MFA (Material Flow Accounting)

1. The international context of policies for sustainability

In recent years the reduction of material flow has become a crucial point and general goal for sustainability policies in many European countries and among international bodies. The CLOSED Project aims at promoting and directly applying this approach to the three industrial districts taken into consideration by using a series of analysis and intervention tools. Material flow analysis plays a very important role in this context.
The concept that ecological equilibrium can be best guaranteed over the long term through the application of the principle of precaution is gaining ground throughout the world. This principle favors long-term strategies based on eco-efficient use of resources and pursuing the general goals of the economic system rather than the traditional monitoring policies based on specific pressures and activities. These traditional policies do, however, remain an essential component of all strategies for sustainability.
This new approach received attention first and foremost in German speaking countries. A few years ago the German Parliament assessed the gradual yet substantial – over time - reduction of resource input starting with the complex project of the 12th Bundestag Inquiry Commission, "Protection of Humans and the Environment – Evaluation Criteria for Environmentally Valid Production Cycles in Industrial Society."

In its final report the commission acknowledged that many environmental problems are related to "our way of doing business", specifically with the extraction and utilization of resources, the amount and structure of wastes, that is material flow, and the methods of using materials that can essentially be characterized as a linear economy of flows that traverse (nature- economy-nature) and impoverish the system.
This linear model is compensated by the "circular" model of an eco-efficient economy in which materials are extracted from nature in smaller amounts, returned in smaller amounts thanks to efficient utilization and what has already been extracted is reutilized.
The Austrian National Environmental Plan seems to have a much more ambitious goal: "To aim at a factor 10 reduction of material flows in the Austrian economy over the coming decades."
In this document the reference to "hidden" flows is very interesting. In an industrialized economy production and consumption give rise to the extraction of resources that is much greater than would appear. Furthermore, many of those flows are "dumped" abroad by the nations that import raw materials and semi-finished goods.
In addition to the materials that are actually incorporated into the raw materials, nature is subjected to the extraction and immediate restitution of enormous masses of material in the form of by-products of all output not used by the human system, or accounted for by the economic system. But they are significant as they are an "ecological burden." They include mineral waste and

waste from mineral processing, water used for cooling or diverted from its natural course by ground impermeabilization, erosion, etc..
The Swedish government's Commission for the Ecological Cycle (*Kretsloppsdelegationens*), established in 1993, speaks of an *increase in the efficiency* in the use of materials and energy by a factor of 10 in the next 25-50 years.
The Danish government has drawn up a development plan based on objectives similar to the one created by the Dutch government and those being studied by other EU governments. On the sector level, the British government stated the same goals regarding recycling. In the DGXI 1997-99 Action Plan, the European Commission speaks of products that are "more respectful of the environment and improving efficiency in the use of energy and resources." Similar statements have been made by the Energy Ministries that are urging the Commission to develop an action plan for increasing efficiency, even though they do not give any specific objectives.
In Switzerland the RIO Interdepartmental Commission (IDARio) maintains that: "Through appropriate strategies (such as internalization of outside costs, technological and organizational innovations) global productivity of resources must be increased at the economic system level."
The National Science and Technology Council in the United States (NSTC) has issued a report entitled "Bridge towards a Sustainable Future". The report, that maintains the need to increase material eco-efficiency, has been adopted by the White House.
The special session of the United Nations General Assembly (UNGASS) on the topic of implementing Agenda 21, of 1997, the UN Commission for Sustainable Development (CSD), and UNEP have considered it necessary to promote national and international programs for efficient use of energy and materials that should lead to Factor 10 and Factor 4 increases in resource productivity in the industrialized nations over the long and short (two or three decades) terms, respectively since these and similar efforts may be needed to achieve the greenhouse gas emission reduction goals agreed upon at Kyoto.
Even the business world sees the possibility of combining environment and development in promoting the efficient use of resources In 1995 the World Business Council on Sustainable Development (WBCSD) offered an operational definition of eco-efficiency: "Eco-efficiency is central in the WBSCD approach to sustainable development and therefore, we are encouraging our member enterprises to take the lead by adopting it as one of their central management principles. We believe that in order to be defined as eco-efficient an enterprise must:

- reduce the material intensity of goods and services;
- reduce the energetic intensity of goods and services;
- reduce the dispersion of toxic substances;
- increase material recyclability
- maximize the sustainable use of renewable resources;
- extend product service life;
- augment the performance levels of goods and services."

2. Reducing material consumption: The main concept

The concept of sustainability and the logic premise of the innovative approach of the environmental policy described below is based on the scientific advances that are seeking the profound causes of environmental degradation and that have set themselves the goal of maintaining the basic conditions for human life on earth.

The *basic conditions* belong to the sphere of ecology, that is to say they lay in the maintenance of natural functions that take place beyond the economic and social spheres *and cannot be replaced by the conduct of human activities.* When we speak of the *threat of the breakdown of those functions* we must ask *what is the source of the potential generation of conditions of ecological unsustainability* of the human system *and where it must be sought.*

To answer this question we must first clearly define the terms of the above sustainability relationship:

the relationship that determines whether or not a human system is sustainable from the ecological standpoint is *the one that the human system establishes with the surrounding environment in the physical sphere.*

Since man can act on the ecosystem solely by manipulating material and energy, in order to assess the sustainability of the *human system/Nature relationship*, we must start from an analysis of the flows and stocks of material and energy.

From the physical standpoint the Earth, as a whole, is a complex system that is open to some energy flows (the most obvious of which is sunlight) with the outside, but closed to material exchanges.

In the material that comprises the earth's crust solar energy drives a complex set of *material flows* with which we can identify Nature's life and hence the essential basis of human life. These flows are characterized by considerable *complexity*, that is the length and interdependency of the transport and transformation chains. And yet, there is also substantial cyclicity: the material transformations are such that material flows from a given natural reserve (water, soil, plants and animals) towards the others are potentially offset by incoming flows of similar quality, dislocation and magnitude.

The cyclical nature of the flows implies *substantial equilibrium in the stocks and reproducibility over time* of the cycles themselves. Over the long term the lack of compensation and hence of equilibrium would lead to non-reproducible cycles, that is of the natural system's functions and in the final analysis to a lack of support for the structures that depend on those functions and that includes the human system.

An organism that were to interrupt the cyclicity of the flows on which it depends – and the complexity involves dependency on many and unpredictable cycles – could surely be defined as "ecologically unsustainable."

Since it is part of the physical world, the human system obeys Nature's laws. Man has learned to exploit those laws in order to give the "technosphere" an order that suits him, but that he cannot *modify*.

Therefore, the human system can be viewed as a living organism within nature.

Like every living organism it is traversed by material and energy flows. It draws materials from the environment and returns both useless materials and entropically degraded energy. These flows per se would not prevent an harmonious mainstreaming of the human system into the natural cycles.

As opposed to other organisms, however, this system in its current form triggers material flows that do not exist in nature, and in amounts that have never before been observed in history:

- it extracts enormous amounts of Nature's minerals from the earth's crust as stocks that are not destined for any use, that is to say it circulates that do not enter into any natural flow;
- it makes wide scale use of a wealth of "fossil" solar energy;
- it has methods of extracting/returning water and biomasses that tend to break up the natural cycles;
- it creates and emits *new substances* that are otherwise not found in Nature.

Material extraction per se is a first potential disturbance of Nature's functions:

- if it is a material that participates in natural cycles, it is removed;
- if it is a material that is not found "circulating" in nature, its mere presence as stock could play an important role in those cycles.

Quite often resources extracted for the human system involve a use of natural resources in amounts that far exceed the material that is actually used by mankind.

The human system's extraction and metabolization of useful materials are always accompanied by movement – often on a large scale – of other, purely instrumental materials that remain unused by man and hence are immediately returned to the environment (extraction wastes, cooling water, residues, etc.). They then become a potential cause of upheaval of habitats, polluting emissions into the air or water, thermal pollution, diversion of waterways, soil depletion, etc..

The major disruptions of the natural cycles occur when what was extracted becomes "waste" (refuse, reflux or emissions) of the human system, especially when they are artificial materials that are not destined to become part of any flow.

In very general terms we can say that *sooner or later everything that enters the human system leaves it as waste going towards Nature.* There is an ineludibile law that creates a close tie between the inputs and outputs of a productive system.

There are two methods for slowing down output returns:

- incorporating materials into the physical structure of the human system;

  If the extracted materials augment the physical structure of the human system, the extraction is not compensated by a return of those materials to the environment *in a short time* even if new materials will always be required for maintenance.
- the creation of closed material cycles within the technosphere.

The creation of essentially closed cycles for some materials slows down their return to the natural environment even if the demand for energy input remains and this, in turn, requires the use of virgin materials. **We must remember this statement for a full understanding of the context of the CLOSED Project for "closing productive cycles."**

In brief, the physical structure of the human system and its extraction and utilization of materials are such in terms of size, quality and composition that it is not possible, in the current state, either for man to avoid massive returns of correctly used materials, or for Nature to absorb all the wastes, that is to replace the returned materials into the proper cycles without their having to undergo any substantial change.

From this viewpoint the amount of the "moved" material can be considered a good indicator of the potential overall disruption that human activities impose on natural cycles. The MFA conducted for the three districts is, therefore, a tool for measuring that disruption.

Considering the situation from a scientific standpoint thus leads to the identification of the heart of environmental degradation in the *excessive and improper use of the materials comprising the environment*, use in the broad sense that includes the extraction of primary resources.

The link between the physical and social elements can be considered the crucial point of every strategy for sustainability. The main site in which this link is created is the economic sphere, where the "metabolism" of the social organism takes place. It is in production and consumption that materials and energy (most of which is incorporated into the materials) are introduced into the system. They are used, exploited, partly incorporated into the physical structure of the human system and then, returned to nature at the end of the cycle.

Regulating the "material metabolism" of a national economic system that does not limit itself to seeking containment of the production-consumption system's by-products (emissions, pollutants, wastes) but that is oriented towards the primary causes cannot, therefore, exclude an awareness of the magnitude of the use of environmental resources due wholly to the activities taking place within the system.

3. MFA – Material Flow Accounting

An awareness of a national economic system's material metabolism can be reconstructed starting from the "Total Material Requirement" obtained from the sum of all the internally extracted or imported materials and the "hidden" or indirect flows, and it includes all deliberate changes in the landscape.

TMR Total Material Requirement

This is the total of the materials required by a national/regional/district/company economy and includes all domestic and imported flows.

The TMR is the sum of the Direct Material Inputs (DMI), Domestic Hidden Flows and Foreign Hidden Flows.

The peculiarity of the TMR is the fact that it also considers the flows that are not manifested economically, the domestic and foreign hidden flows, that do have an effect on the ecological sphere.

DMI Direct Material Input
This is the total of direct inputs that enter the economic process by finding an economic match.
The DMI consists of the "domestic flows" related to the raw materials extracted from the national environment and from the "indirect flows" upstream from the imports, that is the whole of refuse, reflux and emissions generated outside the national territory in the extraction, transportation and transformation of materials into imported goods.

Together, the hidden and indirect flows constitute an "ecological burden" that can be attributed to the materials that are actually used within the economy.

HMF Hidden Material Flow
This is the portion of the TMR that never enters the economy. It is usually linked to the extraction and/or collection phases of the material cycle. It can be either an input or an output.
Since a product's life cycle is played out in several countries (countries where the raw materials are extracted, countries where the semi-finished products are made, countries where the finished products are made, and finally the countries where the goods are consumed and discarded at the end of the cycle) part of this can be divided into two blocks: that of the country that does the accounting (DHF) and the rest of the world (Foreign Hidden Flows).

DHF Domestic Hidden Flows
This is the portion of the HMF that is "moved" within the domestic environment.

FHF Foreign Hidden Flows
This is the portion of the HMF that is "moved" in the outside environment, the rest of the world and "imported."

Material flow accounting makes it possible to contain the analysis by focusing attention also on the output aspects: waste, discards and emissions produced in the domestic economy.

DPO Domestic Processed Output

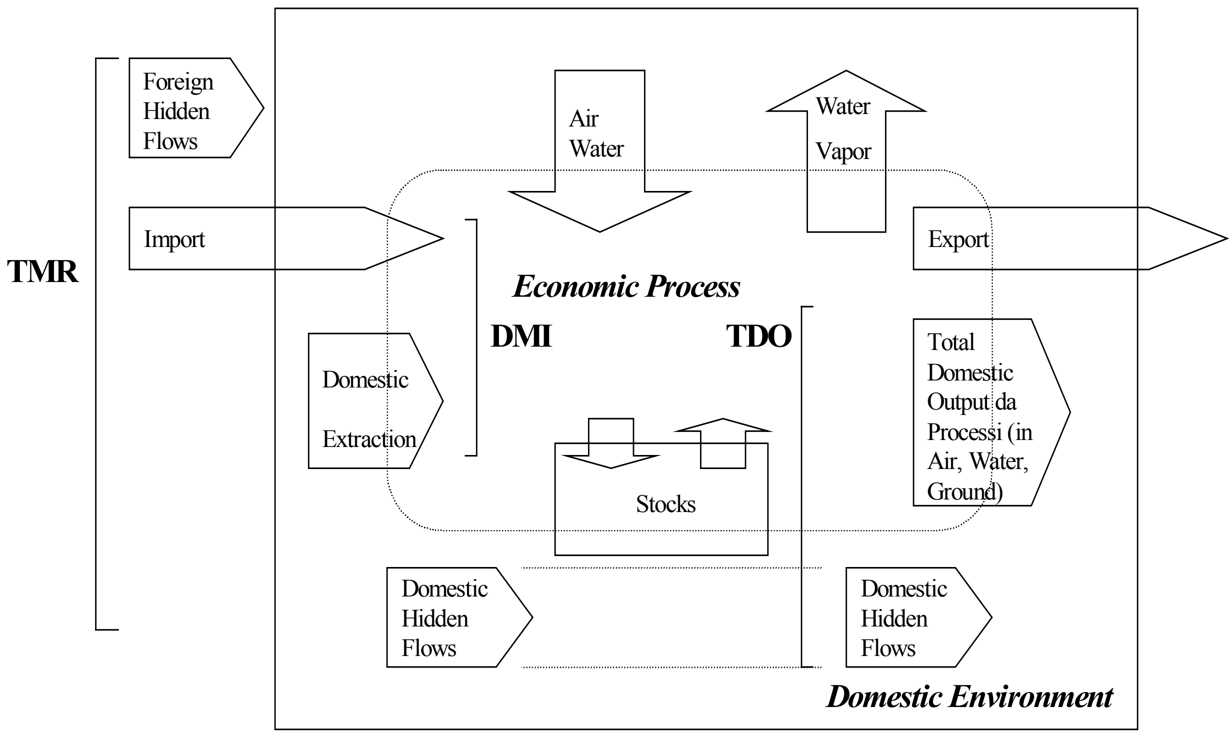
This is the total of direct inputs – consisting of "domestic flows" linked to the raw materials extracted from the domestic environment and the "indirect flows" which are those located upstream from the imports. They represent the total of the wastes, refluxes and emissions generated outside the national territory in the extraction, transport and transformation of the materials into imported goods. From these we must subtract the materials stocked in structures or infrastructures (roads, airports, railroads, manufacturing facilities, buildings) and the materials incorporated into durable goods (the sum of these two elements is the **Net Additions to Stock – NAS**) and all those flows that exit because they are incorporated into exports (and are excluded from the DPO because their wastes impact other countries). Recycled material flows are subtracted from the DPO.

And finally there is another indicator used in material flow accounting and that concerns total domestic output.

TDO Total Domestic Output

This is the total of the DPO and HMF and represents the total domestic material output directly and indirectly caused by human activities.

Chart



TMR Total Materials = DMI + Foreign Hidden Flows + Domestic Hidden Flows
DMI Direct Material Input = Domestic Extraction + Imports
NAS Net Additions to Stock = DMI - DPO - Exports
TDO Total Domestic Output = DPO + Domestic Hidden Flows
DPO Total Domestic Process Output = DMI - NAS - Exports

The empirical TMR evidence available for the past few decades shows how a dramatic increase of the overall activation of the use of natural virgin resources has taken place in industrialized countries in parallel with increases in production and income.
This confirms the intuitive observation of the existence of a close tie between improvements in living conditions and the use of materials in the early stages of modern economic growth and of possibilities of separating development from material consumption in the more advanced stages. However, in spite of the general reduction in the weight of materials used per unit of value of produced, due partly to technological progress and partly to changes in the sectorial makeup of the economy, raw material consumption does not show any sign of diminishing.

In the approaches to sustainability policies, the economy is considered as an *open subsystem of the social system* in terms of relationships with others spheres and structures ("institutions") that determine its organization from the physical standpoint and the results in terms of material flow.
A first step in this direction consists of identifying the intangible outputs from the economic systems towards the other spheres of society in the *values of use* produced, that is in the use of *services* on the part of the final users.
This use of services can be considered the *real social value* of the utilization of natural resources, preservation of which must be reconciled with the reduction in the use of natural resources. This "intuition" is matched by the identification of the *material intensity of the services* as a crucial element in the determination of the overall needs for natural resources. In turn the material intensity of the services used depends crucially on the *social organization of production and consumption*.
Considering the economy in terms of an open system makes it possible to highlight the possibilities of reducing total resource input by acting on the system's overall development in a manner that leads to replacing "traditional" activities with new activities to satisfy social and individual needs. The new activities are distinguished by low intensity resource utilization.
For example, the use of raw materials depends on the technology used (and this determines the physical properties of the goods). There are margins of technological and, above all, they develop by responding to needs dictated by society as a whole. Individual attitudes vis à vis consumption and social organization, that is *lifestyles* are of fundamental importance in determining the quantity of services delivered from given material goods and hence the amount of those goods that are needed.
This is all the more likely in affluent societies where we are witnessing the emergence of economic activities in which the relationship between the material and intangible elements of production is overturned. Knowledge, organization and information are no longer merely applied to the material to give it value such as, for example, in manufacturing. Here they *actually are the value*, since the material is simply a support needed for their transfer.
In the final analysis these elements of value are applied through the use of the labor factor, but to a large extent they constitute the result of generalized and widespread growth of social productivity that benefits from knowledge and skills that are not directly connected to the productive functions. Incidentally, we can see how all this – along with the increase in traditional services –leads to a gradual and increasingly marked separation from the real social value produced by the use of material through the monetary measure of generated income. Hence there is a dramatic loss of significance for the traditional production indicators, that will increase as we achieve separation of material utilization from the production of services.
All this, be it at the individual company, district or national level, makes an improvement in the social quality of development possible (and desirable) independently of the patterns of the traditional growth indices.

4. MFA: Guidelines for a sustainable district industrial policy

4.1 The guidelines for a sustainable district industrial policy

The orientation for strategic decisions and planning solutions that *ward off* the potential pressures on the environment can be summarized in a few guidelines linked to the main concept for the reduction of material flows:

- *reduction of wastes,* i.e. the unjustified and superfluous use of materials. Respect for the environment and parsimonious use of its resources can and must become "common sense." Public actions can contribute in this sense by targeting consumers and producers to *promote awareness* and *reward virtuous behavior* (and hence penalizing improper behavior, according to the principle of who pollutes pays).
- *increasing the service life of goods*, i.e. substantial extension of their life in the economic system. It is important to note how ecologically superior a product is in relation to the services it provides during its life. Usually this also leads to ecological and economic advantages that coincide over the long term.

  On the other hand, high quality, long-lasting goods must be considered an *investment* which suggests that even access to credit can play an important role in favoring consumption.

  From the purely technical standpoint, lasting goods also means the possibility – and advantages of *repairing* them and *upgrading* them as opposed to transforming them into waste and then replacing them.

  Long-lasting goods are "transformed into services" to the extent that enterprises can obtain an advantage from selling their services rather then goods. This way they maintain ownership of the goods – and thus an interest in maintenance and optimum utilization over time – with a voluntary broadening of the manufacturer's responsibilities.

  With regard to durability, it is important to acknowledge the existence of margins that can still be exploited in the development of *markets for used goods* which today is partly hindered by not insignificant transfer fees.

  - *closing the material production-consumption cycles*, i.e. the reutilization of materials from products that are no longer serviceable.

  In addition to differentiated waste collection and material recycling, closing the cycles can also be pursued through production strategies of recovering materials by *extending the manufacturer's responsibility to the use and disposal of the product at the end of its service life.*

  Extending the manufacturer's responsibility must, in any event, keep pace with the creation of a framework of appropriate, complementary economic incentives that will make the reduction of material consumption as well as the closing of the cycles through material recovery economically attractive and psychologically desirable.

- *the development of local markets and in loco production*, i.e. closing the production chains in the sense of reducing the circulation of material goods in the area. Less movement of goods and semi-finished products means a lower demand for packing and storage, as well as transport with obvious ecological and economic benefits.
  The medium-small scale enterprises and the districts that are typical of the Italian industrial structure are elements to exploit properly in view of a more localized production organization along with vertical integration of the enterprises.

4.2 The difficulties connected to the adoption of orientation tools towards sustainability.

Obviously, these guidelines cannot ignore the considerations of the difficulties related to acting in global contexts where the level of interdependency with the economies of the rest of the world is total. We must, in fact consider the following correlated and mutually reinforcing elements:

a) the existence of limited replaceability over the short term among material and intangible production factors. Sometimes, for individual material goods the limits of replaceability are very strong even over the long term. In these cases a reduction in the use of resources cannot be obtained through technology but only through the spread of new ways of organizing consumption that will make it possible to satisfy needs apart of exclusive individual ownership of the goods.
b) the need to maintain the "good health" of the enterprise system *as it is today*, with continuous growth in the demand for material goods;
c) the limited elasticity in the final demand for high environmental impact goods and services (just think of private automobiles) related to customs, habits and the lack of alternatives.

4.3 Sustainability for the ecological integration of the districts

The systematic review of the *complementarity* and *interdependency* relations that exist among the sectors confers a highly inter-sectorial nature on sustainability policies.

The policies must be conceived according to a functional logic of vertically integrated production chains. This means that the identification of better alternatives must be based on the overall analysis of the pressures (resource consumption) generated within the products' life cycles – and not only the most *apparent* pressure –i.e. those are directly generated in the individual stages of production and final consumption.

The great (qualitative and quantitative) differences that exist between the uses of materials typical to the various products are of fundamental importance for the purposes of planning an economic-ecological policy based on the main concept of reducing the use of virgin natural resources.

The analytical assumption of these statements is very simple: the total amount of virgin materials used (directly and indirectly) by a national economy is a function of:

- overall magnitude (as represented by the Gross Domestic Product);
- its sectorial makeup (that is the share of the total output of the various sectors) and
- the efficiency with which the materials are exploited within each sector (the relationship between the value of the sector product and the amount of the materials used in it, that is the inverse of the sector's material intensity).

Each of these three factors is a potential intermediate goal of a policy aimed at reducing Total Material Requirements. However, it must be noted that *taking the other two factors as certain,* less output means less use of resources, so it is appropriate *to exclude the economy's overall output from the set of goals.*

This variable is the final goal of other policies. At the same time, however, it is necessary to show that we cannot consider the volume of the monetary product as an exogenous datum or as an absolute restriction for environmental policy since it is not for other policies (safety, health, justice) that aim at guaranteeing fundamental rights and the application of universally shared moral principles.

As to the sectorial makeup of the economy, this shows that it is influenced over the long term in a manner that increases the weight of the sectors with a greater intensity of added value per consumption unit of resources and decreases that of the sectors where the transformation of material is part of the activity itself. Above all, it is in relation to the objective of changing the sectorial composition that it becomes essential to give the policy a broad temporal horizon. We cannot reasonably think of an economically viable and socially sustainable policy that brings about the necessary structural changes in a short time.

As we have seen it is an "upstream" action logic that must characterize sustainability policies. An adequate system of taxation on extracted materials, for example, would provide the proper incentives for products with low material intensity per service unit and for a substantial reduction in wastes. However, given the problems which, at least for the time being, prevent a prompt and generalized application of similar actions, the product and waste policies take on a role for both the reduction of pressure on the environment and mainly in disseminating greater environmental awareness.

In concrete terms, from time to time it is necessary to launch an adequate information campaign – via the mass media and via effective product labeling so that the goal of the public policy of reducing material consumption is clearly perceived as such.

As to the concrete goals, they must target increased well-being, prosperity and reduction of the base material. The actions therefore must aim at avoiding material waste – often they are very cheap in financial terms but quite evident and easily identifiable – at increasing product service life and decreasing the long-lasting goods' need for materials during their service life.

Such product policies have an automatic impact on waste – they reduce the quantities. It is also obvious that specific measures are also needed for wastes to complement and further what has already been accomplished in recent years.

The analysis makes it possible to present a relatively complete balance sheet of the DPO and DMI for the respective districts.

It would be interesting to review the following indicators for each district over a period of at least five years:

- the curve of the *DMI/GDP ratio* (Intensity of Material Input Flow); in order to examine the existing relationship between the two factors (generally they move in a directly proportional manner) and the possibility of implementing policies for "separation";
- the curve of the *DMI/Product ratio* (Intensity of Material Input Flow per kilogram of product) in order to examine the existing relationship between the two factors which also move in a directly proportional manner;
- *the main curve factors*: these could be linked to the sectorial structure of the economy, the level of each business sector's eco-efficiency, the business cycle phase and the composition of demand;
- the curve of the *per capita DMI ratio*: to examine the "direct material input curves" in relation to the population and employment levels;
- *the composition of the DMI*: the analysis should make it possible to hierarchize the environmental impact factors according to their percentage weight in the creation of the DMI;
- the *sectorial composition of the origin of the DMI*: in this way we should be able to identify those sectors or those phases of the life cycle that produce the most DMI.

The DPO concerns flows exiting the system.

It would be interesting to examine the following aspects for each district over a period of at least five years:

- the curve of the *DPO/GDP ratio* (Intensity of Material Output Flows) in order to examine the existing relationship between the two factors (that generally move in a directly proportional manner) and the possibility of implementing policies for "separation" leading to a possible increase in the gross income of the areas in question without increasing emissions/wastes;
- the *main curve factors:* these may be related to the sectorial organization of the economy, the eco-efficiency level of each business sector, the business-cycle phase and the makeup of the demand;

- the curve of the *per capita DPO ratio*: to examine the patterns of the total output from of economic processes in relation to the population and employment levels;
- the *composition of the DPO*: the analysis should make it possible to hierarchize the environmental impact factors according to their percentage weight in creating the DPO.
- the *sectorial composition of the origin of the DPO*: in this way we should be able to identify those sectors or those phases of the life cycle that produce the most DPO.

Material Flow Accounting Applied to the Districts

The three districts under review were also analyzed as to "material flow", that is the input-output exchanges that traverse the economy, regional areas and the individual enterprises.

The statistical base needed to analysis material flows is the same one used for the life cycle analysis, that is the reprocessing the chain's data per "unit of service of the district."

The data were collected from questionnaires – that were adapted to the specific situations in each district – sent to a significant number of firms that were deemed representative by the districts' Industrial Unions.

The data processing method was limited to the summation of consumption and emissions for each company, for all the companies involved. This summation was done per homogeneous typologies of manufacturing/production situations within each district.

The total value obtained for the entire sample – or its homogeneous production - was then divided by an extended parameter that describes the sample.

This parameter varies from district to district and is indicative of specific material and energy consumption.

And finally, the specific values obtained were multiplied by the value of the extended parameter that quantifies the entire district.

It is obvious that the significance of this procedure differs according to whether the districts have a high or low level of homogeneity. For the districts comprising companies with very similar products the procedure for extrapolating from the sample to the entire district produces a relatively representative image of each company's real situation.

For the districts where data homogeneity is not guaranteed, the extrapolation procedure gives an average image of the district that cannot be as readily compared with the situations in the individual companies.

For Prato the homogeneous manufacturing typologies (phases in the chain) used to sum the consumption and emissions data were:

- from sorting to spinning,
- from twisting to weaving
- from purging to dyeing and finishing.

The extended descriptive parameter of the sample of companies and the district used for the textile district is the amount of product processed, taken as 182,700,000 kilos of product (426 million meters of fabric for a mean weight of 300 g/m + 54,900,000 kilos of yarn) and a total amount of waste flock is therefore, equal to 15% of the total textile output, that is 27,405,000 kg/year.

For Lucca the homogeneous production typologies used to sum the consumption and emissions data were:

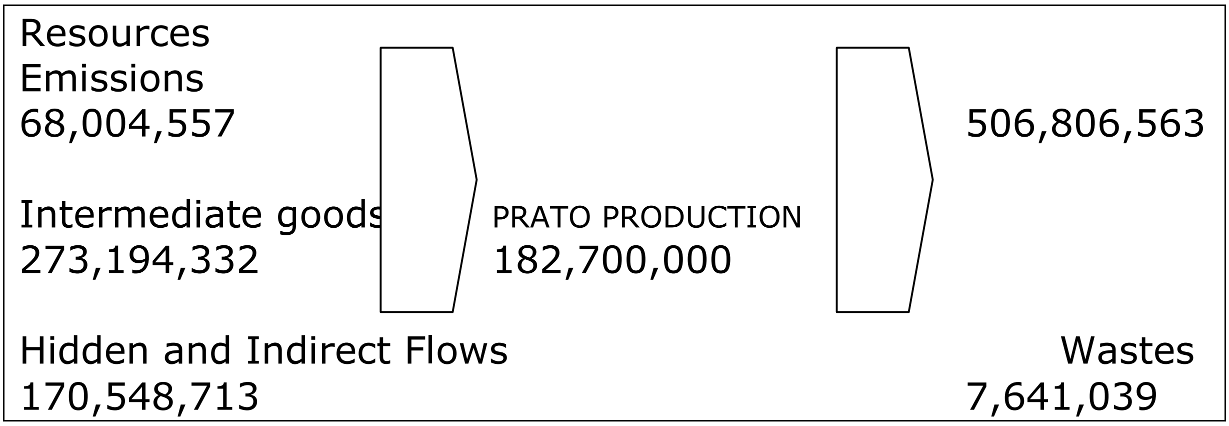
- tissue paper production
- testliner, fluting, corrugated cardboard and packing carton production.

This last group resulted from the fact that most of the companies contacted manufacture paper and corrugated cardboard or packing materials contemporaneously.
The extended descriptive parameter of the sample of companies and the district used for the paper district is the amount of paper or cardboard produced, that is 2,000,000 tones (1,000,000 tons of tissue, 900,000 tons of testliner and fluting and 100,000 tons of corrugated or packing cardboard).

For Pistoia we took the total area of land cultivated annually in the district in 1999, equal to 4880 hectares (4200 full field and 680 for potted plants).

THE PRATO DISTRICT
The Prato district's production, calculated on an extended base is 182,700,000 kilos of processed goods.

The material flow chart for the district is shown below:



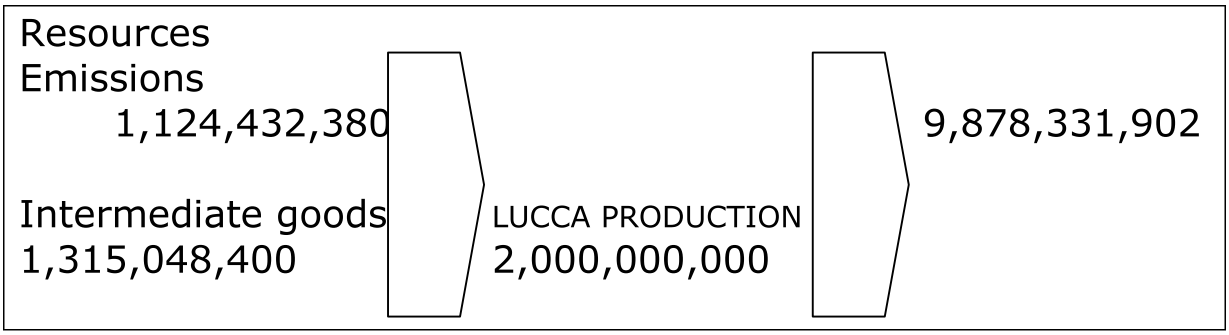
Furthermore, it is important to verify the incoming material/product ratio that is equal to 1.86 (186 kg of material for every 100 kg of product) net of the hidden flows and 2.80 (280 kg of material and hidden flows for every 100 kg of product) inclusive of the hidden flows.

The material flow accounting for the Prato district makes it possible to draw some important conclusions on the whole amount of materials that the district "moves."
We must bear in mind that the materials "moved" by the district are those linked to the entire life cycle of the industrial chain and not those moved by the district's companies.
As to the consumption of "incoming natural resources", we can say that it can be broken down as follows: 52.8% consumption of natural gas extracted from the ground, 25% oil, 11% sodium chloride and finally, coal for 6.4%.
Taken together these four materials account for 95.2% of total resource consumption while the remaining 4.8% is from the extraction of other natural resources which (in order of importance) include potassium chloride and limestone.

As to the "intermediate goods" they are mostly wool (69.6%) and synthetic fibers (14.7%). A non-negligible portion of the intermediate resources is accounted for by incoming rags. In this case we must say that this share is certainly underestimated given the difficulty that the companies have in accounting for this material. The need for a correct material flow accounting is obvious in this case. Although the whole world knows that Prato is characterized by this specific feature (the reutilization of rags) the data would not bear out this thesis.
As to emissions, carbon dioxide accounts for 96.8% of the total. A very small portion of the total tonnage (which obviously does not say anything about the relative importance of the emitted substances, or the dangerousness of a given substances) consists of volatile organic compounds (0.7%) and sulfur dioxide (0.5%).
And finally, we can say that material wastes can be broken down as follows: 53.9% chlorides and 23% sodium. In any event we must bear in mind that wastes account for 1.24% of the total of the incoming resources required for the district's production.

THE LUCCA DISTRICT

The extended descriptive parameter assumed for the sample of companies and the paper manufacturing district is the amount paper or cardboard produced, 2,000,000,000 tons.



Hidden and Indirect Flows	Wastes
8,626,326,927	187,476,405

Furthermore, it is important to verify the incoming material/product ratio that is equal to 1.22 (122 kg of material for every 100 kg of product,) net of the hidden flows and 5.53 (553 kg of material and hidden flows for every 100 kg of product) inclusive of the hidden flows.

The material flow accounting for the Lucca district that is considerably larger than Prato allows us to see what are the most important resources, intermediate goods, emissions and wastes in relation to the district's production chain.
Regarding the consumption of incoming natural resources we can say that the concentrations are not particularly significant. They can be broken down as follows: 49.8% natural gas extracted from the ground, 26.7% oil, 10% coal and 4.1% sodium chloride.
Here it is interesting to note that even though we are speaking of completely different products, natural resource consumption does have similarities with what we found in the Prato district. This is as if to say that even in structurally different production environments, resource consumption can present almost incomprehensible similarities. This is the proof that nature is the true reservoir of wealth and that human activity (activity that must be considered "consumption" even when economic theory presents it as "production") cannot do other than retransform (and this in a more or less eco-efficient manner) preexisting natural assets.

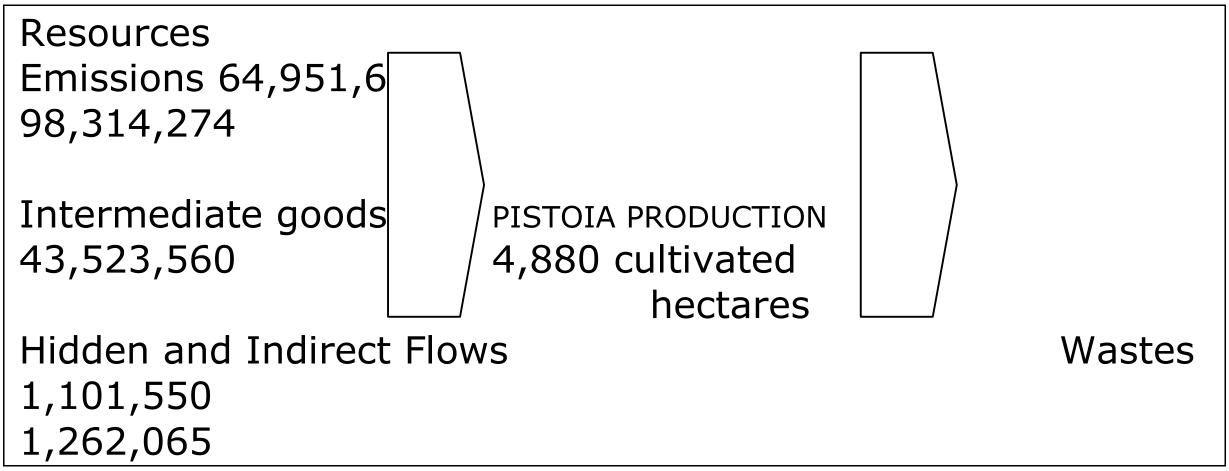
Together these four materials account for 90.6% of the total resources; the remaining 9.4% derives from the extraction of other resources from nature that include (in order of importance) lignite, bauxite and limestone.

As to the "intermediate goods", these are mostly wood (83.6%) and a non-negligible percentage (14.4%) of paper wastes. Maize, an intermediate resource accounts for 2%.
Here too we can show the contribution of recycling that is around 16% demonstrating the district's good performance. Perhaps the issues of underestimating these types of resources is lower than Prato's, but we are still left with the methodological need to improve environmental accounting that could better demonstrate the symbiosis in a given industrial sector.
As to emissions, steam (79.9%) and carbon dioxide (19.6%) account for nearly 100% of the total.

And finally, material wastes consist of suspended particles (53.4%) and chlorides (20.3%).

THE PISTOIA DISTRICT

The reference we used for Pistoia was the total land area cultivated in 1999, that is equal to 4,880 hectares (4,200 full field and 680 for potted plants).



The material flow accounting for the Pistoia district is considerably lower than Lucca and, on the basis of the available data, very similar to Prato.
Before discussing the main aspects of the material flow accounting it is essential to clarify the peculiarity of the plant-flower chain. In this case the most elementary material balance laws do not function. In fact, one feature of "natural production" is to increment the weight of the incoming resources through metabolization processes.
Regarding the consumption of "incoming natural resources" we can say that their concentrations are not particularly high. In fact oil extracted from the ground accounts for 37.5%, oil consumption accounts for 20.7%, iron for 15.6% and coal for 13.6%.
Together these four materials account for 87,4% of the total resources. The remaining 12,6% derives from the extraction of other resources from nature that include (in order of importance) lignite, bauxite and limestone.

As to the "intermediate resources", peat accounts for 75.8% and manure for the remaining 24%.

As to emissions, carbon dioxide alone accounts for 97% of the total.