FEASIBILITY STUDY

NANOMETRIC INPUTS

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PAÍS RICO É PAÍS SEM POBREZA

FEASIBILITY STUDY
OF A NANOMETRIC INPUT PLANT
FOR IMPROVEMENT OF PLASTIC PACKAGING

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Rio de Janeiro
2012

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SENAI - *Serviço Nacional de Aprendizagem Industrial* - SP (National Institute for Industrial Learning)

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1 MOTIVATION AND RATIONALE

1.1 MOTIVATION

To meet the need pointed out by the Nanotechnology Competitiveness Forum, that is, "To make feasible the use of nanometric inputs as raw material of the packaging industry aiming to secure a competitive edge in the national and international market for the Brazilian plastic packaging industry production chain", in order to appropriate, to the industry such competitive edge in relation to the field of advancement of knowledge in nanomaterials.

1.2 RATIONALE

The Innovation Office *(Secretaria de Inovação)* develops several nanotechnology promotion actions in strategic sectors in Brazil. One of them addresses the identification of technologies to be developed to meet future demands in production chains and/or elimination of technological bottlenecks aiming at the increase of competitiveness of national industrialized products.

The plastic industry production chain generates jobs and boosts the regional income distribution. According to ABIPLAST – Brazilian Plastic Industry Association there are approximately 12.000 establishments directly employing over 350.000 people with invoicing above US$ 25 billion in 2010.

The use of nanotechnology in such chain may represent an improvement in quality and cost reduction in final products which would lead to competitive gain to the national industry.

On the other hand there is no systematized information on the amount to be invested as well as on the possibilities of application of nanotechnology in plastic packaging. Such lack of information restrains the industry development.

This Study intends to guide the capacity and interest of Brazilian or foreign entrepreneurs in the financial investment for construction of industrial units aiming at the production of nanometric inputs for improvement of plastic packaging.

The feasible utilization of nanometric inputs as raw material of the packaging industry may lead the industry to secure competitive advantages in the domestic and foreign market both in quality gain represented by weight reduction and improvement of finish of plastic parts and in reduction of operational costs.

2 EXECUTIVE SUMMARY

2.1 INTRODUCTION

The use of nanotechnology in plastic packaging has become a reality throughout the world in the last five years representing a market higher than US$ 250 million in 2011. Among the most used nanometric inputs we find nanoclay with a market share of 70% in volume.

The use of nanoclay as nanometric input for improvement of plastic packaging is present in successful cases of competitive companies located in knowledge-generating countries and leaders in production of patents and innovative products.

The review of characteristics of the Brazilian plastic packaging market enabled us to identify that the food packaging industry holds a strategic position due to Brazil strong and solid tradition as food producer and exporter to the world.

Particularly the advanced /functionalized nanoclays have increasingly gaining more attention from the food packaging industry as they offer benefits related to the presence of new properties such as anti-bacterial and oxygen scavenger.

The demand estimate appearing herein shows that the Brazilian market of nanoinputs for food packaging industry in 2016 will be between R$14 and R$41 million.

2.2 TECHNOLOGICAL ROUTE

The routes studied for production processes of masterbatches of pure or functionalized nanoclay presented herein are based on studies of several national and international patents, scientific papers and case studies.

The proposed technological route covers treatment stages of a bentonite type of clay with an organic modifier thus obtaining an organophilic clay as well as a functionalized organophilic clay with silver and iron salts. With such route it is possible to produce masterbatches of pure or functionalized nanoclay by intercalation of nanoinputs in a resin in cast state.

2.3 PLANT PRODUCTS

The products obtained by the industrial plant will be the masterbatch of pure nanoclay and the masterbatch of functionalized nanoclay.

The above masterbatches are nanocomposites of high concentration in nanoinput (25% in weight) destined to be diluted by transformers / processors of plastic packaging in the proper posology according to the desired properties. This type of supply is standard in the industry for safety reasons and easy handling. The offer of nanometric inputs through a masterbatch instead of powder limits and controls the use and the dispersion thereof out of the industrial plant.
It should also be emphasized that, for a ton of plastic packaging the plastic processing industry should use 80% of conventional resin and add 20% of one of the above masterbatch products.

The plant will have production capacity of 1.800 tons per year of pure nanoclay masterbatches and 400 tons per year of functionalized nanoclay masterbatches with prospective expansion to 4.100 and 900 tons per year respectively.

In this Feasibility Study the nominal production capacity of the nanoinput production industrial plant for the plastic packaging industry will be set forth to meet 100% of the expectation of Brazilian consumption of masterbatch in 2019 with prospect of expansion to meet the demand up to 2025.

2.4 ECONOMIC ANALYSIS

The best scenario assessed in this preliminary study refers to Natural Clay with production of masterbatch of pure nanoclay with plant expansion and MO2 route for operation. Such scenario offers Internal Rate of Return (IRR) of 63% to shareholders and payback of 5,5 years on Capex upper limit. If the sale price will drop by 10%, the IRR will be 44% for the same Capex. The condition of attractiveness of the project is its rate of return being higher than the capital cost.

The IRR is given in a purely economic sense, namely, to measure the project attractiveness degree taking into account the financing of 90% with interest of 4% per year, 4 years of grace period and payment in 6 years according to the BNDES PSI innovation line. Besides this credit operation a tax benefit of 34% (over interest) was also considered.

Scenario 12 – Natural Clay only with production of Pure Nanoclay Masterbatch with Expansion, Route MO2		**Implementation (R$)**	**Expansion (R$)**	**Total (R$)**
CAPEX	Calculated Individual Capex	12.834.760	8.583.440	21.418.200
	Upper Limit (+ 50%)	19.252.140	12.875.160	32.127.300
OPEX	Fixed Costs / Year	2.854.700	3.574.200	3.574.200
	Variable Costs (Case MO2) / year	6.886.945	15.553.915	15.553.915

However it is important to emphasize that the choice of Scenario 12 as the best alterantive is solely based on economic variables and not on a detailed analysis of technological and engineering processes, a common and intrinsic condition at this preliminary stage. The low cost of the organic modifier used in this Route (MO2) compared with MO1 can explain the results of the economic-financial analysis. The next stage of this study will require the validation of the technological routes and characterization of the properties of final products based on reference materials. The choice of precursor raw material (organophilic or natural clay) and organic modifier (high cost MO1 or low cost MO2) are critical varialbles which can represent an important risk to this project.

3 REVIEW OF PLASTIC PACKAGING INDUSTRY

3.1 INTRODUCTION

This chapter will be presenting macroeconomic data of the Brazilian packaging market and a basic structural review of the Brazilian processed plastics industry. Additionally the packaging production processes will also be addressed as well as the segmentation of thermoplastic resins applied to the production of plastic packaging.

3.2 BRAZILIAN PACKAGING MARKET

According to the ABRE/FGV (2012) Macroeconomic Study of Packaging the physical production of the packaging industry should increase by 1.6% in 2012 and the national packaging manufacturers should earn revenues near R$ 46 billion exceeding the R$ 43.7 billion generated in 2011. The employment level in the packaging industry should go on in a moderate expansion being close to 230 thousand jobs in December 2011. The data referring to the evolution of the packaging industry invoicing between 2006 and 2011 are presented in Table 1.

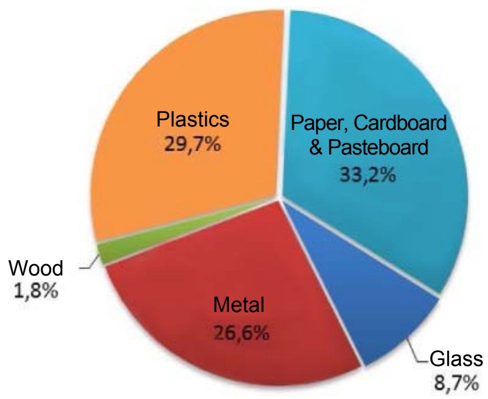
Table 1 – Packaging Industry Invoicing (In billions R$)

Year	Net Sales Revenue	Gross Production Value
2006	31,3	30,9
2007	33,2	32,9
2008	35,3	34,5
2009	35,1	33,8
2010*	40,7	39,2
2011*	43,7	42,1

Companies with 30 employees and above
(*) Estimated Data
Source: *Estudo Macroeconômico da Embalagem* ABRE/FGV – February 2012

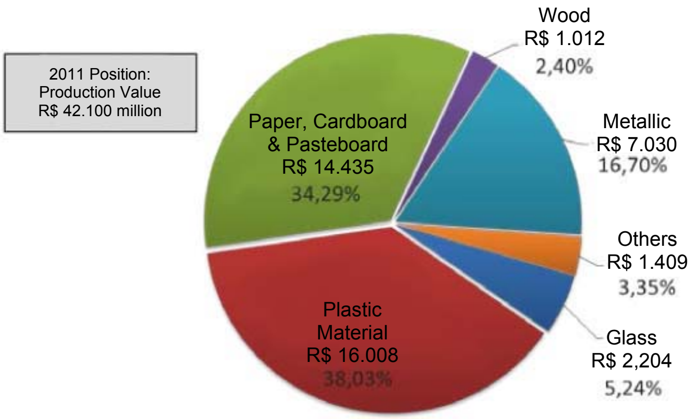
In 2011, the plastic packaging segment in Brazil had a 29.7% share of the total physical packaging production (Chart 1). In relation to the total production value plastic materials represented 38,03% or approximately R$ 16 million in the same period.

Chart 1 – Physical Production



Each segment share in packaging industry
Source: *Estudo Macroeconômico da Embalagem* ABRE / FGV – February 2012

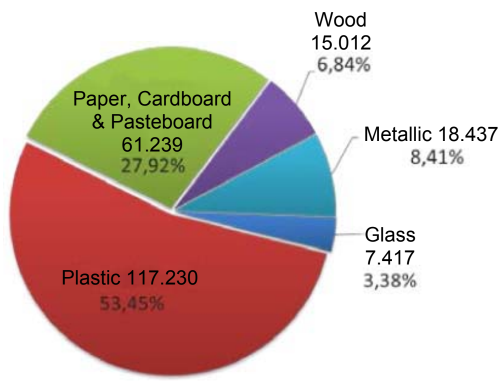
Chart 2 – Production Value



Each segment share in the packaging industry
Source: *Estudo Macroeconômico da Embalagem* ABRE / FGV - February 2012

Plastics is the most hiring industry as compared to other materials of the packaging segment, totaling 117.230 (53,45%) formal jobs in 2011 (Chart 3). Next come the materials such as paper, cardboard and pasteboard with 61.239 employees (27,92%), metallic materials with 18.437 (8,41%), wood with 15.012 (6,84%) and glass with 7.417 (3,38%).

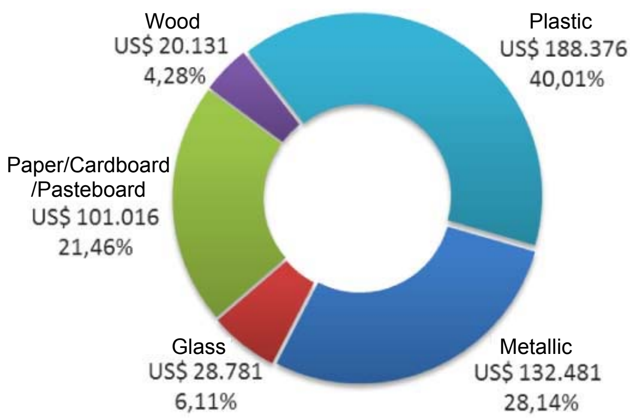
Chart 3 – Formal Jobs



Source: *Estudo Macroeconômico da Embalagem* ABRE / FGV – February 2012

The national packaging industry recorded a total of US$ 470,784 million in 2011 exports totaling 13,2% above 2010, with strong performance by the plastics industry corresponding to 40,01% of the total exported followed by metallic packaging (28,14%).

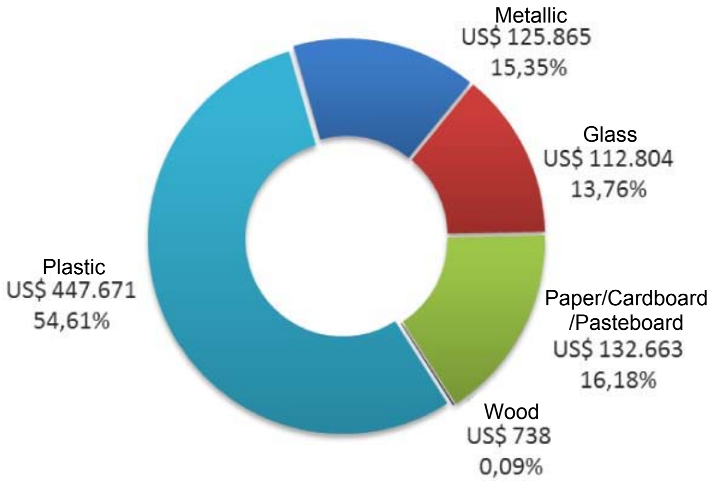
Chart 4 – Exports



Values in thousands of US Dollars
Source: *Estudo Macroeconômico da Embalagem* ABRE / FGV - February 2012

In 2011, imports grew by 3,03% in relation to 2010, reaching an invoicing of US$ 819.741 million. Out of the imported total, the plastic sector corresponds to 54,61% followed by paper, cardboard and pasteboard (16,18%) and metallic packaging (15,35%).

Chart 5 - Imports



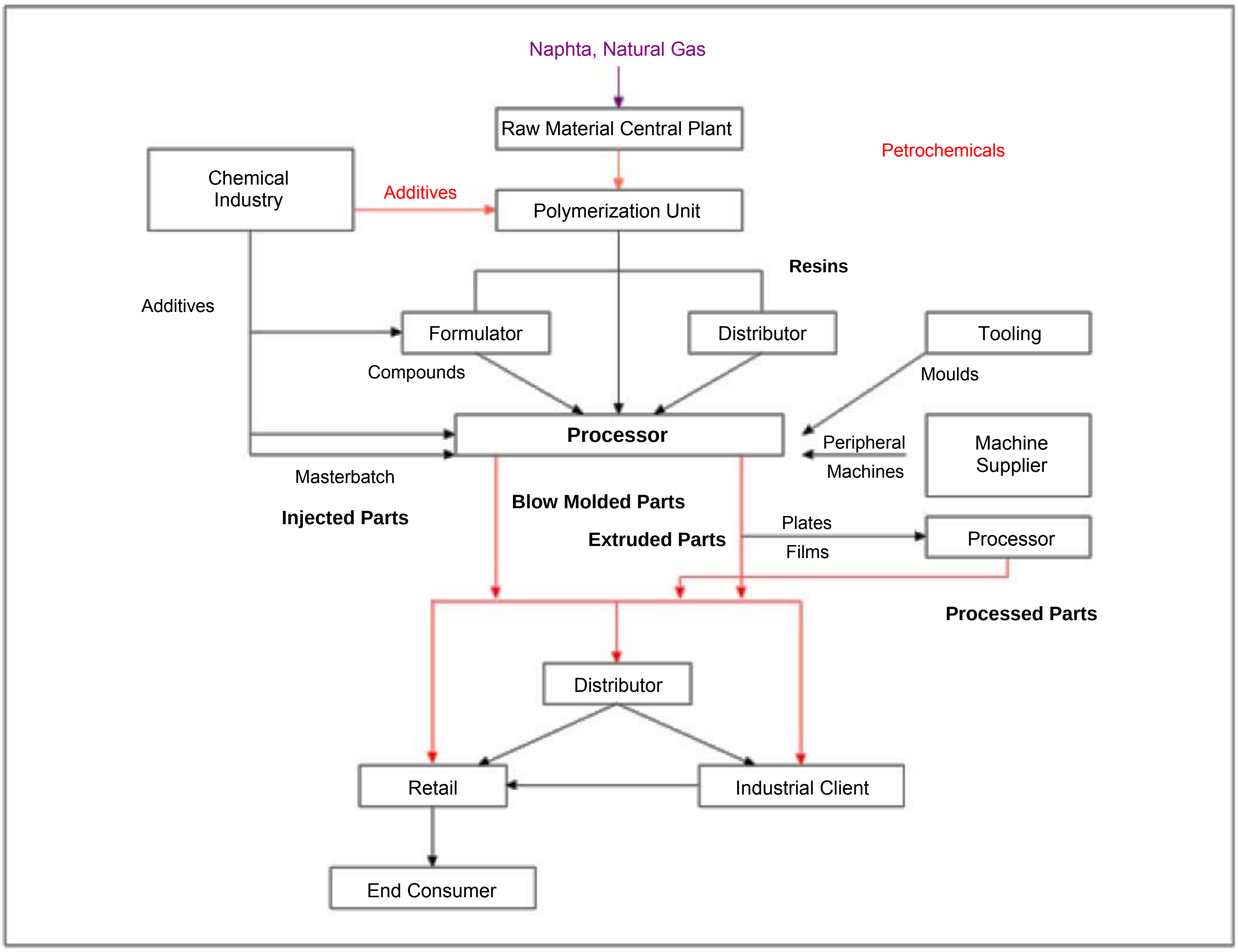
Values in thousands of US Dollars
Source: *Estudo Macroeconômico da Embalagem* ABRE / FGV – February 2012

3.3 PROCESSED PLASTICS INDUSTRY

The plastic processing production chain (Figure 1) is formed by the first generation of the petrochemical industry where the basic raw materials are produced such as olefins and aromatics. The next stage of the chain is formed by the second generation of the petrochemical industry which, based on polymerization processes, answers for the production of thermoplastic resins, a major raw material of the processed plastics industry. In the third generation of the petrochemical industry (processed plastics industry) which answers for 4% of the petroleum consumption (virtually half of the population of the first and second petrochemical generation) a wide range of plastic material products are manufactured and distributed to the end consumer.

According to a BNDES sector review (2010), among these plastic products the production of packaging for several industrial applications uses 43% of the total of thermoplastic resins supplied by the petrochemical industry second generation.

Figure 1 – Plastic Processing Industry Production Chain

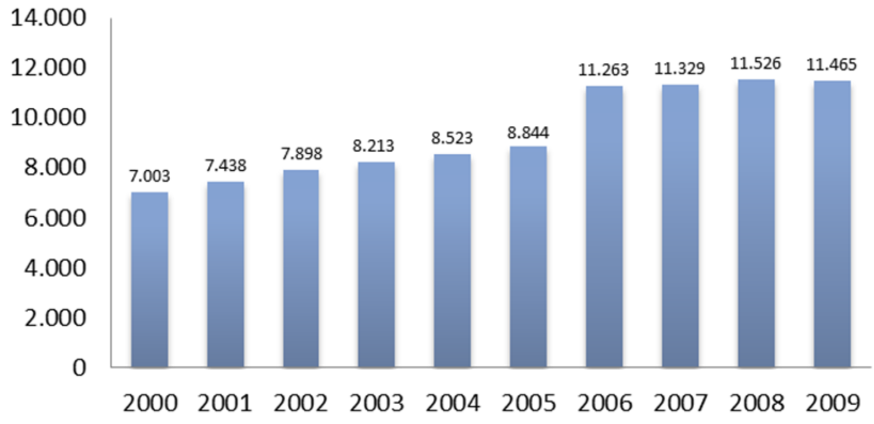


Source: Padilha, G. *"Caracterização e Perfil Competitivo da Indústria de Transformação de Plástico: Um estudo de Indústrias do Rio de Janeiro"*, EQ/UFRJ, 1999

3.4 BASIC STRUCTURAL ANALYSIS OF PROCESSED PLASTICS INDUSTRY

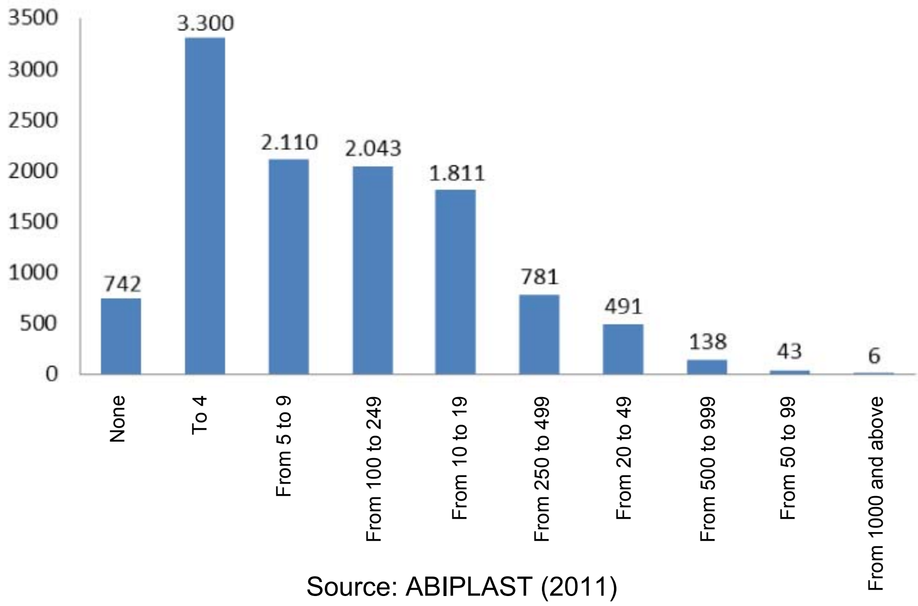
While the first and second generation of the petrochemical industry correspond to a typical case of concentrated oligopoly with significant entrance barriers, a reduced number of companies and with strong investment in research, technology and innovation, the processed plastics industry, on the other hand, has no relevant barriers to the entrance and technological replacement and presents an extremely diluted and pulverized and little concentrated structure. According to Abiplast, the plastic processing industry involves approximately 11.465 companies (Chart 6), most of them under family control where 94,9% correspond to companies up to 90 employees which swing between formal and informal economy. Only 0,43% of the companies have more than 500 employees and 5,48% are medium sized between 99 and 499 employees (Chart 7).

Chart 6 – Companies in the Processed Plastics Industry 2000-2010



Source: ABIPLAST (2011)

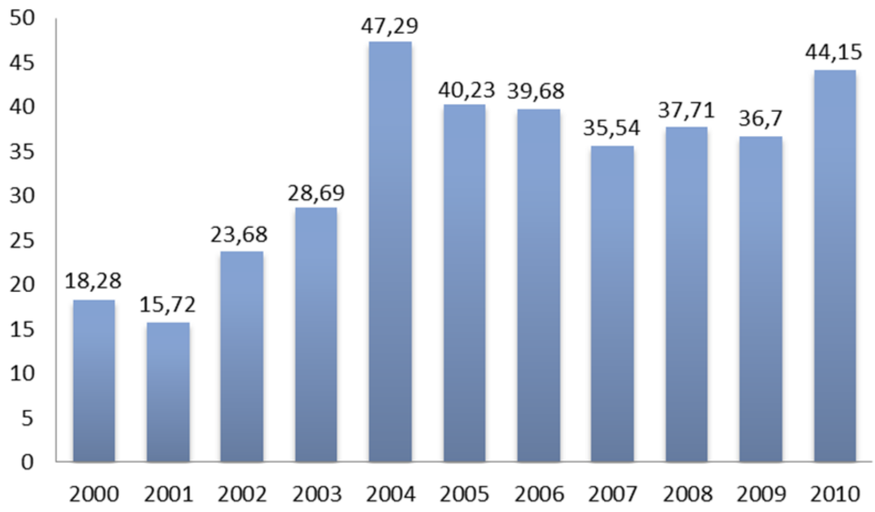
Chart 7 – Size of Companies of the Processed Plastics Industry by Number of Employees



Source: ABIPLAST (2011)

The Brazilian chemical industry invoicing calculated by Abiquim was around R$ 206,7 billion in 2009 half of which correspond to raw materials and intermediate chemicals and out of the latter, 65% of the first and second generation of petrochemical industry. The plastic processing industry, in turn, would have reached, according to Abiplast (2011), an invoicing of R$ 44,15 billion in 2010 (Chart 8).

Chart 8 – Invoicing of Processed Plastics Industry 2000-2010
(In billions R$)

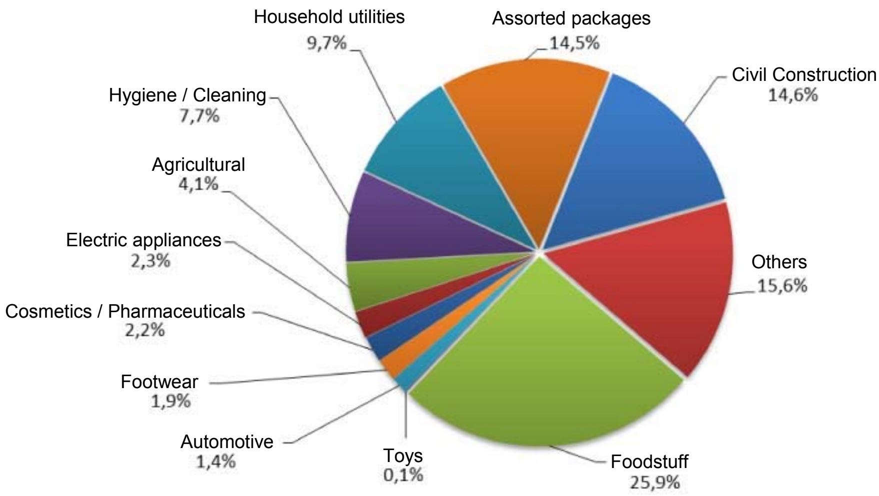


Source: ABIPLAST (2011)

The companies participating in the plastic processing industry, especially those producing plastic packaging for food have no bargaining power among the major raw material suppliers (the thermoplastic resin industry) and the food industry.

Out of the total of processing companies, 25,9% are represented by the food segment (in the manufacturing of PP, PEBD, PEBDL and EVA for the construction of pots, jars, bobbins, jars, lids, buckets and stickers); 14,6% of production goes to the civil construction industry and other 14,5% are delivered to the production of packaging (PEAD and PET for manufacturing of jars, buckets, tanks and containers). The remaining goes to the agricultural segment, household utilities, hygiene and cleaning, footwear, electroelectronic, cosmetics and pharmaceuticals, automotive and toy segments (Chart 9).

Chart 9 – Processed Plastics Market Segmentation by Application



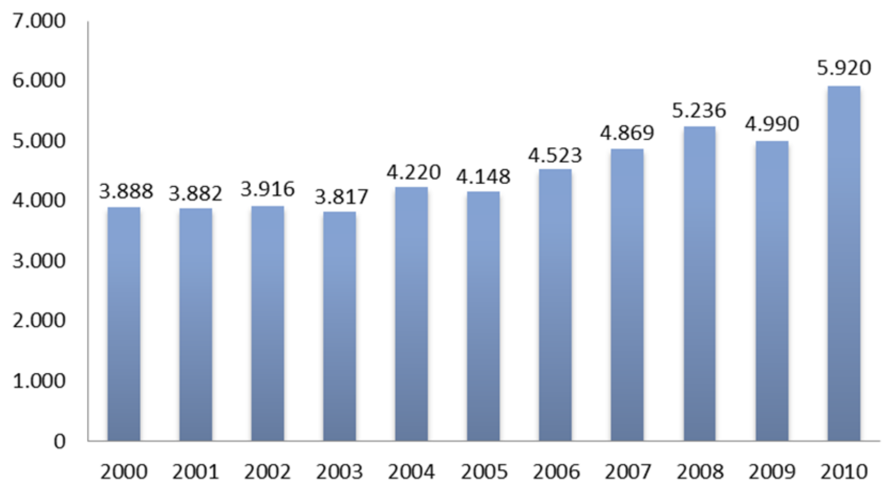
Source: ABIPLAST (2011)

About 43% of processed plastics produced in Brazil are used in the packaging sector, out of which 60% of plastic packaging are consumed by the food industry.

The food industry competitiveness, in turn, requires and opens an opportunity window for innovations and development of new applications in packaging, based on changes in the polymers' physical-chemical characteristics, through additives and formulations of composites (also increasingly using nanocomposites in the international market) which may collaborate to the reduction of technical barriers in food exports and secure new market shares.

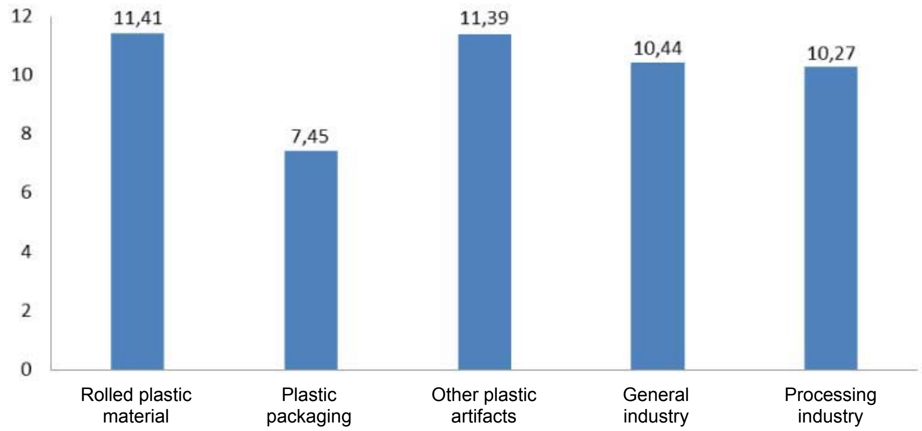
However the introduction of nanotechnology-based technological innovations in the market in the developed countries and also among the BRICS often involves efforts to set up a PPP – Public Private Partnership with participation of the processed plastic industry, manufacturers of capital goods, investors and the Government.

Chart 10 – Production of Processed Plastics 2000-2010
(In thousand tons)



Source: ABIPLAST (2011)

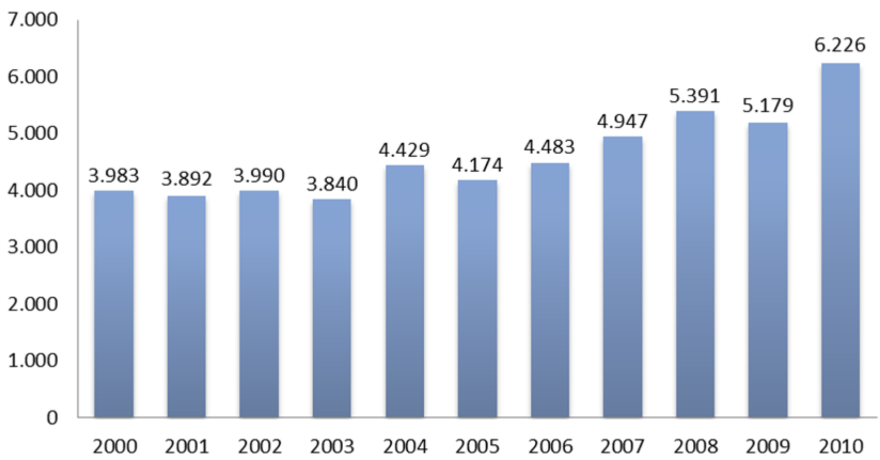
Chart 11 - Evolution of Physical Production Accumulated Index of Processed Plastics Industry - 2009/2010



Source: ABIPLAST (2011)

In 2000, the *per capita* plastic consumption in Brazil was around 22,6 kg/year; in 2010 it went up to 30.5 kg/year. In developed countries the *per capita* consumption is three times higher than the Brazilian consumption. If the expected scale gains obtained through the industry companies' continuity of integration will reach the end consumer it is possible that there will be an acceleration in the growth of the Brazilian *per capita* consumption.

Chart 12 – Apparent Consumption of Processed Plastics - 2000-2010
(In thousands tons)

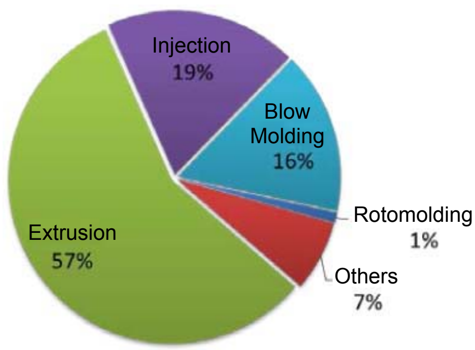


Source: ABIPLAST (2011)

3.5 PACKAGING PRODUCTION PROCESSES

Extrusion is the most common process in the production of plastics (57%), followed by injection process (19%); blow molding (16%), and other processes such as rotational molding (rotomolding), stretch and shrink wrap and thermal-formation (Chart 13).

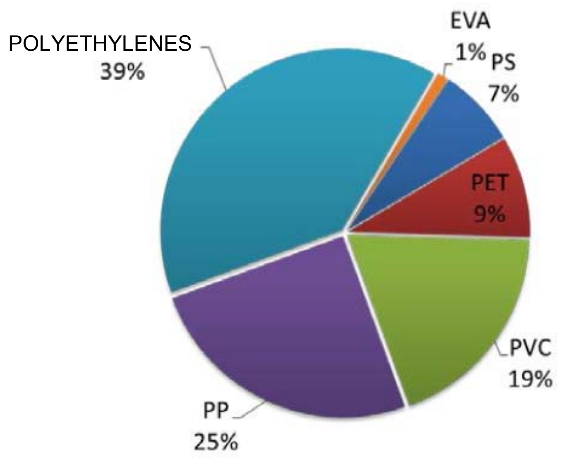
Chart 13 - Processed Plastics Market Segmentation by Production Process



Source: ABIPLAST (2011)

The thermoplastic resins presenting the highest consumption share (Chart 14) by processed plastics industry is polyethylene (39%) followed by PP (25%), PVC (19%), PET(9%), PS (7%) and EVA (1%). Figure 2 and Chart 14 show that these thermoplastic resins are present in the production of food packaging with application in practically all production processes.

Chart 14 – Apparent Consumption of Thermoplastic Resins by Type of Resin



Source: ABIPLAST (2011)

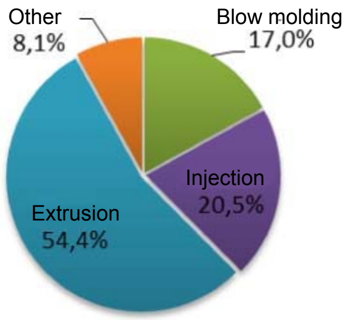
Figure 2 – Plastics according to Application and Transformation Process Sectors

Application Sectors	Transformation Processes					
	Extrusion	Injection	Blow Molding	Rotomolding	Co-extrusion	Thermoformation
Bags Sacks	PEs, PP, PVC					
Household utensils		PP, PEAD, OS, PVC, PET, PS	PP, PEAD, PS, PVC, PET			
Electrical appliances		PS				
Automotive			PEAD, PP	PEAD		
Pipes Tubes	PVC, PEAD, PP					
Civil Construction	PVC, PEAD, PP	PVC, PEAD, PP				
Packaging Medicaments		PEBD, EVA	PEAD			
Packaging Food / Beverage	PEBD, PEBDL	PS, PP, EVA	PET, PP, PEAD, PVC		PEBD, PEBDL, PEAD, PP, PET	PEAD, PS, PP
Packaging Cosmetics		PEBD, EVA	PP, PEAD, PEBD, PVC, PET			

Source: *O apoio do BNDES ao setor de transformados plásticos*, BNDES Sector 31, Page 99-146, 2010

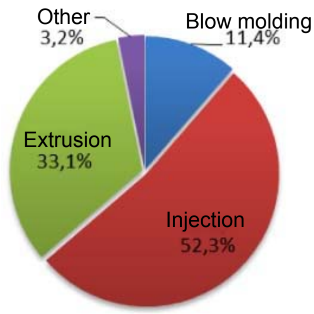
Chart 15 - Processed Plastics Market Segmentation by Production Process / Type of Resin

PEs



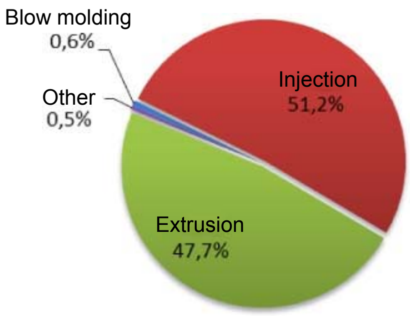
Source: ADIRPLAST (2011)

PP



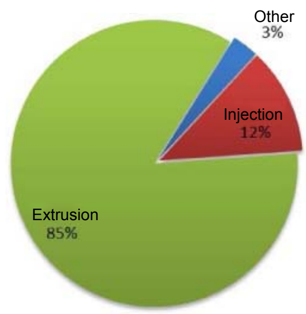
Source: ADIRPLAST (2011)

PS



Source: ADIRPLAST (2011)

PVC



Source: ABIPLAST (2011)

In the case of PET, the blow molding process represents 100% of market segmentation by type of production.

3.6 THERMOPLASTICS FOR PACKAGING – RESIN SEGMENTATION

There are some twelve plastic materials regularly used in packaging offering a wide range of properties to meet certain needs. The main types of thermoplastics used in plastic packaging are Polyethylenes (High Density, Low Density and Linear Low Density) (PEs); Polypropylene (PP); Polystyrene (PS); Polyvinyl chloride (PVC); Polyethylene Terephthalate (PET) and Biopolymers.

3.6.1 Polyethylenes (High Density, Low Density and Linear Low Density)

3.6.1.1 High Density Polyethylene (HDPE)

HDPE answers for about 24,8% of the thermoplastic resins processing industry installed capacity. It is present in food packaging, textile products, cosmetics, disposable packages, soda and soft drinks caps, freezer pots and containers and mineral water bottles in addition to toys and electrical appliances, broom and brush bristles, bags and sacks (lining and waterproofing), adhesive tapes among others.

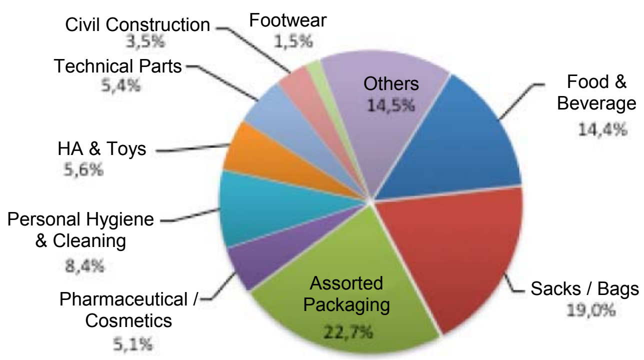
3.6.1.2 Low Density Polyethylene (LDPE and LLDPE)

LDPE is more flexible besides being light, clear and waterproof which makes it appropriate in the production of thermal-controllable films and wraps such as cases / packs for soda bottles, television and telephone wires and cables, general film, industrial bags and sacks, irrigation pipes, hoses, flexible packaging, paper waterproofing (tetrapak) among others.

The copolymer LLDPE enables thinner, more resistant and recyclable wires and films tending to replace traditional LDPE. It is mainly applied in the production of food packaging, diapers, sanitary pads and industrial bags and sacks.

LDPE and LLDPE respectively answer for 9,6% and 19,9% of the processing industry installed capacity.

Chart 16 – PE Market Segmentation



Source: ADIRPLAST (2011)

Table 2 – PE Installed Capacity (t/year)

Company	Location	Installed Capacity in 2010
BRASKEM	BA/RS/RJ/SP	3.035.000
QUATTOR	RJ/SP	(1)
Total		**3.035.000**

(1) Company incorporated by Braskem in February 2011
Source: *Anuário da Indústria Química* (2011) (Chemical Industry Yearbook)

Table 3 – PE Reported Production and Sales (t/year)

Year	Production	Internal Sales	External Sales
2007	2.398.138,60	1.589.463,00	778.747,20
2008	2.121.201,40	1.490.099,10	530.581,80
2009	2.285.612,00	1.501.990,30	902.758,00
2010	2.380.650,50	1.670.426,30	720.361,40

Source: *Anuário da Indústria Química* (2011) (Chemical Industry Yearbook)

Table 4 – PE Import and Export (t/year and US$-FOB)

Year	T	Import (US$1.000 FOB)	T	Export (US$1.000 FOB)
2007	315.340,20	472.892,50	820.493,70	1.100.902,20
2008	433.192,70	764.991,20	591.283,70	940.198,50
2009	502.479,40	633.239,50	883.160,50	902.167,60
2010	662.901,70	928.971,10	763.947,40	1.011.391,30

Source: *Anuário da Indústria Química* (2011) (Chemical Industry Yearbook)

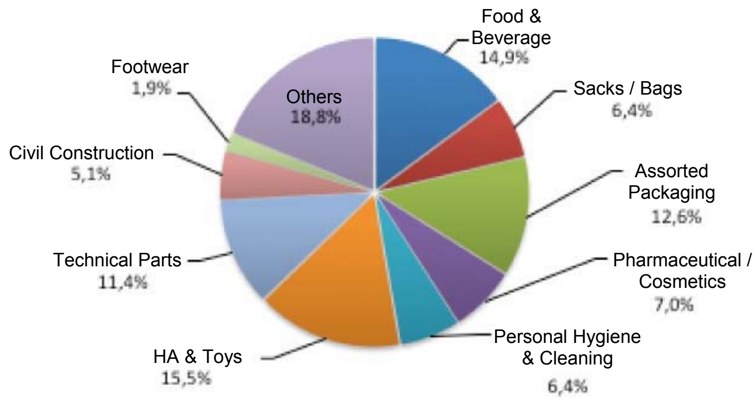
3.6.2 Polypropylene (PP)

Obtained from propene (polymer grade), they have high tensile strength and low density being particularly adequate to filaments and raffia type of cut fibers. Copolymers with 5 to 30% of ethene show higher resistance to impact and easy molding being used for injection of large parts and blow molding. It is used in the production of auto-parts, electroelectronics, crates for produce, food packaging, textile and cosmetic products, soda bottle caps, freezer pots and large bottles for mineral water.

In volume it is the main thermoplastic resin used in Brazil. The increase of amount of plastics in cars and production of non-woven fabric for diapers and sanitary pads can explain the elevated growth in the demand of this resin.

PP answers for 22,8% of the processing industry installed capacity.

Chart 17 – PP Market Segmentation



Source: ADIRPLAST (2011)

Table 5 – PP Installed Capacity (t/year)

Company	Location	Installed Capacity in 2010
BRASKEM	BA/RS/RJ/SP	1.965.000
QUATTOR	RJ/SP	(1)
Total		**1.965.000**

(1) Company incorporated by Braskem in February 2011
Source: *Anuário da Indústria Química* (2011) (Chemical Industry Yearbook)

Table 6 – PP Reported Production and Sales (t/year)

Year	Production	Internal Sales	External Sales
2007	1.239.389,00	1.054.620,00	231.332,80
2008	1.262.252,90	1.042.233,20	160.285,00
2009	1.485.531,00	1.164.005,00	420.457,00
2010	1.586.212,60	1.252.308,50	335.337,80

Source: *Anuário da Indústria Química* (2011) (Chemical Industry Yearbook)

Table 7 – PP Import and Export (t/year and US$-FOB)

Year	t	Import (US$1.000 FOB)	T	Export (US$1.000 FOB)
2007	166.243,60	254.472,60	245.144,90	328.371,90
2008	186.259,70	353.214,00	174.710,80	264.667,70
2009	179.429,00	226.348,20	419.738,00	416.061,10
2010	218.849,20	342.096,90	341.142,90	487.710,60

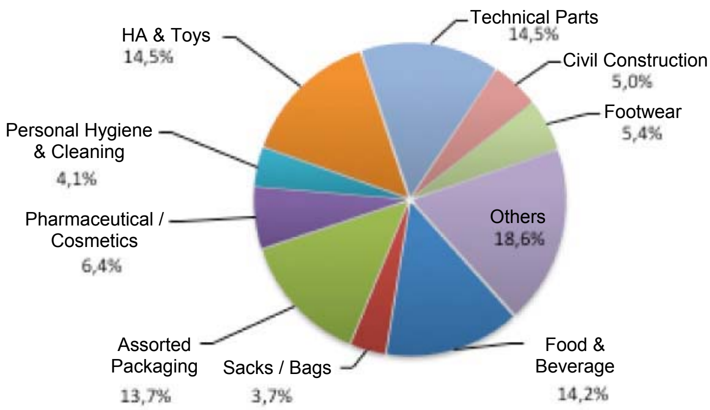
Source: *Anuário da Indústria Química* (2011) (Chemical Industry Yearbook)

3.6.3 Polystyrene (PS)

The PS main characteristics are impermeability, rigidity, lightness and transparency. It was the first thermoplastic but it is bound now to be replaced by polyolefins which are less fragile, more compact and have shorter time of degradation. The most common applications of polystyerene (PS) are assorted material for packaging and disposables (coffee cups, yogurt cups, plates, tableware), manufacture of refrigerators internal parts, CD's cases, electrical appliances and electroelectronic components (Electrolux and Multibrás are major consumers), disposable blades and toys.

In the plastic processing industry polystyrene answers for 6,8% (345 thousand tons in 2008) of the resin demand.

Chart 18 – PS Market Segmentation



Source: ADIRPLAST (2011)

Table 8 – PS Installed Capacity (t/year)

Company	Location	Installed Capacity in 2010
DOW BRASIL	SP	(1)
INNOVA	RS	150.000
UNIGEL	SP	310.000
VIDEOLAR	AM	120.000
Total		**580.000**

(1) Unit sold to Styron in April 2010 and acquired by Unigel in January 2011
Source: *Anuário da Indústria Química* (2011) (Chemical Industry Yearbook)

Table 9 – Reported Production and Sales (t/year)

Year	Production	Internal Sales	External Sales
2007	376.471,40	331.258,60	36.640,90
2008	345.285,30	313.104,90	25.370,60
2009	361.994,90	335.922,10	33.675,90
2010	390.234,20	369.112,80	21.791,90

Source: *Anuário da Indústria Química* (2011) (Chemical Industry Yearbook)

Table 10 – PS Import and Export (t/year and US$-FOB)

Year	T	Import (US$1.000 FOB)	T	Export (US$1.000 FOB)
2007	16.156,10	31.640,10	40.169,30	62.697,10
2008	18.209,40	36.231,30	26.475,20	47.229,20
2009	15.981,10	29.658,90	34.479,90	42.019,70
2010	20.383,30	40.915,80	26.014,60	39.970,20

Source: *Anuário da Indústria Química* (2011) (Chemical Yearbook)

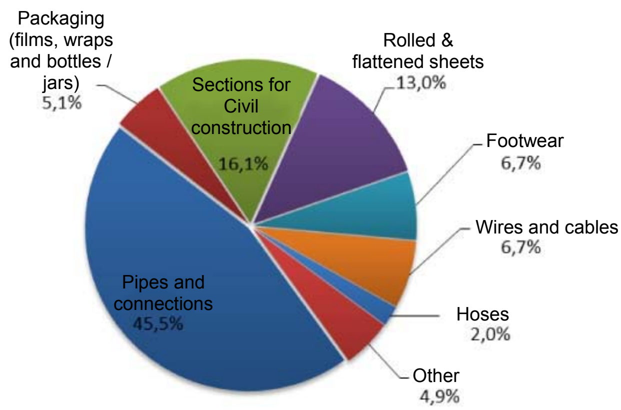
3.6.4 Poly Vinyl Chloride (PVC)

PVC is particularly resistant but its processing is difficult as it must be combined with other ingredients (plastifiers, stabilizers, lubricants, loads, pigments) in the final product and it is quite unstable and viscous. For these reasons it is used by major companies (Sansuy, etc.) with more complex equipment and technology than what is typical in thermoplastic processing companies.

The PVC demand is strongly related to civil construction as it is chiefly used in pipes, connections, electric cables, windows, doors, door and window frames and power cables. It may also be applied in manufacturing of toys, certain types of fabrics, house slippers, credit cards, pipes and tubes for washing machines and food crates and boxes. However in the last years it has been subject to stronger competition from PEAD resins

Poly Vinyl Chloride represents about 9,7% of the plastic processing industry installed capacity and its offer is made by Braskem (63%) and Solvay (37%).

Chart 19 – PVC Market Segmentation



Source: PVC Institute (2011)

Table 11 – PVC Installed Capacity (t/year)

Company	Location	Installed Capacity in 2010
BRASKEM	BA/AL	510.000
SOLVAY INDUPA	SP	300.000*
Total		**810.000**

(*) Multipurpose
Source: *Anuário da Indústria Química* (2011) (Chemical Industry Yearbook)

Table 12 – PVC Reported Production and Sales (t/year)

Year	Production	Internal Sales	External Sales
2007	686.463,00	679.120,00	43.212,00
2008	698.661,00	644.650,00	21.655,00
2009	689.488,00	664.259,00	42.009,00
2010	724.926,80	732.919,30	2.189,00

Source: *Anuário da Indústria Química* (2011) (Chemical Industry Yearbook)

Table 13 – PVC Import and Export (t/year and US$-FOB)

Year	t	Import (US$1.000 FOB)	t	Export (US$1.000 FOB)
2007	176.793,30	188.695,00	58.844,80	64.569,10
2008	365.632,20	447.454,50	37.562,30	52.182,40
2009	285.766,90	269.883,30	52.553,50	40.399,00
2010	386.971,50	454.350,70	12.883,40	18.321,40

Source: *Anuário da Indústria Química* (2011) (Chemical Industry Yearbook)

3.6.5 Polyethylene Terephthalate (PET)

In the polyester family PET is produced from the combination of the terephthalic acid (PTA) with monoethyleneglycol (MEG); it is transparent, unbreakable, impermeable and light; if fiberglass-reinforced it competes with PBT (polybuthylene terephthalate), nylons and metals.

It is used mainly in manufacturing of soda and mineral water bottles, packaging for food products such as cooking oils and juices, cleaning, cosmetics and pharmaceuticals. It is also present in microwave oven trays, films for audio and video, textile fibers to name a few.

In relation to the main packaging user segments soda (soft drinks) leads the ranking with 61% share followed by water with 14% and cooking oil with 13%. The latter which started using PET packaging quite recently, presents a sharp growth – in 2005 it had 7% share.

Table 14 – PET Market Segmentation

Applications	%	Applications
Containers / Vessels for Liquids	100	Containers / Vessels for Liquids
Total	**100**	**Total**

Source: *Anuário da Indústria Química* (2011) (Chemical Industry Yearbook)

Table 15 – PET Installed Capacity (t/year)

Company	Location	Installed Capacity in 2010
M&G FIBRAS	MG/PE	(1)
M&G POLÍMEROS	PE	550.000
Total		**550.000**

(1) Company discontinued in December 2010
Source: *Anuário da Indústria Química* (2011) (Chemical Industry Yearbook)

Table 16 – PET Reported Production and Sales (t/year)

Year	Production	Internal Sales	External Sales
2007	384.338,00	304.382,10	48.349,00
2008	340.317,00	333.075,00	6.939,00
2009	375.569,00	314.037,00	74.858,00
2010	466.978,00	399.356,00	68.285,00

Source: *Anuário da Indústria Química* (2011) (Chemical Industry Yearbook)

Table 17 – PET Import and Export (t/year and US$-FOB)

Year	t	Import (US$1.000 FOB)	T	Export (US$1.000 FOB)
2007	112.033,40	154.084,02	52.378,60	73.003,50
2008	119.389,70	181.222,80	12.548,50	17.085,30
2009	146.858,40	165.100,70	92.751,20	106.213,60
2010	115.144,60	146.078,50	72.729,90	103.057,50

Source: *Anuário da Indústria Química* (2011) (Chemical Industry Yearbook)

3.6.6 Biopolymers

Biopolymers are polymeric materials structurally classified as polysaccharides, polyesters or polyamides. The main raw material for the manufacturing thereof is a source of renewable carbon usually a carbohydrate derived from large scale commercial planting such as sugarcane, corn, potatoes, wheat and beets, or a soybeam, sunflower, palm-based oil or another oleaginous plant.

Chart 20 – Bioplastics World Market Segmentation

Source: Plastemart, 2012

The potential of replacement of conventional polymers by bioplastics is indicated by the literature and shown in Chart 21 (CGEE, 2006).

Examples of current and developing applications for bioplastics are shown in Table 18. Among the replacements are packaging, disposables and textile fiber areas, dominant markets in the consumption of bioplastics.

Chart 21 – Potential of Replacement of Conventional Polymers by Bioplastics

Materials	PVC	PEAD	PEBD	PP	PS	PMMA	PA	PET		PC
Starch Polymers	-	+	+	+	+	-	-	-		-
PLA	-	+	-	+	+	-	+	+		-
PTT	-	-	-	+	-	-	++	++		+
PBT	-	-	-	++	-	-	+	++		+
PHB	-	+	-	++	+	-	-	-		-
PHB/HHx	+	++	++	++	+	-	-	+		-

++ Full replacement;
+ Partial replacement;
- Non replacement.
PVC: Poly Vinyl Chloride
PEAD: High Density Polyethylene
PEBD: Low Density Polyethylene
PBT: Polybuthylene Terephthalate
PP: Polypropylene
PS: Polystyrene
PMMA: Polymethyl Metacrylate
PA: Polyamide
PET: Polyethylene Terephthalate
PC: Polycarbonate

Source: PRO-Bip, 2004

Table 18 – Bioplastics Applications

Polymer	Applications
Modified Starch and Starch-PCL	**Packaging:** Bags, trays, tableware, wrapping film. **Agriculture:** Coating film, vases for cutlings, encapsulation and agrochemicals release agent. **Others:** Use of tire composition as filler
PLA	**Packaging:** Foodstuffs, oils and fatty products. **Fibers & Fabrics:** Use inside cars, carpets, rugs, fabrics for clothing .
PTT	**Packaging:** Fibers and films for packaging, ropes **Fibers and Fabrics:** Use inside cars, carpets, rugs, fabrics for clothing . **Others:** Magnetic tapes, lining flooring, electronic equipment bodies .
PBT	**Electro-electronic:** Insulation in electrical appliances and relays, connection cables, components for switches and plugs
PBS and PBSA	**Packaging:** Bags, jars, wrapping film . **Agriculture:** Coating film . **Others:** Plasticizer for PVC.
PHB; PHB/HV and PHB/HHx	**Packaging:** Jars for foodstuffs and aquous and fatty products; fast disposal articles; coating film of cards. **Agriculture:** Vases for cutlings, encapsulation and agrochemical release agent. **Others:** Micro-capsules for controlled release of actives; moulds for fabric engineering; parts of diapers and sanitary pads .

Source: CGEE, 2006

Table 19 – Bioplastics Installed Capacity (t/year)

Type	United States	Western Europe	Japan	Others	Total
PA	12.000	84.000	n.i.		96.000
PLA	140.000	n.i.	1.000		141.000
PAA (*)	15.000	10.000	4.400		29.400
PHA	1.100	100 (**)	100 (**)	50 (***)	1.350
Others	5.450				5.450
Totals	**173.550**	**94.100**	**5.500**		**273.150**

(*) Excluding the production of polybutylene terephthalate (PBT) of about 200.000 t/year
(**) Estimate values.
(***) Production in Brazil.

Source: PRO-BIP, 2004

4 SELECTION OF TECHNOLOGY AND MARKET STUDY

4.1 INTRODUCTION

This Section will be presenting information on the market of nanometric inputs applied to plastic packaging. The selection of technology of nanoinputs applied to plastic packaging is established based on competitive intelligence methods associated with a model of characterization of the technological level and identification of opportunity windows proposed by NanoBusiness®.

4.2 NANOMETRIC INPUTS FOR PLASTIC PACKAGING

Nanometric inputs offer new possibilities for improvement of plastic composite materials. It is currently estimated that some 500 packaging products in commercial use have some nanotechnology; it is also estimated that the use of nanometric materials for improvement of packaging will participate in the manufacturing process of 25% of all food packaging in the next decade (Reynolds, 2007).

Unlike the conventional inputs nanocomposite materials require only a small amount of nanometric input (less than 10% in weight) to present significant improvements in their properties, for example:

- Mechanics
- Thermal
- Electrics
- Impermeability for gases
- Dimensional stability; and
- Flame retardation.

Furthermore the addition of such improvements does not adversely interfere with the composite density or the plastics light transmission.

Table 18, prepared by NanoBusiness® based on articles, patents and research of packaging products existing in the market, presents an exhaustive list of nanometric inputs applied in packaging as well as the main effects in their properties.

Table 20 – List of Nanometric Inputs and their Main Effects on the Changes of Properties in Packaging

	Mechanical properties	Oxygen barrier	Water barrier	Light barrier	Plastic durability	Thermal properties	Electrical properties	Bactericidal action	Oxygen scavenger	CO_2 scavenger	Ethylene scavenger	Nanosensors	Leak indicators	Enzyme immobilization	Deterioration detector	RFID nanobarcodes
Nanoclays & Silicates	+	+	+			+					+			+		
Nanoclays (Layer by layer)	++	++	++			++					+			+		
Carbon nanotube	++	+	+			++	++	+				+			+	+
Nanosilver	+			+		+		++							+	
Gold nanoparticle												+				
Silicon nanooxides	+	+	+											+		
Titanium nanooxides				+	+			+	+				+			
Tin nanooxides													+			
Aluminum nanooxides	+			+												
Zinc nanooxides				+	+			+					+			
Iron nanooxides				+					+	+	+					
Cobalt nanooxides								+					+			
Magnesium nanooxides								+								
Copper nanooxides								+								
Zirconium nanooxides																
Calcium nanocarbonates	+															
Chitin / chitosan nanoparticles	+	+	+					+						+		
Nano starches	+	+	+													
Cellulose nanofibers	+	+	+			+										

Source: In-house preparation based on articles, patents and commercial packaging products updated as of March 2012; +: the nanoinput has a significant improvement in the property; ++: the nanoinput is considered as gold standard to obtain the property.

4.3 TECHNOLOGICAL INTELLIGENCE

The data related to the application of nanoinputs to packaging of food and beverage, hygiene and personal care products were assessed based on advanced technological intelligence methods and applications.

Information sources include academic publications, market reports, press releases, patents and news in the general media. The reviewed documents were generated between 2000 and 2012. The period of review of such documents was betwee 07/02/2012 and 14/02/2012.

The considered databases aggregate information and data from marks and patents offices and institutions throughout the world:

- *Instituto Nacional de Propriedade Industrial* (INPI), Brazil;
- European Patent Office (EPO), Europe;
- United States Patent Office (USPTO), USA;
- Japan Patent Office (JPO), Japan; and
- World Intellectual Property Organization (WIPO).

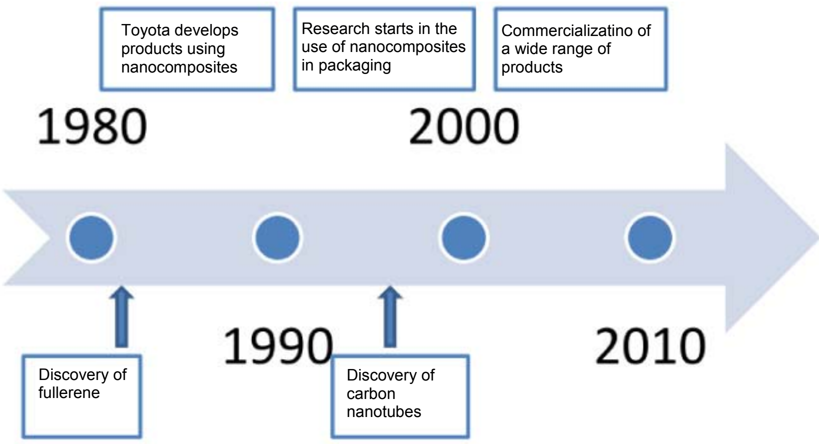
It is worth emphasizing that, in the case of patents, the filings in the last 18 months were not identified due to the confidentiality period, a practice observed by virtually all countries having legislation on intellectual property rights.

4.3.1 Aggregate Result

- 857 patent documents were found; out of those, 174 patent families and 727 scientific articles.

- Evidences of appearance of technology in mid-nineties, with a high increase of production in the last 5 years (as of 2007).

Figure 3 – Major Nanotechnology Products Timeline



Source: Barnett, 2011

In the technological intelligence study the types of packaging were classified as:

Figure 4 – Packaging Classification

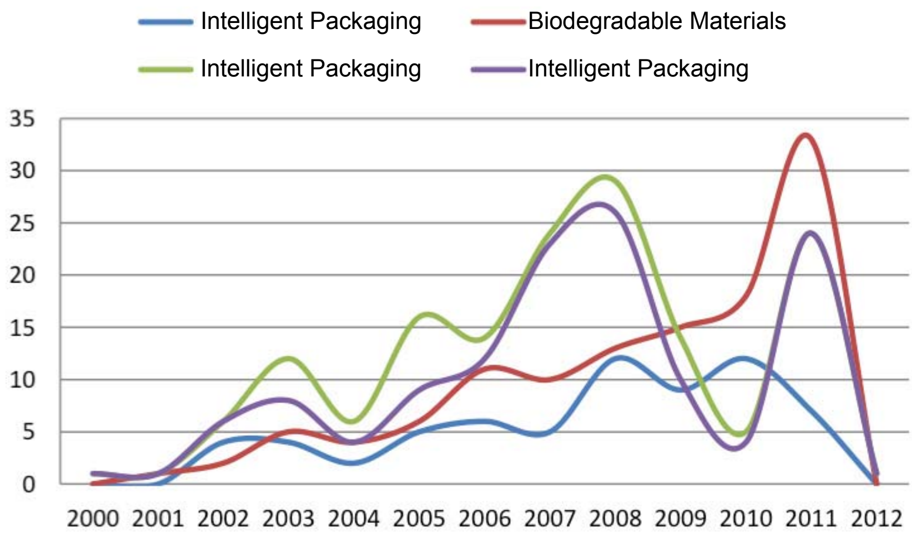
Technological Characterization	Associated Terminologies
1. Advanced materials incorporating nanomaterials to maintain direct contact with foodstuffs aiming to enhance the packaging functionalities such as temperature and humidity, stability, flexibility and resistance;	• Mechanical properties • Oxygen barrier • Water barrier • Light barrier • Anti-ageing & durability • Thermal properties
2. Active packaging (internal environment control including interaction with the food contained therein);	• Anti-bacterial • Oxygen scavenger • CO_2 scavenger • Ethylene scavenger • Enzyme immobilization
3. Intelligent (smart) packaging (including functionalities such as tracking and indication of authenticity)	• Nano sensors • Oxygen or leakage indicators • RFID
4. Biodegradable materials for packaging	• Nano cellulose • Nano starch

Source: NanoBusiness (2012)

4.3.2 Technological Evolution

The purpose of the Technological Evolution indicator is to reveal the degree of maturity of a technology from the intensity of information flow generated on the studied theme and helps to explain the why of the interest therein.

Chart 22 – Technological Evolution



Source: NanoBusiness (2012)

4.3.3 Technological Evolution Review

There is a great association between Advanced Packaging and Active Packaging, that is, a capacity's material to work as gases barrier / protection is also strongly integrated with active packaging responsible for eliminating or scavenging gases like CO_2 , O_2 and ethylene.

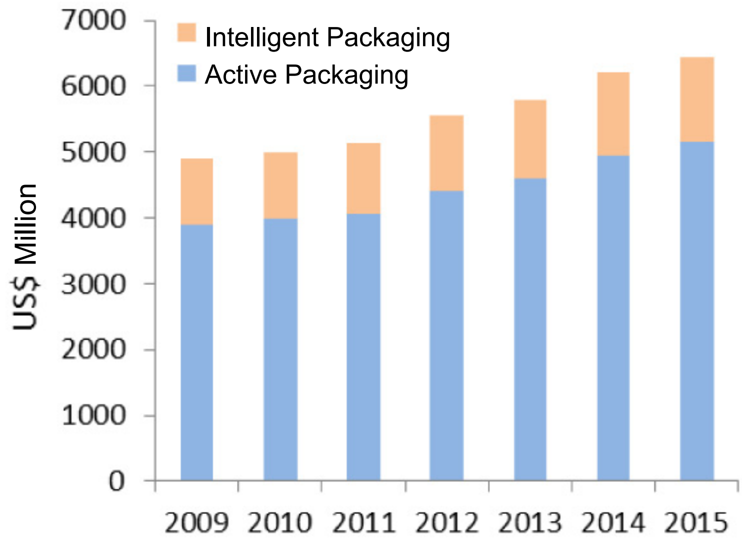
The intensity of publications of applications for patents referring to Smart Packaging has presented a stable growth as of 2001, but its relevant or patent interest is still low as compared to Advanced or Active Packaging. Smart packaging responsible for the direct and indirect communication to the producer / distributor / consumer on the physical and chemical conditions of foodstuffs or other consumer goods is still showing a low evolution intensity. From a commercial standpoint, the radiofrequency identification tags (RFID) could go through an important growth through the improvements in distance of emission and reduction of the tag size assigned by the use of carbon nanotube.

It is also possible to observe that the citations concerning biodegradable materials show a growing evolution of publications of patent documents, thus illustrating the increasing interest in the use of nanotechnology-based solutions to make their properties yet more adequate to their uses.

4.3.4 Active and Intelligent (Smart) Packaging Market

Market data confirm the technological analysis by showing that, besides being more mature as compared with intelligent packaging, the active packaging market presents a sharper growth.

Chart 23 – Intelligent (Smart) and Active Packaging Market Evolution



Source: Business Insights (2009)

The active packaging market should grow at 5,3% per year between 2009 and 2015 and the intelligent packaging market at 3,7%, mainly due to investments required for the development of intelligent technologies and the cost of integration and diffusion.

Food safety as well as extension of expiration date should play an important role in the demand for active and smart packaging for food products and beverages (Raithatha, 2010).

4.3.5 Technological Map

Chart maps are graphic tools grouping the documents from the analysis of information in patent documents. Such examination is based on the study of correlation of terminologies. The generated visualization makes possible to obtain indications related to technological fields and more developed technologies.

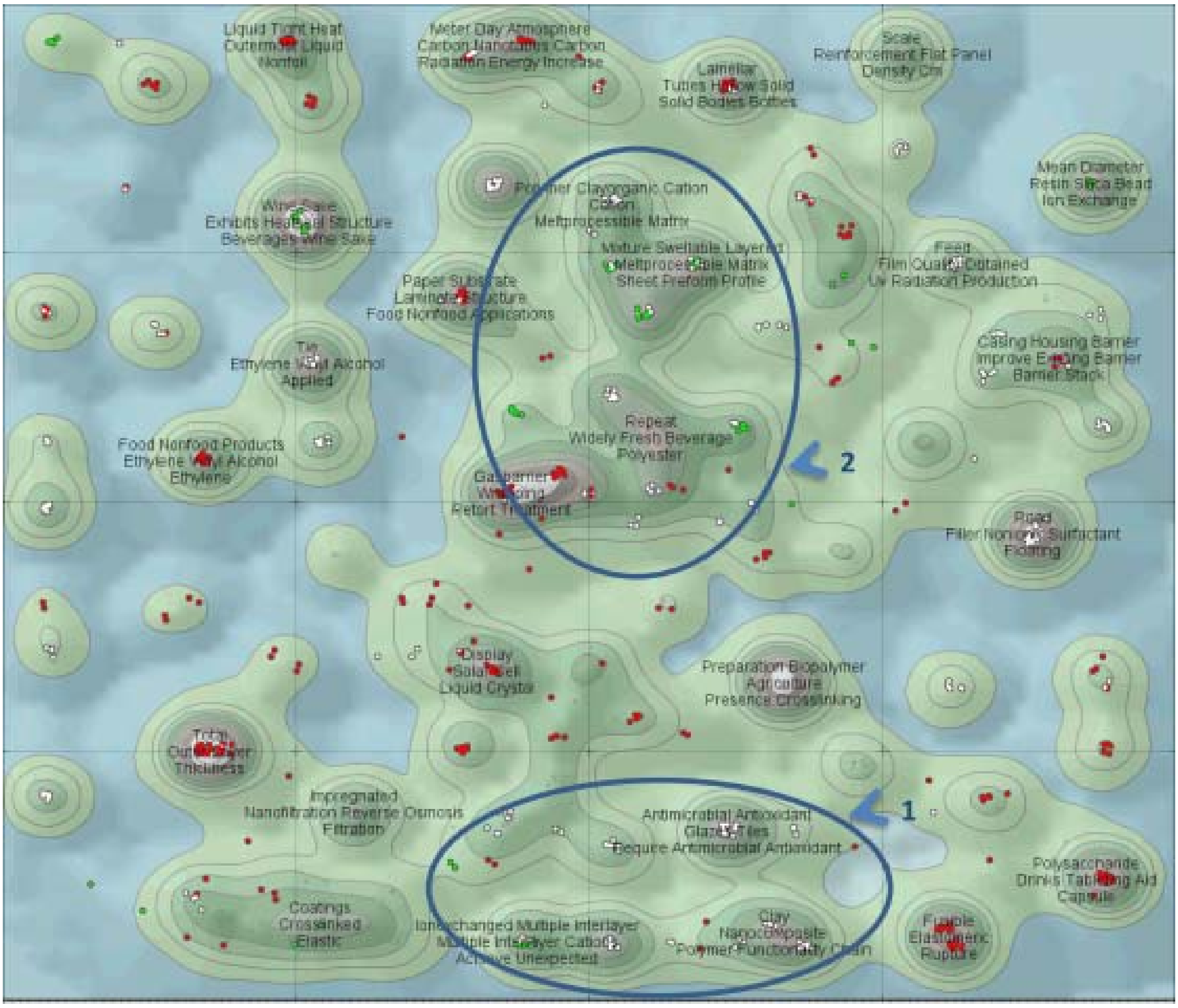
The points appearing in the map are the patent documents and the contour lines aim to group the different technologies or applications found in this study based on the correlation of technological concepts described therein. Patent documents have a higher degree of technological creation the closer they are to one another. The contour height reflects the concentration of documents and consequently the areas offering greater technological advancement.

A Technological Map (Figure 5) of selected documents illustrates the technological environmental generated from all patents found for the preparation of this study.

The red-colored points refer to nanomaterials applied in food packaging; green points refer to nanocomposites and white ones refer to the intersection between red and green points.

Thus it is possible to observe that white points referring to nanocomposites applied in packaging for the food industry are located in the two main groups represented by the blue-colored circles.

Figure 5 – Technological Map



Source: NanoBusiness (2012)

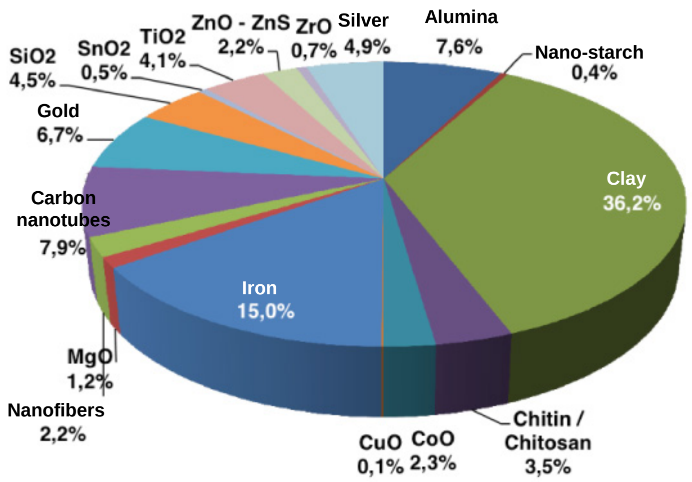
Group 1, located on the lower border of the Figure presents the white points located in the top of the regions and the terminologies are associated with clays, polymers and anti-oxidizing and antimicrobial.

Thus although there are several nanomaterials applied in food packaging the most common or technologically more mature refer to the polymer-clay nanocomposites.

4.3.6 Number of Citations of Nano-Inputs in Patents

The study also presents a quantitative analysis of the nanoinputs used for the development of packaging, the preparation of which was based on 1002 patent documents.

Chart 24 – Number of Citations of Nano-Inputs in Patents



Source: NanoBusiness (2012)

In Chart 24 we can observe that the three major nanoinputs are clay (36,2%), oxides (22,7%), metals (11,7%) and carbon nanotubes (7,9%). It is important to point out that a document may cite more than one nanoinput.

4.3.7 Technological Leaders

There are many companies and Science and Technology Institutions (STI) operating in the world nanotechnology sector with more than 2.000 nanotechnology companies research and/or manufacturing nanoparticles. Packaging is only one of many applications for nanotechnology with most of these 2.000 companies focusing in other applications from medicaments to electronics (Barnett, 2011).

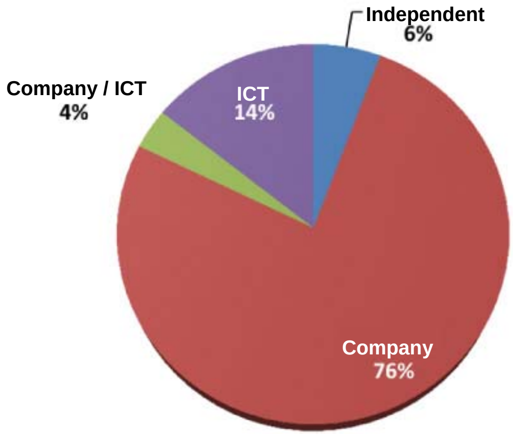
Relatively there are few companies dedicated to production of nanomaterials for packaging. Those directly involved may be widely divided into two groups: manufacturers of plastic resins and manufacturers of additives to the plastic industry (Barnett, 2011).

4.3.7.1 Analysis of Technological Leaders

It was possible to observe that approximately 77% of holders / applicants have only one invention, 22% of holders have between two and five inventions and 1% of the holders have more than five inventions or patents published in the world.

The analysis indicates that the technological development has not yet been mastered and consequently there is a market concentration by the applicants / holders on products incorporating nanotechnologies applied to packaging.

Chart 25 – Nature of Applicants / Holders



Total: 184 Inventions and 855 patents
Source: NanoBusiness (2012)

The R&D activities are concentrated in companies (76%), which indicates that the solutions presented have a higher degree of maturity already subject of industrial application by means of product development and commercial exploration.

Therefore it is possible to assume that the technological challenge is also associated with the companies' capacity to develop products with nanotechnologies offering a cost/benefit ratio acceptable to consumers.

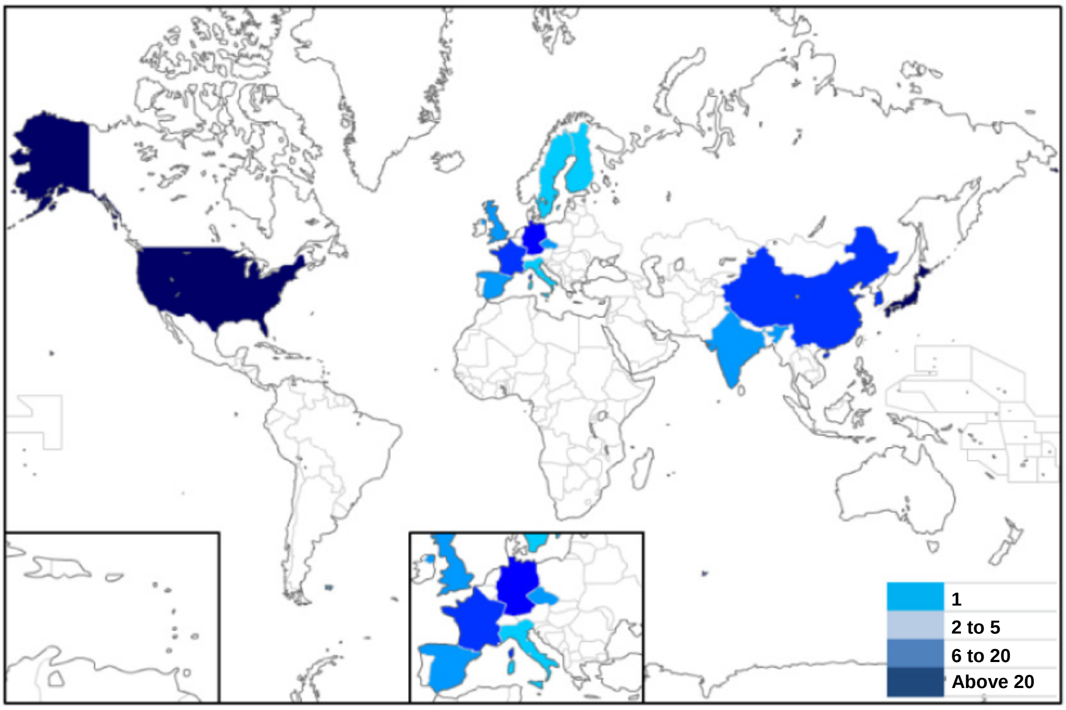
It is also worth highlighting the STIs participation (14%) including in joint projects with companies (4%), indicating that there are research activities applied to the sector being studied.

4.3.8 Technological Information Study – Market Environment

4.3.8.1 Geographic Strategy

The Geographic Strategy indicator analyzes the main regions and/or countries answering for the generation of knowledge and consequently the origin of inventions as well as the publishing mechanisms used for protection, which enables to identify the commercial interest in common and different markets.

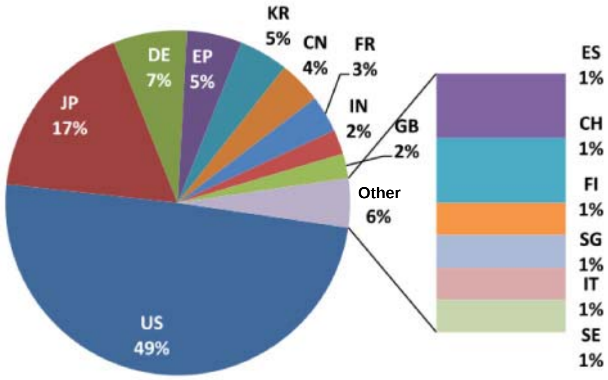
Figure 6 – Knowledge Generating Countries and Regions



Source: NanoBusiness (2012)

Knowledge and inventions generating regions indicate the countries or regions which, under the concerned study, have contributed most towards technological advancements associated with nanomaterials for packaging and accordingly the most important ones at the R&D level in this line of research.

Chart 26 – Knowledge-Generating Countries and Regions



Source: NanoBusiness (2012)

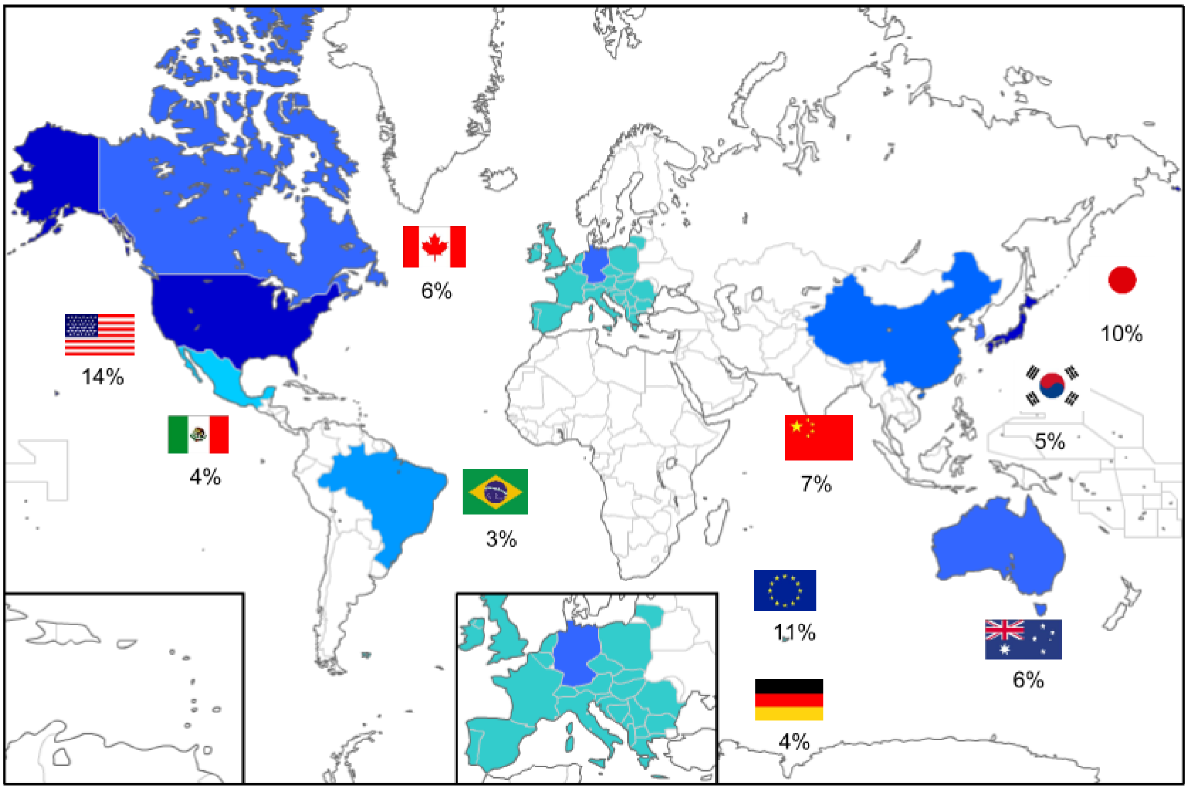
After analyzing the knowledge and inventions generating regions and starting from the principle that the choice of the designated countries in the selection of patents under study corresponds to the most important countries in the concerned technological area, we can see that the solutions associated with the development of nanomaterials for packaging are concentrated in three countries as major generators of knowledge: United States and Japan with 86 and 30 inventions respectively, which correspond to 67% of the total inventions in 2012, followed by Germany with an equivalent share of 6,9% of the total inventions as pointed out by Chart 26 – Knowledge Generating Countries and Regions.

It is interesting to observe that the USA are ahead of the current use of technology while the technology is less generalized in Europe and has experienced a slower growth especially due to legislative restrictions, fears of long-term harmful effects and consumers' reluctance and lack of knowledge. Although the European Union has created several research initiatives and discussion groups on the matter the current applications of commercial technologies still remain relatively limited (Barnett, 2011).

4.3.8.2 Major Markets of Interest

Estimates were made on the size of the market per region by examining the market under a geographical viewpoint. The consulting company Innovative Research and Products Inc. (IRAP) suggests the Asia-Pacific region, specifically Japan, as the leader in nanotechnology for foodstuffs and active packaging of beverages with 45% of the market (Barnett, 2011).

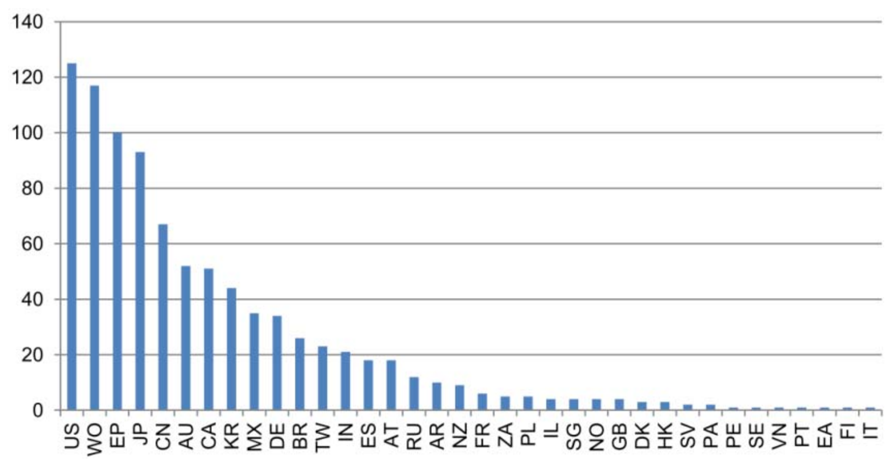
Figure 7 – Major Markets of Interest



Source: NanoBusiness (2012)

An examination of the number of patent applications filed in the major markets of interest suggests that the USA are much more active in this area than other countries with 14% of destination of patent documents. The European Union and Japan correspond approximately to 11% and 10%, respectively, of patent documents. Other countries of interest are China, Australia, South Korea, Brazil, Canada and Mexico. This does not necessarily mean that these patents are used in commercial products but it provides us with an indication of the region's interest in the development of nano-materials.

Chart 27 – Publication Entities



Fonte: NanoBusiness (2012)

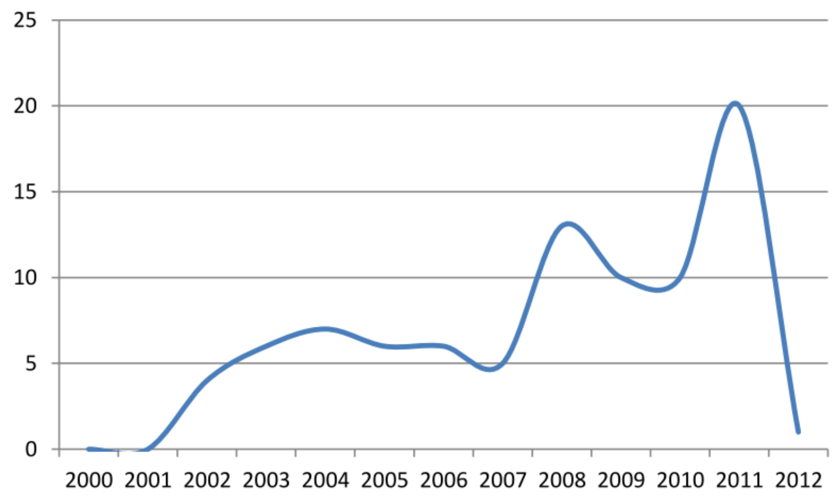
This geographic division in patent applications with bias towards the USA is also seen in the regional division of launching of products with allegations of nanocomposites. Data from the Emerging Technology Project suggest that the US represent the largest part of these products in the market ahead of Europe and Eastern Asia.

As to publishing entities, United States, Japan and European Union are the main destinations of publication of patent documents (filed and granted).

4.3.8.3 Technological Information - Brazil

Another purpose of this study was to analyze the patent documents filed in Brazil in reference to nanocomposites. The search strategy did not involve terminologies which could be associated with food and beverage packaging.

Chart 28 – Technological Evolution



Source: NanoBusiness (2012)

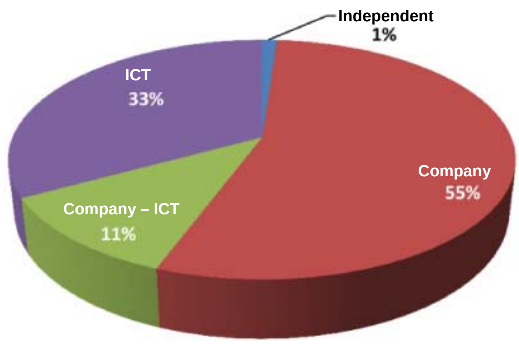
In Chart 28 we can observe a moderate intensity of publications of patents in the first half of the years 2000 as well as a more intense growth in the last five years with peak of publications in 2011.

4.3.8.4 Holders / Applicants with their number of Inventions

An important point to be emphasized refers to the fact that patent documents involving the STIs participation represent 44%, an expressive figure pointing out that the nanocomposites are still at a stage of basic and applied research in the Country.

This understanding is supported by the fact that only 27% of the companies having patent publications related to nanocomposites are national. The other 73% belong to companies out of the Country which have already a tradition in the technological and productive development of these nanoinputs.

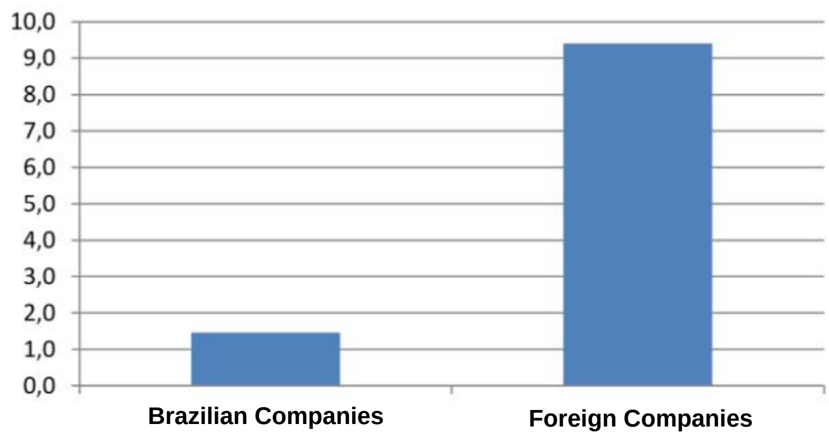
Chart 29 – Nature of Holders / Applicants in Brazil



Source: NanoBusiness (2012)

Besides, Brazilian companies have a low average of extensions to other countries (1,5), while foreign companies, in turn, have an average of 9,4 countries.

Chart 30 – Average of Patent Documents' Extensions to Countries of Interest

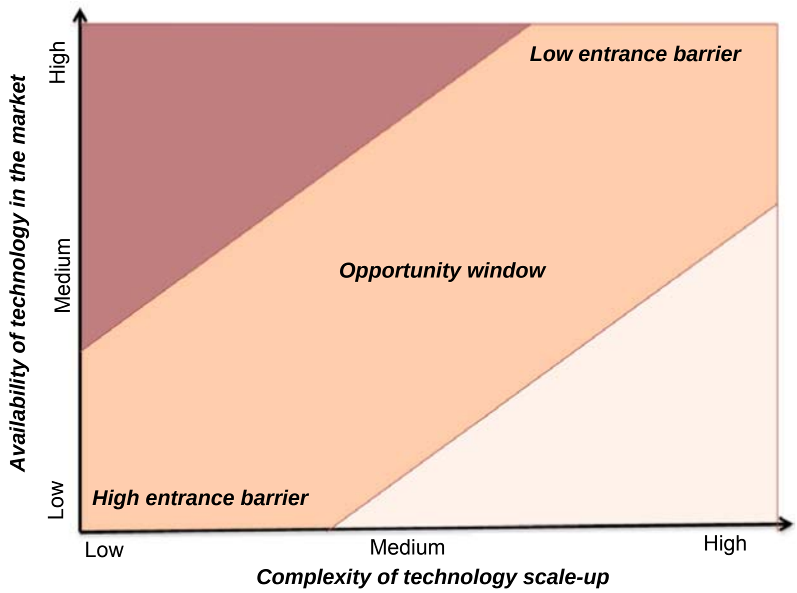


Source: NanoBusiness (2012)

4.4 CONCLUSION ON THE RESULTS OF TECHNOLOGICAL INTELLIGENCE AND THE NANO INPUT WORLD MARKET ANALYSIS

To complete the technology selection stage, NanoBusiness® developed a model of characterization of technological level and identification of opportunity windows. This model, Figure 8, presents the relation of availability of a technology in the market according to its scale-up complexisty. From such model it was possible to map and identify opportunity windows and select technologies which would make sense to the Brazilian market. In addition to the selection of technologies to carry out the feasibility study it was possible to set forth a taxological classification of nanometric inputs applied in plastic packaging.

Figure 8 – Model of Characterization of Technological Level and Identification of Opportunity Windows



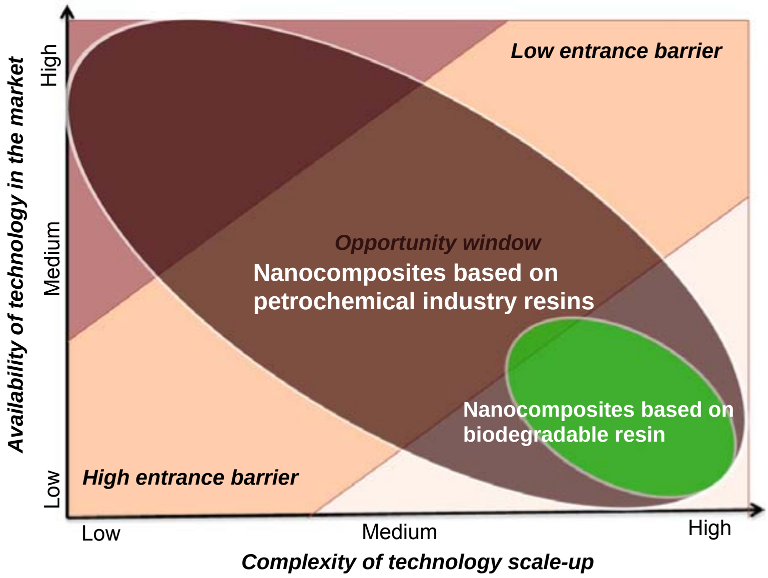
Source: NanoBusiness (2012)

4.4.1 Resin Types Classification

Nanocomposites may be classified in two families:

- Nanocomposites based on petrochemical industry resins (PE, PP, PVC, PET etc.)
- Nanocomposites based on biodegradable resins (PLA, cellulose, corn starch, etc.)

Figure 9 – Availability of Nanocomposites according to the Nature of their Resin



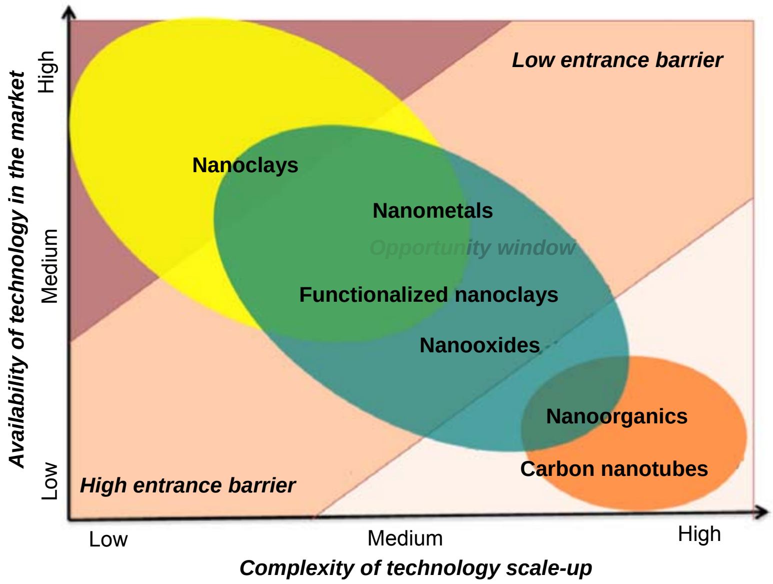
Source: NanoBusiness (2012)

Nanocomposites based on petrochemical industry resins are already available in the market and their level of availability depends on the complexity of scale-up of associated technologies. Nanocomposites based on biodegradable resins are not disseminated in the market and their properties are still lower as compared with nanocomposites based on petrochemical resins.

4.4.2 Nanoinputs Classification

Certain families of nanoinputs stand out in the market which may be classified using the following model:

Figure 10 – Availability of Nanocomposites according to the Nanoinput used



Source: NanoBusiness (2012)

Nanoclays are the most abundant nanoinputs in the market due to their production technology which enables a relatively low price. One of their scale-up complexities comes from the type of precursor clay used, the montmorillonite clay of high purity, the cheapest and easiest-to-process precursor.

New families of nanoinputs are currently available in the market with a medium technological complexity (ex.: nano silver), nano oxides (ex.: nano silica, nano alumina, nano titania etc.) and functionalized nanoclays (ex: with silver, iron, etc.).

With high scale-up complexity we have the carbon nanotubes. The price according to this complexity causes these nanoinputs to have a relatively low production volume. Their target market is located in high aggregated value products.

Nanoorganics (ex.: nano cellulose, nano starch, etc.) are not yet produced in large scale although their bio-compatibility properties are drawing special attention.

5 DEMAND ANALYSIS

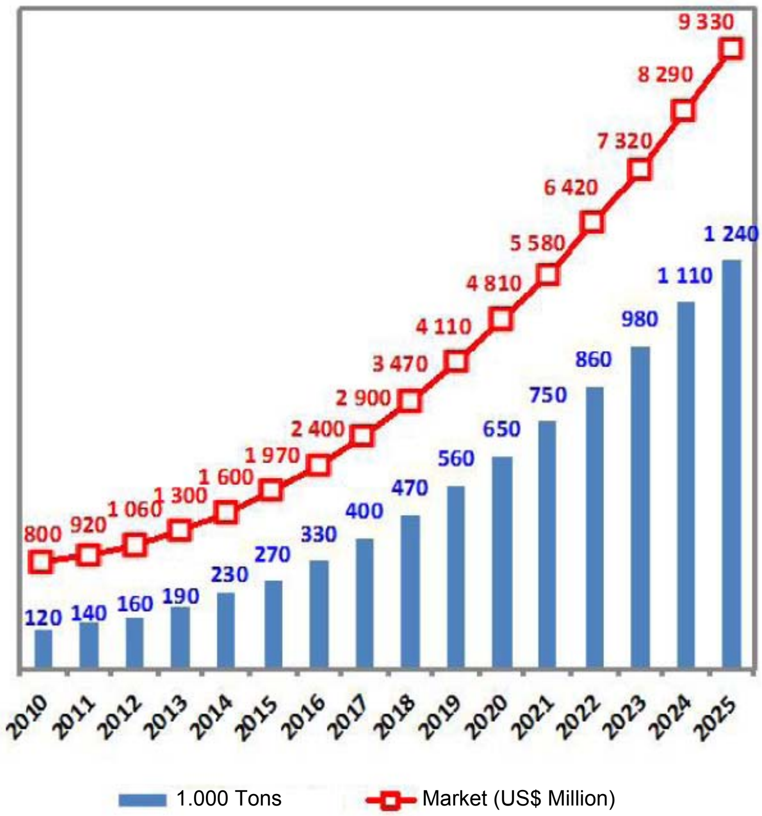
5.1 INTRODUCTION

This chapter presents an overview of the market of nanocomposites and nanoinputs applied to the plastic packaging industry as well as a parameterized estimate of demand for nanometric inputs. Aiming to validate the demand estimate the results obtained by competitive intelligence and characterization of technological level were presented to the plastic processing industry in a Workshop held by Abiplast - *Associação Brasileira da Indústria do Plástico* (Brazilian Plastic Industry Association) on March 20, 2012. The Workshop result is also presented in this chapter.

5.2 NANO COMPOSITES WORLD MARKET

In 2010, the global consumption of nanocomposites was around 120.000 tons with a value above US$ 800 million, possibly reaching 138.389 tons and US$ 920 million in 2011. In 2016, the market should reach 330.000 tons and US$ 2,4 billion at an annual compound growth rate (CAGR – 5 years) of 19,2% in units and 20,9% in value (BCCResearch, 2012). Based on the data presented a prediction of the evolution of consumption and world market of nanocomposites was prepared, Chart 31.

Chart 31 – Evolution of Consumption and World Market of Nano Composites



Source: In-house preparation from several researches and BBCResearch (2012)

Packaging represented 19% of the nano composites market in 2005, having reached 28% in 2011 (BCCResearch, 2006). According to the market study report prepared by consulting company Helmut Kaiser in 2007, the number of food packages containing nanoinputs increased from less than 40 in 2002 to more than 400 in 2006.

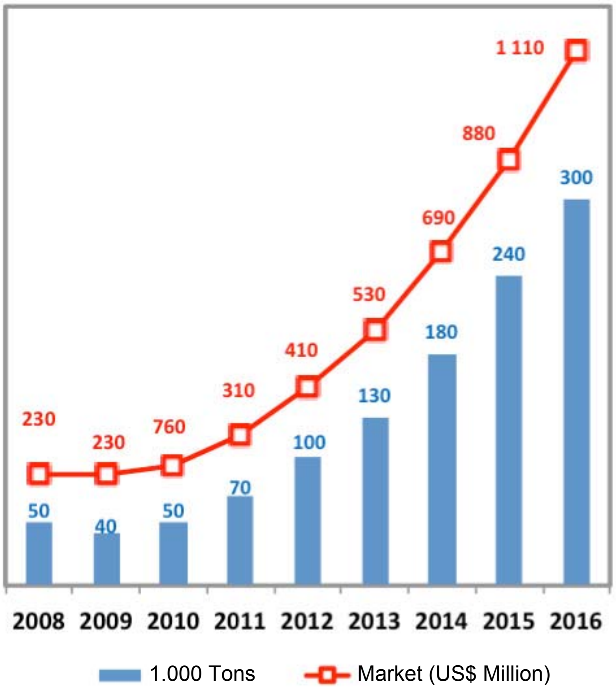
5.2.1 Nano Clay World Market

In 2010, the clay nano-composites answered for more than 50% of the total consumption of nanocomposites in value while in 2005 their share was only 24%. In 2016, their share should increase to 58% approximately. (BCCReseach, 2012).

Nano clays have a vast commercial potential in the packaging industry due to their cost-benefit ratio. These inputs were the first nano-composites to reach the packaging market and answer for approximately 70% of commercial nanomaterials (Royal Society of Chemistry, Nanotechnologies in Food, 2010), due to their natural structure of several layers providing an optimal protection for gases permeation. Nano clays can be used with standardized materials to improve the quality of the packaging making them more resistant, flexible and permeable. In 2011, 44% of nanoclay production went to the packaging industry (BCCResearch, 2012)

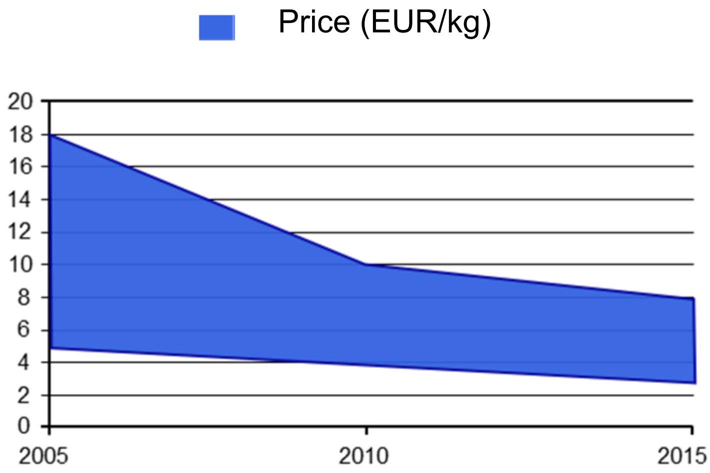
In general the nanoclay market is consolidated in the world and more recently advanced / functionalized nanoclays have drawn increasingly more attention in the industry due to the presence of new properties such as antibacterial action and oxygen scavenger.

Chart 32 – Evolution of Consumption and World Market of Nano Clay-based Nanocomposites.



Source: In-house preparation from several researches and BBCResearch (2012)

Chart 33 – Evolution of Nano Clay Price (Montmorillonite)



Source: Willems & van den Wildenberg - Roadmap Report on Nanoparticles - November 2005

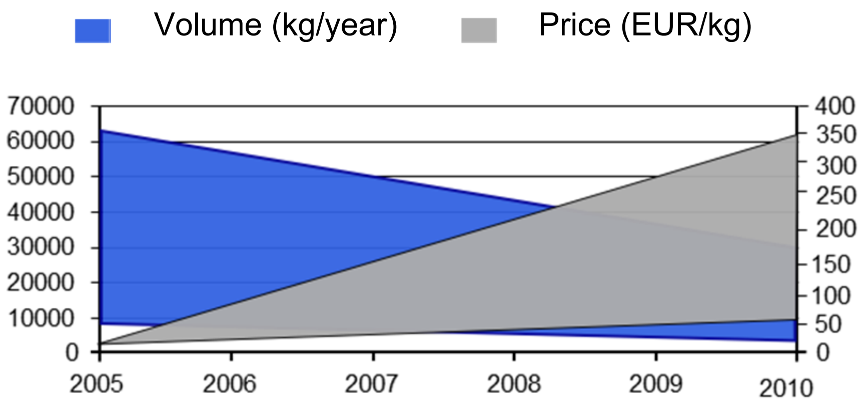
5.2.2 Nano Silver World Market

According to Mueller and Nowack, the global production of nanosilver would have reached 500 t/y in 2008 with 28% (140 t/y) of its production destined to applications to provide antibacterial property. According to predictions by the Silver Institute Report (2011), the use of nanosilver in packaging and hygiene goods will be generating a demand of 124,4 tons of silver in the next five years. The average price of nanosilver in the market is US$ 80.000/ton (Willems & van den Wildenberg - Roadmap Report on Nanoparticles – November 2005).

5.2.3 Nano Oxides World Market

Commercially the most important nanooxides are the simple metal oxides such as silica (SiO_2), titania (TiO_2), alumina (Al_2O_3), iron oxide (Fe_3O_4, Fe_2O_3), zinc oxide (ZnO) and zirconium (ZrO_2). Chart 34 shows the expected average price of these nano oxides

Chart 34 – Expectation of Price and World Market of Nano Oxides



Source: Willems & van den Wildenberg - Roadmap Report on Nanoparticles - November 2005.

5.2.4 Carbon Nano Tubes World Market

Carbon nanotubes (CNTs) were responsible for 21% of the total nanocomposites consumption in 2010, but their market share should drop to 16% in 2016 (BCCResearch, 2012).

The CNTs price dropped substantially from more than US$ 150/g in 2000 to less than US$ 50/g nowadays (2010).

The global leaders are:

- Arkema Group (França) – Production 400 t/y, production start-up: 2011;
- Bayer AG (Alemanha) – Production 200 t/y; and
- ShowaDenko K.K. (Japão) – Production 400 t/y.

CNTs are not being used in the plastic packaging industry as they present a cost incompatible with the sector characteristic low aggregate value products. However they are found in RFID prototype for packaging where the reduced required amount does not make the product unfeasible.

5.2.5 Summary on the Nanoinput World Market

Nanotechnology is already being used now in plastic packaging around the world with a market higher than US$ 250 million in 2011.

Among the used nanoinputs nanoclay stands out with a market share of 70% in volume. This is due to its low cost which brings improvements to the packages without compromising the production costs.

Advanced / functionalized nanoclays have been drawing increasingly more attention in the industry due to the presence of new properties: antibacterial action and oxygen scavenger.

Although less used nanosilver can also be found in packaging for its antibacterial property.

According to the sources relied by this study carbon nanotubes are not being used in the plastic packaging industry except in the Asian electronic component industry packaging.

The use of nanoclay as nanometric input for enhancement of plastic packaging is present in successful cases of competitive companies located in countries responsible for knowledge generation and leaders in the production of patents and innovative products.

5.3 DEMAND ANALYSIS METHODOLOGY

The methodology used in this stage of the Feasibility Study was based on parameterized estimates of the demand for nanometric inputs for plastic packaging. Such estimate was validated in a Workshop held on March 20, 2012 at Abiplast - *Associação Brasileira da Indústria do Plástico* (Brazilian Plastic Industry Association). The gathering of information for validation of the demand estimate relied on a questionnaire prepared on the basis of the results generated by the technological intelligence. The Workshop presented successful case studies of nanometric inputs for plastic packaging as well as their technical characteristics and potential benefits to the plastic packaging industry production chain.

5.4 DEMAND ESTIMATE

According ABIQUIM/Coplast (2011), the demand for the main thermoplastic resins is presented in Table 21.

Table 21 - Volume of Demand of Main Thermoplastic Resins in 2011

Resin	Volume (t)
Polypropylene	2.758.213
PET	1.238.976
Polyethylenes	3.551.159
Polyvinyl Chloride	1.348.346
Polystyrene	528.285

Out of this volume, the food and beverage industry uses about 2.3 million as detailed in Table 22.

Table 22 – Demand Volume Segmentation of Main Thermoplastic Resins used in Food and Beverage Industry in 2011

Resin	Demand Percentage in Resins	Volume (t)
Polypropylene	17%	466.138
PET	100%	1.238.976
Polyethylenes	14%	507.816
Polyvinyl Chloride	0%	0
Polystyrene	22%	116.223
TOTAL		**2.329.152**

Source: Adirplast, 2010

In 2011, the world market of nanocomposites for packaging (US$ 257 million) represented 0,14% of plastic packaging world market value (BCC Research 2012 and Visiongain 2011).

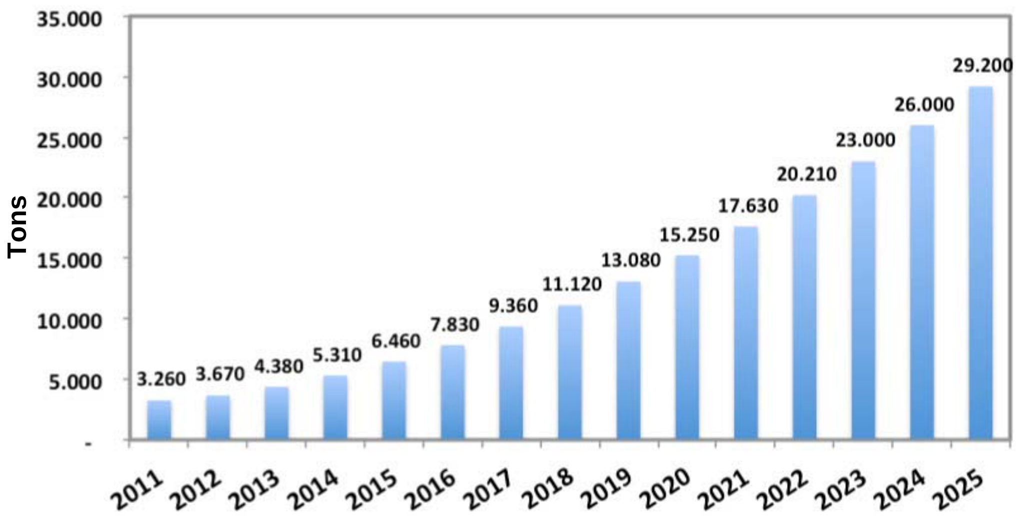
This study assumed the hypothesis that such percentage also applies to the sales volume considering that the price of nancomposites should be similar to that of conventional resins (to become economically viable).

By applying this value to the Brazilian case in 2011, a total of **3.260 tons** of potential demand for nanocomposites was estimated in the food packaging industry in Brazil in 2011.

Considering that the typical value in percentage of nanoload in one nanocomposite is 5% in weight, the estimated demand of nanoinput in 2011 was **163 tons**. Such value represents the consumption potential in 2011.

Considering that the evolution of Brazilian consumption follows the evolution of world consumption in nanocomposite the expectation of evolution of Brazilian consumption in nanocomposites was created as seen in Chart 35).

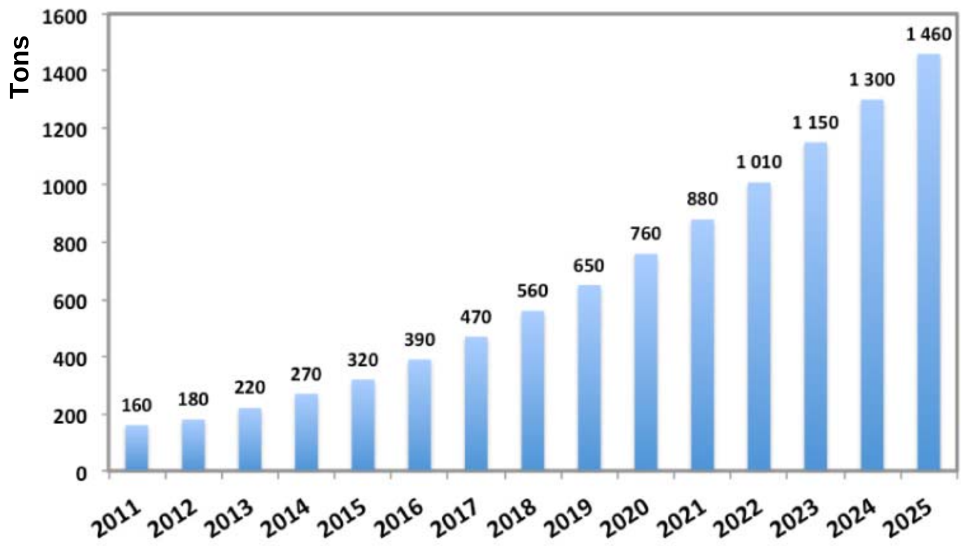
Chart 35 – Expectation of Evolution of Brazilian Consumption of Nanocomposites



Source: NanoBusiness (2012)

Considering that the typical value in percentage of nanoload in one nanocomposite is 5% in weight the evolution of the estimated demand of nanoinputs was created as seen in Chart 36).

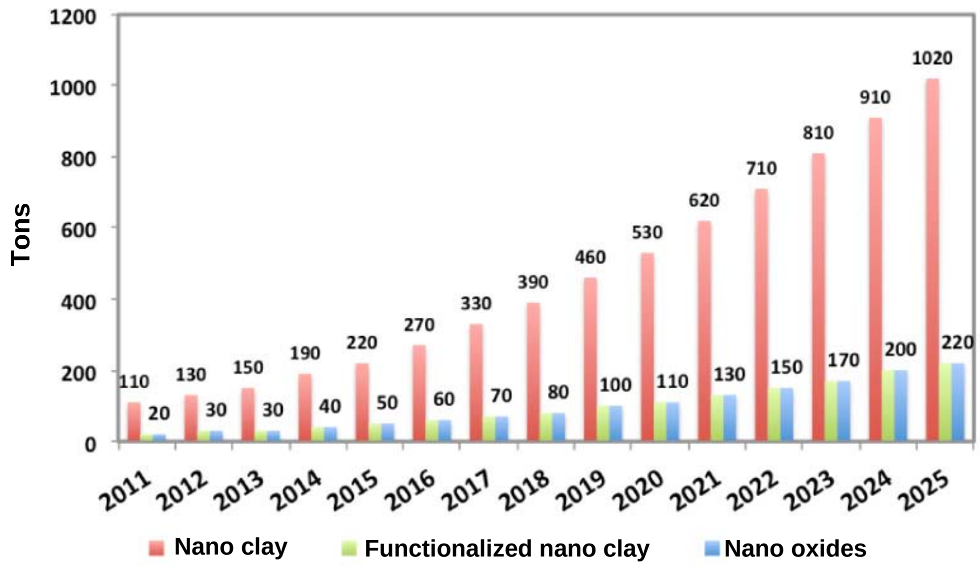
Chart 36 – Expectation of Brazilian Consumption of Nanoinputs



Source: NanoBusiness (2012)

The main reference of the expectation of evolution of Brazilian consumption in nanoclay, functionalized nanoclay and nanooxides (Chart 37) is the world consumption of nanoclay applied to the packaging sector which represents 70% of the world market. In connection therewith, the expectation of consumption evolution by each of the above nanoinput was distributed in 70% of nanoclay, 15% of functionalized nanoclay with silver or iron and in 15% of nanooxides.

Chart 37 – Expectation of Evolution of Brazilian Consumption of Nano Clay, Functionalized Nano Clay and Nanooxides



Source: NanoBusiness (2012)

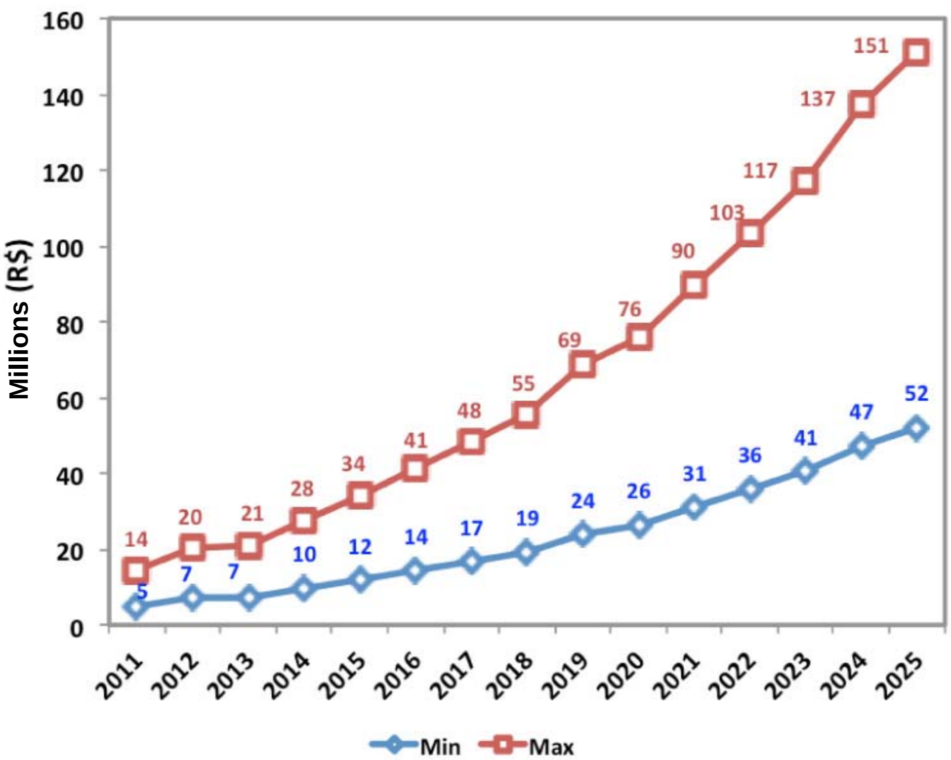
The evolution of the Brazilian market of nanoinputs for the plastic packaging industry (Chart 38) was calculated considering the prices of the above nanoinputs summarized in Table 23.

Table 23 – Estimate of Consumption and Market by Input for Different Scenarios

	Price (R$ / Kg)	
Nano input	**Minimal**	**Maximal**
Nano clay	R$ 9,16	R$ 22,90
Nano clay with silver	R$ 137,40	R$ 180,20
Nano oxides	R$ 57,25	R$ 400,75

Source: Willems & van den Wildenberg - Roadmap Report on Nanoparticles - November 2005.

Chart 38 – Brazilian Market Estimate – Maximum and Minimum Scenarios



Source: NanoBusiness (2012)

5.4.1 Validation of Demand Estimate – Abiplast Workshop

Four hundred companies were invited according to Abiplast. Micro and small businesses represent 94.9% of the number of plastic processing companies, but none of them participated in the Workshop by showing little interest in the matter. On the other hand SEBRAE-SP participated as a representative of these businesses in the nanotechnology area.

The participation of medium and large businesses represented 9.4% of the invited companies in such category. Such participation seems to indicate that the main stakeholders in innovation based on nanotechnology in the plastic processing industry are the medium and large size businesses.

Company	Department	Title (Participant)	Company ranking in production chain	Number of employees
A (SP)	Development	Technical Assistant	3ª	> 500
B (PE)	Commercial	Regional Sales Manager	3ª	>500
C (SP)	Industrial Engineering	Manager	3ª	100 – 499
D (SP)	Projects	Competitiveness Consultants	Others: Projects in Plastics Area	>500

Source: NanoBusiness (2012)

5.4.1.1 Questionnaire Answers and Review

This item presents a compilation of the questionnaire with the relevant answers. The full questionnaire can be found in Annex 1 hereto.

Question 1

Is your company aware of the nanotechnology impact on the plastic packaging industry?

☐ Yes ☐ No

Answers:

Yes: One company minimally aware
No: Two companies

Question 2

Does your company use nanotechnology?

☐ Yes ☐ No

If negative, what is the probability of using it in the next five years?

Probability:

None	0-10%	10-25%	25-50%	50-75%	75-100%
☐	☐	☐	☐	☐	☐

Answers:

None of the companies uses nanotechnology at this point

The probability of using in the next five years is:

0-10%: One company
25%-50%: Two companies

Analysis of answers 1 and 2:

Nanotechnology is not being used at this point in medium and large-sized businesses, but the results of Question 2 show some interest and an opening to nanotechnology and benefits thereof.

Question 3

What is the current participation of biodegradable biopolymers in your company production?

Participation in volume:

None	0-10%	10-25%	25-50%	50-75%	75-100%
☐	☐	☐	☐	☐	☐

What will be the participation of biodegradable biopolymers in your company production five years from now?

Participation in volume:

None	0-10%	10-25%	25-50%	50-75%	75-100%
☐	☐	☐	☐	☐	☐

Answer:

Question: *What is the current participation of biodegradable biopolymers in your company production?*

None: One company
0-10%: One company
10-25%: One company

Question: *What will be the participation of biodegradable biopolymers in your company production five years from now?*

0-10%: One company
10-25%: One company
25-50%: One company

Analysis of answers:

Biodegradable biopolymers are still weak participants in the production and cost pressure was pointed out by the participants as the main reason for that, Besides we could see that the weak barrier properties of these resins are substantially limiting their use in the plastic packaging industry.

But in the next five years the interviewed companies have indicated a growth in the demand of such resins.

Question 4

Does your company use nanoinputs in the production of plastic packaging? Which ones? Which is the volume per nanoinput? Which is the practiced cost?

- ☐ Nano clay _______Kg/year _______ average cost
- ☐ Nano oxides _______Kg/year _______ average cost
- ☐ Nano silver _______Kg/year _______ average cost
- ☐ Nano organics _______Kg/year _______ average cost
- ☐ Carbon nanotubes _______Kg/year _______ average cost
- ☐ Others:___________ _______Kg/year _______ average cost
- ☐ Does not use

Answers:

N/A

Analysis of answers:

According to the answers to Questions 1, 2 and 4, nanotechnology is not yet being used in the processed plastics sector.

Question 5

Which of the following properties should be improved to make your products more competitive?

Properties	**Need of improvement (Scoring from 1 to 5 per increasing order of importance)** 0	1	2	3	4	5
Cost reduction	☐	☐	☐	☐	☐	☐
Plastic durability	☐	☐	☐	☐	☐	☐
Antibacterial action	☐	☐	☐	☐	☐	☐
Light/UV barrier	☐	☐	☐	☐	☐	☐
Water barrier	☐	☐	☐	☐	☐	☐
Oxygen barrier	☐	☐	☐	☐	☐	☐
CO_2 scavenger	☐	☐	☐	☐	☐	☐
Ethylene scavenger	☐	☐	☐	☐	☐	☐
Oxygen scavenger	☐	☐	☐	☐	☐	☐
Enzyme immobilization	☐	☐	☐	☐	☐	☐
Leakage indicator	☐	☐	☐	☐	☐	☐
Nano sensors	☐	☐	☐	☐	☐	☐
Electrical properties	☐	☐	☐	☐	☐	☐
Mechanical properties	☐	☐	☐	☐	☐	☐
Thermal properties	☐	☐	☐	☐	☐	☐
RFID	☐	☐	☐	☐	☐	☐
Deterioration Detector	☐	☐	☐	☐	☐	☐

Answers:

See Page 69.

Question 6

If the improvements of properties will imply increase of production costs would there be interest in implementing them?

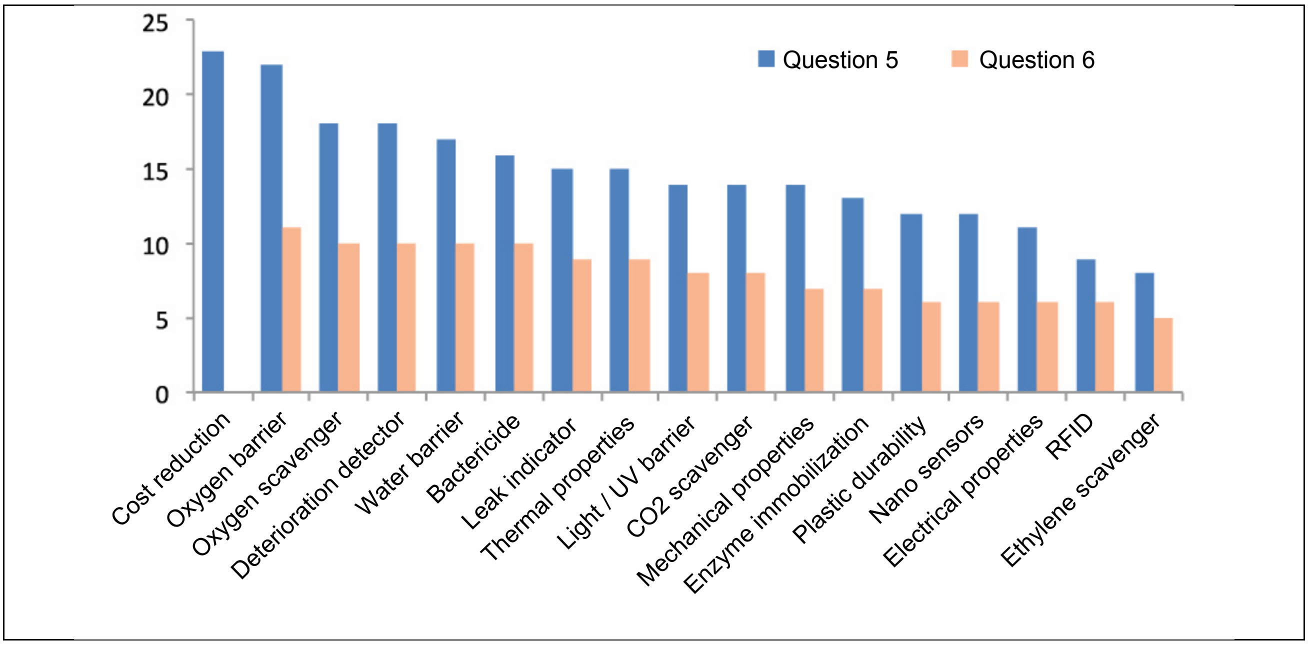
	Interest (Scoring from 1 to 5 per increasing order of interest)					
Properties	**0**	**1**	**2**	**3**	**4**	**5**
Cost reduction	☐	☐	☐	☐	☐	☐
Plastic durability	☐	☐	☐	☐	☐	☐
Antibacterial action	☐	☐	☐	☐	☐	☐
Light/UV barrier	☐	☐	☐	☐	☐	☐
Water barrier	☐	☐	☐	☐	☐	☐
Oxygen barrier	☐	☐	☐	☐	☐	☐
CO_2 scavenger	☐	☐	☐	☐	☐	☐
Ethylene scavenger	☐	☐	☐	☐	☐	☐
Oxygen scavenger	☐	☐	☐	☐	☐	☐
Enzyme immobilization	☐	☐	☐	☐	☐	☐
Leakage indicator	☐	☐	☐	☐	☐	☐
Nano sensors	☐	☐	☐	☐	☐	☐
Electrical properties	☐	☐	☐	☐	☐	☐
Mechanical properties	☐	☐	☐	☐	☐	☐
Thermal properties	☐	☐	☐	☐	☐	☐
RFID	☐	☐	☐	☐	☐	☐
Deterioration Detector	☐	☐	☐	☐	☐	☐

Answers:

See Page 69.

Aiming to obtain a comprehensive view of the results the scores of each property were added (1 to 5 per increasing order of importance)

In this case the answers of all participants were considered.



Analysis of answers:

The industry's greatest interest in using nanoinputs is the possibility of reduction of packaging costs.

Second the greatest interest properties are those related to the atmosphere control within the packaging: Oxygen barrier, oxygen scavenger, deterioration detector, water barrier, antibacterial action and leak indicator.

The industry also pointed out the fact that competitive advantages cannot represent an increase in costs beyond which the clients would be willing to pay for the new properties

Question 7

What is the proportion of packaging produced by your company in need of barrier properties?

Participation in volume:

None	**0-10%**	**10-25%**	**25-50%**	**50-75%**	**75-100%**
☐	☐	☐	☐	☐	☐

In the case of products with high need of gas barrier which types of film are used by your company?

☐ Mono-layer ☐ Multi-layers

In the case of products with high need of gass barrier which resins are used by your company?

☐ PET
☐ Polynylon
☐ PP
☐ LDPE
☐ HDPE

☐ Others:_______________

Which barrier plastics are used in your production of plastic packaging?

☐ EVOH - (Ethylene copolymer and vinyl alcohol)
☐ PVdC – Polyvinyldene chloride)
☐ Amorphous nylon
☐ PVOH - (Polyvinyl alcohol)

☐ Others:_______________

Comments:

Question: *Which proportion of packaging produced by your company requires barrier property?*

Between 0-10%: One company
Between 10-25%: One company
Between 50-70%: One company

Question: *In case of products with high need of gas barrier which types of film are used?*

Mono-layer: One company
Multi-layer: The three companies

Question: In case of products with high need of gas barrier which resins are used?

PET: Two companies
Polynylon: One company
PP: The three companies
LDPE: One company

Question: Which barrier films are used?

Amorphous nylon: One company

Analysis of answers:

The proportion of packaging requiring barrier property in the industry is high taking into account a niche for the insertion of nanoinputs to meet the industry needs.

The most used type of film is multi-layer.

The most used resin is polypropylene resin followed by PET.

From the answers, we can conclude that the conventional films with barrier property are not disseminated in the industry due to the difficulty of application. As to the amorphous nylon film the company purchases co-extruded material.

Comments offered during the Workshop

"Today there is a great demand not met by the processing industry due to lack of more specific / technological products".

"The development of nanotechnology satisfies the consumers' / packaging manufacturers' wishes".

"Biodegradable plastics are already a non-reversible trend. If the nanoinputs can aggregate new competitive edges they will be highly required".

"In the project we are working at Sebrae – Development of Plastic Packaging for Ready-to-Eat Food (...) for our clients is to make them adopt first the multi-layer systems. Nanotechnology is still quite far away from the reality of Micro and Small Businesses".

5.5 CONCLUSIONS

As shown by the Workshop results and discussions with several experts the current consumption of nanoinputs in the packaging industry is virtually non-existent.

However the Workshop result shows an opening to the use of nanotechnology to improve the properties of plastic packaging and the industry willingness to innovate in that segment.

The technological intelligence analysis points out that most nanomaterials used or to be developed for use in the food packaging industry contain nanoclay particles. However the literature describes that other food packaging containing nanoparticles or nanofibers of metals and metallic oxides are being developed.

The industry highest interest properties emphasized in the Workshop point out nanoclay as the greater potential nanoinput for the plastic packaging industry.

The analysis of the technological intelligence and world market of nanoinputs for the plastic packaging industry shows that nanosilver and nanooxides, although in lower quantities, are also being used in the industry.

The demand estimate shows that the nanoinput market for food packaging in 2016 will be between R$ 14 and 41 million with a consumption of 390 tons.

It is important to emphasize that these calculations used the value of 0.14% as participation of the nanocomposite consumption volume in relation to the packaging consumption. Thus this indicator represents the main critical variable contributing towards the estimate error margin.

6 ENGINEERING

6.1 INTRODUCTION

The purpose of this descriptive memorandum is to present the process basic criteria and project for the future development of the Design Engineering Project of production of masterbatches of nanoclay and masterbatches of functionalized nanoclay with Estimate of Investments – CAPEX – (Accuracy: ±50%) and OPEX from organophilic clay or natural clay and standard resins used in the plastic packaging processing industry.

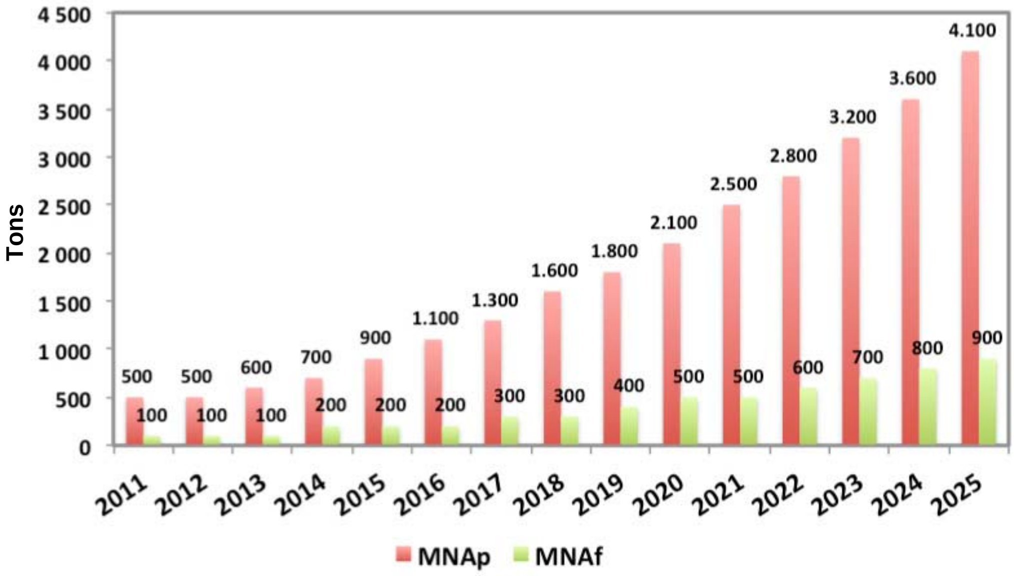
Clay minerals are hydrated alumino-silicates which are generally classified as filosilicates or silicates in layers. These layers are organized as a stacking of lamella or fine sheets, out of which one dimension is nanometric (<100 nm). When these lamella are homogeneously dispersed within a polymeric matrix, this structural characteristic provides the nanocomposite with an increase of its properties such as mechanical, barrier, thermal stabilty and flame resistance.

The main stages in the production of clay nanocomposites are the transformation of a natural clay into an organophilic clay following its incorporation into a polymeric matrix.

The above masterbatches are nancomposites of high concentration in nanoinput (25% in weight) destined to be diluted by the processors of plastic packaging in the proper posology according to the desired properties. This type of supply is standard in the industry and for safety reasons and easeness of handling the choice of supply of masterbatch instead of nanoinput powder limits the use of nanometric powder off the plant.

Based on the data presented in Chart 37, Chart 39 shows the expectation of evolution of Brazilian consumption in masterbatches with 25% in weight of pure nanoclay (MNAp) and functionalized nanoclay (MNAf).

Chart 39 – Expectation of Evolution of Brazilian Consumption of Masterbatch containing 25% in weight of pure nanoclay (MNAp) and functionalized nanoclay (MNAf)



Source: NanoBusiness (2012)

6.2 TRANSFORMATION STAGES OF NATURAL CLAY INTO ORGANOPHILIC CLAY

The nanoclay production process consists in transforming natural clay into a clay which size, purity and structure are compatible with their incorporation into a polymer matrix.

In general the hydrated inorganic cations present between the natural clay lamella are replaced through an ionic exchange by organic cations. This stage modifies the hydrophilic characteristics of the clay lamella to make them more compatible with the polymer chains (resin). The choice of the type of organic modifier is one of the fundamental parameters of the clay-based nanocomposites production route. Usually these modifiers are cations of quaternary ammonium salt produced from reaction of aminas with hydrogenated fatty acids.

6.3 STAGES OF INTERCALATION OF ORGANOPHILIC CLAY INTO A POLYMER MATRIX

There are mainly three methods to obtain clay nanocomposites: intercalation in solution, *in situ* polymerization and intercalation in cast state.

The process of intercalation in cast state presents three major advantages in relation to the others: it does not require organic solvents being less harmful to the environment, it offers flexibility in the choice of polymeric matrixes besides being compatible with industrial extrusion and injection processes. For these reasons this method has been most studied recently and it seems to be most adequate to the intercalation of nanoclay in the resins used in the plastics packaging processing industry with minimum environmental impact.

In the cast state intercalation technique the organophilic clay is mixed with the polymer above its softening point (for amorphous thermoplastics) or melting point (for semicrystalline thermoplastics), so that the latter will penetrate in the clay galleries by intercalating the lamella and eventually exfoliating them. However in order the intercalation to occur a certain degree of affinity is required between the polymer and clay. The intercalation may be static from static annealing or with the aid of shearing by extrusion or mixer. Several polymers were used in the preparation of nanocomposites via cast polymer with the most studied ones being polypropylene and polyamide 6.

Intercalation in cast state is the preferred method to obtain the nanocomposites montmorillonite clay and polyolefin because of the easy processability of this polymer family. However due to the low compatibility between polyolefin (hydrophobic) and montmorilonite (hydrophilic) several strategies have been used to overcome such restriction generally based on the utilization of specific organic modifiers or the addition of compatibilizing agents. Compatibilizing agents are bifunctional molecules presenting functional groups capable to interact with the clay surface and having an apolar chain that interacts with the polymeric matrix.

The modification of polypropylene with different polar groups have been widely used to obtain compatibilizing agents such as maleic anhidride, acrylic acid and glycidyl methacrylate in obtaining polypropylene and montmorillonite clay nanocomposites. A higher increment was observed in the dispersion of reinforcement as well as in the mechanical properties of the compatibilized nanocomposites when compared to non-compatibilized materials. Additionally, studies on the processing conditions indicate that such conditions as speed of rotors, shearing rate, time of residence and cast temperature strongly affect the levels of dispersion of clay in the polymeric matrix.

6.4 FUNCTIONALIZATION OF NANOCLAY

The functionalization of nanoclays is chiefly used to transform nanocomposites into active nanocomposites. The activity is obtained through the addition of a specific additive based on the intercalation of metals between the clay lamella or its salts to give antibacterial and/or oxygen elimination activity.

6.5 PROJECT CHARACTERIZATION

6.5.1 Technological Routes

The nanoinput production industrial plant for plastic packaging was designed considering different technological routes:

- Starting clay: Organophilic clay (OC) or natural clay (NC);
- Organic modifiers: Of high (MO 1) or low (MO 2) cost; and
- Types of products commercialized by the plant: Masterbatches of pure nanoclay (MNAp) and/or Masterbatches of functionalized nanoclay (MNAf).

The selected technological routes and their parameters are summarized in Table 24.

Table 24 – Parameters of Technological Routes considered

Technological Routes	Type of Products	Starting Clay	Organic Modifier
1	MNAp and MNAf	AO	Not applicable
2	MNAp	AO	Not applicable
3	MNAp and MNAf	AN	MO 1
4	MNAp	AN	MO 1
5	MNAp and MNAf	AN	MO 2
6	MNAp	AN	MO 2

Source: NanoBusiness (2012)

The routes established for the production processes of masterbatches of pure nanoclay or functionalized nanoclay are based on the identified and characterized technologies described in Chapter 3, through studies of several national and international patents, scientific articles and papers and case studies.

The proposed technological route covers stages of treatment of starting clay with an organic modifier (for technological routes 3 to 6 only), obtaining an organophilic clay; functionalization of organophilic clay with silver and iron salts (for technological routes 1, 3 and 5 only), obtaining a functionalized organophilic clay; drying (for technological 1 and 3 to 6 only); intercalation in cast state (all technological routes), producing masterbatches of pure or functionalized nanoclay.

6.5.2 Plant Capacity

The nominal production capacity of the industrial plant producing nanoinputs for the plastic packaging industry will be established to meet 100% of the expectation of the Brazilian consumption in masterbatch (Chart 39) in 2019, with perspective of expansion to meet the demand until 2025.

The plant nominal production capacity from organophilic clay or natural clay will be 1.800 ton / year of masterbatches of pure nanoclay and/or 400 tons / year of masterbatches of functionalized nanoclay, as summarized in Table 25, with perspective of expansion to 4.100 and 900 tons per year respectively, as summarized in Table 26.

At this preliminary stage of the study an operational yield of 100% was assumed for all stages of the technological routes.

Table 25 – Production Capacity of Masterbatches of Pure Nanoclay - 1.800 t/year and Masterbatches of Functionalized Nanoclay - 400 t/year

ITEM	UNIT	TOTAL
Production of MNAp	t/y	1.800
Production of MNAf	t/y	400
Scheduled days / year	Day / year	264
Operating yield	%	100
Actual hours / year	h/year	2112
Hourly production of pure nanoclay	kg/h	160
Hourly production of functionalized nanoclay	kg/h	30
Hourly production of MNAp	kg/h	850
Hourly production of MNAf	kg/h	190
Clay content in feed	%	100
Yield of treatment with organic modifier	%	100
Functionalization process yield	%	100
Drying process yield	%	100
Intercalation process yield in cast state	%	100
Global yield	%	100

Source: NanoBusiness (2012)

Table 26 – Production Capacity of Masterbatches of Pure Nanoclay - 4.100 t/year and Masterbatches of Functionalized Nanoclay - 900 t/year

ITEM	UNIT	TOTAL
Production of MNAp	t/y	4.100
Production of MNAf	t/y	900
Scheduled days / year	Day / year	264
Operating yield	%	100
Actual hours / year	h/year	2112
Hourly production of pure nanoclay	kg/h	490
Hourly production of functionalized nanoclay	kg/h	100
Hourly production of MNAp	kg/h	1940
Hourly production of MNAf	kg/h	430
Clay content in feed	%	100
Yield of treatment with organic modifier	%	100
Functionalization process yield	%	100
Drying process yield	%	100
Intercalation process yield in cast state	%	100
Global yield	%	100

Source: NanoBusiness (2012)

6.5.3 General Plant Parameters

The plant will be operating continuously during two hundred and sixty-four (264) days per year and eight (8) hours per day.

Considering operating yield of 100% we will have 2.112 actual hours / year.

6.6 STANDARD PROJECT DATA

6.6.1 Project Areas

The codes below will be used to identify and locate the different equipment related to technological routes.

100 – PROCESSING AREAS
110 – Treatment with organic modifier
120 – Functionalization process
130 – Drying process
140 – Intercalation process in cast state
150 – Granulation

200 – AUXILIARY UNITS
210 – Deionized water
220 – Effluent treatment

300 – STORAGE OF REAGENTS
310 – Starting clay
320 – Deionized water
330 – Organic modifier
340 – Silver nitrate
350 – Iron /ammonium sulfate
360 – Resin
361 – Polypropylene
362 – PET
363 – Low density polyethylene
364 – High density polyethylene
365 – Linear low density polyethylene
366 – Polystyrene
370 – Pure nanoclay
380 – Functionalized nanoclay

400 – UTILITIES
410 – Water

500 – AUTOMATION
600 – ELECTRIC SYSTEM

700 – INFRASTRUCTURE AND ADMINISTRATIVE SUPPORT

6.6.2 List of Major Equipment

Raw Material	Products	Stage	Project Area	Tag	Description	Specification Type	Spec	Unit	Quantity
AO	MNAp + MNAf	Implementation AO	500	SistCont-AO1	Control System			Unit	1
AO	MNAp + MNAf	Expansion AO	500	SistCont-AO2	Control System			Unit	1
AN	MNAp + MNAf	Implementation AN	500	SistCont-AN1	Control System			Unit	1
AN	MNAp + MNAf	Expansion AN	500	SistCont-AN2	Control System			Unit	1
AO	MNAp + MNAf	Implementation AO	361	SILO2-PP-AO1	Stainless steel conic bottom silo	Volume	10000	L	1
AO	MNAp + MNAf	Implementation AO	362	SILO2-PET-AO1	Stainless steel conic bottom silo	Volume	10000	L	1
AO	MNAp + MNAf	Implementation AO	366	SILO2-PS-AO1	Stainless steel conic bottom silo	Volume	1500	L	1
AO	MNAp + MNAf	Implementation AO	364	SILO2-PEHD-AO1	Stainless steel conic bottom silo	Volume	3000	L	1
AO	MNAp + MNAf	Implementation AO	363	SILO2-PEBD-AO1	Stainless steel conic bottom silo	Volume	3000	L	1
AO	MNAp + MNAf	Implementation AO	365	SILO2-PEBDL-AO1	Stainless steel conic bottom silo	Volume	3000	L	1
AO	MNAp + MNAf	Implementation AO	140 & 150	MASTERBATCH-PP-AO1	Double screw extruder and granulator system	Production	200	kg/h	1
AO	MNAp + MNAf	Implementation AO	140 & 150	MASTERBATCH-PET-AO1	Double screw extruder and granulator system	Production	200	kg/h	2
AO	MNAp + MNAf	Implementation AO	140 & 150	MASTERBATCH-PS-AO1	Double screw extruder and granulator system	Production	200	kg/h	1
AO	MNAp + MNAf	Implementation AO	140 & 150	MASTERBATCH-PEs-AO1	Double screw extruder and granulator system	Production	200	kg/h	1
AO	MNAp + MNAf	Implementation AO	210	PUR.ÁGUA-AO1	Water purification plant	Flow rate	1	m^3/h	1
AO	MNAp + MNAf	Implementation AO	220	FILTRO-AO1	Bag filter	Flow rate	1	m^3/h	1
AO	MNAp + MNAf	Implementation AO	310	SILO1-AO-AO1	Stainless steel conic bottom silo	Volume	10000	L	1
AO	MNAf	Implementation AO	320	SILO3-AD-AO1	Stainless steel conic bottom silo	Volume	3000	L	1
AO	MNAf	Implementation AO	340	SILO4-NP-AO1	Stainless steel conic bottom silo	Volume	200	L	1
AO	MNAf	Implementation AO	350	SILO5-SFA-AO1	Stainless steel conic bottom silo	Volume	200	L	1

AO	MNAf	Implementation AO	380	SILO6-NAf-AO1	Stainless steel conic bottom silo	Volume	1500	L	1
AO	MNAf	Implementation AO	120	REATOR 2-NAf-AO1	Agitator reactor with internal coil	Volume	1000	L	1
AO	MNAf	Implementation AO	130	SPRAY-DRYER2-NAf-AO1	High speed centrifugation spray dryer	Flow rate	500	L/h	1
AO	MNAf	Implementation AO	120	SISTEMA-ULTRA-SOM-AO1	Disagglomeration with ultrasonic sonotrode	Power	2	kW	1
AN	MNAp + MNAf	Implementation AN	361	SILO2-PP-AN1	Stainless steel conic bottom silo	Volume	10000	L	1
AN	MNAp + MNAf	Implementation AN	362	SILO2-PET-AN1	Stainless steel conic bottom silo	Volume	10000	L	1
AN	MNAp + MNAf	Implementation AN	366	SILO2-PS-AN1	Stainless steel conic bottom silo	Volume	1500	L	1
AN	MNAp + MNAf	Implementation AN	364	SILO2-PEHD-AN1	Stainless steel conic bottom silo	Volume	3000	L	1
AN	MNAp + MNAf	Implementation AN	363	SILO2-PEBD-AN1	Stainless steel conic bottom silo	Volume	3000	L	1
AN	MNAp + MNAf	Implementation AN	365	SILO2-PEBDL-AN1	Stainless steel conic bottom silo	Volume	3000	L	1
AN	MNAp + MNAf	Implementation AN	140 & 150	MASTERBATCH-PP-AN1	Double screw extruder and granulator system	Production	200	kg/h	1
AN	MNAp + MNAf	Implementation AN	140 & 150	MASTERBATCH-PET-AN1	Double screw extruder and granulator system	Production	200	kh/h	2
AN	MNAp + MNAf	Implementation AN	140 & 150	MASTERBATCH-PS-AN1	Double screw extruder and granulator system	Production	200	kg/h	1
AN	MNAp + MNAf	Implementation AN	140 & 150	MASTERBATCH-PEs-AN1	Double screw extruder and granulator system	Production	200	kg/h	1
AN	MNAp + MNAf	Implementation AN	210	PUR-ÁGUA-AN1	Water purification plant	Flow rate	1	m^3/h	1
AN	MNAp + MNAf	Implementation AN	220	FILTRO-AN1	Bag filter	Flow rate	1	m^3/h	1
AN	MNAp + MNAf	Implementation AN	310	SILO1-AN-AN1	Stainless steel conic bottom silo	Volume	5000	L	1
AN	MNAp + MNAf	Implementation AN	330	SILO8-SQA-AN1	Stainless steel conic bottom silo	Volume	20000	L	1
AN	MNAp + MNAf	Implementation AN	320	SILO3-AD-AN1	Stainless steel conic bottom silo	Volume	15000	L	1
AN	MNAf	Implementation AN	340	SILO4-NP-AN1	Stainless steel conic bottom silo	Volume	200	L	1
AN	MNAf	Implementation AN	350	SILO5-SFA-AN1	Stainless steel conic bottom silo	Volume	200	L	1
AN	MNAp	Implementation AN	370	SILO6-NAp-AN1	Stainless steel conic bottom silo	Volume	3000	L	1
AN	MNAf	Implementation AN	380	SILO7-NAf-AN1	Stainless steel conic bottom silo	Volume	1500	L	1
AN	MNAp	Implementation AN	110	REATOR1-NAp-AN1	Agitator reactor with internal coil	Volume	5000	L	1
AN	MNAf	Implementation AN	110 & 120	REATOR2-NAf-AN1	Agitator reactor with internal coil	Volume	1000	L	1

AN	MNAp	Implementation AN	130	SPRAY-DRYER 1-NAp-AN1	High speed centrifugation spray dryer	Flow rate	2000	L/h	1
AN	MNAf	Implementation AN	130	SPRAY-DRYER 2-NAf-AN1	High speed centrifugation spray dryer	Flow rate	500	L/h	1
AN	MNAp + MNAf	Implementation AN	110 & 120	SISTEMA-ULTRA-SOM-AN1	Disagglomeration with ultrasonic sonotrode	Power	10	kW	1
AO	MNAp + MNAf	Expansion AO	361	SILO2-PP-AO2	Stainless steel conic bottom silo	Volume	10000	L	1
AO	MNAp + MNAf	Expansion AO	362	SILO2-PET-AO2	Stainless steel conic bottom silo	Volume	10000	L	1
AO	MNAp + MNAf	Expansion AO	366	SILO2-PS-AO2	Stainless steel conic bottom silo	Volume	1500	L	1
AO	MNAp + MNAf	Expansion AO	364	SILO2-PEHD-AO2	Stainless steel conic bottom silo	Volume	3000	L	1
AO	MNAp + MNAf	Expansion AO	363	SILO2-PEBD-AO2	Stainless steel conic bottom silo	Volume	3000	L	1
AO	MNAp + MNAf	Expansion AO	365	SILO2-PEBDL-AO2	Stainless steel conic bottom silo	Volume	3000	L	1
AO	MNAp + MNAf	Expansion AO	140 & 150	MASTERBATCH-PP-AO2	Double screw extruder and granulator system	Production	200	kg/h	1
AO	MNAp + MNAf	Expansion AO	140 & 150	MASTERBATCH-PET-AO2	Double screw extruder and granulator system	Production	200	kg/h	3
AO	MNAp + MNAf	Expansion AO	140 & 150	MASTERBATCH-PS-AO2	Double screw extruder and granulator system	Production	200	kg/h	-
AO	MNAp + MNAf	Expansion AO	140 & 150	MASTERBATCH-PEs-AO2	Double screw extruder and granulator system	Production	200	kg/h	1
AO	MNAf	Expansion AO	210	PUR-ÁGUA-AO2	Water puriification plant	Flow rate	1	m^3/h	1
AO	MNAf	Expansion AO	220	FILTRO-AO2	Bag filter	Flow rate	1	m^3/h	1
AO	MNAp + MNAf	Expansion AO	310	SILO1-AO-AO2	Stainless steel conic bottom silo	Volume	5000	L	1
AO	MNAf	Expansion AO	320	SILO3-AD-AO2	Stainless steel conic bottom silo	Volume	3000	L	1
AO	MNAf	Expansion AO	340	SILO4-NP-AO2	Stainless steel conic bottom silo	Volume	200	L	1
AO	MNAf	Expansion AO	350	SILO5-SFA-AO2	Stainless steel conic bottom silo	Volume	200	L	1
AO	MNAf	Expansion AO	380	SILO6-NAf-AO2	Stainless steel conic bottom silo	Volume	1500	L	1
AO	MNAf	Expansion AO	120	REATOR 2-NAf-AO2	Agitator reactor with internal coil	Volume	1000	L	1
AO	MNAf	Expansion AO	130	SPRAY-DRYER 2-NAf-AO2	High speed centrifugation spray dryer	Flow rate	500	L/h	-
AO	MNAf	Expansion AO	120	SISTEMA-ULTRA-SOM-AO1	Disagglomeration with ultrasonic sonotrode	Power	2	kW	1
AN	MNAp + MNAf	Expansion AN	361	SILO2-PP-AN2	Stainless steel conic bottom silo	Volume	10000	L	1
AN	MNAp + MNAf	Expansion AN	362	SILO2-PET-AN2	Stainless steel conic bottom silo	Volume	10000	L	1

AN	MNAp + MNAf	Expansion AN	366	SILO2-PS-AN2	Stainless steel conic bottom silo	Volume	1500	L	1
AN	MNAp + MNAf	Expansion AN	364	SILO2-PEHD-AN2	Stainless steel conic bottom silo	Volume	3000	L	1
AN	MNAp + MNAf	Expansion AN	363	SILO2-PEBD-AN2	Stainless steel conic bottom silo	Volume	3000	L	1
AN	MNAp + MNAf	Expansion AN	365	SILO2-PEBDL-AN2	Stainless steel conic bottom silo	Volume	3000	L	1
AN	MNAp + MNAf	Expansion AN	140 & 150	MASTERBATCH-PP-AN2	Double screw extruder and granulator system	Production	200	kg/h	1
AN	MNAp + MNAf	Expansion AN	140 & 150	MASTERBATCH-PET-AN2	Double screw extruder and granulator system	Production	200	kg/h	3
AN	MNAp + MNAf	Expansion AN	140 & 150	MASTERBATCH-PS-AN2	Double screw extruder and granulator system	Production	200	kg/h	-
AN	MNAp + MNAf	Expansion AN	140 & 150	MASTERBATCH-PEs-AN2	Double screw extruder and granulator system	Production	200	kg/h	1
AN	MNAp + MNAf	Expansion AN	210	PUR-ÁGUA-AN2	Water purification plant	Flow rate	1	m^3/h	1
AN	MNAp + MNAf	Expansion AN	220	FILTRO-AN2	Bag filter	Flow rate	1	m^3/h	1
AN	MNAp + MNAf	Expansion AN	310	SILO 1-AN-AN2	Stainless steel conic bottom silo	Volume	5000	L	1
AN	MNAp + MNAf	Expansion AN	330	SILO 8-SQA-AN2	Stainless steel conic bottom silo	Volume	20000	L	1
AN	MNAp + MNAf	Expansion AN	320	SILO 3-AD-AN2	Stainless steel conic bottom silo	Volume	10000	L	1
AN	MNAf	Expansion AN	340	SILO 4-NP-AN2	Stainless steel conic bottom silo	Volume	200	L	1
AN	MNAf	Expansion AN	350	SILO 5-SFA-AN2	Stainless steel conic bottom silo	Volume	200	L	1
AN	MNAp	Expansion AN	370	SILO 6-NAp-AN2	Stainless steel conic bottom silo	Volume	3000	L	1
AN	MNAf	Expansion AN	380	SILO 7-NAf-AN2	Stainless steel conic bottom silo	Volume	1500	L	1
AN	MNAp	Expansion AN	110	REATOR 1-NAp-AN2	Agitator reactor with internal coil	Volume	5000	L	1
AN	MNAf	Expansion AN	110 & 120	REATOR 2-NAf-AN2	Agitator reactor with internal coil	Volume	1500	L	1
AN	MNAp	Expansion AN	130	SPRAY-DRYER 1-NAp-AN2	High speed centrifugation spray dryer	Volume	500	L/h	1
AN	MNAf	Expansion AN	130	SPRAY-DRYER 2-NAf-AN2	High speed centrifugation spray dryer	Volume	500	L/h	-
AN	MNAp + MNAf	Expansion AN	110 & 120	SISTEMA-ULTRA-SOM-AN2	Disagglomeration with ultrasonic sonotrode	Power	10	kW	-

6.7 DESCRIPTION OF PROCESSES

This section will be presenting the different production processes of nanoclay masterbatches. These will be 4 different processes using organophilic clay or natural clay as precursors and their possible functionalizations.

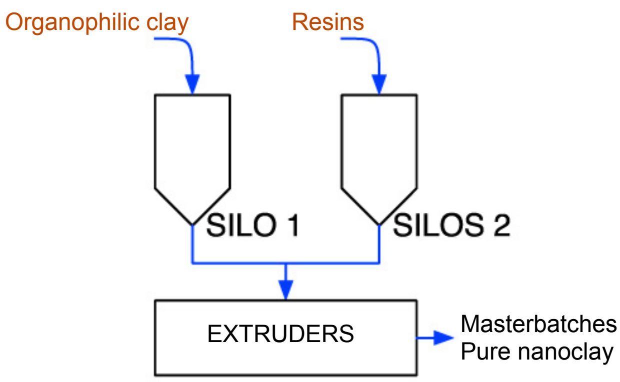
6.7.1 Production processes using Organophilic Clay as Raw Material – Technological Routes 1 and 2

6.7.1.1 With no Functionalization

The intercalation of clay in the resins will be carried out with a commercial organophilic clay of density 0,8 g/cm^3 in a ratio of 250 Kg of organophilic clay by 750 kg of resin.

The production process may be summarized according to Figure 11.

Figure 11 - Lay-out of the MNap Production Process from Organophilic Clay



Source: NanoBusiness (2012)

A masterbatch production unit will be used including a double screw co-rotating extruder and a granulator system (both represented in Figure 11 by “EXTRUDERS”).

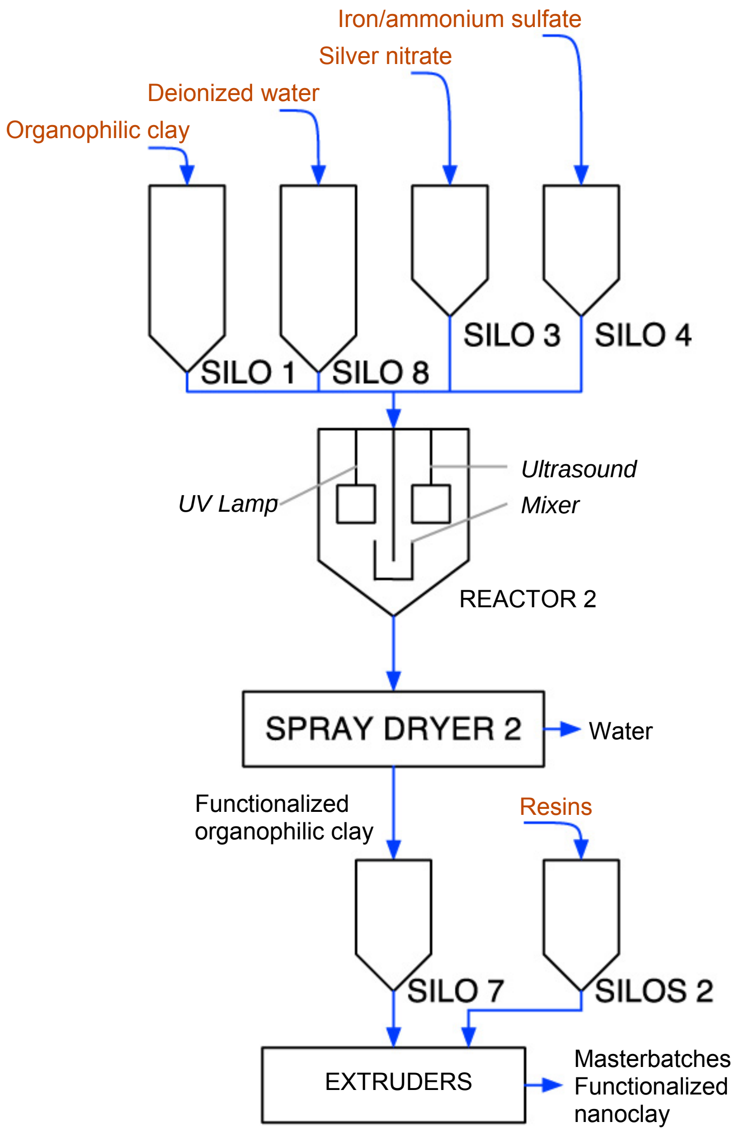
The clay powder and resin pellets will be introduced in the unit by a side-feeder.

6.7.1.2 With Functionalization

Masterbatches will be produced from a commercial organophilic clay of density 0,8 g/cm^3. After functionalized with silver nitrate and iron / ammonium sulfate, the organophilic clay will be introduced in the resins at a ratio of 250 Kg of functionalized organophilic clay by 750 kg of resin.

The production process can be summarized according to Figure 12.

Figure 12 - Lay-out of the MNAf Production Process from Organophilic Clay



Source: NanoBusiness (2012)

The functionalization stage will be carried out by dispersing the organophilic clay with silver nitrate and iron/ ammonium sulfate in deionized water in a reactor under mixture and heating (REACTOR 2). An ultrasonic unit will be coupled to the reactor to reduce the reactional time as well as to assure the efficiency of the functionalization.

The powder of the functionalized organophilic clay will be collected after going through a spray-dryer (SPRAY-DRYER 2).

The intercalation of organophilic clay in the resins will be executed in a masterbatch production unit including a double-screw co-rotating extruder and a granulator system (both represented in Figure 12 by “EXTRUDERS”).

The clay powder and the resin pellets will be introduced in the unit by a side-feeder.

6.7.2 Production Processes using Natural Clay as Raw Material – Technological Routes 3 to 6

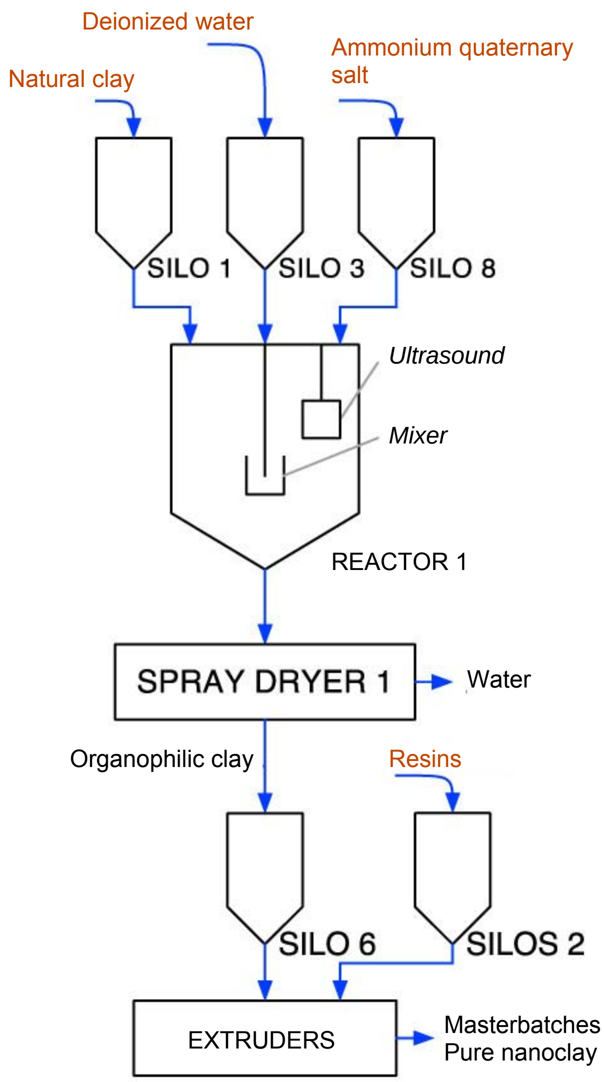
6.7.2.1 With no Functionalization

A bentonite type of clay, density of 0,96 g/cm^3, particle size < 5 µm will be transformed into organophilic clay by addition of an organic modifier in form of an ammonium quaternary salt.

The organophilic clay produced this way will be introduced in the resins at a ratio of 250 Kg of organophilic clay by 750 kg of resin.

The production process can be summarized according to Figure 13.

Figure 13 – Layout of MNAp Production Process from Natural Clay



Source: NanoBusiness (2012)

The stage of transformation of natural clay into organophilic clay will be carried out by dispersing the bentonite with the organic modifier in deionized water within a reactor under mixture and heating (REACTOR 1). An ultrasonic unit will be coupled to the reactor to reduce the reactional time as well as to assure the efficiency of the organic modification.

The organophilic clay powder will be collected after going through a spray-dryer (SPRAY-DRYER 1).

The intercalation of organophilic clay in the resins will be executed in a masterbatch production unit including a double-screw co-rotating extruder and a granulator system (both represented in Figure 13 by “EXTRUDERS”).

The clay powder and resin pellets will be introduced in the unit by a side-feeder.

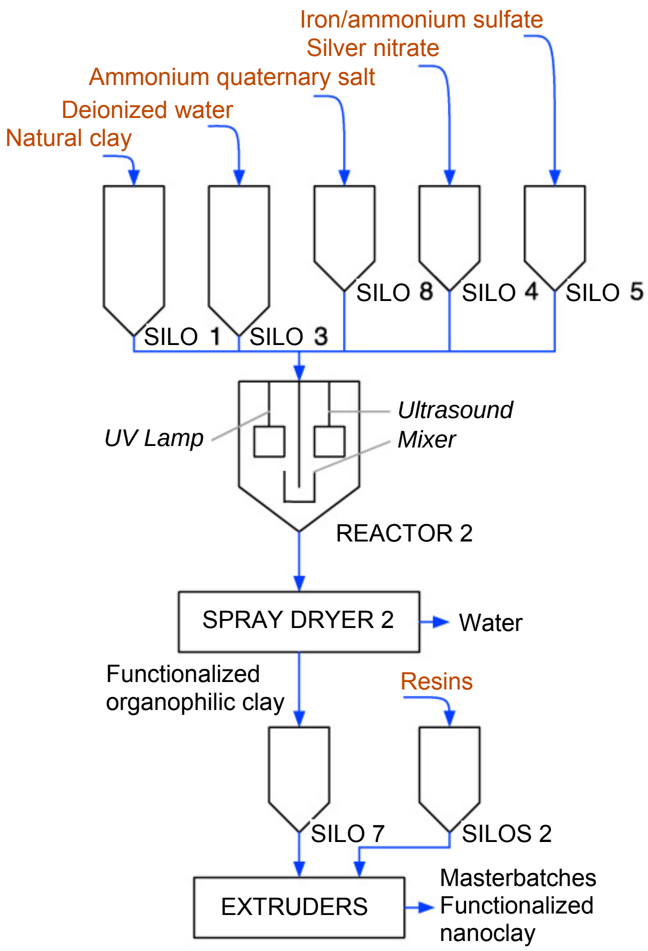
6.7.2.2 With functionalization

A bentonite type of clay, density of 0,96 g/cm^3, particle size <5 μm will be transformed in organophilic clay by addition of an organic modifier in form of ammonium quaternary salt.

After functionalization with silver nitrate and iron/ammonium sulfate, the organophilic clay produced this way will be introduced in the resins at a ratio of 250 Kg of organophilic clay by 750 kg of resin.

The production process can be summarized according to Figure 14.

Figure 14 – Layout of MNAf Production Process from Natural Clay



Fonte: NanoBusiness (2012)

The stage of transformation of natural clay into organophilic clay will be carried out by dispersing the bentonite with organic modifier in deionized water within a reactor under mixture and heating (REACTOR 2.) The stage of functionalization will be carried out by adding the silver nitrate and the iron/ammonium sulfate within the reactor. An ultrasonic unit will be coupled to the reactor to reduce reactional times as well as to assure the efficiency of organic modification and functionalization.

The powder of functionalized organophilic clay will be collected after going through a spray-dryer (SPRAY-DRYER 2).

The intercalation of the functionalized organophilic clay in the resins will be executed in a masterbatch production unit including a double-screw co-rotating extruder and a granulator system (both presented in Figure 14 as “EXTRUDERS”).

The clay powder and resin pellets will be introduced in the unit by a side-feeder.

6.8 INFRASTRUCTURE

To be developed in the Basic Project.

6.9 ELETRIC ENERGY

To be developed in the Basic Project.

6.10 WATER

To be developed in the Basic Project.

6.11 EFFLUENT TREATMENT

To be developed in the Basic Project.

6.12 PLANT DIMENSIONS

The optimal size or Minimum Efficient Scale (MES) was estimated for installation of the nanometric input industrial plant. In connection therewith 300 m² will be required for accommodation of the production plant of 1.800 tons per year of MNAp and 400 tons per year of MNAf. The considered size should enable the sufficient production of the product to meet demand up to Year 7, with an expansion being required as of Year 8 for an area of 500 m².

PROJECT CRITERIA

We are presenting below the codes referring to each raw material and equipment presented below:

CODE	SOURCE
A	Data recommended in various national and international patents
B	Data recommended in scientific articles
C	Industrial practices
D	Data indicated by supplier
E	Data obtained by calculations
F	Engineering standard data
G	Assumed data
H	Case study data

6.12.1 Feed Characteristics

6.12.1.1 Organophilic Clay

Code		
AB	Substance	Organophilic Clay
D	Chemical name or common name comum	Quaternary-Alkylammonium – Bentonite
D	Synonym	Quaternary-Alkylammonium- Montmorillonite
D	CAS registration number	68953-58-2
D	Apparent density	0,80-1,00 g/cm^3
D	Solubility	Insoluble in water but soluble in acids
D	Decomposition temperature	Decomposes from 200° C
C	Storage in plant	Required volume to meet 2 days of production

6.12.1.2 Natural Clay

Code		
AB	Substance	Natural Clay
D	Chemical name or common name	Bentonite, Smectite clay
D	Chemical formula	$(Na, Ca)(Al,Mg)_6(Si_4O_{10})_3(OH)_{6n}$-$H_2O$
D	CAS registration number	52623-66-2
D	Apparent density	0,96 g/cm3
D	Solubility	Insoluble in cold water
D	Decomposition temperature	N/A
AB	Particle size	< 5 µm
C	Storage in plant	Required volume to meet 2 days of production

6.12.2 Organic Modifier

6.12.2.1 Organic Modifier 1

Code		
AB	Substance	Organic Modifier 1
AB	Chemical name or common name	Hexadecyltrimethylammonium bromide
D	Synonym	Cetyltrimethylammonium bromide (CTAB)
D	Chemical formula	$C_{19}H_{42}BrN$
D	CAS registration number	57-09-0
G	Apparent density	~ 0,95 g/cm^3
D	Solubility	36.4 g/l a 20 °C – fully soluble I
D	Decomposition temperature	N/A
C	Storage in plant	Required volume to meet 1 month of production

6.12.2.2 Organic Modifier 2

Code		
AB	Substance	Organic Modifier 2
AB	Chemical name or common name	Alkyl dimethylbenzyl ammonium chloride
D	Synonym	Alkyl dimethylbenzyl ammonium chloride
D	CAS registration number	8001-54-5
G	Apparent density	~ 0,98 g/cm^3
D	Solubility	Fully soluble

D	Decomposition temperature	N/A
C	Storage in plant	Required volume to meet 1 month of production

6.12.3 Silver Nitrate

Code		
AB	Substance	Silver nitrate
D	Chemical name or common name	Silver nitrate
D	Chemical formula	$AgNO_3$
D	CAS registration number	7761-88-8
D	Apparent density	4,350 g/cm^3
D	Solubility	N/A
D	Decomposition temperature	N/A
C	Storage in plant	Required volume to meet 1 month of production

6.12.4 Iron / Ammonium Sulfate

Code		
AB	Substance	Iron/Ammonium sulfate
D	Chemical name or common name	Hexahidrated ammonium-iron(II) sulfate
D	Chemical formula	$H_8FeN_2O_8S_2 \cdot 6H_2O$
D	CAS registration number	7783-85-9
G	Apparent density	~ 2,84 g/cm^3
D	Solubility	N/A
D	Decomposition temperature	N/A
C	Storage in plant	Required volume to meet 1 month of production

6.12.5 Resins

Code		
AB	Substance	Polypropylene
F	Chemical name or common name	Polypropylene
F	CAS registration number	9003-07-0
F	Apparent density	0,855 g/cm^3
C	Storage in plant	Required volume to meet 2 days of production

Code		
AB	Substance	PET
F	Chemical name or common name	Polyethylene tetraphtalate
F	CAS registration number	25038-59-9
F	Apparent density	1,4 g/cm^3
C	Storage in plant	Required volume to meet 2 days of production

Code		
AB	Substance	PEs
F	Chemical name or common name	Polyethylene
F	CAS registration number	9002-88-4
F	Apparent density	0.91 g/cm^3
C	Storage in plant	Required volume to meet 2 days of

production

Code		
AB	Substance	PS
F	Chemical name or common name	Polystyrene
F	CAS registration number	9003-53-6
F	Apparent density	1,05 g/cm^3
C	Storage in plant	Required volume to meet 2 days of production

6.12.6 Operational Unit Schedule

The plant will be operating continuously during two hundred and sixty-four (264) days per year and eight (8) hours per Day.

Considering operating yield of 100% we will have 2.112 effective hours / year.

6.13 PROCESS STAGES – OPERATING CONDITIONS

6.13.1 Storage of Reagents

6.13.1.1 Starting Clay

Code		
D	Type	Stainless steel conic bottom silo
E	Number of silos	Variable (see in equipment list)
C	Storage period	2 days
C	Silo capacity	Variable (see in equipment list)
G	Temperature	20 - 30 ^{0}C

6.13.1.2 Deionized Water

Code		
D	Type	Stainless steel conic bottom silo
E	Number of silos	Variable (see in equipment list)
C	Storage period	1 dia
C	Silo capacity	Variable (see in equipment list)
G	Temperature	20 - 30 ^{0}C

6.13.1.3 Organic Modifier

Code		
D	Type	Stainless steel conic bottom silo
E	Number of silos	Variable (see in equipment list)
C	Storage period	1 month
C	Silo capacity	Variable (see in equipment list)
G	Temperature	20 - 30 ^{0}C

6.13.1.4 Silver Nitrate

Code		
D	Type	Stainless steel conic bottom silo
E	Number of silos	Variable (see in equipment list)
C	Storage period	1 month
C	Silo capacity	Variable (see in equipment list)

G	Temperature	20 - 30 ^{0}C

6.13.1.5 Iron / Ammonium Sulfate

Code		
D	Type	Stainless steel conic bottom silo
E	Number of silos	Variable (see in equipment list)
C	Storage period	1 month
C	Silo capacity	Variable (see in equipment list)
G	Temperature	20 - 30 ^{0}C

6.13.1.6 Resins

Code		
D	Type	Stainless steel conic bottom silo
E	Number of silos	Variable (see in equipment list)
C	Storage period	2 days month
C	Silo capacity	Variable (see in equipment list)
G	Temperature	20 - 30 ^{0}C

6.13.2 Reactors

Code		
D	Type	Mixer / Agitator / Heater
E	Number of reactors	Variable (see in equipment list)
E	Reactor volume	Variable (see in equipment list)
C	Filling factor	85%
AB	Organic modifier / Natural clay ratio	33% in weight
AB	Each additive / organophilic clay ratio	5% in weight
E	Number of batches / day / reactor	03
G	Total batch time	2 hours
G	Addition of organic modifier	30 min
G	Heating of mixture	2 hours
G	Addition of additives	30 min
G	Reaction time	2 hours
G	Transfer time	2 min
AB	Temperature	50 ºC
D	Heating system	Coil

6.13.3 Utrasound

Code		
AB	Type	Ultrasonic processor
E	Number of units	Variable (see in equipment list)
D	Power	Variable (see in equipment list)

6.13.4 Spray-dryers

Code		
AB	Type	High speed centrifugation spray-dryer
E	Number of units	Variable (see in equipment list)
D	Flow rate	Variable (see in equipment list)

6.13.5 Masterbatch Processing System

Code		
AB	Type	Assembly of double screw co-rotating extruder, thread 46mm L/D 40, side feeder, granulation head, cooling tank and granulator
E	Number of assemblies	Variable (see in equipment list)
D	Production speed	200 kg/h

6.13.6 Packaging

To be developed in Basic Project.

6.13.7 Effluent Treatment

To be developed in Basic Project.

6.14 UTILITIES

To be developed in Basic Project.

6.15 TECHNICAL COEFFICIENTS

6.15.1 Raw Material: Organophilic Clay

6.15.1.1 Masterbatches of Pure Nanoclay (MNAp)

Base:

- 1 t of masterbatches of pure nanoclay; and
- Masterbatch partition: PP (20%), PET (53%), PEBD (7,33%), PEHD (7,33%), PEBDL (7,33%), PS (5%).

Raw Material - Clay:

Organophilic Clay	kg	250

Raw Material – Resins:

PP	kg	150
PET	kg	398
LDPE	kg	55
HDPE	kg	55
LLDPE	kg	55
PS	kg	38

Utility:

Water	m^3	N/A
Electricity	Kwh	N/A

6.15.1.2 Masterbatches of Functionalized Nanoclay (MNAf)

Base:
- 1 t of masterbatches of functionalized nanoclay;
- The organophilic clay is transformed into functionalized clay with addition of 5% wt of silver and 5% of iron; and
- Masterbatch partition: PP (20%), PET (53%), PEBD (7,33%), PEHD (7,33%), PEBDL (7,33%), PS (5%).

Raw Material – Clay:

Organophilic Clay	kg	227

Reagents:

Silver Nitrate	kg	11,4
Iron / Ammonium Sulfate	kg	11,4

Solvents:

Deionized Water	m^3	1,25

Raw Material - Resins:

PP	kg	150
PET	kg	398
LDPE	kg	55
HDPE	kg	55
LLDPE	kg	55
PS	kg	38

Utility:

Water	m^3	N/A
Electricity	Kwh	N/A

6.15.2 Raw Material: Natural Clay

6.15.2.1 Masterbatches of Pure Nanoclay (MNAp)

Base:
- 1 t of masterbatches of pure nanoclay;
- The natural nanoclay is transformed into organophilic clay with addition of 33% wt of organic modifier; and
- Masterbatch partition: PP (20%), PET (53%), PEBD (7,33%), PEHD (7,33%), PEBDL (7,33%), PS (5%).

Raw Material - Clay:

Natural Clay	kg	188

Reagents:

Organic Modifier	kg	62

Solvents:

Deionized Water	m^3	1,25

Raw Material - Resins:

PP	kg	150

PET	kg	398
LDPE	kg	55
HDPE	kg	55
LLDPE	kg	55
PS	kg	38

Utility:

Water	m^3	N/A
Electricity	Kwh	N/A

6.15.2.2 Masterbatches of Functionalized Nanoclay (MNAf)

Base:

- 1 t of masterbatches of functionalized nanoclay;
- The natural clay is transformed into organophilic clay with addition of 33% wt of organic modifier;
- The organophilic clay is transformed into functionalized clay with addition of 5% wt of silver and 5% iron; and
- Masterbatch partition: PP (20%), PET (53%), PEBD (7,33%), PEHD (7,33%), PEBDL (7,33%), PS (5%).

Raw Material - Clay:

Natural Clay	kg	171

Reagents:

Organic Modifier	kg	56
Silver Nitrate	kg	11
Iron/ Ammonium Sulfate	kg	11

Solvents:

Deionized Water	m^3	1,25

Raw Material - Resins:

PP	kg	150
PET	kg	398
LDPE	kg	55
HDPE	kg	55
LLDPE	kg	55
PS	kg	38

Utility:

Water	m^3	N/A
Electricity	Kwh	N/A

7 COMPETENCIES REQUIRED FOR PRODUCTION PROCESSES

7.1 INTRODUCTION

The main source of this project of identification of skills and competencies required to the production processes of the industrial plant for plastic packaging is the Pedagogical Project of College Course – Technology in Polymers of SENAI College – National Service of Industrial Learning – São Paulo Regional Department.

This course qualifies professionals with college degree called Polymer Technologist. The quality of these professionals' skills and competencies may be compared with professionals graduated from the best universities in the Country in Industrial Chemistry; B. Sc in Chemistry, Food Engineering (development of packaging); Materials Engineering; Chemical Engineering Technology in Materials and Production Engineering – Materials.

In addition to the traditional education professionals the industrial plant of nanometric inputs for plastic packaging may rely in the future on the first college level professionals graduated in Brazil in B. Sc. In Nanotechnology (UFRJ and INMETRO campi) and Engineering in Nanotechnology (PUC-Rio).

It should be mentioned that, in the current international economic scenario, Brazil has the capacity to attract and retain high level professionals with master's and doctor's degrees through the continuity of programs such as RHAE and Sciences without Borders, the latter being the result of a joint effort by the Ministry of Science, Technology and Innovation (MCTI) and the Ministry of Education (MEC), through their own development institutions – CNPq and Capes and MEC Higher Education and Technological Learning Offices.

7.2 REQUIRED PROFESSIONAL COMPETENCIES

Professionals selected for work at the industrial plant of nanometric inputs for plastic packaging should have the ability to manage polymeric materials industry processes and develop products by assuring quality, workers' safety and health and environment protection. The desirable competency profiles may have classified in managerial or technical with the duties and titlesl set forth by the following competency units:

Competency Unit 1:
To manage polymeric materials industry processes by assuring the quality, workers' safety and health and environment protection.

Competency Unit 2:
To develop products by assuring the quality, the workers' safety and health and environment protection.

Competency Unit 1: To manage polymeric materials industry processes by assuring the quality, the workers' safety and health and environment protection.	
Competency Elements	**Performance Standards**
1.1. Planning polymeric materials industry processes	1.1.1 Establishing material and human resources in relation to equipment, utilities, inputs and costs; 1.1.2 Preparing flowchart; 1.1.3 Defining the control systematics; 1.1.4 Preparing technical documentation and recors; 1.1.5 Assessing impacts on the workers' health and safety and environment.
1.2. Controling physical and human resources	1.2.1. Orienting work teams; 1.2.2. Monitoring goals, process variables and performance indicators; 1.2.3. Providing Technical Support; and 1.2.4. Minimizing process and jobs risks.
1.3. Implementing production processes	1.3.1 Mobilizing material and human resources; 1.3.2 Establishing process critical points; 1.3.3 Identifying job risks; 1.3.4 Applying technical health, safety and environment standards; and 1.3.5 Adjusting process variables
1.4. Planning polymeric materials industry processes	1.4.1 Establishing material and human resources in relation to equipment, utilities, inputs and costs; 1.4.2 Preparing flowchart; 1.4.3 Defining control systematics; 1.4.4 Preparing technical documentation and records; 1.4.5 Assessing impacts on the workers' health and safety and environment.
1.5. Controlling physical and human resources humanos	1.5.1. Orienting work teams; 1.5.2. Monitoring goals, process variables and performance indicators; 1.5.3. Providing Technical Support; and 1.5.4. Minimizing process and jobs risks.
1.6. Implementing production processes	1.6.1 Mobilizing material and human resources; 1.6.2 Establishing process critical points; 1.6.3 Identifying job risks; 1.6.4 Applying technical health, safety and environment standards; and 1.6.5 Adjusting process variables
1.7. Implementing a quality system	1.7.1 Preparing technical documentation and records; 1.7.2 Orienting work teams; 1.7.3 Applying quality and productivity tools; and 1.7.4 Following up indicators.
1.8. Optimizing processes and results	1.8.1 Qualifying the work team; 1.8.2 Reviewing costs, values, times and methods; 1.8.3 Proposing alternative technologies; 1.8.4 Adequating the Process Flowchart; 1.8.5 Assessing impacts on workers' health and safety and the environment; and 1.5.6 Reducing waste and losses.

Competency Unit 2: To develop products by assuring the quality, the workers' health and safety and environment protection	
Competence Elements	**Performance Standards**
2.1. Planning research and develop activities	2.1.1 Defining the variables involved in research; 2.1.2 Defining material, human and infrastructure resources; 2.1.3 Defining the Activity Timetable; and 2.1.4 Recording the research process.
2.2. Assessing technical and economic feasibilty	2.2.1 Carrying out bibliographic research; 2.2.2 Analyzing methods and processes; 2.2.3 Composing costs; and 2.2.4 Reviewing costs, values and market;
2.3. Analyzing the product risk to health and environment	2.3.1 Carrying out bibliographic research; 2.3.2 Interpreting the legislation, rules and standards; 2.3.3 Consulting analyses results; 2.3.4 Identifying hazards and probability of occurrence; and 2.3.5 Analyzing the product life cycle.
2.4. Conducting chemical, physical and physical-chemical analyses	2.4.1 Defining required tests; 2.4.2 Using methodologies and standards; 2.4.3 Using analytical techniques; and 2.4.5 Using statistical tools.
2.5. Validating raw material, process and product	2.5.1 Defining the product technical and functional specifications; 2.5.2 Developing the product; 2.5.3 Testing the finished product performance; 2.5.4 Utilizing analyses results; and 2.5.5 Simulating processes.

Source: Pedagogical Project of College Course in Polymer Technology - SENAI São Paulo (2011)

7.3 PROFESSIONAL QUALIFICATION WORK CONTEXT

Means (Equipment, Machinery, Tools, Instruments, Materials and others.)
- Information Technology (User's level); - Technical Standards and specific methodologies; - Legislation on labor, environment, health and safety; - Computers; - Process simulation software; - Assisted drawing / design software; - Production and process management software; - Man-Machine Interface – MMI (machine and equipment command / control panels); - Personal and collective protection equipment – PPE and CPE; - Product protection equipment – PPE; - Pilot plants: continuous destillation, evaporation, multi-processes, (industrial) effluent treatment, reaction, vacuum filtration, processes with membrances; - Surface treatment pilot plant; - Study benches / counters: biotechnological production processes; flow regimes (Reynolds-Osborne); hydraulic transport; drying and humidifcation; flow rate, pumps pressure and power; agitation, mixture and drivers; load loss (process efficiency); - Semi-industrial multi-process plant; - Measuring, checking and controlling instruments; - Process controllers; - Wireless data communication systems; - Environment control equipment; - Valves and servo-valves (automation); - Frequency inverters; - Alternate and direct current engines / motors; - Pneumatic, hydraulic and electroelectronic systems; - Office software (Microsoft Office®); - Pumps; - Compressors; - Piping and accessories; - Vacuum system; - Heat exchangers; - Boiler; - Cooling tower; - Cyclone; - Lab glassware and instruments; - Chromatographs (gaseous and liquid); - Spectrometers (atomic absorption, UV-visible, flame, infrared, mass); - Scales (analytical and semi-analytical); - Muffles; - Ovens/Furnaces (with and without air circulation, incubators); - Deionizers (weld and cut machine, blowers, painting and stamping); - Distillers (water); - Industry publications (technical journals, technical articles and papers, product and service catalogs, Internet, congress annuals); - Data-show; - Karl Fischer; - Potentiometers / conductivimeters and pH-meters; - Gas meters; - Microscopes; - Hoods (laminar flow and other types); - Autoclaves; - Mills; - Glossmeter (surface glow meter); - Mechanical and magnetic agitators; - Bain-Marie;

- Heating sets / assemblies (plates, pads, batteries);
- Samplers (collectors of periodic samples);
- Refractometers (refraction index);
- Special gases;
- Chemical reagents;
- Colony counters (biodegradable polymers);
- Viscosimeters (Ford cup, Brookfield, Saybolt, capillaries);
- Direct current rectifiers;
- Layer thick meters (films and tubes);
- Calorimeters;
- Industrial washers;
- Paint applicators (extensors and electro-powered);
- Paint drying time indicators;
- Flash point (open and closed vessel);
- Voltage meter (used in silk-screen);
- Densimeters;
- Pycnometers (density for solids);
- Polarimeters;
- Ultrasound;
- Jet blast machine (texturing in tools);
- Power polisher;
- Salt-spray chambers;
- Microwave oven (load content);
- Specific íon meters;
- Industrial furnaces;
- Jar-test (turbidity test);
- Thermal blowers;
- Plastic injectors;
- Filters in general;
- Single and double screw extruders;
- Roto-molder;
- Micronizers;
- Robots and process handler;
- Packers;
- Saw;
- Material movement, handling and transport equipment;
- Machining equipment;
- Mixers;
- Winders;
- Agglutinator;
- Forklift / Stacker;
- Thermal molder;
- Silos;
- Rotary valves;
- Fluidized beds;
- Hoppers (bulk feed systems);
- Simulation resin injectors;
- Vacuum chamber;
- Equipment and tools for fast prototyping;
- Tridimensional modeler;
- Hand lay up equipment;
- Spray up equipment;
- Centrifugation equipment;
- Equipment for pultrusion;
- Equipment for casting;
- Equipment for modeling of thermalfixed resins (RIM, RTM, SMC, BMC);
- Equipment for binding (ultrasound, friction, glueing, bonding, electric resistance, incasing, thermal, chemical);
- Equipment for Nuclear Magnetic Ressonance Imaging;
- X-Ray Difractometer;
- X-Ray fluorescence analyzer;

- Weight controller for films;
- Thickness meters;
- Vacuum metallizer;
- Dimension gauge;
- Thermoplastics welding machine;
- Cutting and welding and machine and peripherals;
- Co-extruder;
- Press;
- Corona treatment machine (bi and tri-dimensional);
- Gravimetric and volumetric dosers;
- Printing machies (tampographic, serigraphic, rotogravure, heat stamping, heat transfer, flexographic, ink jet, laser sublimation);
- Vibratory sieves;
- Labelers;
- Dryers and de-humidifiers;
- Molds and mold supports;
- Temperature controllers;
- Pressure controllers;
- Resins (thermal-fixed, thermoplastics, composites, blends and elastomers);
- Loads and reinforcements (organic and inorganic);
- Polymeric plates for molding;
- Pre-formed for machining;
- Mold heaters;
- Die opening calibrator;
- Polymerization reactors;
- Banbury;
- Calander;
- Rheometer;
- Plastometer;
- Universal testing machine (stress, pull, compression, flexure among others);
- Industrial automation system;
- Durometer;
- Impact testing equipment;
- Fans and compressors;
- Cooling unit;
- Calorimetry
- Differential Scanning Calorimetry (DSC);
- Thermogravimetric Analyzer (TGA);
- HDT/ VICAT equipment;
- Abrasion equipment;
- Incandescent wire equipment;
- Flammability equipment;
- Industrial aspirators;
- Means (equipment, machinery, tools, instruments, materials and others);
- Equipment for blister packages;
- Heads and dies;
- Equipment for combustibility test;
- Light cabin;
- Accelerated aging machine (ozone, weather-Ometer, among others);
- Friction coefficient meter;
- Equipment for electric testing (voltaic arc, electric condutibility, dielectrical rupture);
- Braiders;
- Load cells;
- PVT analyzer (pressure, volume, temperature);
- Equipment for internal hydrostatic pressure test;
- Baggers;
- Porosimeterss;
- Mixers for pigment dispersion;
- Diagonal struts (cross bracing);
- Flatteners;
- Loaders;

- Side feeders;
- Weaving looms;
- Equipment for determination of permeability;
- Equipment for production of non-fabric;
- Weld stress meter;
- Static load meter;
- High power ultrassound equipment; and
- Spray-dryer.

Source: Pedagogical Project of College Course in Polymer Technology - SENAI São Paulo (2011)

Work Methods and Techniques

- Quality management;
- Work safety and hygiene techniques;
- Environmental management system;
- Human relations techniques at work;
- Process failure detection techniques;
- Chemical, physical, thermal,mechanical, electrical and physical-chemical analyses and testing techniques;
- Instrumentation and process control techniques;
- Process operation techniques;
- Equipment operation techniques;
- Application of standards and procedures;
- Writing techniques for preparation of reports and procedures;
- Interpretation techniques and representation of industrial processes;
- Standards for management of analyses labs;
- Calibration techniques;
- Analyses instrumental techniques;
- Microbiological techniques;
- Sampling techniques;
- Good manufacturing practices and good lab practices;
- Statistical techniques for analyses of results (chemical metrology);
- Test validation techniques;
- Sample preparation techniques;
- Fast corrosion test techniques;
- Analytical and lab techniques;
- Electro-deposition techniques;
- 6-Sigma;
- Management integrated systems techniques; and
- Independent work group techniques.

Source: Pedagogical Project of College Course in Polymer Technology - SENAI São Paulo (2011)

Work Conditions

- Factory, lab and field environments;
- Work under emotional stress;
- Use of machines, tools and equipment with different degrees of risk;
- Unhealthy and hazardous environments;
- Environments with chemical, ergonomical, physical, biological and accident risks;
- Environments with large volume of information;
- Work with high speed of decisions and responses;
- Work with requirement of prioritization capacity;
- Availability for work in shifts and trips;
- Handling of hazardous materials – Preventive actions: Use of personal protection and collective protection equipment – PPE and CPE, vaccination, periodic medical exams;
- Possible unfavorable ergonomic conditions;
- Assistance and purchases / technical sales;
- Negotiation environment; and
- Environments with possitive pressure.

Source: Pedagogical Project of College Course in Polymer Technology - SENAI São Paulo (2011)

8 SIZE AND LOCATION

8.1 INTRODUCTION

This chapter presents the optimal size of the nanometric inputs industrial plant and offers a decision model with factors and options of location by attempting to contribute towards the investor's decision in the definition of optimal location of the nanometric input industrial plant in the next stage of this study.

8.2 OPTIMAL SIZE

Bearing in mind the calculations of volume and production and the dimensions of equipment presented in Chapter 6, the optimal size or Minimum Efficient Scale (MES) was estimated for installation of the nanometric input industrial plant. In this aspect, 300 m² will be required for acommodation of the production plant of 1800 tons per year of MNAp and 400 tons per year of MNAf. The considered size should enable a sufficient production of product to meet the demand until Year 7 with an expansion being necessary as of Year 8 for an area of 500 m².

8.3 LOCATION

As the quantitative analysis of macro-location and micro-location of the nanometric input plant involve quite complex aspects, the study attempted first to identify options of potential locations so the investor would subsequently validate them by the methodology of Front End Loading – FEL through logistical and econometric models focused on project scale, production costs and logistics of inputs and nanoproducts I.

Among the various possible alternatives of locatoin the investor's decision should be on that implying the lowest cost / benefit ratio when jointly considering all macro-locational factors suggested in this study.

However the high technology nanomanufacture industry requires highly specialized technologists and engineers. In this case, the conditions of access to recreation, leisure and culture, work conditions and environment and access logistics required by such qualified labor have a greater weight in hiring and retaining of talents and contribute to the importance of qualitative and non-economic factors in the study of location.

8.3.1 INDUSTRIAL MACRO-LOCATION FACTORS

Considering the premise that the nanometric input industrial plant will be a private profit legal entity and should provide attraction to highly qualified labor, its location should contribute with maximum profitability of the capital to be invested by potential investors as well as being near an environment favorable to the development of technological innovations.
In connection therewith, a basic model of macro-location factors of the nanometric inputs plant was prepared to contribute to the investors' future decisions. Besides the model, Annex 2 hereto offers maps generated by geo-processing technology with information based on macro-location factors considered most relevant.

Table 27 – Basic Model of Macro-Location Factors

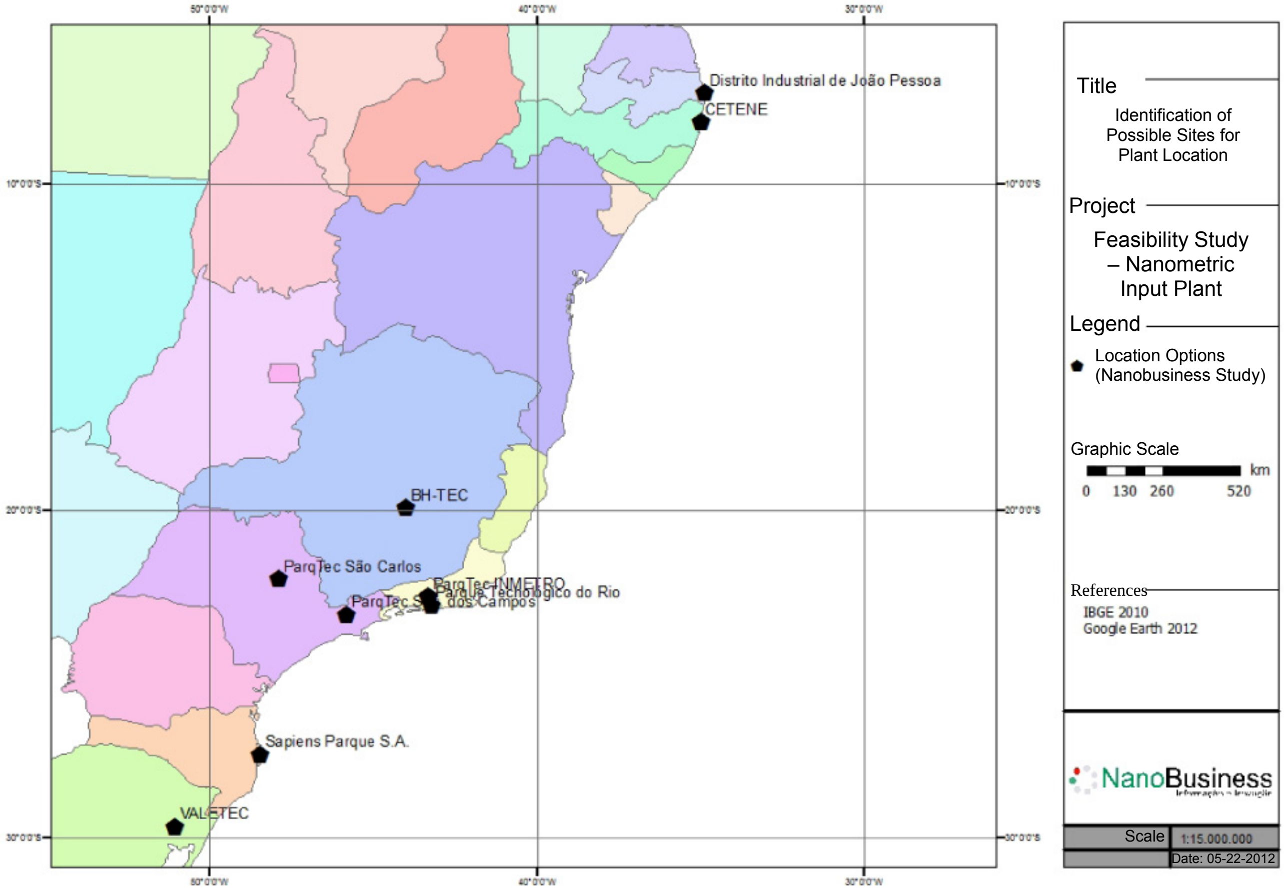
Factors	Grade for Options of Location					Importance for the Nanometric Input Project
	w_1	w_2	w_3	w_4	w_n	
Access to the Capital	a_{11}	a_{12}	....	a_{ij}	a_{1n}	Irrelevant
Access to metrology labs, reference materials and nanomaterials characterization procedures						Conditioning factor
Access to R&D&I labs						Conditioning factor
Access to research network and analyses in nano toxicology						Conditioning factor
Activities by partners such as public sector, class associations, etc .						Low conditioning factor
Local scientific and patent base						Critical
Conditions of access to know-how in the production of nanoinputs						Critical
Land cost						Conditioning factor
Transport cost and efficiency						Conditioning factor
Energy and water availability						Conditioning factor
Labor availability and costs						Conditioning factor
Existence of facilities						Low conditioning factor
Tax and financial incentives						Conditioning factor
Infrastructure for removal of waste						Critical
Environmental license						Conditioning factor
Location of competitors						Irrelevant
Number of industrial establishments						Low conditioning factor
Offer of air transport						Low conditioning factor
Proximity to college level courses in nanotechnology						Critical
Proximity to technical schools						Conditioning factor
Proximity to thermoplastic resins industry						Low conditioning factor
Proximity to plastic processing industry						Critical
Proximity to clay-mineral inputs						Low conditioning factor
Proximity and supply of other material inputs						Low conditioning factor
Environment quality (conditions of achievement of man's wellbeing)						Conditioning factor
Research-oriented universities (science-industry connection)	a_{m1}	a_{m2}	a_{11}	a_{mj}	a_{mn}	Critical

a_{ij} = Grade for location options (4 - Excellent, 3 - Good, 2 - Regular and 1 - Poor)
w_i = Location options

Source: NanoBusiness (2012)

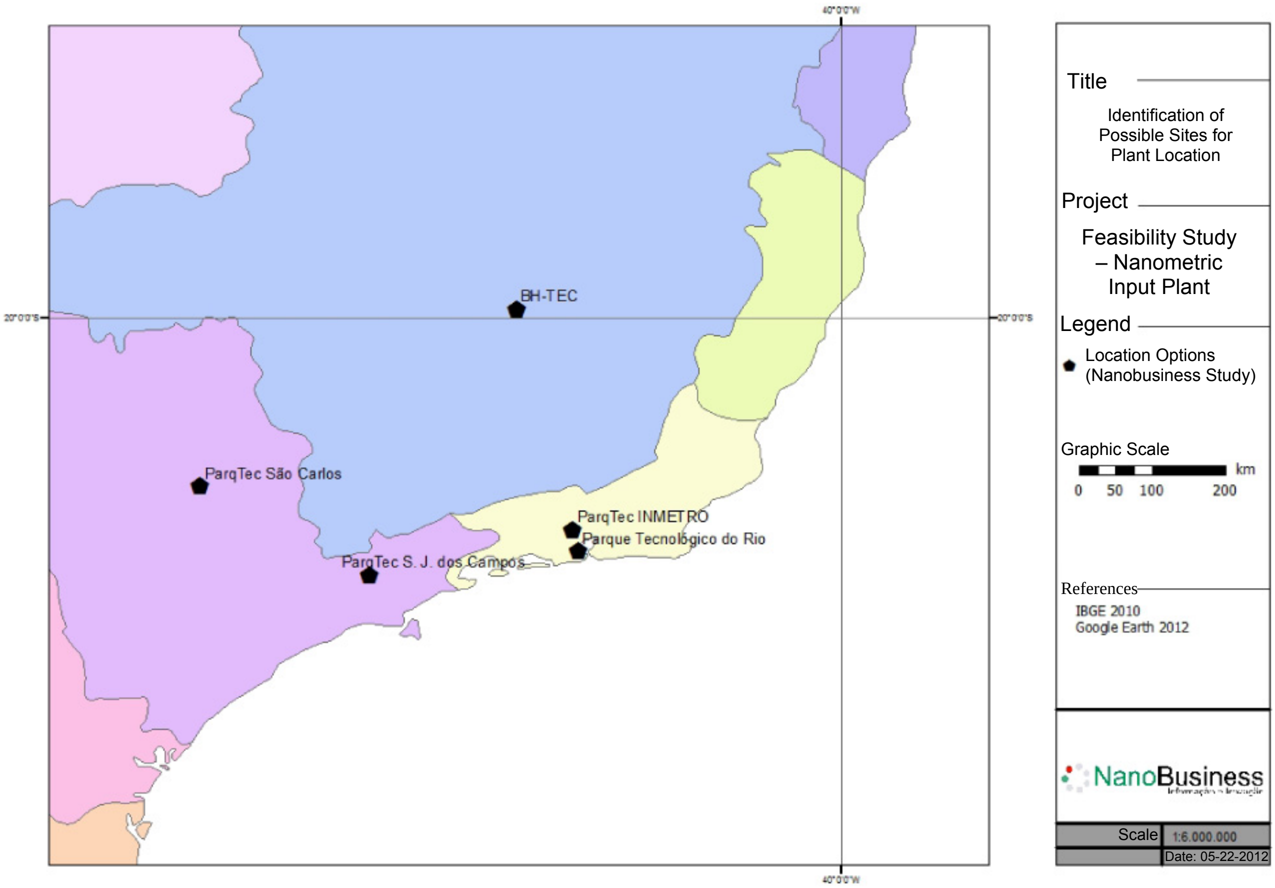
The location options suggested at this preliminary stage are technological facilities (parks) and industrial districts existing in Brazil. At this stage FEL1 the suggested options are the João Pessoa Industrial District, Cetene, BH-tec, INMETRO Technological Park, Rio Technological Park, São Carlos Technological Park, São José dos Campos Technological Park, Sapiens Park and Valetec.

Figure 15 – Option of Location – Brazil



Source: NanoBusiness (2012)

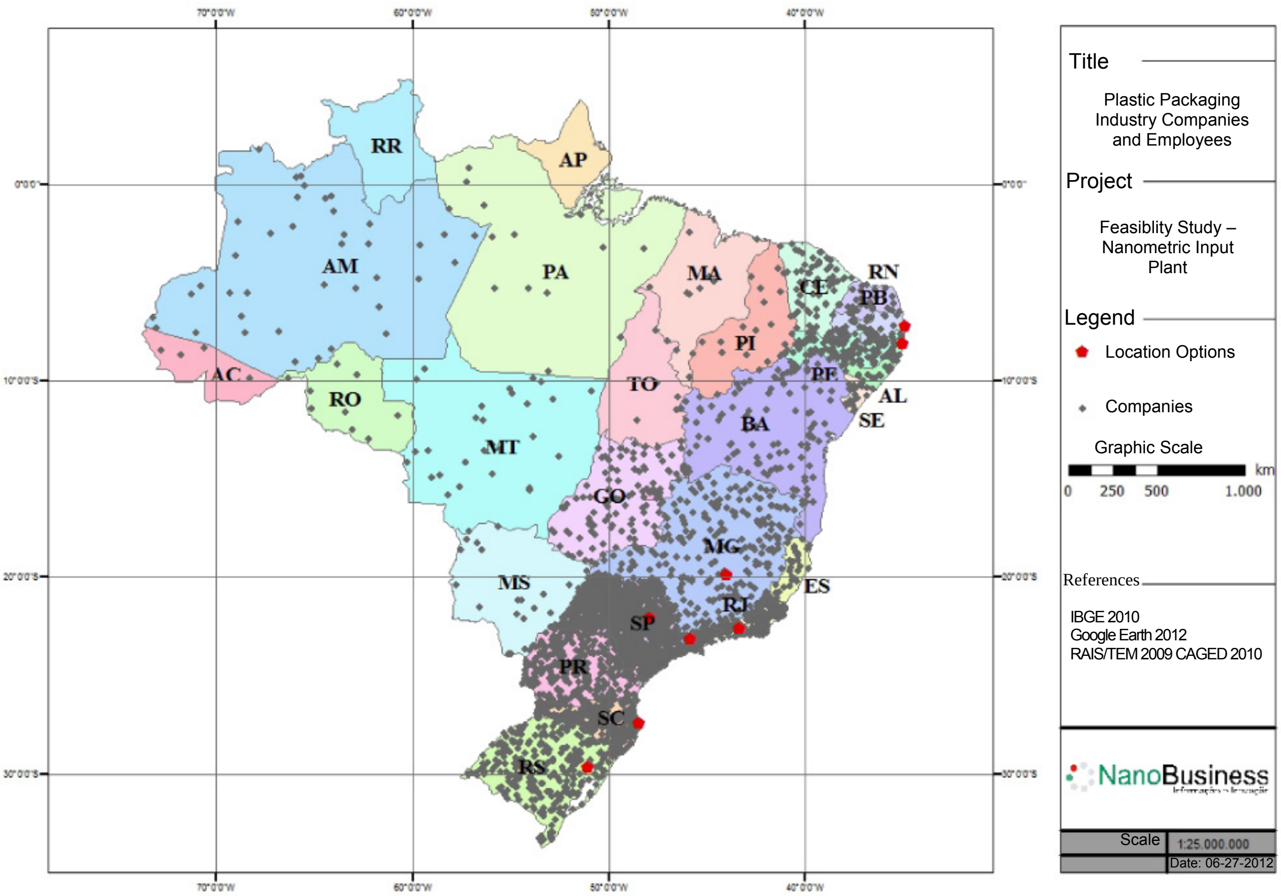
Figure 16 – Option of Location – Southeast



Source: NanoBusiness (2012)

Since the macro-location factor (proximity to plastic processing industry) is considered of critical importance, a map was prepared with the distribution of companies manufacturing plastic packaging associated with the location options.

Figure 17 – Distribution of Companies manufacturing Plastic Packaging associated with Location Options



Source: NanoBusiness (2012)

9 ECONOMIC-FINANCIAL ASSESSMENT

This document presents the Capex (Capital Expenditure), Opex (Operational Expenditure) and the results of the economic-financial assessment of alternatives studied for implementation of the nanometric inputs project.

9.1 SCENARIOS

The following scenarios were considered for Capex, Opex and economic-financial analysis, totaling 8 scenarios for Capex and 12 scenarios for Opex.

SCENARIOS				
Raw Material	**Product**	**Stage**	**Opex**	**Cod.**
Organophilic Clay	**MNAp + MNAf (Masterbatch Pure Nanoclay + Masterbatch Functionalized Nanoclay)**	**Implementation**		AO.a.1
		Expansion		AO.a.2
	MNAp (Masterbatch Pure Nanoclay)	**Implementation**		AO.b.1
		Expansion		AO.b.2
Natural Clay	**MNAp + MNAf (Masterbatch Pure Nanoclay + Masterbatch Functionalized Nanoclay)**	**Implementation**	1. MO 1 2. MO 2	AN.a.1-MO1 AN.a.1-MO2
		Expansion	1. MO 1 2. MO 2	AN.a.2-MO1 AN.a.2-MO2
	MNAp (Masterbatch Pure Nanoclay)	**Implementation**	1. MO 1 2. MO 2	AN.b.1-MO1 AN.b.1-MO2
		Expansion	1. MO 1 2. MO 2	AN.b.2-MO1 AN.b.2-MO2

Source: NanoBusiness (2012)

The production capacity of pure and functionalized nanoclay at Implementation and Expansion for the case of Masterbatch Pure Nanoclay + Functionalized Nanoclay (MNAp + MNAf) is represented by the total below. For the case of Masterbatch Pure Nanoclay (MNAp) only the production of pure nanoclay was considered.

Stages	Product	Production	
Implementation	Masterbatch Pure Nanoclay	1.800	t/a
	Masterbatch Functionalized Nanoclay	400	t/a
Expansion (As of Year 8)	Masterbatch Pure Nanoclay	4.100	t/a
	Masterbatch Functionalized Nanoclay	900	t/a

Source: NanoBusiness (2012)

9.2 CAPEX

This item presents the estimate of costs required for the implementation of alternatives of nanoinput plants and the assumtions considered in such estimate.

9.2.1 General Assumptions

The methodology for funding (financing) was partially by quotations and also by the application of factors by analogy to othe projects. The criteria and assumptions are indicated below:

Item	Date	Premise
Engineering	6%	Of direct costs for design project, basic project and detailed project.
Construction management	4%	Of direct costs to cover the management team during the construction works .
Civil construction implementation	900.000	R$ 3000/m2. Built area 300m2. Unit cost shed with medium level finishing, shallow foundations and eventually deep foundations for certain pieces of equipment, electric installation
Civil construction expansion	20%	Appropriation for renovation and reinstallations. Percentage of the value of Civil Construction of implementation.
Installation / Erection	20%	Of supply
Equipment		Funding method: 80% quotation + estimate + database + factor to cover items not listed by Engineering at this stage
Percentage items not listed	15%	Of equipment value
Freight	1%	For national road freight
Other materials: piping, etc.	40%	Estimated percentage of equipment
Other costs	6%	Appropriation based on percentage of the total to cover the costs below.
Temporary infrastructure (store room, office)		
Project Team		Team following up the project by Nanobusiness including wages, charges, transport and meals expenses.
Light, energy, water, sewage for the construction period		
Security		
Operators training		
Land		
Others		
Contingency	15%	Percentage adopted to cover project uncertainties
Insurance	1%	Estimated percentage based on history and background
Environment Fee	0,5%	Environment fee
Taxes and Charges	Inclusos	Premise: Rio de Janeiro
Currency	Real	
Base-Date	Junho 2012	The equipment proposals are as of June 2012 and are valid for 90 days .

Source: NanoBusiness (2012)

9.2.2 Capex Summary

The estimates of costs presented below are for the 8 Capex scenarios: Organophilic Clay and Natural Clay at Implementation and Expansion, for production of Masterbatch Pure and Functionalized Nanoclay and alternatively for the production of Masterbatch Pure Nanoclay only.

	ORGANOPHILIC CLAY (OC) (Values in R$)								NATURAL CLAY (NC) (Values in R$)							
	MASTERBATCH NATURAL AND FUNCTIONALIZED CLAY				MASTERBATCH NATURAL CLAY				MASTERBATCH ARGILA NATURAL E FUNCIONALIZADA				MASTERBATCH ARGILA NATURAL			
Item	Implementation AO	Expansion AO	Total AO	%	Implementation AO	Expansion AO	Total AO	%	Implementation AN	Expansion AN	Total AN	%	Implementation AN	Expansion AN	Total AN	%
Engineering	453.000	383.000	836.000	4%	418.000	354.000	772.000	4%	577.000	382.000	959.000	4%	564.000	377.000	941.000	4%
Construction Management	302.000	255.000	557.000	3%	278.000	236.000	514.000	3%	385.000	255.000	640.000	3%	376.000	251.000	627.000	3%
Civil Construction	900.000	180.000	1.080.000	6%	900.000	180.000	1.080.000	6%	900.000	180.000	1.080.000	5%	900.000	180.000	1.080.000	5%
Installation / Erection	1.108.800	1.032.920	2.141.720	11%	1.009.960	952.000	1.961.960	11%	1.452.360	1.030.960	2.483.320	11%	1.415.960	1.017.240	2.433.200	11%
Equipment	3.960.000	3.689.000	7.649.000	40%	3.607.000	3.400.000	7.007.000	40%	5.187.000	3.682.000	8.869.000	41%	5.057.000	3.633.000	8.690.000	41%
Materials	1.584.000	1.475.600	3.059.600	16%	1.442.800	1.360.000	2.802.800	16%	2.074.800	1.472.800	3.547.600	16%	2.022.800	1.453.200	3.476.000	16%
Other Costs	530.000	448.000	978.000	5%	489.000	414.000	903.000	5%	675.000	447.000	1.122.000	5%	660.000	441.000	1.101.000	5%
Subtotal	8.837.800	7.463.520	16.301.320	86%	8.144.760	6.896.000	15.040.760	86%	11.251.160	7.449.760	18.700.920	86%	10.995.760	7.352.440	18.348.200	86%
Contingency	1.326.000	1.120.000	2.446.000	13%	1.222.000	1.034.000	2.256.000	13%	1.688.000	1.117.000	2.805.000	13%	1.649.000	1.103.000	2.752.000	13%
Insurance	102.000	86.000	188.000	1,0%	94.000	79.000	173.000	1,0%	129.000	86.000	215.000	1,0%	126.000	85.000	211.000	1,0%
Environment	51.000	43.000	94.000	0,5%	47.000	40.000	87.000	0,5%	65.000	43.000	108.000	0,5%	64.000	43.000	107.000	0,5%
Total	10.316.800	8.712.520	19.029.320	100%	9.507.760	8.049.000	17.556.760	100%	13.133.160	8.695.760	21.828.920	100%	12.834.760	8.583.440	21.418.200	100%
Estimate Accuracy:																
Upper Limit + 50%	15.475.200	13.068.780	28.543.980		14.261.640	12.073.500	26.335.140		19.699.740	13.043.640	32.743.380		19.252.140	12.875.160	32.127.300	

Source: NanoBusiness (2012)

9.3 OPEX

This item presents the estimate of operating costs and premises considered.

9.3.1 General Assumptions

The assumptions adopted for Opex are presented below:

The nominal production capacity of the nanoinput production industrial plant for the plastic packaging industry from organophilic clay (AO) or natural clay (AN) will be 1.800 tons/ year of masterbatches of pure nanoclay (MNAp) and/or 400 tons/ year of masterbatches of functionalized nanoclay (MNAf) with perspective of expansion for 4.100 and 900 tons per year respectively.

The plant will be operating continuously during two hundred and sixty-four (264) days per year and eight (8) hours per day.

9.3.2 Variable Costs

9.3.2.1 Reagents and Inputs

Table 28 - Reagents & Inputs MNAp – Raw Material: Organophilic Clay

AO – Costs Input per Ton of MNAp				
	Fraction	Quantity (t)	Unit Price (R$/t)	Value (R$)
Charge	**25%**			
Organophilic Clay	100%	0,25	15.000,00	3.750,00
Resina	**75%**			
Resin PP	20%	0,15	4.699,00	705,32
Resin PET	53%	0,40	3.531,15	1.408,78
Resin PEs	22%	0,16	4.170,33	681,93
Resin PE	5%	0,04	4.281,00	160,21
Total Price MNAp (R$/t)				**6.706,24**

Source: NanoBusiness (2012)

Table 29 - Reagents & Inputs MNAf – Raw Material: Organophilic Clay

AO – Costs Input per Ton of MNAf				
	Fraction	Quantity (t)	Unit Price (R$/t)	Value (R$)
Charge	**25%**			
Organophilic Clay	90%	0,23	15.000,00	3.375,00
Silver Nitrate	5%	0,01	1.936.000,00	24.200,00
Iron / Ammonium Sulfate	5%	0,01	698.000,00	8.725,00
Resin	**75%**			
Resin PP	20%	0,15	4.699,00	705,32
Resin PET	53%	0,40	3.531,15	1.408,78
Resin PEs	22%	0,16	4.170,33	681,93
Resin PE	5%	0,04	4.281,00	160,21
Total Price Ton of MNAf (R$/t)				**39.256,24**

Source: NanoBusiness (2012)

Table 30 - Reagents & Inputs MNAp – Raw Material: Natural Clay – Organic Modifier 1

AN – Costs Input per Ton of MNAp using MO1				
	Fraction	Quantity (t)	Unit Price (R$/t)	Value (R$)
Charge	**25%**			
Natural Clay	75%	0,19	900,00	169,17
Organic Modifier 1	25%	0,06	874.000,00	54.214,29
Resin	**75%**			
Resin PP	20%	0,15	4.699,00	705,32
Resin PET	53%	0,40	3.531,15	1.408,78
Resin PEs	22%	0,16	4.170,33	681,93
Resin PE	5%	0,04	4.281,00	160,21
Total Price Ton of MNAp (R$/t)				**57.339,70**

Source: NanoBusiness (2012)

Table 31 - Reagents & Inputs MNAf – Raw Material: Natural Clay – Organic Modifier 1

AN – Costs Input per Ton of MNAf using MO 1				
	Fraction	Quantity (t)	Unit Price (R$/t)	Value (R$)
Charge	**25%**			
Natural Clay	68%	0,17	900,00	152,26
Organic Modifier 1	22%	0,06	874.000,00	48.792,86
Silver Nitrate	5%	0,01	1.936.000,00	24.200,00
Iron /Ammonium Sulfate	5%	0,01	698.000,00	8.725,00
Resin	**75%**			
Resin PP	20%	0,15	4.699,00	705,32
Resin PET	53%	0,40	3.531,15	1.408,78
Resin PEs	22%	0,16	4.170,33	681,93
Resin PE	5%	0,04	4.281,00	160,21
Total Price Ton of MNAf (R$/t)				**84.826,35**

Source: NanoBusiness (2012)

Table 32 - Reagents & Inputs MNAp – Raw Material: Natural Clay – Organic Modifier 2

AN – Costs Input per Ton of MNAp using MO2				
	Fraction	Quantity (t)	Unit Price (R$/t)	Price (R$/t)
Charge	**25%**			
Natural Clay	75%	0,19	900,00	169,17
Organic Modifier 2	25%	0,06	10.363,29	642,84
Resin	**75%**			
Resin PP	20%	0,15	4.699,00	705,32
Resin PET	53%	0,40	3.531,15	1.408,78
Resin PEs	22%	0,16	4.170,33	681,93
Resin PE	5%	0,04	4.281,00	160,21
Total Price Ton of MNAp (R$/t)				**3.768,25**

Source: NanoBusiness (2012)

Table 33 - Reagents & Inputs MNAf – Raw Material: Natural Clay – Organic Modifier 2

AN – Costs Input per Ton of MNAf using MO2				
	Fraction	Quantity (t)	Unit Price (R$/t)	Value (R$)
Charge	**25%**			
Natural Clay	68%	0,17	900,00	152,26
Organic Modifier 2	22%	0,06	10.363,29	578,55
Silver Nitrate	5%	0,01	698.000,00	8.725,00
Iron / Ammonium Sulfate	5%	0,01	698.000,00	8.725,00
Resin	**75%**			
Resin PP	20%	0,15	4.699,00	705,32
Resin PET	53%	0,40	3.531,15	1.408,78
Resin PEs	22%	0,16	4.170,33	681,93
Resin PE	5%	0,04	4.281,00	160,21
Total Price Ton of MNAf (R$/t)				**21.137,05**

Source: NanoBusiness (2012)

9.3.2.2 Summary of Variable Costs

The annual costs of inputs and utilities are summarized in Tables 34, 35 and 36 according to the raw material, organic modifier, final products and plant stage.

At this preliminary stage of the study a fixed value was assumed in utilities of R$ 104.000,00 for all scenarios according to a similar study.

Table 34 – Variable Costs – Raw Material: Organophilic Clay

	Reagents & Inputs		Utilities	Variable Cost
	R$/t	R$/year	R$/year	R$/year
Implementation				
MNAp	6.706,24	12.071.230	104.100	12.175.330
MNAp + MNAf	6706,24 / 39.256,24	27.773.725	104.100	27.877.825
Expansion				
MNAp	6.706,24	27.495.578	104.100	27.599.678
MNAp + MNAf	6706,24 / 39.256,24	62.826.193	104.100	62.930.293

Source: NanoBusiness (2012)

Table 35 – Variable Costs – Raw Material: Natural Clay – Organic Modifier 1

	Reagents & Inputs		Utilities	Variable Cost
	R$/t	R$/year	R$/year	R$/year
Implementation				
MNAp	57.339,70	103.211.455	104.100	103.315.555
MNAp + MNAf	57.339,70 / 84.826,35	137.141.996	104.100	137.246.096
Expansion				
MNAp	57.339,70	235.092.759	104.100	235.196.859
MNAp + MNAf	57.339,70 / 84.826,35	311.436.475	104.100	311.540.575

Source: NanoBusiness (2012)

Table 36 – Variable Costs – Raw Material: Natural Clay – Organic Modifier 2

	Reagents & Inputs		Utilities	Variable Cost
	R$/t	RS/year	R$/year	R$/year
Implementation				
MNAp	3.768,25	6.782.845	104.100	6.886.945
MNAp + MNAf	3.768,25 / 21.137,05	15.237.664	104.100	15.341.764
Expansion				
MNAp	3.768,25	15.449.815	104.100	15.553.915
MNAp + MNAf	3.768,25 / 21.137,05	34.473.156	104.100	34.577.256

Source: NanoBusiness (2012)

9.3.3 Fixed Costs

9.3.3.1 Total Operation Cost

9.3.3.1.1 Labor Costs

For all scenarios at implementation stage:

Table 37 – Labor Costs - Implementation

R&D and Management	Quantity	Wages	Charges	No. Wages (*)	Total (R$/year)
Executive Director	1	14.000	80%	15	378.000
R&D Director	1	12.000	80%	15	324.000
Sales Manager	1	9.500	80%	15	256.500
Financial Manager	1	9.500	80%	15	256.500
				Total:	1.215.000
Labor (Process)	**Homens / Turno**	**Salários**	**Encargos**	**No. Salários**	**Total (R$/ano)**
Engineer	1	7.000	80%	15	189.000
Technician	1	3.500	80%	15	94.500
Operator	2	2.000	80%	15	108.000
Intern	1	600		13	7.800
				Total:	399.300

Source: NanoBusiness (2012)

(*) A bonus of 14^{th} and 15^{th} wages was included for all employees.

For all scenarios at expansion stage:

Table 38 – Labor Costs – Expansion

R&D & Management	Quantity	Wages	Charges	No.Wages (*)	Total (R$/year)
Executive Director	1	14.000	80%	15	378.000
R&D Director	1	12.000	80%	15	324.000
Sales Manager	1	9.500	80%	15	256.500
Financial Manager	1	9.500	80%	15	256.500
				Total:	1.215.000
Labor (Process)	**Men /Shift**	**Wages**	**Charges**	**No. Wages**	**Total (R$/year)**
Engineer	2	7.000	80%	15	378.000
Technician	2	3.500	80%	15	189.000
Operator	3	2.000	80%	15	162.000
Intern	1	600		13	7.800
				Total:	736.800

(*) A bonus of 14^{th} and 15^{th} wages was included for all employees.

9.3.3.1.2 Other

For all scenarios:

Table 39 – Lease of Facilities

Unit Value (R$/m^2/year)	Total Area (m^2)	Total (R$/year)
48	1.000	48.000

Source: NanoBusiness (2012)

Table 40 – Personal Protection Equipment

Value (R$/set)	Sets / Year	Total (R$/year)
120	120	14.400

Source: NanoBusiness (2012)

9.3.3.1.3 Maintenance

The value presented under this entry was calculated on the basis of application of average rate of 2% over the estimated fixed investments.

This value corresponds to expenditures with varied parts and supplies.

For all scenarios according to raw materials, products manufactured by the plant and the stage thereof:

Table 41 – Maintenance Services

Raw Material	Products	Installation (R$/year)	Expansion (R$/year)
AO	MNAp + MNAf	309.504,00	537.279,60
	MNAp	285.232,80	495.682,80
AN	MNAp + MNAf	393.994,80	621.357,60
	MNAp	385.042,80	642.546,00

Source: NanoBusiness (2012)

9.3.3.1.4 Indirect Fixed Costs

Indirect fixed costs comprise the plant overhead (10% of the total operation cost) and insurance (3% of total investment cost)

For all scenarios according to raw materials, products manufactured by the plant and the stage thereof:

Table 42 – Indirect Fixed Costs

Raw Material	Products	Installation (R$/year)	Expansion (R$/year)
AO	MNAp + MNAf	663.716,40	1.061.907,36
	MNAp	624.882,48	995.352,48
AN	MNAp + MNAf	798.901,68	1.196.432,16
	MNAp	784.578,48	909.060,60

Source: NanoBusiness (2012)

9.3.4 Opex Summary

Opex (R$/year for total tons)				Implementation	Expansion
Natural Clay	MNAp + MNAf (Pure Clay + Funcionalized Clay)	Fixed Costs	Both	2.878.000	3.840.400
		Variable Costs	MO1	137.246.096	311.540.575
			MO2	15.341.764	34.577.256
	MNAp (Pure clay only)	Fixed Costs	Both	2.854.700	3.574.200
		Variable Costs	MO1	103.315.555	235.196.859
			MO2	6.886.945	15.553.915

Opex (R$/year for total tons)				Implementation	Expansion
Organophilic Clay	MNAp + MNAf (Pure Clay + Funcionalized Clay)	Fixed Costs		2.658.300	3.621.800
		Variable Costs		27.877.825	62.930.293
	MNAp (Pure clay only)	Fixed Costs		2.595.200	3.513.600
		Variable Costs		12.175.330	27.599.678

Source: NanoBusiness (2012)

9.4 ECONOMIC-FINANCIAL ASSESSMENT RESULTS

For purposes of this preliminary approach, the criteria dopted for calculation of the project profitability were the discounted cash flow in the period of thirteen (13) years. Under such criteria profitability is expressed by the rate which equates the current values of the series of disbursements for investments occurred at implementation and expansion and the series of net cash inflows related to the project operation.

The internal profitability rate is assigned from a strictly economic stanpoint, that is, to calculate the degree of project attractiveness taking into account a financing of 90% with interest of 4% per year, 4 years of grace period and payment in 6 years according to the BNDES PSI Innovation Line. Also a tax benefit of 34% (over interest) was considered in addition to this credit operation.

The Capex upper limit of 50% was used due to intrinsic inaccuracy presented by this stage of the feasibility study.

The bases and assumptions adopted for the preparation of the project cash flow as well as the resulting values are presented below.

9.4.1 Implementation and Operation Periods

The deadline considered for implementation of the project was one (01) year with investment in the implementation in such period and an investment option in Year 8 in the expansion of the production capacity.

The operating period considered was thirteen (13) years and in the first operating year the plant will reach 33% of its nominal capacity and in the remaining years what is described in Table 43 in two scenarios: (1) with no expansion, and (2) with expansion.

In these scenarios the premise of the annual production capacity is to meet 100% of the Brazilian market estimated in the Demand Estimate.

Table 43 – Annual Production (% Capacity)

Year	Implementation + Expansion	Implementation
1	33%	33%
2	35%	35%
3	50%	50%
4	61%	61%
5	72%	72%
6	89%	89%
7	100%	100%
8	52%	100%
9	60%	100%
10	69%	100%
11	75%	100%
12	89%	100%
13	100%	100%

Source: NanoBusiness (2012)

9.4.2 Gross Revenue Formation

The revenue formation considers the sale price (FOB) for Masterbatch Pure Nanoclay of R$ 15.000,00 per ton of product and for Masterbatch Functionalized Nanoclay R$ 30.000,00 per ton of product.

It should be mentioned that, for a ton of plastic packaging, the plastic processing industry would have to consume 80% of conventional resin and add 20% of one of the above Masterbatch products.

9.4.3 Working Capital Formation

The working capital adopted was 1/12 over the projected revenue of the following year.

9.4.4 Charges on Sales

Taxes applicable on Sales were calculated as follows:

- PIS / COFINS: Calculated based on the application of rate of 9.25% over the sales values.
- ICMS: Calculated based on 19% over the sales value (Rio de Janeiro)

9.4.5 Depreciation

- Buildings in 25 years
- Machinery and equipment in 10 years

9.4.6 Income Tax

- 34% over the net profit determined in the year, It includes CSLL equal to 25% + 9%.

9.4.7 Residual Value

- The residual value considered was 5% of the investment value.

9.4.8 Results

Table 44 below indicates the results of the 12 assessed scenarions. From the Internal Return Rate (IRR) we can observe that the best scenario is Scenario 12 in relation to Natural Clay, production of Pure Clay only, with expansion with route MO2. Besides Scenario 12, Scenarios 9, 10 and 11, all of them of Natural Clay with route MO2, show positive results. Scenarios with IRR < 0 may be disregarded as they offer no return.

Table 44 – Results of Assessed Scenarios

Scenario	Number		1	2	3	4	5	6	7	8	9	10	11	12
	Name		AO.a.1	AO.a.2	AO.b.1	AO.b.2	AN.a.1-Nb	AN.a.2-Nb	AN.b.1-Nb	AN.b.2-Nb	AN.a.1-MO2	AN.a.2-MO2	AN.b.1-MO2	AN.b.2-MO2
	Clay type		AO	AO	AO	AO	AN	AN	AN	AN	AN	AN	AN	AN
	Expansion		No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes
	Products		MNAp+f	MNAp+f	MNAp	MNAp	MNAp+f	MNAp+f	MNAp	MNAp	MNAp+f	MNAp+f	MNAp	MNAp
Input	Initial Capacity MNAp	ton/year	1.800	1.800	1.800	1.800	1.800	1.800	1.800	1.800	1.800	1.800	1.800	1.800
	Initial Capacity MNAf	ton/year	400	400	0	0	400	400	0	0	400	400	0	0
	Post-expansion Capacity MNAp	ton/year	1.800	4.100	1.800	4.100	1.800	4.100	1.800	4.100	1.800	4.100	1.800	4.100
	Post-expansion Capacity MNAf	ton/year	400	900	0	0	400	900	0	0	400	900	0	0
	Sale Price MNAp	R$/ton	15.000	15.000	15.000	15.000	15.000	15.000	15.000	15.000	15.000	15.000	15.000	15.000
	Sale Price MNAf	R$/ton	30.000	30.000	30.000	30.000	30.000	30.000	30.000	30.000	30.000	30.000	30.000	30.000
	Initial Fixed Costs	R$/year/ton	1.208	1.208	1.442	1.442	1.308	1.308	1.586	1.586	1.308	1.308	1.586	1.586
	Post-expansion Fixed Costs	R$/year/ton	1.208	724	1.442	857	1.308	768	1.586	872	1.308	768	1.586	872
	Initial Variable Costs	R$/ton	12.672	12.672	6.764	6.764	62.385	62.385	57.398	57.398	6.974	6.974	3.826	3.826
	Post-expansion Variable Costs	R$/ton	12.672	12.586	6.764	6.732	62.385	62.308	57.398	57.365	6.974	6.915	3.826	3.794
	Capex - Implementation	R$	15.475.200	15.475.200	14.261.640	14.261.640	19.699.740	19.699.740	19.252.140	19.252.140	19.699.740	19.699.740	19.252.140	19.252.140
	Capex - Expansion	R$	0	13.068.780	0	12.073.500	0	13.043.640	0	12.875.160	0	13.043.640	0	12.875.160
Output	IRR Company	%	IRR <0	IRR <0	11%	11%	IRR <0	IRR <0	IRR <0	IRR <0	19%	20%	19%	21%
	IRR - Shareholder	%	IRR <0	IRR <0	23%	20%	IRR <0	IRR <0	IRR <0	IRR <0	58%	56%	65%	63%
	VLP @ 10% p.a.	R$'000	-19.778	-31.576	-1.876	4.794	-283.389	-627.603	-222.525	-489.798	5.000	21.950	5.210	22.502
	VLP @ 20% p.a.	R$'000	-17.053	-20.349	583	106	-286.202	-339.486	-223.701	-265.419	8.032	8.929	8.414	9.508
	Payback	year			7,5	10,2					5,8	5,8	5,6	5,5

Source: NanoBusiness (2012)

9.4.9 Cash Flow

Table 45 presents the cash flow and Internal Return Rate for alternative 12 as it is the best scenario.

Table 45 – Cash Flow of Scenario 12

Year	IRR	-1	2	3	4	5	6	7	8	9	10	11	12	13
Company Cash Flow	21%	(20.002.140,00)	1.607.273,00	2.522.881,00	4.525.361,00	5.430.932,00	6.901.315,00	7.612.090,00	(3.788.352,00)	10.557.396,00	10.641.483,00	12.406.888,00	14.305.687,00	23.667.643,00
Shareholder Cash Flow	63%	(2.675.214,00)	1.607.273,00	2.522.881,00	908.109,00	1.896.118,00	3.448.937,00	4.242.151,00	(7.075.854,00)	7.352.331,00	10.641.483,00	12.406.888,00	14.305.687,00	23.667.643,00

Source: NanoBusiness (2012)

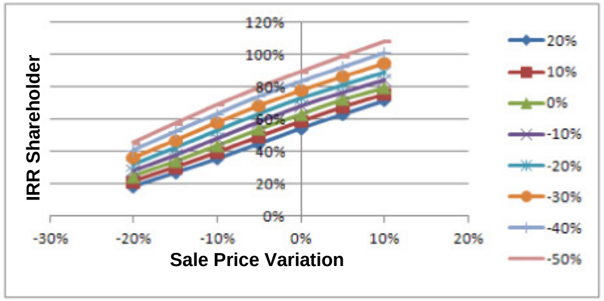
9.4.10 Sensitivity Analysis

The IRR sensitivity analyses was carried out to assess the impacts from Capex variations and also the sale price of Masterbatch Functionalized and Pure Clay on the IRR. This report presents the review for Scenario 12 since this was considered the best scenario.

Considering that the economic-financial model used the Capex upper limito f 50%, the IRR related to the calculated individual Capex is at -33% (y = 150%x → x=67%y). The Capex reduction tends to a yet more attractive IRR and can compensate reductions of the sale price.

IRR Sensitivity for Company – Scenario 12

		Sale Price Variation						
		-20%	-15%	-10%	-5%	0%	5%	10%
Capex Variation	20%	9%	12%	14%	16%	18%	20%	21%
	10%	10%	13%	15%	17%	19%	21%	23%
	0%	12%	14%	17%	19%	21%	22%	24%
	-10%	13%	16%	18%	20%	22%	24%	26%
	-20%	15%	17%	20%	22%	24%	26%	28%
	-30%	16%	19%	22%	24%	26%	28%	30%
	-40%	18%	21%	24%	26%	29%	31%	33%
	-50%	21%	24%	27%	29%	32%	34%	36%



IRR Sensitivy for Shareholder - Scenario 12

		Sale Price Variation						
		-20%	-15%	-10%	-5%	0%	5%	10%
Capex Variation	20%	19%	27%	36%	45%	54%	63%	72%
	10%	22%	30%	40%	49%	59%	68%	76%
	0%	25%	34%	44%	54%	63%	72%	80%
	-10%	28%	38%	48%	59%	68%	77%	84%
	-20%	32%	42%	53%	64%	73%	81%	89%
	-30%	36%	47%	58%	69%	78%	87%	95%
	-40%	41%	52%	63%	74%	84%	93%	101%
	-50%	46%	58%	69%	80%	90%	99%	109%

9.4.11 Conclusions

The best scenario presented refers to Natural Clay with production of Masterbatch Pure Nanoclay with Expansion Route MO2 for operation. This scenario offers IRR of 63% for shareholders at Capex upper limit. If the sale price drops by 10% the IRR of will be 44% for this same Capex. The condition for the project to be attractive is the project return rate being higher than the capital cost.

Table 46 – Best Scenario Presented

Scenario 12 –Natural Clay only with production of Masterbatch Pure Nanoclay with Expansion, Route MO2		**Implementation (R$)**	**Expansion (R$)**	**Total (R$)**
CAPEX	Calculated Individual Capex	12.834.760	8.583.440	21.418.200
	Upper Limit (+ 50%)	19.252.140	12.875.160	32.127.300
OPEX	Fixed Costs / Year	2.854.700	3.574.200	3.574.200
	Variable Costs / Year	6.886.945	15.553.915	15.553.915

Source: NanoBusiness (2012)

The Capex accuracy will be improved with the development of engineering in the design project, next stage. At this present study the return rates related to Capex variations can already be verified through the sensitivy analysis.

However it is important to emphasize that the selection of Scenario 12 as the best alternative is solely based on economic variables and not on a detailed analysis of the technological and engineering processes, a common and intrinsic condition at this FEL1 stage. The low cost of the organic modifier used in this route (MO2) compared with MO1 can explain the results of the economic-financial analysis. At the next stage of this study it will be necessary to validate the technological routes and characterize the properties of final products, based on reference materials. The selection of precursor raw material (organophilic or natural clay) and the organic modifier (high cost MO1 or low cost MO2) are critical variables which may represent an important risk to the project.

In addition to such risk, a list of project and engineering risks with suggested actions for mitigation is presented in Table 46.

Table 47 – List of Project and Engineering Risks with Actions for Mitigation

CRITICAL VARIABLES	GROUP	DESCRIPTION OF RISKS	ACTIONS
Price /ton of products	Economic	Price considered high by plastic processing companies	Demonstrate benefits to the industry competitiveness Be within the BNDES Card registered suppliers
Demand rate	Economic	Low rate of demand by plastic processing companies	Set up policies in partnership with food industry Identify new markets of application of nanoclay
Wages	Personnel	Unattractive wages	Include benefits and participation program in the company
Tax costs	Political	High tax burden	Make use of *Lei do Bem* and other tax incentives Define location in a region with favorable tax incentives
Costs of inputs	Operational process	High cost of main inputs	Set up business model with suppliers considered critical Check economic and technical feasiblity of verticalization
Costs of distribution	Operational process	High cost of product distribution	Set up partnership with company having capillarity of distribution in Brazil
Costs of process	Operational process	High cost in the clay nanonization process	Examine other routes at the design engineering stage
Costs of process	Operational process	Low efficiency of clay exfoliation in resins	Use another organic modifier Use a compatibilizing agent
Nanoinputs quality índex	Operational process	Absence of reference material	Speed up development with INMETRO and/or research networks
Technology transfer cost	Technological	High cost of transfer of technologies from international companies	Use national patent base
Know how cost	Technological	High cost of transfer of know how from international companies	Use national scientific base and develop own know-how
Royalty cost	Technological	Unfeasible royalty costs	Develop own technology with support from development bodies and R&D&I institutions
Environmental impact index	Environment	Absence of protocols of characterization of nanoclay	Speed up development with INMETRO and/or research networks
Market introduction fee	Management process	Delay in fund raising for implementation of plant	Develop attractive business model
Health impact índex	Health and Safety	Absence of regulation	Collaborate with the development of protocols of characterization of nanoparticles with FIOCRUZ network and Nanotox