the production of NT sheets - environmental impact categories



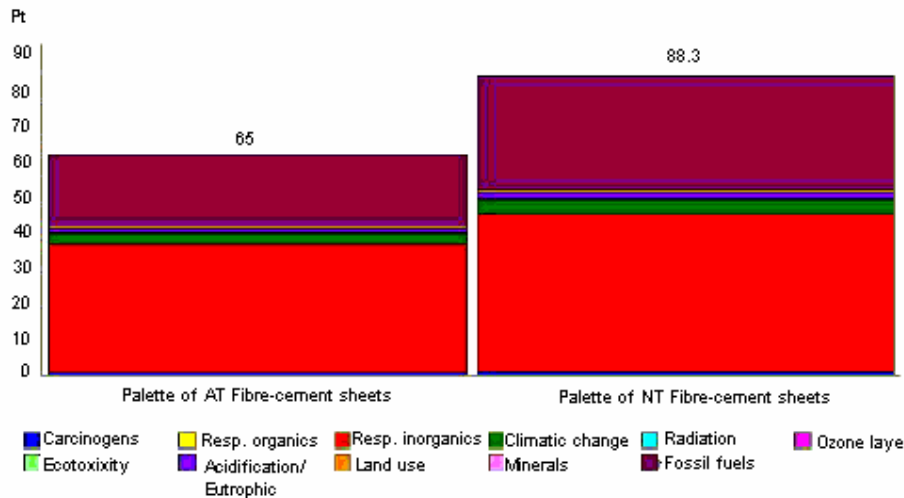
Assessment of the production of NT sheets – components

Comparison of the impact assessment results of the pre-production and manufacture of AT and NT fibre-cement sheets



Comparing 1 p assembly of 'Palette of AT fibre-cement sheets' with 1 p assembly of 'Palette of NT fibre-cement sheets'
 Method: Eco-Indicator 99 (H) / Europe EI 99 H/A.

Environmental impact comparison



Comparing 1 p assembly of 'Palette of AT fibre-cement sheets' with 1 p assembly of 'Palette of NT fibre-cement sheets'
 Method: Eco-Indicator 99 (H) / Europe EI 99 H/A.

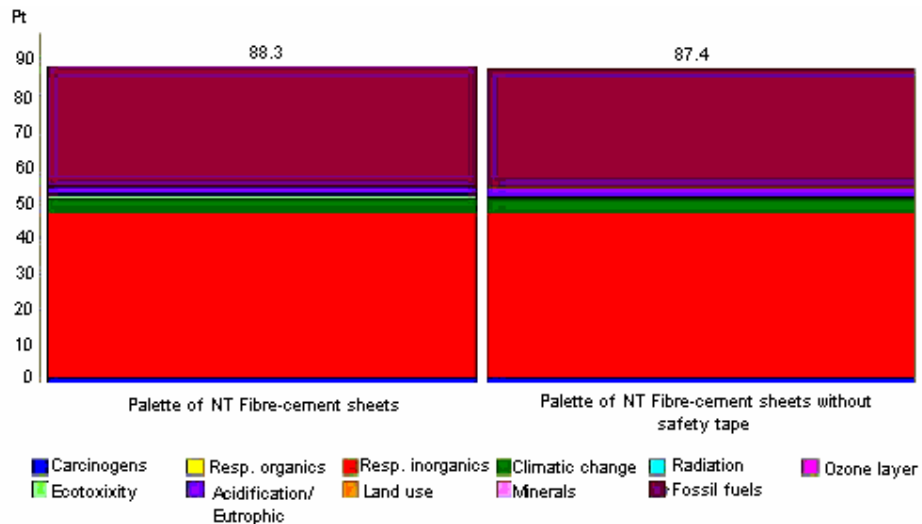
Comparison of the fibre-cement sheet assembly total impact values

APPENDIX IV

Comparison of NT sheets with and without Safety Tape

During the presentation of the results to Cimianto, the issue of the environmental impact of safety tape used in NT fibre-cement sheets was raised.

In response, the comparative results of the impact of the pre-production and manufacture phases of one palette of sixty NT sheets with safety tape and without safety tape are illustrated below.



Comparing 1 p assembly of 'Palette of NT fibre-cement sheets' with 1 p assembly of 'Palette of NT fibre-cement sheets without safety tape
Method: Eco-Indicator 99 (H) / Europe EI 99

Comparison of the total impact of the production of NT sheets with and without safety tape

On the basis of the above graph, it can be concluded that the difference between the total environmental impact values is minuscule.

Moreover, it can further be stated that the main impact of safety tape occurs in the “extraction of fossil resources” category, due to the fact that the material used (polypropylene) is a non-renewable resource.