A micro-founded hybrid Input Output framework

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1. Introduction

Input-output tables (IOTs) are very common in the economic literature because of their characteristics to act as both accounting and analytical tools. Since 1968, thanks to the work of Richard Stone (UN, 1968), IOTs are calculated by an elaboration of Supply and Use tables (SUTs).

SUTs are essentially accounting tools that can be optimal snapshots to know how a complex economic system is organized. On the other hand, IOTs are proper analytical tools to simulate the behavior of a system under certain conditions. But to act in a proper way, IOTs need to have a structure "with appropriate physical units for the characteristic output of each sector" (Weisz and Duchin, 2006). It follows that monetary IOTs (MoIOTs) and physical IOTs (MaIOTs)[1] fail to accomplish this task, hence a different framework has to be developed if one wants to assess the real interactions of an economic system.

Therefore this paper introduces a micro-founded hybrid Input Output table (mHIOT) with the aim to solve the problems encountered by MoIOT and MaIOTs. Furthermore, briefly, some concepts on the meaning of SUTs and IOTs are presented.

The paper is thus structured. Section 2 introduces some general knowledge about SUTs and IOTs mostly present in economic literature and highlights the limits of MoIOTs and MaIOTs. Section 3 introduces hybrid SUTs (HSUTs), and shows the link with MoSUTs and MaSUTs. Furthermore some concepts about the meaning of SUTs are deepened. Section 4 describes how to obtain a mHIOT that keeps all the information of HSUTs and, at the same time, models a complex system in a proper way. Section 5 introduces a *demand-driven model* (Miller and Blair, 1995) in a micro-founded hybrid framework, calculating the environmental pressures and the value-added chain. This helps to validate and generalize the well-known Input Output modeling (IOM) in a hybrid framework. Section 6 shows a numerical example that encompasses most of the concepts introduced in the previous parts and, finally, Section 7 is dedicated to conclusions.

2. Input Output framework

IOTs were introduced by Wassily Leontief in the first half of the last century (Leontief, 1941)[2]. They account for all the transactions taking place in an economic system in a given time (usually one year).

In the System of National Accounts 1968 (SNA68), thanks to the work of Richard Stone, a MoIOT is considered as the result of an elaboration of MoSUTs (UN, 1968, Eurostat, 2006).

MoSUTs can be considered as snapshots of the reality and are mostly represented by (rectangular) matrices where there are commodities are structured in rows and industries

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[1] Here, for exposition purposes, instead of the most famous acronyms MIOT (Monetary IOTs) and PIOT (physical IOTs) are used respectively MoIOT and MaIOT but the meaning is exactly the same.

[2] A former idea of an IOT can be traced back to Francois Quesnay (1694-1774) with his *Tableau Economique*.

in columns. The monetary Supply table shows the worth of different products realized in every industry or imported in a given time. It has to be noted that an industry, group of establishments engaged in the same, or similar, kinds of activity (UN, 1999), can realize more than one type of outputs. In this case the main production is defined as principal and the other ones as secondary[3].

On the other side, the monetary Use table describes the costs of production in every industry (UN, 1999).

Fig. 1 – SUTs, MoIOT and MaIOT

Monetary Use table

		Industries	Final Demand	Total
Commodities	$1....\alpha_M$	U_M	Y_M	q_M
Primary Inputs	$1....\eta_M$	K_M		
Use of Residuals	$1....\gamma_M$	R_M		
Total		g_M'		

Industries	Final Demand	Total

Physical Use table

		Industries	Final Demand	Total
Commodities	$1....\alpha_P$	U_P	Y_P	q_P
Raw Materials	$1....\beta_P$	D_P		
Use of Residuals	$1....\gamma_P$	R_P		
Total		g_P'		

Physical Supply table

		Industries	Final Demand	Total
Commodities	$1...\alpha_P$	V_P	Y_P	q_P
Supply of Residuals	$1....\gamma_P$	W_P		
Emission to Nature	$1....\varepsilon_P$	E_P		
Total		g_P'		

MoIOT

		Production units	Final Demand	Total
Production units	$1....\alpha_M$	Z_M	Y_M	q_M
Primary Inputs	$1....\eta_M$	K_M		
Use of Residuals	$1....\gamma_M$	R_M		
Supply of Residuals	$1.....\gamma_M$	$-W_M$		
Total		q_M'		

Monetary Balance

$$Z_M'\cdot i_\alpha + K_M'\cdot i_\eta + R_M'\cdot i_\gamma - W_M'\cdot i_\gamma = Z_M\cdot i_\alpha + Y_M\cdot i_\alpha = q_M \quad (1)$$

MaIOT

		Production units	Final Demand	Total
Production units	$1....\alpha_P$	Z_P	Y_P	q_P
Raw Materials	$1....\beta_P$	D_P		
Use of Residuals	$1....\gamma_P$	R_P		
Supply of Residuals	$1....\gamma_P$	$-W_P$		
Emission to Nature	$1....\varepsilon_P$	$-E_P$		
Total		q_P'		

Mass Balance

$$Z_P'\cdot i_\alpha + D_P'\cdot i_\eta + R_P'\cdot i_\gamma - W_P'\cdot i_\gamma - E_P'\cdot i_\varepsilon = Z_P\cdot i_\alpha + Y_P\cdot i_\alpha = q_P \quad (2)$$

α	Industries/market commodities/production units	D	Use of raw material by industries/production units
η	Types of primary inputs	V	Supply of market good and services by industries
β	Types of raw materials	W	Production of residuals by industries/production units
γ	Types of residuals (emissions, waste, etc.)	E	Emissions to environment by industries/production units
M	Concerning to monetary variables	Y	Final demand of commodities/production units
P	Concerning to physical variables	g	Total production by industries/production units
U	Use of intermediate goods and services by industries	q	Total production by commodities/production units
K	Inputs of primary factors by industries/production units	*i*	Summation vectors
R	Use of residuals by industries/production units		

sources: elaboration of Hoekstra (2003) and Hoekstra and van der Bergh (2006)

[3] A principal production is used to allocate a firm in the appropriate industry. For more information see UN (1968) or Eurorostat (1995).

A MoIOT derived from MoSUTs (Fig.1) has instead a symmetric structure – square shape - that can be either *commodity by commodity* or *industries by industries.* The former describes technological relations and is based on the so-called unit of homogeneous production whilst the latter shows market relations and is based on the homogeneity of activity (Eurostat, 2006).
Each of the two types of IOTs relies upon two different assumptions; in the case of commodity *by commodity* there are assumptions about either *product technology or industry technology.* In the case of *industries by industries* there are assumptions about either *fixed product sales structures* or f*ixed industry sales structures* (Eurostat 2006). Thus, though starting from the same MoSUTs, the choice of the type and the use of one or a mix of the above mentioned assumptions may generate different MoIOTs: it all depends on the decisions taken by analysts.
MaIOTs (Konijn et al., 1995; Stahmer et al. 1997; Gravgård-Pederson, 1999; Nebbia, 2000; Mäenpáá and Muukkonen, 2001; Giljum and Hubacek, 2003) are analogous to MoIOT but with the difference that, accounting the mass instead of worth, they can take into account the flows with no economic value, for example natural resources and emissions (Fig.1). For these reasons, in the last decades, MaIOTs have been intensely developed to analyze the interactions between technosphere and biosphere in order to assess the environmental impact of economic systems.
However, though there is a quite long story of uncountable input-output studies to assess the behavior of economic systems and their environmental impacts, there are still some doubts of how IOTs are handled.
Firstly, as it has been seen above, known the MoSUTs, the content of a MoIOT is not unequivocally determined but relies on the choices of the analyst in charge to calculate it.
Furthermore, in a recent article, Weisz and Duchin (2006) clearly show the limits of an approach based on MoIOT to model the transactions in an economy. Indeed, whenever the prices differ per purchaser, a MoIOT modifies the real relations of a production system (Hoekstra, 2003; Weisz and Duchin, 2006).
On the other side, a MaIOT has the limit that, accounting just the mass, excludes the process with a no-mass-output (Hendrickson et al, 1998, Weisz and Duchin, 2006).
Moreover every time there are processes in a economic system providing by-products[4], every symmetric input output table, either MoIOT or MaIOT, is a mathematical simplification that may fail to asses the real transactions: the more by-products are realized, the more distant the IOT is from the real behavior of a system (see Section 4).
So, once such problems are exposed, it is time to focus on how it can be possible overcome them and develop an IOT able to model a complex economic system in a proper way. Hereafter this will be the task of the paper, with the help of interesting clues already included in the Input-Output Literature.
As usual, following the Stone's teaching, first SUTs will be introduced and then an IOT as result of their transformation.

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[4] By-products are part of secondary productions and, because of adopted technology, are strictly linked to the principal outputs processes. See UN (1999) for further information.

3. Hybrid Supply and Use tables (HSUTs)

A macro tool, like the SUTs, is a snapshot of what occurs in an economic system where the actions of many different agents take place. The agents can be essentially divided in two groups: consumers and producers. The former ask for a specific amount of commodities to satisfy their own needs - *demand* - and the latter carry out production processes to satisfy these requests - *supply*[5]. After the consumption, or after the production processes, refuses are realized and managed by industrial activities or discharged to the environment. Indeed, for the law of mass conservation (first law of Thermodynamics), nothing can utterly disappear into the void (Ayres and Kneese, 1969). Furthermore producers and consumers, to carry out their processes, interact with the environment extracting natural resources and producing emissions. Finally, it is important to note that all the actions of consumers and producers are strictly connected but do not happen in the same time period (Settani and Heijungs, 2008).

This description of an economic system, even though quite simplistic, can give a rough idea of the mechanisms SUTs have to deal with. Firstly, it is important to describe all the processes undertaken by both actors: producers and consumers. Hence it seems reasonable to extend SUTs introducing the consumption as a set of processes, with inputs and outputs, and not only as a "black hole" of commodities as it is normally treated in the usual SUTs[6]. The c*omplete-system hypothesis* encompasses these properties.

Furthermore, to account all the transactions of a system, SUTs must include many different measures peculiar to commodities - kg, MJ, m^2, hours and so on (Miller and Blair, 1985; Hendrickson et al, 1998; Hoekstra, 2003[7]; Weisz and Duchin, 2006). It creates a *hybrid framework (multi-units framework)*.

Figure 2 illustrates a generalized HSUTs based on the concepts mentioned so far; for the sake of simplicity a closed economy is shown[8].

It can be noticed that, due to hybrid framework, HSUTs include all the flows shown in the MaSUTs and in the MoSUTs (Fig. 1) and many more with a no-mass and no-monetary metrix. Indeed Eq.3 shows that the number of elements in a hybrid framework is not less than the sum of elements in MoSUTs and MaSUTs.

In Fig.1 packaging processes are included. Process residuals display the refuse produced by industries to carry out their common activities.

As it has been displayed in the previous section, SUTs respect the flows consistency hence the incoming flows (use table) can be easily connected to the outgoing ones (supply table). In a hybrid framework some more words have to be said.

In HSUTs, a material[9] balance – sum per row – is quite simple and it can be easily done

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5 For further information see Mas Colell et al. (1995)

6 Indeed IOTs are considered T-accounts. In this paper it is considered a wider dimension that partially remember a Social Accounting Matrix (SAM) (Eurostat, 2006).

7 Hoekstra (2003) refers to them as "natural units".

8 Notice that only intermediate (or "ordinary") inputs are included in the framework. But, in an accounting period, fixed assets or durable goods might be produced, purchased or delivered to waste management and so they should be introduced into the framework. For simplicity those cases are not dealt with in these pages but some words will be said in the numerical example at Section 6. Furthermore, as stated by Hoekstra and van den Bergh (2006), the inputs can be used to calculate the composition of commodities.

9 The term *material* is used to refer to a generic commodity, resource, emission, refuse, etc.

because of homogeneity of unit of measurement down the rows. So, during an accounting period, materials supplied are somehow used (Fig.2)

Fig. 2 – HSUTs

Hybrid Use table		Industries	Households Demand	Stocks	Total
Commodities	1........α	U	Y	SU	q
Primary Inputs Services	1.........η	K			k
Packaging	1.........τ	A	YA	SA	a
Process Residuals	1.........γ	R		SR	r
Raw Materials	1.........β	D	YD		d

Hybrid Supply table		Industries	Households	Stocks	Total
Commodities	1........α	V		SV	q
Packaging	1.........τ	B		SB	b
Process Residuals	1.........γ	W	CW	SW	r
Emission to Nature	1.........ε	E	CE		e

(3) $$\alpha \geq \alpha_M \cup \alpha_P ; \eta \geq \eta_M \cup \mu_P ; \gamma \geq \gamma_M \cup \gamma_P ; \beta \geq \beta_M \cup \beta_P ; \varepsilon \geq \varepsilon_M \cup \varepsilon_P$$

U	Use of commodities by industries (includes services of waste management)	SR	Formation of process waste stocks
K	Inputs of primary factors by industriesx	V	Supply of commodities by industries
A	Packaging of input commodities by purchasing industries	B	Packaging of supplied commodities divided by industries
R	Use of (process) residuals by waste management industries	W	Production of (process) residuals by industries
D	Use of raw material by industries	E	Emissions and waste to environment by industries
Y	Demand of commodities by consumers	CW	Production of (ordinary) waste by consumers
YA	Packaging of purchased commodities by households	CE	Emissions and waste to environment by consumers
YD	Use of raw material by consumers	SV	Supply of commodities by stock activities
SU	Formation of stocks of commodities	SB	Packaging of supplied commodities by stock activities
SA	Packaging of commodities to stock	SW	Supply of (ordinary) pre-accumulated waste by stock activities
	q, k, r, d, c, g, r, e and *p* are row totals.		

Instead a balance per industrial process[10] – sum per column – is meaningless: it is impossible to sum materials with different units of measurement[11]. Hence, for balance purposes, a further homogenization of data is required and a proof of coherence could be the respect of balance laws, for example the first law of thermodynamics, the cash balance, the energy balance (Jones, 1989) and so on. The rest of the Session will be used to explain how to do that.

It is well known that each material may have different ways to be represented. For

10 Same thing for consumers and stocks.

11 Indeed, a thing that can be easily noticed is the absence of the row of totals in Fig. 2.

example crude oil can be represented using the mass value but also following its energy content or worth. These can be referred to as *units-of-balance.* Moreover it can be assumed that each unit-of-balance has a selected unit of measurement for accounting. Tab.1 below shows some possible units-of-balance and their relative units of measurement.

Tab. 1 – Units-of-balance and their related units of measurement

Units-of-balance (*u*)	**Unit of measurement**
Mass	Kg
Energy	MJ
Worth	euro (€)

The idea is that a balance per industry can be done using one of the above units-of-balance. But, before speaking about that, some other things have to be introduced

Let Φγ be a *material characteristic vector* where γ indicates the type of material (see note 10). Φγ has at least as many elements as the units of balance *u* and each of those elements indicates the units of measurement a single-unit of γ-material, expressed in “natural unit” (see note 6), contains. Hence, for a chosen a material, if the “natural unit” is the same of a unit-of-balance *u*, that corresponding element of Φ▯ will be equal to 1 (for example apples, measured in kg, have a unitary value for the mass). Instead, when the chosen material cannot be represented by a unit-of-measurement, that specific element will be zero (for example, electric energy has a zero value for the mass or, to say more, oxygen may have a null price[12]).

Therefore, based on Tab.1 above, a *γ-material characteristic vector* may have the following composition:

(4)
$$\Phi_{\gamma} = \left(\begin{matrix} mass\ of\ 1 \\ unit\ of\ \gamma \end{matrix} ; \begin{matrix} energy\ content \\ of\ 1\ unit\ of\ \gamma \end{matrix} ; \begin{matrix} worth\ of\ 1 \\ unit\ of\ \gamma \end{matrix} \right) \qquad \forall \gamma$$

Once the *material characteristic vectors* are known for all the materials[13] shown in the HSUTs the homogeneous elements are selected and clustered in order to create three different *balance vectors:* φ_{mass}, φ_{energy} and φ_{money} (Fig.3)*.* In this way, taking for example the vector φ_{mass}, it indicates the mass for all the materials of the HSUTs.

To this point, each of the *balance vectors* pre-multiply the quantities in HSUT so as to have three different SUTs, respectively:

1. MaSUTs;
2. energy SUTs (EnSUTs);
3. MoSUTs.

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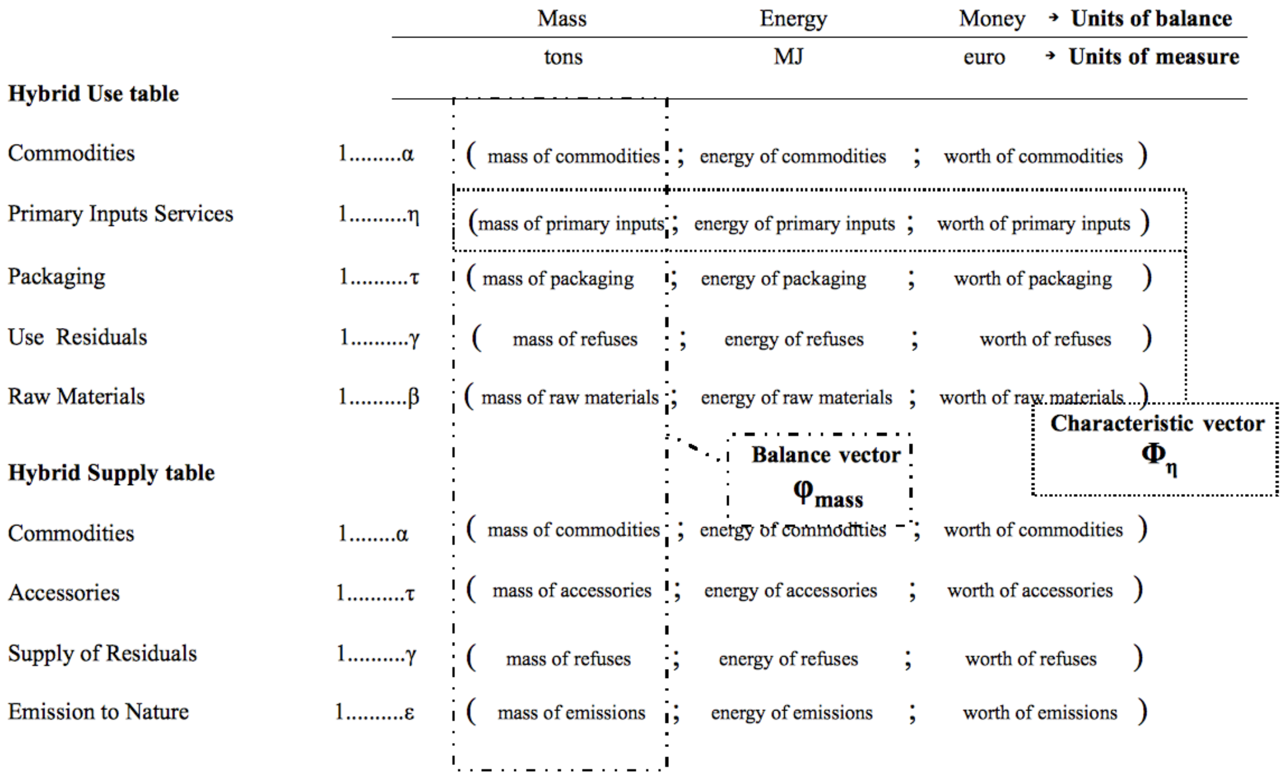
[12] Indeed, the worth of a material is the price of a single-unit.

[13] Notice that, according to the hybrid framework here exposed, the *characteristic vectors* should have elements as many as to include all the flows in the reality (for example also hours, pieces, m^2 and so on). Here, for exposition purposes, just three-elements vectors are considered and the others are deliberately not included.

Fig. 3 – Characteristic vectors and balance vectors



This can be expressed in matrices algebra. For example the matrix U_p of MaSUTs (Fig.1) can be calculated as follows:

(5.a) $$U_P = f\left(diag\left(\varphi^{\alpha}_{mass}\right)\cdot U\right)$$

where $diag\left(\varphi^{\alpha}_{mass}\right)$ is a diagonal matrix with the value of mass-balance vector of α-commodities down the diagonal, U is the hybrid Use table and f( ) is a function deleting null rows and columns.
In an analogous way to Eq.5.a, the remaining matrices of MaSUTs can be calculated and, using the energy-*balance vector,* the EnSUTs can be traced too[14].
Instead some more words have to be said in the case of MoSUTs. Indeed, in an economic system, when the price differs per consumer, as state Weisz and Duchin (2006), φ_{money} is a matrix rather than a single vector. In this case the Eq.5.a becomes:

(5.b) $$U_M = f\left(\left(\varphi^{\alpha}_{money}\right) * U\right)$$

where the operator * indicates the *Hadamard product* (Horn and Johnson, 1994)[15].
Once the three SUTs are obtained, the units of measurement are homogenous and,

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[14] Eq. 5 can be used to build all the SUTs where the unit-of-balance of a material is unequivocally determined by a single value.

[15] Be $A \in \Re^{nXm}$ and $B \in \Re^{nXm}$ then $A * B = C \in \Re^{nXm}$ where the elements of C are given by: $A_{i,j} * B_{i,j} = C_{i,j}$.

finally, three different balances for industries, households and stocks can be determined:

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(6)\qquad
\begin{aligned}
& i_U \cdot U + i_K \cdot K + i_A \cdot A + i_R \cdot R + i_D \cdot D = i_V \cdot V + i_B \cdot B + i_W \cdot W + i_E \cdot E \\
& i_Y \cdot Y + i_{YA} \cdot YA + i_{YD} \cdot YD = i_{CW} \cdot CW + i_{CE} \cdot CE \\
& i_{SU} \cdot SU + i_{SA} \cdot SA + i_{SR} \cdot SR = i_{SV} \cdot SV + i_{SB} \cdot SB + i_{SW} \cdot SW
\end{aligned}
$$

where the row vectors $i_U, i_K, i_R, i_D, i_C, \ldots, i_{SW}$ are appropriate summation vectors. Eq. 6, in the case of the mass balance, represents the first law of Thermodynamics, in the case of the monetary worth, the cash-flow and so on.

Before concluding, some considerations are necessary. First, a single-unit framework (for example mass or monetary) excludes flows happening in the reality because its relative balances vectors contain some null values. Practically, the more null values a single-unit framework has, the more transactions are not taken into account. Hence a loss of information appears.

Second, it is important to say that practically it is quite difficult to have all the data necessary to satisfy this hybrid framework. Hence, from a practical point of view, because of lack of collected data, this framework represents an ideal structure to approach to and all the reality-flows might be inserted as soon as they are collected.

Anyway a value of residuals could indirectly be calculated in order to assess missing materials, allowing the balance property.

4. Micro Hybrid Input-Output Table (mHIOT)

In the previous sections HSUTs have been introduced which account perfectly the transactions in the reality in a span of time and allow the construction of different unit-based SUTs on the condition that the *characteristic vectors* are known for all the materials. But to pass from a hybrid to unit-based framework determines a loss of information due to null values in the *balance vectors.*

So now, supposing that there is already an economy perfectly depicted by HSUTs, the next step is to know what are the changes that the *movement* of such system carries out. Changes are meant to be the differences between the starting and the finish lines. To do that an IOT has to be built. Indeed the latter is quite often used for these aims being an effective *steady-state* model - where it is assumed that the structure of an economy does not change with time - to trace the *movement* of a (pre)accounted economic system[16].

But until now the IOTs used for these purposes were built in monetary or in mass terms or using a mix of both of them (Hawkins et al, 2007) and little attention has been dedicated to a hybrid framework where multi-units are included nonetheless Leontief already in the '70s used this framework (Leontief, 1970). The relevance of a hybrid framework is to link production units more and more to reality reducing considerably the loss of information. Indeed, having the advantage to include all the flows in a system, many limits of IOM (Hoekstra, 2003; Weisz and Duchin, 2006) can be overcome and a consistent and coherent IOT can be realized and properly used in modeling.

But before developing an IOT in a hybrid framework some concepts about classification

[16] Practically an IOT may be also used as an accounting tool but, essentially, adds no further information to the SUTs. That is the why here the IOT is exclusively treated as a modelling tool.

and symmetry have to be told. In a hybrid framework it is reasonable to have an asymmetric *commodity by activity* IOT. This helps a lot when there is a production process that realizes two or more market commodities and it is not feasible to split it into separated processes. For example, considering the case of a sheep husbandry producing both milk and wool by the same animals, if an analyst wants to obtain two separated processes – to construct a *commodity by commodity* IOT[17] - he or she might incur into serious annoying problems. For example negative values can appear, as with the MoIOT, which is well known in literature (UN, 1999; Eurostat 2006). But in a hybrid framework this problem becomes even bigger: the analyst has to correct the negative values of many different units of measurement. This job can be quite annoying and, essentially, not necessary.

Indeed, a solution consists in embracing the *activity classification* as stated by Konijn and Steenge (1994) down the columns of IOT rather than and industry or commodity ones. An *activity classification,* based on the idea of Konijn and Steenge (1994), is indeed more related to the really enforced industrial processes and it does not imply to split artificially processes when it is not necessary hence negative values do not appear. In the example above, the sheep husbandry represents an activity, or in other words a process, producing two commodities, milk and wool. The milk might be considered as the principal production and the wool as a by-product.

Down the rows, where there are the (intermediate) inputs or the purchased goods, it seems reasonable to keep a *commodity* classification so as to generate an asymmetric IOT. A cheese factory, to be bound to the previous example, buys sheep milk to process it but does not purchases the wool as well or, in other words, all the heterogeneous outputs of the activity. The same thing is valid for consumers.

So resuming, it should be preferable to have an asymmetric IOT, i.e. *commodity by activity,* because it coherently synthesizes the real production processes and does not generate negative values. Indeed, there is no need to have symmetric IOT in modeling, as it will be showed in the next pages. Hence, unlike Fig.2, it is assumed that the HSUTs are revised and reclassified using an *activity classification* for the columns and not an industry one[18].

Clarified these basic concepts, time is ripe to practically construct an IOT starting from HSUTs.

For the sake of simplicity it is assumed that matrices $\boldsymbol{V}$ and $\boldsymbol{U}$ of HSUTs are square. This means that the number of commodities is the same of activities.

Furthermore it is assumed that rows and columns classifications are strictly linked, hence the outputs down the diagonal of $\boldsymbol{V}$ are all positive and represent the principal productions[19]. All the other produced and traded commodities, included in $\boldsymbol{V}$, are treated as by-products (*Stone method* (Stone, 1961; UN, 1999) or *by-product technology assumption* (Miller and Blair, 1985)).

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[17] Note that, in a micro founded hybrid framework, the industry by industry IOT loses its importance because there are heterogeneous productions with different units of measurement that make not possible to realize a sum.

[18] Note that industry and activity are often used as synonymous in many statistical manuals. Instead, here the activity has a meaning more related to the real (physical) processes as stated by Konijn and Steeng (1994) than the socio-economic one where the establishment is the basic unit (see UN 1993, par V).

[19] No reuse is considered.

Therefore the principal productions in *V* are deleted and clustered in a proper vector indicated with x_S. The resultant matrix, indicated with $\grave{V}$, describes the production of by-products by activities.
So now everything is ready to calculate the *micro-founded hybrid transaction matrix* Z in the following way:

(7) $$Z = U - \grave{V}$$

The matrix ***Z*** can be thought as a hybrid Use table with the by-product introduced as negative inputs. It represents the core of IOT. Notice that, for homogeneity of commodity along the rows, a by-product has the same characteristics of the commodity whose it is substitute for[21]. The matrix Z has an asymmetric structure, commodity by activity.
The other matrices composing the IOT can be easily traced taking the remaining matrices of Use table with a positive sign and those of Supply one with a negative. This resulting IOT is defined as *micro-founded hybrid Input Output table* (mHIOT). Fig.4 shows it.

Fig. 4 – mHIOT

		Activities	Households	Stocks	Total
Commodities	1..........α	Z	Y	SZ	q
Primary Inputs Services	1..........η	K			k
Use of Process Residuals	1..........γ	R		SR	r
Use of packaging	1..........τ	A	YA	SA	a
Raw Materials	1..........β	D	YD		d
Supply of packaging	1..........τ	-B		-SB	-b
Supply of Residuals	1..........γ	-W	-CW	- SW	-r
Emission to Nature	1..........ε	-E	-CE		-e
Primary Outputs		x_S'			

A mHIOT, compared to the famous IOT, monetary or in mass terms, is asymmetric, has many units of measurement and respects the complete-system hypothesis[22].
Now moving more into IOM, the *micro-founded hybrid coefficient matrix* ***T*** can be derived in the usual way of the Leontief model (Miller and Blair, 1985):

(8) $$T = Z \cdot diag(x_S^{-1})$$

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[21]In reality, it is the function of the commodities that should be homogenous along a row. See Numerical example for clarifications. However in general, taking a row, if a by-product differs somehow from the principal output whose substitutes for a recalibration should be realized for activities using that by-product as input. For the sake of simplicity, here this is not realized hence it is assumed that there is a complete homogeneity of commodity per row.
[22] There are many possible links between HSUTs and the full-MaIOT (Hoekstra and van den Bergh, 2006).

It is worth noticing that matrix ***T*** has all pure numbers down the diagonal. So the *micro-founded hybrid inverse matrix of Leontief* can be defined as follows*:*

(9) $L_H = (I - T)^{-1}$

In this way it is possible to use the IOM that potentially includes all the flows occurring in the reality accounted in the HSUTs and, at the same time, to respect the complete system hypothesis and so the balance properties. Moreover it is fundamental to notice that, using a mHIOT in the IOM (Eq. 9) rather than MoIOT or MaIOT, the problems exposed by Weitz and Duchin (2006) are overtaken. Indeed, it is not a case if also Leontief used a multi-units IOT in modeling (Leontief, 1970).

A generic column of L_H indicates the use of commodities (positive values) by activities to produce one single unit of principal commodity and at the same time, because of the *by-product technology assumption*, all the produced-and-traded by-products and the saved goods (negative value).

This framework using matrix L_H is defined as *micro-founded hybrid Input-Output model* (mHIOM) since it can be easily inferred that matrix $(I - T)$ can be considered as a "macro" version of the Technology Matrix (TM) used in Life Cycle Assessment (LCA) (Guinée, et al., 2002; Heijungs and Suh, 2002; Heijungs, 1994)*.* Indeed the use of IOM (Eq.9) techniques implies that even if one starts from a macro accounting tool, i.e. the SUTs, he or she ends up to use an *average single-unit production* matrix, i.e. coefficients matrix ***T*** (Eq.8), that in the context of mHIOM can doubtless be considered as a set of processes (*representative activity processes or production recipes*). Hence, roughly speaking, the main differences between the framework of LCA and mHIOM are the choice of classification detail, more aggregated activities in the case of IOM, and the inclusion of *complete-system hypothesis* whilst in the LCA there are truncations (Heijungs and Suh, 2002)*.*

5. Demand-driven model and micro-founded Hybrid Input-Output Modeling (mHIOM)

In Section 4 it has been seen that it is possible to build an IOT that keeps all the information availability of HSUTs and overcomes the limits of MoIOTs and MaIOTs. Furthermore some brief concepts about modeling have been introduced. Now, to go a little bit further into modeling, the *demand-driven model* (Miller and Blair, 1985)[23], the most famous IO model, will be introduced. This model assumes that the production follows the (exogenous) demand and no infrastructure limits are applied.

In particular it will be shown how to calculate the environmental pressures (EPs), determined by total exploited natural resources and by total emissions to biosphere, of a given final demand vector $\boldsymbol{y_H}$ and*,* furthermore, how the demand worth, i.e. the consumer outlay, is distributed to the primary factors taking part in the production process (*value-added chain*). Indeed with a hybrid framework all of that can be calculated simultaneously.

Here the final demand includes the request of commodities $\boldsymbol{y_Y}$ and also post-consumption waste management service demand $\boldsymbol{y_{CW}}$ as consequence of the *complete system*

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[23] See Ghosh (1958) and Papadas and Dahl (1999) for *supply-driven models.*

hypothesis adoption (Fig. 4).
Vector $\boldsymbol{x_D}$ indicates the number of single-unit-processes carried out, directly and indirectly, by activities to satisfy the final demand[24]*:*

(10.a) $x_D = L_H \cdot (y_Y + y_{CW}) = L_H \cdot y_H$

Instead, the quantities of commodities, principal and by-products, realized as consequence of x_D processes are equal to:

(10.b) $x_T = \hat{V} \cdot x_D$.

where $\hat{V} = V \cdot diag(x_s^{-1})$ is the supply matrix by activities producing a single-unit output. The differences between $\boldsymbol{x_D}$ and $\boldsymbol{x_T}$ are due to the presence of by-product productions.
So resuming, $\boldsymbol{x_D}$ indicates the enforced processes as consequence of the demand y_H while x_T is the production of commodities associated to x_D.
Eq.10.a needs some more precautions. Indeed it may happen that $\boldsymbol{x_D}$ has a negative value component, i.e. $x_D(\ddot{a})$, due to the use of *by-product technology assumption* in a *demand driven model*. A negative quantity of processes means that in an economic system, to satisfy the request of consumers, some activities produce more commodities (by-products) than those demanded. In other words, a negative production indicates that an overproduction of by-products has occurred. It follows that the final demand has to increase to absorb the overproduction. To this aim, the following iterative procedure is introduced to correct negative values on a chosen threshold ξ by the allocation of the overproduction to stocks thus increasing the final demand.
So, chosen a threshold negative value $\xi \in \Re$ close to zero, initially $n = 0, n \in \Re$, and so x_D^n represents the original production vector from Eq. 10.a. $\ddot{A}$ is the set of commodities produced by all activities both as principal output and as by-products. The condition below determines the start of the iterative procedure:

(*Condition 1*) $\quad if \quad \exists \ddot{a} \in \ddot{A}: \quad x_D^n(\ddot{a}) < \xi$

then $n = n+1$ and let $\tilde{y}_n$ be a vector with all zeros except for the $\ddot{a}-th$ component equal to:

(11) $\quad \tilde{y}_n(\ddot{a}) = -x_D^{n-1}(\ddot{a}) / L_H(\ddot{a}; X(\ddot{a}))$

where $L_H(\ddot{a}; X(\ddot{a})$ is the $\ddot{a}-th$ value down the diagonal of *micro-founded hybrid inverse matrix of Leontief* (Eq. 9). $\tilde{y}_n(\ddot{a})$ indicates the amount of commodity $\ddot{a}$ which has to be

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24 Consumer demand could be classified per needs or purposes (see Classification of Individual Consumption According to Purpose, COICOP: http://unstats.un.org/unsd/cr/registry/regcst.asp?Cl=5%20&Lg=1). It follows that consumption is represented by matrix. In that case the demand vectors are the sums per rows. For example $y_Y = Y \cdot i$ and $y_{CW} = CW \cdot i$ where *i* is an appropriate summation vector.

(extra)demanded to eliminate the negative value in x_D^n. The introduction of $L_H(\ddot{a};X(\ddot{a})$ allows, considering the indirect productions, a reduction of the numbers of loops. It follows that:

(12) $$x_D^n = x_D^{n-1} + L_H \cdot \tilde{y}_n$$

Procedure has to be repeated until *condition 1* is not valid.

When the loops are finished, the last x_D^n represents the real vector of direct and indirect processes to carry out in order to satisfy the demand y_H. In this case, the overproduction that is equal to the output realized but not demanded becomes part of the stocks:

(13) $$\sum_n \tilde{y}_n = overproduction$$

After having solved the negative-values problem, time is ripe to calculate the EPs, as indicated in Miller and Blair (1985). Let $\bar{d}$ be the total vector of natural resource extracted and $\bar{e}$ the total vector of emission disposed to biosphere in order to satisfy the demand y_H. Eq.14 describes how to determine them:

(14.a) $$\bar{d} = \hat{D} \cdot x_D^n + \breve{d}\,|_y$$
(14.b) $$\bar{e} = \hat{E} \cdot x_D^n + \breve{e}\,|_y$$

The matrices $\hat{D} = D \cdot diag(x_s^{-1})$ and $\hat{E} = E \cdot diag(x_s^{-1})$ indicate the average natural resources extracted and emissions disposed to nature by each activity to produce a single-unit output while $\breve{d}\,|\,y_H$ and $\breve{e}\,|\,y_H$ are respectively the requirements of natural resources and the emissions referred to consumption bundle and, due to demand driven model hypothesis, are exogenous.
Now, moving to monetary level, the value-added chain is calculated. To this aim the values-added of each activity have to be traced[25].
Indeed in a hybrid framework, assuming that prices differ per consumer, the values-added of activities are not unequivocally determined in the IOT because they depend on *who is the buyer*. For this reason some other calculations have to be introduced in respect to the well-know methodology (Duchin, 2004).
Let y_M be the monetary demand vector determined as follows:

(15) $$y_M = diag(p_C) \cdot y_H$$

where p_C is a vector of consumer prices and y_H is the demand in natural units. The sum of

[25] Note that a 2 period model is considered: the first period (t) is relative to the purchase of intermediate inputs and the second one (t+1) to the purchases of consumers. See Settani and Heijungs (2008) for further information about dynamic in IOM.

the elements of y_M is the total consumers' outlay (see . Then, the vector of the worth of direct and indirect produced commodities is so obtained:

(16) $$x_{T;M} = y_M + [(p_I * \hat{U}) \cdot x_D^n]$$

where p_I is the matrix of intermediate inputs prices by activities, * indicates the Hadamard product, $\hat{U} = U \cdot diag(x_S^{-1})$ is the use matrix U per single-unit output. Looking at the right side of Eq.16, the first addend indicates the direct worth generated by demand, the second one the indirect value. After this the vector of *average prices, i.e.* p_A*,* can be calculated as follows:

(17) $$p_A = diag(x_T^{-1}) \cdot x_{T;M}$$

Indeed p_A is a consequence of market transactions according to final demand hence it is not determined a priori but can be thought as a weighted mean of consumer and intermediate inputs prices[26].

Once the average prices paid out to producers are known, the value-added per each activity can be traced as follows:

(18) $$v = [\hat{V}' \cdot p_A] - [(p_I * \hat{U})' \cdot i]$$

The vector *v* represents the worth paid out to primary factors of activities per unit of output when their productions are valued following average prices p_A[27].

So finally the value-added chain disaggregated per activity can be calculated in the following way:

(19) $$G = diag(v) \cdot x_D^n - \ddot{g}(p_A * S_U)] \quad \text{where} \quad G' \cdot i = y_M' \cdot i$$

$\ddot{g}()$ is a function that subtracts the worth of overproduced commodities, if they occur, to the specific activities producing them as by-products.

Equation 19 shows how the outlay of consumers is distributed to the primary factors of activities.

Concluding, a mHIOM keeps all the information availability of HSUTS and, at the same time, makes the modeling developed for MoIOT more consistent. mHIOM can be useful in connecting coherently mass (Adriaanse et al. 1997; Eurostat, 2001; van der Voet, 1996) and economic levels, helping, for example, to address eco-efficiency. Additionally, many more interdisciplinary analyses can be realized easing the fulfillment of sustainability challenges. Indeed, the more units of balance are known, the more SUTs can be

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[26] Indeed, an alternative way to write Eq.17 is $p_A = (I - \alpha) * \{[diag(\hat{U} \cdot x_D)^{-1}] \cdot [(p_I * \hat{U}) \cdot x_D]\} + \{\alpha * p_C\}$ where the vector α indicates the ratio between the consumed commodities and the total commodities production: $\alpha = diag(x_T^{-1}) \cdot y_H$.

[27] Eq.18 could be even written using the time dimension: $v_{t+1} = [\hat{V}' \cdot p_{A;t+1}] - [(p_{I;t} * \hat{U})' \cdot i]$

calculated[28] and the broader spectrum of analyses will be. For example also the loss of quality of materials and primary factors (Georgescu-Roegen, 1971) and the exergy analysis (Lozano and Valero, 1993; Sciubba, 2005) could be easily included.

6. Numerical example

Before concluding an example is included in order to resume all the concepts shown so far and to clarify some of potentialities of mHIOM. A hypothetical economy has been built[29] for this aim.

22 activities are enforced and, because of square shape, 22 commodities are realized too. There are agricultural activities, manufacturers and service providers; recycling processes are also included. Seven different units of measurement - natural units - are used in the economy.

Three activities produce the same commodity, i.e. electricity. But each of them has its own type of process: two use renewable resources, wind and sun, whilst the third one uses fossil fuels. The mix of electricity production is not decided by the purchaser but by the producers through the grid.

Recycle plants exist just for metals, plastics and organic solid waste. Produced waste is recycled according to a determined rate, the rest of refuses are assumed to end in landfills and in the incinerator plant. Recycling plants and incinerators produce by-products, i.e. recycled materials and electric energy, which are indicated as negative inputs in the transaction matrix. In particular the plant recycling organic matter produces compost that can substitute for nitrogen fertilizers. The nitrogen percentage of compost is five times less than that of chemical fertilizer. So 1kg of compost substitutes for 0.2 kg of N-fertilizer. The recycling rate is assumed be the same for both producers and consumers.

Electricity produced by incinerators substitutes for the energy obtained only by fossil fuels[30].

Note that it is assumed that the function and the mass of commodities are homogeneous along the row hence all the by-products have the same characteristic (mass and price) of goods they substitute for. The only exception is for the compost that has same function but a different mass[32]

Construction activities produce new fixed assets that last after the end of an accounting period.

Plastics are mostly used by activities for packaging their outputs. The packaging arrives in the hands of purchasers that, according to the recycling rate, decide how to handle it.

Eleven different natural resources and seven kinds of disposals to nature are introduced; all, except the land, are expressed in mass quantity. Furthermore an extra row in the disposals shows the residual values that are all the unaccounted losses of processes, calculated by balancing properties.

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[28] Stahmer (2001) has realized three IOTs for Germany: a MaIOT, a MoIOT and hours-based IOT. Well, the three matrices belong to the same hybrid one.

[29] The elaboration of data harks back to Ecoinvent dataset (www.ecoinvent.ch) and Ribaudo (2002)

[30] A mix of crude oil, natural gas and soy oil is used to produce the non-renewable energy.

[32] Keeping constant the nitrogen ratio, the mass of compost is bigger than that of a mineral fertilizer hence there is an extra-mass. A farmer who buys the compost rather than fertilizers adds to his ground the extra-mass increasing the accumulation of materials.

In this exercise the attention is focused particularly on the mass and worth balance hence the characteristic vector is supposed to have, for each material, values indicating the mass and the prices per purchaser. Land use is shown but not further highlighted.
It is assumed that the state-of-art of the imaginary economy is:

production of electric energy: 90% by fossil fuels, 5% by wind turbines and 5% by photovoltaic cells;
management of waste: 10% to recycling, 27% to incinerator and 63% to landfill.

Fig. 5 shows the micro-founded coefficient matrix of transactions in the hypothetical economy (Eq. 8), Fig 6 the other incoming and outgoing flows of mHIOT accounted per single unit of principal output[33] and, finally, Fig. 7 shows the characteristic vectors of intermediate inputs where mass and prices are traced.
Now, to show how a mHIOM may work, two different greener scenarios are discussed with the aim to immediately ameliorate the actual bad situation but without touching the citizens consumption bundle of goods. The two green scenarios are the followings:

<u>Green energy solution (GE):</u>
energy: 20% by fossil fuels, 40% by wind turbines and 40% by photovoltaic cells;
waste: 10% to recycling, 27% to incinerator and 63% to landfill.

<u>High-recycling solution (HR):</u>
energy: 90% by fossil fuels, 5% by wind turbines and 5% by photovoltaic cells;
waste: 75% to recycling, 7.5% to incinerator and 17.5% to landfill.

The task of mHIOM is to determine which of the two scenarios could be considered as a better eco-efficient solution in respect to the former situation.
Fig. 8 shows the quantity and the worth of the demand of commodities and of waste management services for the two scenarios. As it can be seen, the demand of some products is unchanged whilst for the commodities related to the scenarios, electricity and waste management services, quantities differ.
Fig. 9 shows the quantity of realized commodities, the worth generated by activities and the number of productive processes (single-unit activity) that directly and indirectly should be engaged to satisfy the households demands (Fig. 8). In Fig.9 it can be seen that, as consequence of by-technology assumption, the quantity of produced commodities is not equal to the number of single-unit processes.
Fig.10 shows how the worth paid out by consumers is distributed to primary factors of activities, capital and labor, in other words the value-added chain (Eq.19). Finally Fig.11 describes the environmental pressures of two mentioned scenarios where a mass balance is realized too.

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[33]The choice of showing just the coefficients matrix is mainly driven by the interest to show the characteristics of mHIOT. Note that in the Fig. 6 and 7 the use of negative values for input and positive ones for outputs is exactly the contrary of that shown in Fig 4. Furthermore, for balance reasons, within the inputs in Fig. 6 it has introduced a part describing also the inputs from other activities (defined as: Flows in - Technosphere), duplicating in some rows the information already included in the coefficient matrix (Fig. 5).

Here follows a brief discussion of the results.

Crude oil, CO2 and other gasses emissions:

The scenario GE, as was predictable, entails a reduction of extraction of crude oil (-1.75%) and a subsequent reduction of CO_2 (-1.70%) and of no-CO_2 gases (-4.25%) emissions[34]. However such reduction is quite low because the consumption of fossil fuels is still high in the economy, due to usage in other activities.

Instead, the scenario HR, providing raw materials in a more environmentally friendly way, implies a higher reduction of fossil fuels extraction (-5.28%) and, on the emissions side, CO_2 (-4.7%) and other gasses (-9.65%) emissions[35].

Other natural resources and waste:

Scenario HR implies a higher reduction of natural resources extracted (-11.96% of metals; - 80.36% of ammonium) and a lower production of solid waste disposed to the environment (-15.99%) than GE where there is slight reduction of solid waste discharged to the environment (-0.71%) while for the other components almost nothing changes compared to the baseline.

Households' outlay, employment ad distribution of income:

Moving to the monetary level it can be seen that scenario GE implies a very slight reduction of demand outlay; this is due to the lower price of wind energy that compensate for higher cost of solar energy. Instead, in HR, because the landfill solution is the cheapest, there is a small increase of the households' expense.

Furthermore some considerations can be made about the employment. New productions imply a shift of the request of labor services from the energetic sector to renewable energy activities. While for HR scenarios this occurs from mining, electric and transportation activities to the recycling plants.

Instead the partition of consumers' outlay between labor and capital remain the same for both scenarios. But one thing to note in the HR scenario is that the capital holder in the sugar beet production loses money because the gains do not cover the variable and labor costs[36].

Eco-efficiency remarks:

An eco-efficient solution depends on hazardousness of treated materials, aims of decision makers, availability of natural resources, cultural aspects and so on. Hence an eco-efficient path valid in one place might not be elsewhere.

Notwithstanding in this simple example, roughly speaking, to strive for higher recycling rates seems to be the eco-efficient solution because most impact categories shrink as shown above.

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[34] For simplicity the use of gas homogenization, for example by Global Warming Potentials (GWP), is avoided.

[35] When the inverse matrix of Leontief is calculated for mHIOT (Eq.9), the savings in materials are explicitly showed.

[36] Here in this example it is assumed that the compensation to capitalists is a residual value once paid the other costs.

However, this example does not want to give any real suggestions; the only aim is to show the potentialities of IOM built on a hybrid framework, because of plenty of information that simultaneously can be derived from it.

7. Conclusions

In this paper a mHIO framework has been presented.

It has been shown that it is possible to have HSUTs that account all the possible flows and stocks occurring in the reality. It follows that the HSUTs embody every kind of SUTs: monetary, physical, energetic and so on.

Additionally a mHIOT has been calculated that enables an analyst to use the IOM properties keeping the full information availability of HSUTs. Moreover, by using mHIOT, an analyst succeeds to model the behavior of a system, overcoming the limits met by MoIOT or MaIOTs (Weisz and Duchin, 2006).

The unique hypothesis used in this methodology relies on principal production as the main reason for enforcing productions - *by-product technology assumption*. Hence, neither technology nor sales structure hypotheses are used as for the construction of usual MoIOTs.

Furthermore the mHIOT, including heterogeneous flows, permits an elaboration of complex models of an (economic) system and enables the link between Economics and other Social and Natural Sciences, addressing eco-efficiency and allowing many more organic analyses. For these reasons a mHIOT may be really useful in searching for sustainable development paths.

Finally, from a statistical point of view, the presence of many flows in a hybrid framework, allowing more connections between different variables, may help to validate data of National Accounts coming out from different sources and surveys, ameliorating the databases consistency. Furthermore the comparison between economies of different countries can be more easily realized without any data treatment, for example the purchasing power parity.

Fig. 5 – Coefficients matrix

INPUT	unit of measurement	Production of Wheat	Production of Sugar beet	Production of Soya beans	Production of metals	Production of rubber and plastics	Production of soy oil	Production of nitrogen compounds	Production of chemicals	Distribution of water	Production of electricity from fossil fuels	Production of electricity from photovoltaic cells
Commodities:		1	2	3	4	5	6	7	8	9	10	11
Wheat	kg	0.0025	0.0005	0.0006	0.0025	0.0025	0.0025	0.0025	0.0018	0.0001	0.0008	0.0006
Sugar beet	kg	0.0013	0.0002	0.0003	0.0013	0.0013	0.0013	0.0013	0.0009	0.0001	0.0004	0.0003
Soya beans	kg	0.0000	0.0000	0.0000	0.0000	0.0000	1.1000	0.0000	0.0000	0.0000	0.0000	0.0000
Metals	kg	0.0000	0.0000	0.0000	0.0000	0.0005	0.0000	0.0000	0.0000	0.0000	0.0001	0.0002
Rubber and plastics	kg	0.0010	0.0020	0.0009	0.0000	0.0000	0.0123	0.0030	0.0050	0.0000	0.0000	0.0000
soy oil	kg	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Fertilizers and pesticides	kg	0.0620	0.0430	0.0380	0.0000	0.0000	0.0000	0.0000	0.0500	0.0000	0.0000	0.0000
Chemicals	kg	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Water	kg	10.0000	8.0000	5.0000	0.0000	0.0603	0.0000	0.0000	0.0002	0.0000	0.0000	0.0000
Electrical energy from fossil fuels	KWh	0.0450	0.0450	0.0450	0.0144	1.3734	0.0650	0.0461	1.7550	0.0004	0.0000	0.0000
Photovoltaic energy	KWh	0.0025	0.0025	0.0025	0.0008	0.0763	0.0036	0.0026	0.0975	0.0000	0.0000	0.0000
Wind energy	KWh	0.0025	0.0025	0.0025	0.0008	0.0763	0.0036	0.0026	0.0975	0.0000	0.0000	0.0000
Manufactured gas	kg	0.0000	0.0000	0.0000	0.0140	0.5000	0.0410	2.4506	1.5150	0.0000	0.0000	0.0000
Refined petroleum products	kg	0.0273	0.0210	0.0658	0.9750	0.8057	0.0300	0.1200	0.0672	0.0000	0.0440	0.0000
Construction work	m2	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Railway transportation services	tkm	0.0084	0.0031	0.0040	0.0032	0.0000	0.3510	1.3101	0.1362	0.0000	0.0001	0.0000
Freight transportation services by road	tkm	0.0108	0.0004	0.0077	0.0016	0.0000	0.9600	0.3389	0.0227	0.0000	0.0000	0.0003
Recycling plastic and rubber services	kg	0.0001	0.0001	0.0000	0.0000	0.0000	0.0002	0.0000	0.0001	0.0000	0.0000	0.0000
Recycling metals service	kg	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Recycling organic waste service	kg	0.0502	0.0500	0.0300	0.0002	0.0002	0.0202	0.0002	0.0001	0.0000	0.0001	0.0000
Incinerating waste service	kg	0.1356	0.1353	0.0812	0.0004	0.0004	0.0560	0.0005	0.0005	0.0000	0.0001	0.0001
Landfill of waste service	kg	0.5418	0.9591	0.5104	0.7022	0.5670	0.1553	2.6750	1.5572	0.0000	0.0054	0.0005
OUTPUT		1	1	1	1	1	1	1	1	1	1	1
unit of measurement:		kg	kg	kg	kg	kg	kg	kg	kg	kg	KWh	KWh
		Wheat	Sugar beet	Soya beans	Metals	Rubber and plastics	soy oil	Fertilizers and pesticides	Chemicals	Water	Electrical energy from fossil fuels	Photovoltaic energy
Labor	hours	0.025	0.005	0.006	0.025	0.025	0.025	0.025	0.018	0.001	0.008	0.006

INPUT	unit of measurement	Production of electricity from wind	Manufact. of gas	Oil-refining	Activity of construction	Railway service provision	Freight road transport. provision	Recycle plastics and rubber activity	Recycle metals activity	Composting activity	Incinerator activity	Garbage disposal in landfill
Commodities:		1	2	3	4	5	6	7	8	9	10	11
Wheat	kg	0.0004	0.0003	0.0025	1.0000	0.0025	0.0025	0.0030	0.0050	0.0050	0.0025	0.0013
Sugar beet	kg	0.0002	0.0001	0.0013	0.5000	0.0013	0.0013	0.0015	0.0025	0.0025	0.0013	0.0006
Soya beans	kg	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Metals	kg	0.0004	0.0000	0.0000	12.0000	0.0058	0.0092	0.0000	-0.9000	0.0000	0.0000	0.0000
Rubber and plastics	kg	0.0000	0.0000	0.0000	7.0000	0.0000	0.0003	-0.2500	0.0000	0.0003	0.0000	0.0000
soy oil	kg	0.0000	0.0000	0.0500	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Fertilizers and pesticides	kg	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	-0.1000	0.0000	0.0000
Chemicals	kg	0.0000	0.0000	0.0004	3.5000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0004	0.0000
Water	kg	0.0000	0.0000	0.0150	0.0000	0.0000	0.0052	0.0091	0.0000	0.0000	4.3000	0.0010
Electrical energy from fossil fuels	KWh	0.0000	0.0001	0.0113	0.2700	0.0434	0.0000	0.2060	0.0110	0.0106	-0.8500	0.0106
Photovoltaic energy	KWh	0.0000	0.0000	0.0006	0.0150	0.0024	0.0000	0.0114	0.0006	0.0006	0.0000	0.0006
Wind energy	KWh	0.0000	0.0000	0.0006	0.0150	0.0024	0.0000	0.0114	0.0006	0.0006	0.0000	0.0006
Manufactured gas	kg	0.0000	0.0000	0.4800	0.0000	0.0000	0.0000	0.0750	0.0140	0.0000	0.0500	0.0000
Refined petroleum products	kg	0.0000	0.0000	0.0000	15.0000	0.0016	0.0363	0.0806	0.4875	0.0087	0.0000	0.0806
Construction work	m2	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Railway transportation services	tkm	0.0000	0.0000	0.0080	0.0000	0.0000	0.0000	0.0000	0.0091	0.0000	0.0009	0.0000
Freight transportation services by road	tkm	0.0000	0.0001	0.0013	10.0000	0.0000	0.0000	0.0000	0.0091	0.0062	0.0001	0.0062
Recycling plastic and rubber services	kg	0.0000	0.0000	0.0001	0.7034	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Recycling metals service	kg	0.0000	0.0000	0.0000	0.2400	0.0001	0.0002	0.0000	0.0000	0.0000	0.0000	0.0000
Recycling organic waste service	kg	0.0000	0.0000	0.0002	0.0600	0.0002	0.0002	0.0002	0.0003	0.0000	0.0002	0.0001
Incinerating waste service	kg	0.0001	0.0000	0.0006	2.7041	0.0007	0.0010	0.7500	0.0008	0.0008	0.0004	0.0002
Landfill of waste service	kg	0.0005	0.0001	0.4943	16.9110	0.0071	0.0328	0.1248	0.2194	0.0160	0.1132	0.0000
OUTPUT		1	1	1	1	1	1	1	1	1	1	1
unit of measurement:		KWh	kg	kg	m2	tkm	tkm	kg	kg	kg	kg	kg
		Wind energy	Manufactured gas	Refined petroleum products	Construction work	Railway transportation services	Freight transportation services by road	Recycling plastic and rubber services	Recycling metals service	Recycling organic waste service	Incinerating waste service	Landfill of waste service
Labor	hours	0.004	0.003	0.025	10.000	0.025	0.025	0.030	0.050	0.050	0.025	0.013

Fig. 6 – Physical Flows: Natural Resources, Waste, Commodities and Emissions.

	unit of measurement	Production of Wheat	Production of Sugar beet	Production of Soya beans	Production of metals	Production of rubber and plastics	Production of soy oil	Production of nitrogen compounds	Production of chemicals	Distribution of water	Production of electricity from fossil fuels	Production of electricity from photovoltaic cells
		1	2	3	4	5	6	7	8	9	10	11
environmental resources (IN)												
land	m2	-4.0000	-0.2500	-2.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
metals ore	kg	0.0000	0.0000	0.0000	-1.2000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
ammonium	kg	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	-0.9000	0.0000	0.0000	0.0000	0.0000
CO2	kg	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	-1.1000	0.0000	0.0000	0.0000	0.0000
oil	kg	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
gas	kg	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
calcium	kg	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
silicon	kg	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
water	kg	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	-0.3800	-1.5000	0.0000	0.0000
oxygen	kg	-0.0683	-0.0525	-0.1646	-2.4381	-2.0341	-0.0766	-0.3980	-0.2286	0.0000	-0.1100	0.0000
nutrients/minerals	kg	-0.1500	-0.2000	-0.1800	0.0000	-0.6100	0.0000	0.0000	-0.6000	0.0000	0.0000	0.0000
waste (IN)												
plastics	kg	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
metals	kg	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
organic matter	kg	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
mix	kg	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
IN (all materials in natural units)												
	kg	-10.0941	-8.0667	-5.1056	-0.9928	-1.3702	-1.1871	-2.5773	-1.6401	-0.0002	-0.0454	-0.0012
	KWh	-0.0500	-0.0500	-0.0500	-0.0160	-1.5260	-0.0722	-0.0513	-1.9500	-0.0004	0.0000	0.0000
	MJ	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	m2	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
services	tkm	-0.0191	-0.0035	-0.0117	-0.0048	0.0000	-1.3110	-1.6490	-0.1589	0.0000	-0.0001	-0.0003
concrete	kg	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	-0.0002	0.0000
plastics packaging from the inputs	kg	-0.0002	-0.0001	-0.0001	0.0000	0.0000	-0.0007	0.0000	-0.0001	0.0000	0.0000	0.0000
OUT (all materials in natural units; by-products are expressed in equivalent functional commodity)												
	kg	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	0.0000	0.0000
	KWh	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	1.0000	1.0000
	MJ	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	m2	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
services	tkm	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
concrete	kg	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
packaging of by-product	kg	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
plastics packaging primary output	kg	0.0007	0.0014	0.0006	0.0000	0.0000	0.0074	0.0027	0.0045	0.0000	0.0000	0.0000
extra-mass of by-product	kg	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
waste to recycle/incinerator/landfill (OUT)												
plastics	kg	0.0001	0.0001	0.0000	0.0000	0.0000	0.0002	0.0000	0.0001	0.0000	0.0000	0.0000
metals	kg	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
organic matter	kg	0.0502	0.0500	0.0300	0.0002	0.0002	0.0202	0.0002	0.0001	0.0000	0.0001	0.0000
mix (incineration)	kg	0.1356	0.1353	0.0812	0.0004	0.0004	0.0560	0.0005	0.0005	0.0000	0.0001	0.0001
mix (landfill)	kg	0.3163	0.3157	0.1895	0.0010	0.0010	0.1272	0.0011	0.0012	0.0000	0.0003	0.0003
stock – concrete (OUT)	kg	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0002	0.0000
disposals/emission (OUT)												
use of land	m2	4.0000	0.2500	2.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
solid emission (landfill)	kg	0.0000	0.6434	0.3208	0.7013	0.5660	0.0281	2.6738	1.5560	0.0000	0.0051	0.0002
hazardous materials	kg	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
water vapor	kg	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
other gases (no-CO2)	kg	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0170	0.0000
sewage	kg	8.5000	6.1100	3.6300	0.0000	0.0000	0.0000	0.8000	0.0000	0.5000	0.0000	0.0000
CO2	kg	0.0819	0.0630	0.1975	2.9258	2.4445	0.0231	0.4947	0.2849	0.0000	0.1320	0.0000
residuals	kg	0.0022	0.0004	0.0005	0.0022	0.0022	0.0022	0.0022	0.0016	0.0001	0.0007	0.0006
MASS BALANCE	kg	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

		Production of electricity from wind	Manufact. of gas	Oil-refining	Activity of construction	Railway service provision	Freight road transport. provision	Recycle plastics and rubber activity	Recycle metals activity	Composting activity	Incinerator activity	Garbage disposal in landfill	Households
		12	13	14	15	16	17	18	19	20	21	22	
environmental resources (IN)													
land	m2	0.0000	0.0000	0.0000	-1.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	-0.0100	
metals ore	kg	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.000
ammonium	kg	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.000
CO2	kg	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.000
oil	kg	0.0000	0.0000	-1.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.000
gas	kg	0.0000	-1.0200	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.000
calcium	kg	0.0000	0.0000	0.0000	-640.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.000
silicon	kg	0.0000	0.0000	0.0000	-210.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.000
water	kg	0.0000	0.0000	0.0000	-200.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.000
oxygen	kg	0.0000	0.0000	-0.0192	-37.5000	-0.0039	-0.0908	-0.2044	-1.2193	-0.0217	-0.0020	-0.2014	-0.200
nutrients/minerals	kg	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.000
waste (IN)													
plastics	kg	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	-1.0000	0.0000	0.0000	0.0000	0.0000	0.000
metals	kg	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	-1.0000	0.0000	0.0000	0.0000	0.000
organic matter	kg	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	-1.0000	0.0000	0.0000	0.000
mix	kg	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	-1.0000	-1.0000	0.000
IN (all materials in natural units)													
	kg	-0.0009	-0.0004	-0.5492	-39.0000	-0.0111	-0.0548	-0.1691	-0.5090	-0.0165	-4.3541	-0.0834	-275.000
	KWh	0.0000	-0.0001	-0.0125	-0.3000	-0.0482	0.0000	-0.2289	-0.0122	-0.0116	0.0000	-0.0118	-50.000
	MJ	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.000
	m2	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	-50.000
services	tkm	0.0000	-0.0001	-0.0093	-10.0000	0.0000	0.0000	0.0000	-0.0182	-0.0062	-0.0010	-0.0062	-25.000
concrete	kg	0.0000	0.0000	0.0000	0.0000	0.0000	-0.0109	0.0000	0.0000	0.0000	0.0000	0.0000	-50000.000
plastics packaging from the inputs	kg	0.0000	0.0000	-0.0004	-0.0172	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	-0.252
OUT (all materials in natural units; by-products are expressed in equivalent functional commodity)													
	kg	0.0000	1.0000	1.0000	0.0000	0.0000	0.0000	0.2500	0.9000	0.1000	0.0000	0.0000	0.0000
	KWh	1.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.8500	0.0000	0.0000
	MJ	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	m2	0.0000	0.0000	0.0000	1.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
services	tkm	0.0000	0.0000	0.0000	0.0000	1.0000	1.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
concrete	kg	0.0000	0.0000	0.0000	1000.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
packaging of by-product	kg	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0003	0.0000	0.0000	0.0000
plastics packaging primary output	kg	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
extra-mass of by-product	kg	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.4001	0.0000	0.0000	0.0000
waste to recycle/incinerator/landfill (OUT)													
plastics	kg	0.0000	0.0000	0.0001	0.7034	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.025
metals	kg	0.0000	0.0000	0.0000	0.2400	0.0001	0.0002	0.0000	0.0000	0.0000	0.0000	0.0000	0.000
organic matter	kg	0.0000	0.0000	0.0002	0.0600	0.0002	0.0002	0.0002	0.0003	0.0003	0.0002	0.0001	6.300
mix (incineration)	kg	0.0001	0.0000	0.0006	2.7041	0.0007	0.0010	0.7500	0.0008	0.0008	0.0004	0.0002	17.076
mix (landfill)	kg	0.0002	0.0001	0.0014	6.3268	0.0017	0.0023	0.0016	0.0019	0.0019	0.0009	0.0000	39.849
stock – concrete (OUT)	kg	0.0000	0.0000	0.0000	0.0000	0.0000	0.0109	0.0000	0.0000	0.0000	0.0000	0.0000	50000.000
disposals/emission (OUT)													
use of land	m2	0.0000	0.0000	0.0000	1.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0100	0.0000
solid emission (landfill)	kg	0.0003	0.0000	0.4929	10.5843	0.0054	0.0305	0.1232	0.2175	0.0141	0.1123	0.8718	10.9250
hazardous materials	kg	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0010	0.0000	0.3000	0.0000	0.0000
water vapor	kg	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.4815	0.0000	0.0000	0.0000
other gases (no-CO2)	kg	0.0000	0.0200	0.0450	0.0000	0.0000	0.0003	0.0000	0.0400	0.0100	0.0974	0.0700	0.0000
sewage	kg	0.0000	0.0000	0.0000	60.0000	0.0000	0.0000	0.0000	0.1000	0.0000	4.1000	0.1000	0.0000
CO2	kg	0.0000	0.0000	0.0264	45.0000	0.0047	0.1089	0.2458	1.4633	0.0260	0.7428	0.2417	201.0000
residuals	kg	0.0004	0.0002	0.0022	0.8986	0.0022	0.0022	0.0027	0.0035	0.0034	0.0023	0.0011	0.2750
MASS BALANCE	kg	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

Fig. 7 – Characteristic vectors: mass and worth components.

	mass		prices (per purchaser)	Production of Wheat	Production of Sugar beet	Production of Soya beans	Production of metals	Production of rubber and plastics	Production of soy oil	Production of nitrogen compounds	Production of chemicals	Distribution of water	Fossil fuel power plant	Photovoltaic power plant
Commodities:	unit:		unit:	1	2	3	4	5	6	7	8	9	10	11
Wheat	kg	1	euro/kg	0.58	0.58	0.57	0.58	0.58	0.58	0.58	0.60	0.58	0.58	0.58
Sugar beet	kg	1	euro/kg	0.46	0.46	0.46	0.46	0.46	0.46	0.46	0.46	0.46	0.46	0.46
Soya beans	kg	1	euro/kg	0.43	0.43	0.43	0.43	0.43	0.43	0.43	0.43	0.43	0.43	0.43
Metals	kg	1	euro/kg	1.90	1.90	1.90	1.90	1.90	1.90	1.90	1.90	1.90	1.90	1.90
Rubber and plastics	kg	1	euro/kg	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00
soy oil	kg	1	euro/kg	1.30	1.30	1.30	1.30	1.30	1.30	1.30	1.30	1.30	1.30	1.30
Fertilizers and pesticides	kg	1	euro/kg	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
Chemicals	kg	1	euro/kg	1.25	1.25	1.25	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20
Water	kg	1	euro/kg	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Electrical energy from fossil fuels	kg	0	euro/KWh	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.18
Photovoltaic energy	kg	0	euro/KWh	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20
Wind energy	kg	0	euro/KWh	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13
Manufactured gas	kg	1	euro/kg	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
Refined petroleum products	kg	1	euro/kg	1.20	1.20	1.20	1.30	1.30	1.30	1.30	1.30	1.30	1.30	1.30
Construction work	kg	1000	euro/m2	230.00	230.00	230.00	250.00	250.00	250.00	250.00	250.00	250.00	250.00	250.00
Railway transportation services	kg	0	euro/tkm	0.23	0.23	0.23	0.23	0.23	0.23	0.23	0.23	0.23	0.23	0.23
Freight transportation services by road	kg	0	euro/tkm	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30
Recycling plastic and rubber services	kg	0	euro/kg	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30
Recycling metals service	kg	0	euro/kg	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30
Recycling organic waste service	kg	0	euro/kg	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30
Incinerating waste service	kg	0	euro/kg	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30
Landfill of waste service	kg	0	euro/kg	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25

	prices (per purchaser)	Wind power plant	Manufacture of gas	Refinery	Construction enterprise	Railway company	Freight road transportation company	Recycle plastics and rubber plant	Recycle metals plant	Composting plant	Incinerator plant	Landfill	Households
Commodities:	unit:	12	13	14	15	16	17	18	19	20	21	22	
Wheat	euro/kg	0.58	0.58	0.58	0.58	0.58	0.58	0.58	0.58	0.58	0.58	0.58	0.65
Sugar beet	euro/kg	0.46	0.46	0.46	0.46	0.46	0.46	0.46	0.46	0.46	0.46	0.46	0.53
Soya beans	euro/kg	0.43	0.43	0.43	0.43	0.43	0.43	0.43	0.43	0.43	0.43	0.43	0.48
Metals	euro/kg	1.90	1.90	1.90	1.90	1.90	1.90	1.90	1.90	1.90	1.90	1.90	1.95
Rubber and plastics	euro/kg	2.00	2.00	2.00	1.95	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.05
soy oil	euro/kg	1.30	1.30	1.30	1.30	1.30	1.30	1.30	1.30	1.00	1.30	1.30	1.35
Fertilizers and pesticides	euro/kg	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.55
Chemicals	euro/kg	1.20	1.20	1.20	1.20	1.20	1.20	1.25	1.25	1.25	1.25	1.25	1.30
Water	euro/kg	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.06
Electrical energy from fossil fuels	euro/KWh	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.23
Photovoltaic energy	euro/KWh	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.25
Wind energy	euro/KWh	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.18
Manufactured gas	euro/kg	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.05
Refined petroleum products	euro/kg	1.30	1.30	1.30	1.30	1.30	1.30	1.30	1.30	1.30	1.30	1.30	1.35
Construction work	euro/m2	250.00	250.00	250.00	250.00	250.00	250.00	250.00	250.00	250.00	250.00	250.00	255.00
Railway transportation services	euro/tkm	0.23	0.23	0.23	0.23	0.23	0.23	0.23	0.23	0.23	0.23	0.23	0.23
Freight transportation services by road	euro/tkm	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.35
Recycling plastic and rubber services	euro/kg	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30
Recycling metals service	euro/kg	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30
Recycling organic waste service	euro/kg	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30
Incinerating waste service	euro/kg	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30
Landfill of waste service	euro/kg	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25

Fig. 8 – Physical and monetary demand and total households outlay by scenarios

	BASELINE				GREEN ENERGY					HIGH RECYCLING				
Commodities:	physical		worth		physical		worth		variation	physical		worth		variation
Wheat	kg	100.0	euro	65.0	kg	100.0	euro	65.0	0.00%	kg	100.0	euro	65.0	0.00%
Sugar beet	kg	50.0	euro	26.5	kg	50.0	euro	26.5	0.00%	kg	50.0	euro	26.5	0.00%
Soya beans	kg	60.0	euro	28.8	kg	60.0	euro	28.8	0.00%	kg	60.0	euro	28.8	0.00%
Metals	kg	0.0	euro	0.0	kg	0.0	euro	0.0	0.00%	kg	0.0	euro	0.0	0.00%
Rubber and plastics	kg	0.0	euro	0.0	kg	0.0	euro	0.0	0.00%	kg	0.0	euro	0.0	0.00%
soy oil	kg	10.0	euro	13.5	kg	10.0	euro	13.5	0.00%	kg	10.0	euro	13.5	0.00%
Fertilizers and pesticides	kg	0.0	euro	0.0	kg	0.0	euro	0.0	0.00%	kg	0.0	euro	0.0	0.00%
Chemicals	kg	0.0	euro	0.0	kg	0.0	euro	0.0	0.00%	kg	0.0	euro	0.0	0.00%
Water	kg	150.0	euro	9.0	kg	150.0	euro	9.0	0.00%	kg	150.0	euro	9.0	0.00%
Electrical energy from fossil fuels	KWh	45.0	euro	10.4	KWh	10.0	euro	2.3	-77.78%	KWh	45.0	euro	10.4	0.00%
Photovoltaic energy	KWh	2.5	euro	0.6	KWh	20.0	euro	5.0	700.00%	KWh	2.5	euro	0.6	0.00%
Wind energy	KWh	2.5	euro	0.5	KWh	20.0	euro	3.6	700.00%	KWh	2.5	euro	0.5	0.00%
Manufactured gas	kg	5.0	euro	0.3	kg	5.0	euro	0.3	0.00%	kg	5.0	euro	0.3	0.00%
Refined petroleum products	kg	0.0	euro	0.0	kg	0.0	euro	0.0	0.00%	kg	0.0	euro	0.0	0.00%
Construction work	m2	50.0	euro	12750.0	m2	50.0	euro	12750.0	0.00%	m2	50.0	euro	12750.0	0.00%
Railway transportation services	tkm	15.0	euro	3.5	tkm	15.0	euro	3.5	0.00%	tkm	15.0	euro	3.5	0.00%
Freight transportation services by road	tkm	10.0	euro	3.5	tkm	10.0	euro	3.5	0.00%	tkm	10.0	euro	3.5	0.00%
Recycling plastic and rubber services	kg	0.0	euro	0.0	kg	0.0	euro	0.0	0.00%	kg	0.2	euro	0.1	650.00%
Recycling metals service	kg	0.0	euro	0.0	kg	0.0	euro	0.0	0.00%	kg	0.0	euro	0.0	0.00%
Recycling organic waste service	kg	8.4	euro	2.5	kg	8.4	euro	2.5	0.00%	kg	63.0	euro	18.9	650.00%
Incinerating waste service	kg	22.7	euro	6.8	kg	22.7	euro	6.8	0.00%	kg	6.3	euro	1.9	-72.22%
Landfill of waste service	kg	53.1	euro	13.3	kg	53.1	euro	13.3	0.00%	kg	14.7	euro	3.7	-72.22%
Total households outlay			euro	12934.1			euro	12933.5	0.00%			euro	12936.0	0.01%

Fig. 9 – Quantity of commodities, worth and number of processes directly and indirectly generated by the demand (variation respect to the baseline)

	BASELINE					GREEN ENERGY							
	quantity of (functional) commodities		worth		number of processes	quantity of (functional) commodities		variation	worth		variation	number of processes	variation
Wheat	kg	166.82	euro	103.76	166.82	kg	166.45	-0.23%	euro	103.55	-0.21%	166.45	-0.23%
Sugar beet	kg	83.41	euro	42.54	83.41	kg	83.22	-0.23%	euro	42.45	-0.21%	83.22	-0.23%
Soya beans	kg	179.14	euro	80.03	179.14	kg	177.24	-1.06%	euro	79.21	-1.02%	177.24	-1.06%
Metals	kg	607.27	euro	1153.81	596.34	kg	607.37	0.02%	euro	1154.01	0.02%	596.44	0.02%
Rubber and plastics	kg	353.06	euro	688.61	344.2	kg	353.03	-0.01%	euro	688.56	-0.01%	344.17	-0.01%
soy oil	kg	108.31	euro	141.3	108.31	kg	106.58	-1.59%	euro	139.06	-1.58%	106.58	-1.59%
Fertilizers and pesticides	kg	29.53	euro	44.3	26.29	kg	29.43	-0.35%	euro	44.14	-0.35%	26.2	-0.34%
Chemicals	kg	175.94	euro	211.13	175.94	kg	175.92	-0.01%	euro	211.11	-0.01%	175.92	-0.01%
Water	kg	4481.22	euro	49.08	4481.22	kg	4464.26	-0.38%	euro	48.93	-0.32%	4464.26	-0.38%
Electrical energy from fossil fuels	KWh	947.24	euro	172.75	741.11	KWh	210.28	-77.80%	euro	38.35	-77.80%	4.48	-99.40%
Photovoltaic energy	KWh	52.62	euro	10.65	52.62	KWh	420.57	699.18%	euro	85.11	699.19%	420.57	699.18%
Wind energy	KWh	52.62	euro	6.97	52.62	KWh	420.57	699.18%	euro	55.67	699.20%	420.57	699.18%
Manufactured gas	kg	1479.54	euro	32.7	1479.54	kg	1462.67	-1.14%	euro	32.33	-1.13%	1462.67	-1.14%
Refined petroleum products	kg	1966.11	euro	2554.13	1966.11	kg	1931.68	-1.75%	euro	2509.39	-1.75%	1931.68	-1.75%
Construction work	m2	50.01	euro	12751.84	50.01	m2	50.01	0.00%	euro	12751.79	0.00%	50.01	0.00%
Railway transportation services	tkm	131.83	euro	30.32	131.83	tkm	130.76	-0.81%	euro	30.07	-0.81%	130.76	-0.81%
Freight transportation services by road	tkm	653.87	euro	196.66	653.87	tkm	652.06	-0.28%	euro	196.12	-0.28%	652.06	-0.28%
Recycling plastic and rubber services	kg	35.44	euro	10.63	35.44	kg	35.43	-0.01%	euro	10.63	-0.01%	35.43	-0.01%
Recycling metals service	kg	12.15	euro	3.64	12.15	kg	12.15	0.02%	euro	3.64	0.02%	12.15	0.02%
Recycling organic waste service	kg	32.45	euro	9.74	32.45	kg	32.31	-0.44%	euro	9.69	-0.44%	32.31	-0.44%
Incinerating waste service	kg	242.51	euro	72.75	242.51	kg	242.12	-0.16%	euro	72.64	-0.16%	242.12	-0.16%
Landfill of waste service	kg	3169.29	euro	792.32	3169.29	kg	3146.68	-0.71%	euro	786.67	-0.71%	3146.68	-0.71%

	HIGH RECYCLING							
	quantity of (functional) commodities		variation	worth		variation	number of processes	variation
Wheat	kg	167.54	0.43%	euro	104.18	0.40%	167.54	0.43%
Sugar beet	kg	83.77	0.43%	euro	42.71	0.40%	83.77	0.43%
Soya beans	kg	173.42	-3.19%	euro	77.57	-3.07%	173.42	-3.19%
Metals	kg	606.93	-0.06%	euro	1153.16	-0.06%	524.99	-13.55%
Rubber and plastics	kg	352.97	-0.02%	euro	688.45	-0.02%	286.55	-18.84%
soy oil	kg	103.11	-4.79%	euro	134.55	-4.78%	103.11	-4.79%
Fertilizers and pesticides	kg	29.37	-0.54%	euro	44.06	-0.54%	5.16	-82.52%
Chemicals	kg	175.9	-0.02%	euro	211.08	-0.02%	175.9	-0.02%
Water	kg	4529.77	1.08%	euro	49.59	1.03%	4529.77	1.08%
Electrical energy from fossil fuels	KWh	908.16	-4.13%	euro	165.72	-4.07%	688.06	-27.36%
Photovoltaic energy	KWh	50.45	-4.13%	euro	10.22	-4.08%	50.45	-4.13%
Wind energy	KWh	50.45	-4.13%	euro	6.68	-4.05%	50.45	-4.13%
Manufactured gas	kg	1367.03	-7.60%	euro	30.22	-7.57%	1367.03	-7.60%
Refined petroleum products	kg	1862.26	-5.28%	euro	2419.16	-5.28%	1862.26	-5.28%
Construction work	m2	50.01	0.00%	euro	12751.8	0.00%	50.01	0.00%
Railway transportation services	tkm	101.98	-22.65%	euro	23.45	-22.65%	101.98	-22.65%
Freight transportation services by road	tkm	640.31	-2.08%	euro	192.59	-2.07%	640.31	-2.08%
Recycling plastic and rubber services	kg	265.69	649.78%	euro	79.71	649.78%	265.69	649.78%
Recycling metals service	kg	91.04	649.58%	euro	27.31	649.58%	91.04	649.58%
Recycling organic waste service	kg	241.57	644.41%	euro	72.47	644.41%	241.57	644.41%
Incinerating waste service	kg	258.95	6.78%	euro	77.68	6.78%	258.95	6.78%
Landfill of waste service	kg	2663.42	-15.96%	euro	665.86	-15.96%	2663.42	-15.96%

Fig. 10 – Value-added chains, breakdown by primary factors (variation respect to the baseline)

		BASELINE		GREEN ENERGY				HIGH RECYCLING			
activities:		labor	capital	labor	variation	capital	variation	labor	variation	capital	variation
Wheat	euro	29.19	3.66	29.13	*-0.23%*	3.75	*2.60%*	29.32	0.43%	1.73	-52.75%
Sugar beet	euro	2.69	0.55	2.68	*-0.23%*	0.59	*8.81%*	2.70	0.43%	-0.42	-176.51%
Soya beans	euro	7.02	9.17	6.95	*-1.06%*	9.2	*0.30%*	6.80	-3.19%	7.78	-15.09%
Metals	euro	104.36	164.19	104.38	*0.02%*	164.32	*0.08%*	91.87	-11.96%	144.53	-11.97%
Rubber and plastics	euro	60.23	102.98	60.23	*-0.01%*	108.49	*5.35%*	50.15	-16.75%	85.72	-16.76%
soy oil	euro	18.95	15.89	18.65	*-1.59%*	15.73	*-1.03%*	18.04	-4.79%	14.67	-7.65%
Fertilizers and pesticides	euro	4.6	0.68	4.58	*-0.34%*	0.69	*1.72%*	0.9	-80.36%	0.13	-80.39%
Chemicals	euro	21.55	16.66	21.55	*-0.01%*	20.26	*21.62%*	21.55	-0.02%	16.65	-0.06%
Water	euro	31.37	16.89	31.25	*-0.38%*	16.88	*-0.08%*	31.71	1.08%	17.04	0.88%
Electrical energy from fossil fuels	euro	43.23	47.75	0.26	*-99.40%*	0.29	*-99.40%*	40.14	-7.16%	44.4	-7.03%
Photovoltaic energy	euro	2.3	8.28	18.4	*699.18%*	66.2	*699.19%*	2.21	-4.13%	7.95	-4.07%
Wind energy	euro	1.44	5.47	11.5	*699.18%*	43.68	*699.20%*	1.38	-4.13%	5.25	-4.04%
Manufactured gas	euro	25.89	6.36	25.6	*-1.14%*	6.29	*-1.10%*	23.92	-7.60%	5.88	-7.50%
Refined petroleum products	euro	344.07	1803.82	338.04	*-1.75%*	1772.47	*-1.74%*	325.9	-5.28%	1708.39	-5.29%
Construction work	euro	3500.51	5782.63	3500.5	*0.00%*	5782.77	*0.00%*	3500.5	0.00%	5771.2	-0.20%
Railway transportation services	euro	23.07	3.86	22.88	*-0.81%*	3.9	*0.90%*	17.85	-22.65%	2.98	-22.81%
Freight transportation services by road	euro	114.43	30.71	114.11	*-0.28%*	30.63	*-0.27%*	112.05	-2.08%	30.03	-2.22%
Recycling plastic and rubber services	euro	7.44	6.08	7.44	*-0.01%*	6.16	*1.39%*	55.79	649.78%	45.56	649.52%
Recycling metals service	euro	4.25	11.66	4.25	*0.02%*	11.66	*0.03%*	31.86	649.58%	87.36	649.53%
Recycling organic waste service	euro	11.36	2.46	11.31	*-0.44%*	2.46	*-0.27%*	84.55	644.41%	18.53	652.34%
Incinerating waste service	euro	42.44	49.64	42.37	*-0.16%*	49.56	*-0.16%*	45.32	6.78%	53.02	6.80%
Landfill of waste service	euro	277.31	166.94	275.33	*-0.71%*	166.14	*-0.48%*	233.05	-15.96%	140.02	-16.12%
Partial total		4677.72	8256.34	4651.4	*-0.56%*	8282.13	*0.31%*	4727.56	1.07%	8208.42	-0.58%
Total			12934.06			12933.53	*0.00%*			12935.97	0.01%

Fig. 11 – Environmental pressures (variation respect to the baseline)

		BASELINE	GREEN ENERGY		HIGH RECYCLING	
environmental resources (IN)		physical	physical	variation	physical	variation
land	m2	-1128.12	-1122.56	-0.49%	-1114.58	-1.20%
metals ore	kg	-715.6	-715.73	0.02%	-629.99	-11.96%
ammonium	kg	-23.66	-23.58	-0.34%	-4.65	-80.36%
CO2	kg	-28.92	-28.82	-0.34%	-5.68	-80.36%
oil	kg	-1966.11	-1931.68	-1.75%	-1862.26	-5.28%
gas	kg	-1509.13	-1491.93	-1.14%	-1394.37	-7.60%
calcium	kg	-32004.7	-32004.59	0.00%	-32004.6	0.00%
silicon	kg	-10501.54	-10501.51	0.00%	-10501.51	0.00%
water	kg	-16790.15	-16764.68	-0.15%	-16862.94	0.43%
oxygen	kg	-4974.44	-4887.71	-1.74%	-4710.33	-5.31%
nutrients/minerals	kg	-389.47	-389.01	-0.12%	-353.44	-9.25%
disposals/emission (OUT)						
use of land	m2	1128.12	1122.56	-0.49%	1114.58	-1.20%
waste (landfill)	kg	2762.84	2743.13	-0.71%	2320.94	-15.99%
hazardous materials	kg	72.77	72.65	-0.16%	77.77	6.88%
water vapor	kg	2337.13	2327.22	-0.42%	2427.58	3.87%
other gases (no-CO2)	kg	377.14	361.11	-4.25%	340.75	-9.65%
sewage	kg	6982.93	6969.13	-0.20%	7012.95	0.43%
CO2	kg	6151.65	6047.29	-1.70%	5846.45	-4.96%
residuals	kg	198.94	198.6	-0.17%	199.28	0.17%
new fixed assets						
concrete	kg	50007.34	50007.18	0.00%	50007.18	0.00%
new accumulation (extra-mass)						
ground (organic fertilizer)	kg	12.98	12.93	-0.44%	96.85	645.86%
MASS BALANCE	kg	0.00	0.00		0.00	

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