FORWAST

Training on Forwast environmental accounts

December 2009

Geoscience for a sustainable Earth

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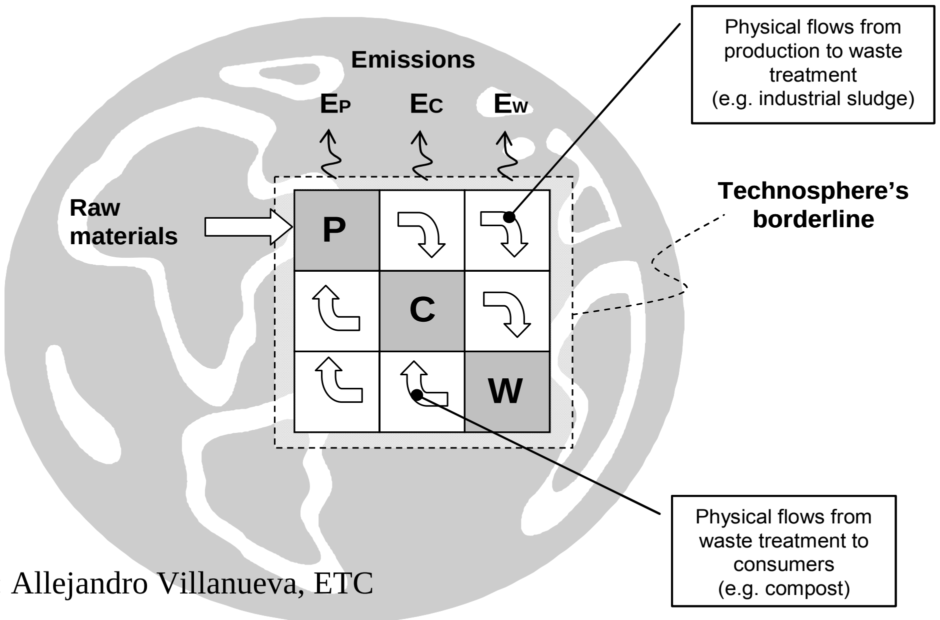
Forwast (http://forwast.brgm.fr)

> Forwast is designed for:

- Mapping of physical flows and stocks of resources
- Forecasting future waste quantities (including those from stocks) in the next 25 years
- Identify life-cycle environmental stakes of waste recycling and prevention



Graphics: Allejandro Villanueva, ETC

Organisation of the document

> **3 chapters**

- Model building for mapping of physical flows and stocks of resources
- Scenarios for forecasting future waste quantities
- Model’s results: Life-cycle environmental stakes of waste recycling and prevention

Preliminary note

- Forwast is built on a Leontief-type environmentally extended, quasi-dynamic, physical input-output model covering the EU27.
- The structure of the project includes some 60% effort on the mining of basic national data to feed the model.
- It is a choice of the designer of this “learning” to drive the presentation with the structure of the work plan rather than the objectives of the project.

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Model building for mapping of physical flows and stocks of resources

Scenarios for forecasting future waste quantities

Model's results: Life-cycle environmental stakes of waste recycling and prevention

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Mapping of physical flows and stocks of resources - topic

- The economy consumes resources to make products
  - **A part of these resources do not end in products and are transformed into waste or emissions**
  - **Products build up the “stock” of materials in the economy**
- The stock degrades in time
  - **Products end in waste after their life time**
  - **Waste are collected and treated to generate recycled materials and energy**
  - **A part of these waste ends in landfills and emissions**

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Model building for the mapping of physical flows and stocks of resources - summary

> The situation of resources use in Europe
> National accounting – Supply and Use Tables, Input/Output Table
> Environmental extensions – accounting for waste - disaggregation
> Principle of the Forwast Mass balance per activity
> Principles for calculating waste flows and stocks
> Feeding the SUTs – a tour on available databases
> How the model work? - summary

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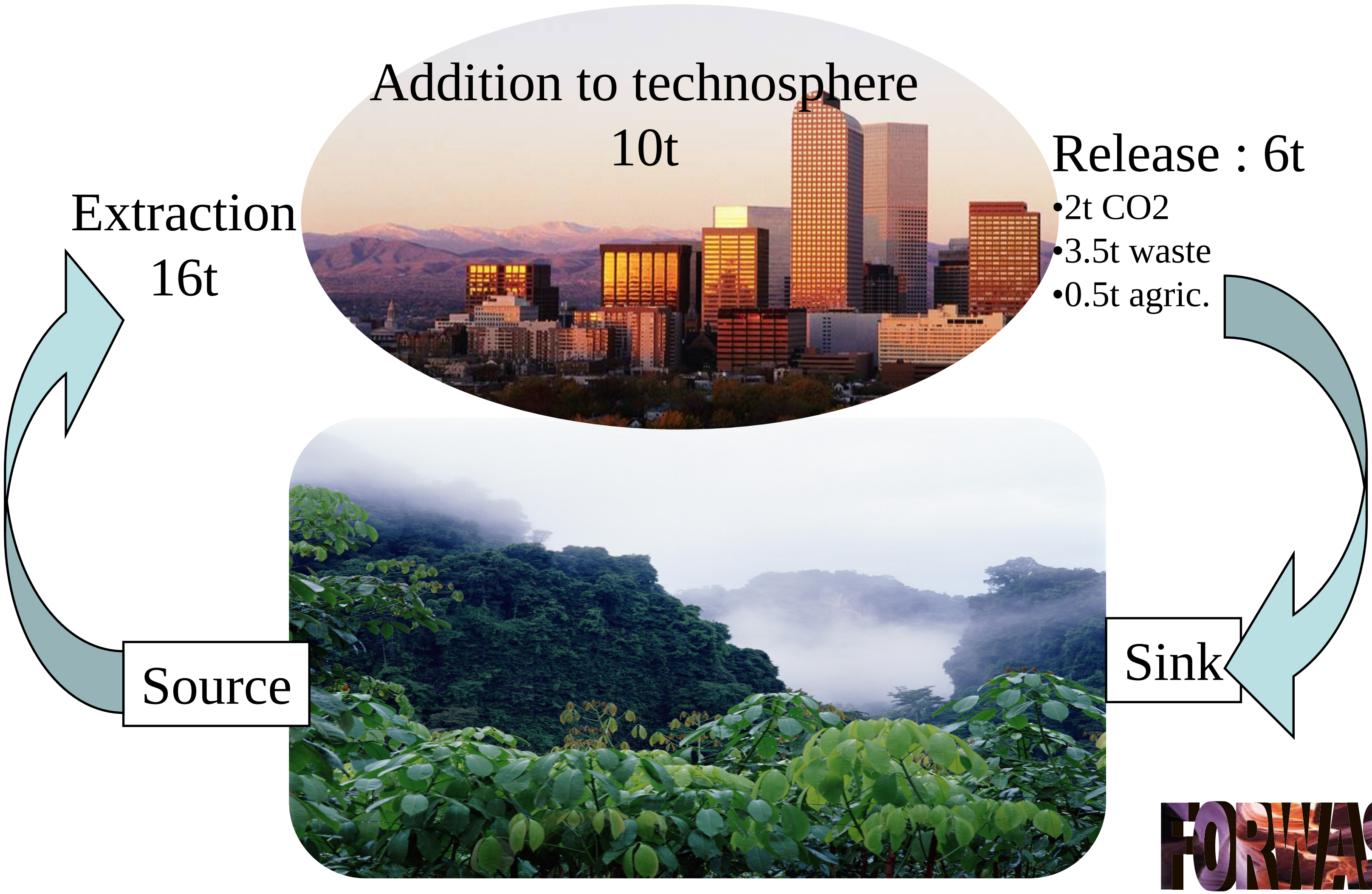
Enormous resource use in Europe (per capita per year)



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The situation of resources use in Europe

> **Natural resources use in Europe**

- Supporting study

To support the development of a *Thematic Strategy for Sustainable Use and Management of Resources*, a material flow accounting (MFA) study conducted by the European Topic Centre on Waste and Material flows provided in 2003 “an estimate of materials and waste streams in the Community, including imports and exports”.

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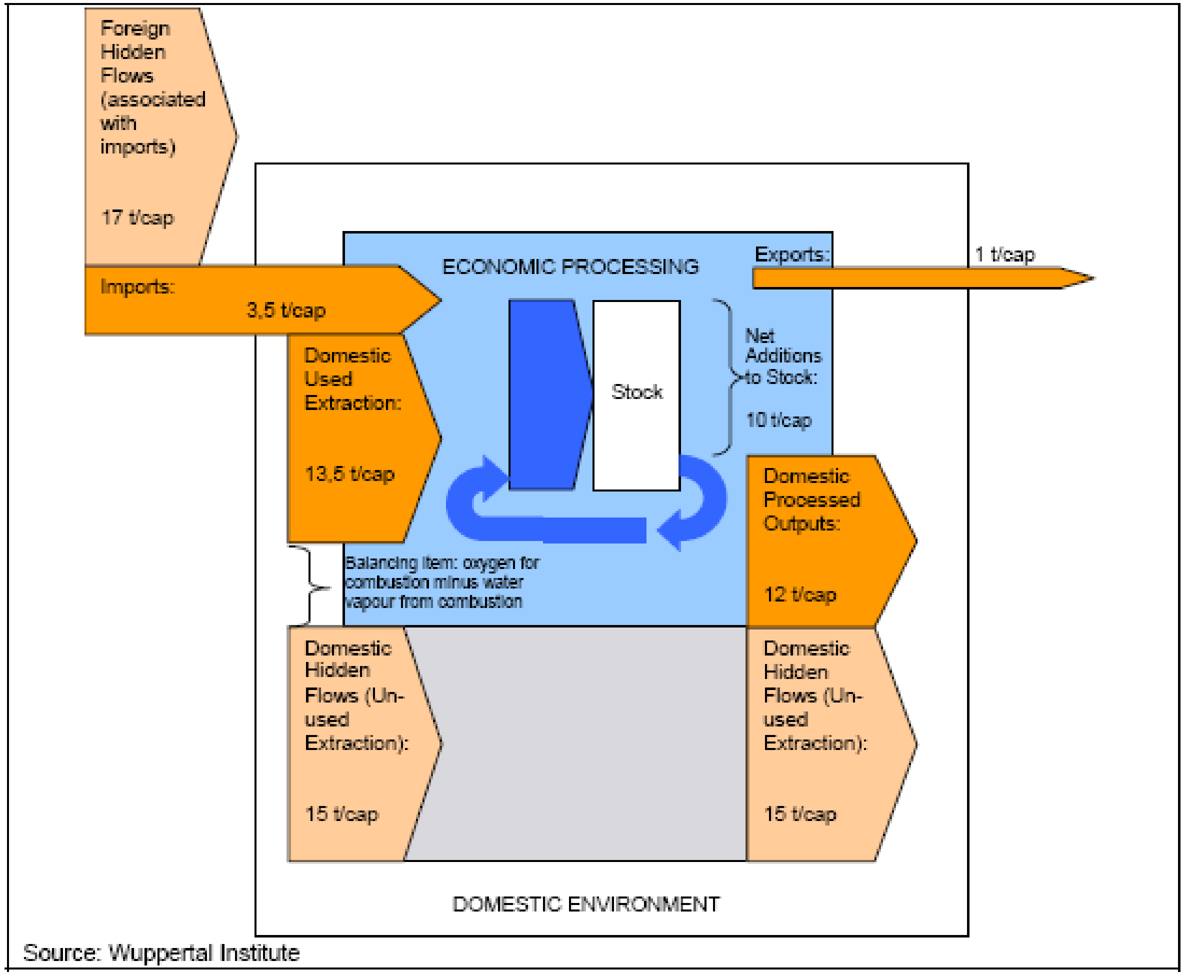
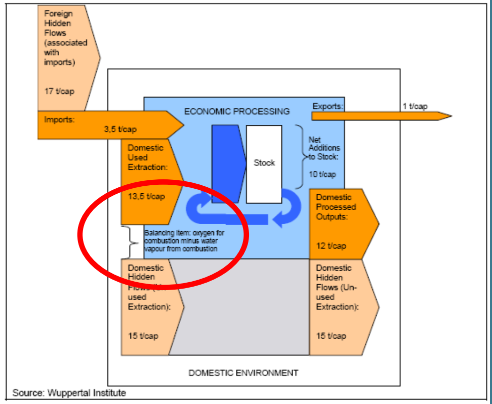
Estimated economy-wide material flows in the EU

> on a per capita and year basis and for the second half of the 1990ies



Source: “Resource Use in European Countries”, March 2003, European Topic Centre on Waste and Material Flows (ETC-WMF) http://ec.europa.eu/environment/natres/pdf/zero_study_final.pdf

MFA and “balancing item”



> **Imports + domestic used extraction**
- 17 t/cap

> **Exports + addition to stock + domestic processed outputs**
- 23 t/cap

> **Combustion:**
- Example of fuel : $H\text{-}(CH_2)_8\text{-}H + 12.5\ O_2 \rightarrow 8\ CO_2 + 9\ H_2O$
- In kg: 1 Fuel + 3.5 O_2 -> 3.1 CO_2 + 1.4 H_2O
- (+) Oxygen (-) water = 2.1 kg created by combustion
- 2.1 kg represents the “balancing item” when counting Fuel as input and CO2 as output

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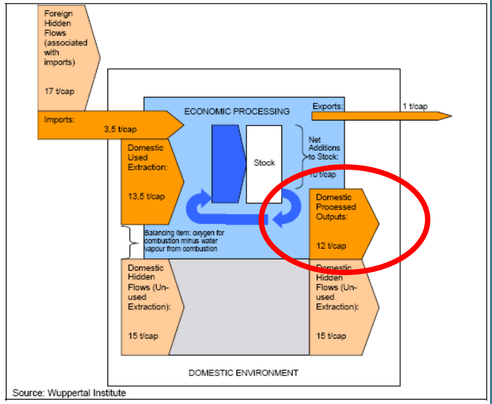
Domestic processed outputs



> **Outputs of the economy to the environment : 12 t/cap**

- Air emissions 10 – 11 t/cap
  - 95% as CO_2, or 9-10 t/cap (2 t/cap as C)
- Waste landfilled
  - 1t/cap
- Dissipative losses (ex: tyres, corrosion), dissipative use of products (ex: fertilisers)
  - 300 kg/cap

What are the main flows of resources used in European Economy?

- A resource is understood to be coming “from environment” (Natural resources)
  - A mineral deposit is a resource; a concentrate from mine is a product
  - Grass used for growing cattle is a resource

- Selection of resources

The selection of resources to be considered has been made by assessing their importance through the amount of their total material turnover. By identifying the most important resource flows, the most important waste flows are known as well.

Bibliography

> Example: Yearly turnover of Austria´s most important resources based on ABASG-II-Güter [Daxbeck et al., 2003].

Resource category	Amount [t]	Amount [%]
Total turnover	**143.540.000**	**100,0%**
Gravel & Sand	65.000.000	45,3%
Stone	30.000.000	20,9%
Crude oil	11.200.000	7,8%
Wood	9.450.000	6,6%
Iron / Iron Ore	7.000.000	4,9%
Coal	6.600.000	4,6%
Food biomass (solid)	6.000.000	4,2%
Paper & Cardboard	4.400.000	3,1%
Clay	1.700.000	1,2%
Plastics	1.100.000	0,8%
Salt	600.000	0,4%
Aluminium	230.000	0,2%
Textiles	150.000	0,1%
Copper [1]	110.000	0,08%

Natural resources considered in Forwast

> **Selected resources categories**
- Different sources of carbon
- Metals
- Oxygen as a component of products
- Weighty materials

> **This list constitutes a minimum set but may be enlarged**

Material No.	**Material**
1	Aluminium
2	Fibre carbon
3	Food carbon, (including tobacco)
4	Coal carbon
5	Crude oil and natural gas carbon
6	Carbonate carbon
7	Copper
8	Iron
9	Metals, n.e.c.
10	Minerals, n.e.c. (including nitrogen)
11	Oxygen (only in products, but not in H2O)
12	Clay and soil
13	Sand, gravel and stone
14	**Total material (T)**

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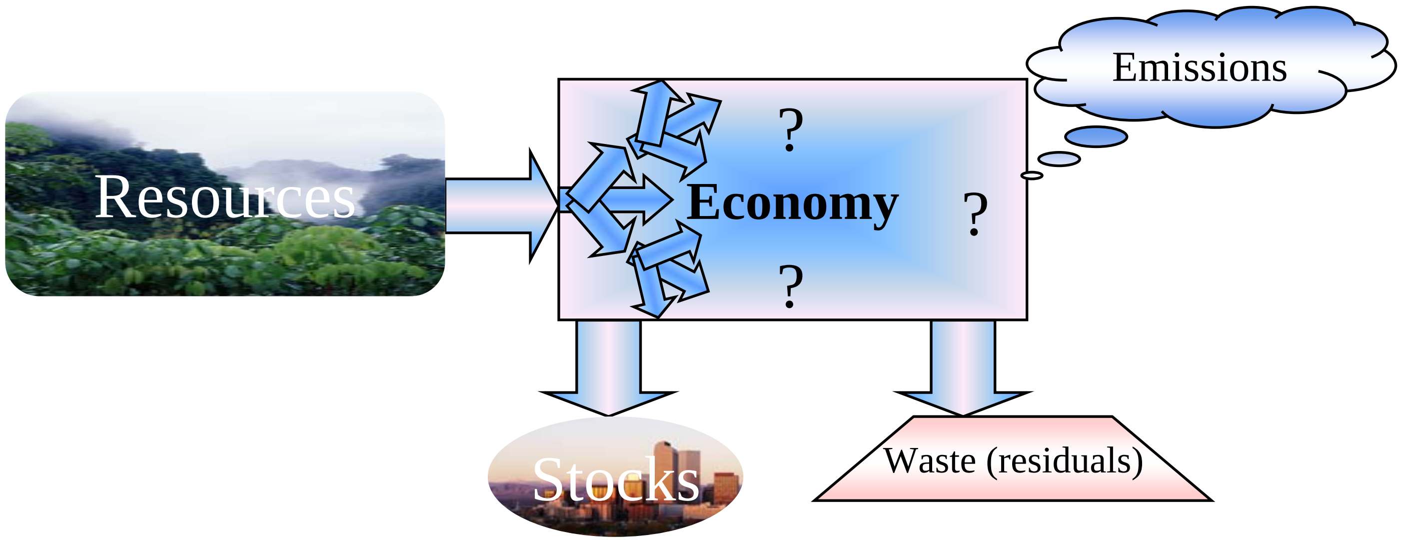
Problem statement

> **Where are the resources used?**



> **Mass balance of the economy**

Within the FORWAST project the most important resource flows throughout the economy of the EU-27 are identified and balanced.
The national economy describes the whole of public and private economic activities of a nation and the economic relations between different nations.
To picture the mass flows between the activities, the economic framework of Input/Ouput tables is used.

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Sectors of the economy

> **In general, economy is divided in three sectors:**

- **Primary sector:** initial production that covers the extraction of resources and supply of primary products made from resources.
- **Secondary sector:** covers the processing and manufacture of primary and secondary products to consumer products by business and industry.
- **Tertiary sector:** represents the consumption and covers the provision of services incl. public and private administration as well as private households.

> **The sectors are divided in a number of "industries" or "activities" or also "commodities"**

- This comes from the fact that an "industry" is named as the main commodity it supplies. Example: "Agriculture" supplies "Agricultural products"

Industries / Products	Industries		
	Agriculture	Industry	Service activities
Agricultural products			
Industrial products		Output by product and by industry	
Services			
Total		Total output by industry	

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National accounting - supply table (monetary)

> Simplified supply table

- Gives the (monetary) production of products by industries
- Should ideally be diagonal, but industries may supply co-products

NACE classification

Products \ Industries	Industries			Imports	Total
	Agriculture	Industry	Service activities		
Agricultural products	Output by product and by industry			Imports by product	Total supply by product
Industrial products					
Services					
Total	Total output by industry			Total imports	Total supply

Source: Eurostat Manual of Supply, Use and Input-Output Tables, ISSN 1977-0375

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National accounting - use table (monetary)

> Simplified use table

- Gives the (monetary) use of products by industries (intermediate consumption)
- Gives the “final uses”

Industries / Products	Industries			Final uses			Total
	Agriculture	Industry	Service activities	Final consumption	Gross capital formation	Exports	
Agricultural products Industrial products Services	Intermediate consumption by product and by industry			Final uses by product and by category			Total use by product
Value added	Value added by component and by industry						Value added
Total	Total output by industry			Total final uses by category			

Source: Eurostat Manual of Supply, Use and Input-Output Tables, ISSN 1977-0375

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National Accounting Matrix (NAM) - Supply and Use balances

> Combining the SUTs

- Output by industry = Input by industry
- Total supply by product = Total use by product

		Products			Industries			Final uses			Total
		Agri-cultural products	Industrial products	Services	Agri-culture	Industry	Service activities	Final con-sumption	Gross capital formation	Exports	
Products	Agricultural products				Intermediate consumption by product and by industry			Final uses by product and by category			Total use by product
	Industrial products										
	Services										
Industries	Agriculture	Output of industries by product									Total output by industry
	Industry										
	Service activities										
Value added					Value added by component and by industry						Total value added
Imports		Total imports by product									Total imports
Total		Total supply by product			Total output by industry			Total final uses by category			

= not applicable

Source: Eurostat Manual of Supply, Use and Input-Output Tables, ISSN 1977-0375

Calculating symetrical IO table from NAM

> **Build a matrix of input coefficients for intermediate consumption (technology matrix A)**
- If S is diagonal, we can have from U the uses of products and services per unit of supply
- In general, S is not diagonal (several products are supplied by an industry)

⇨ Hypothesis to "allocate" the uses to the different supplied products

> **Solve the Leontief system:**
- Total output = intermediate consumption + final demand

$$\mathbf{q = A.q + f}$$

- Total output as a function of the final demand

$$\mathbf{(I\text{-}A).q = f :\ \ q = (I\text{-}A)^{-1}.f}$$

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Interest of IOT

> **To calculate the inputs requirements per unit output**

- **How much of each inputs from other industries/sectors to produce 1€ of a product?**
- **How much is produced in each industry/sector to satisfy 1€ of final demand from a specific sector?**

Products / Products	Homogeneous units of production			Final uses			Total use
	Agricultural products	Industrial prodcts	Services	Final con-sumption	Gross capital formation	Exports	
Agricultural products Industrial products Services	Intermediate consumption by product and by homogeneous units of production			Final uses by product and by category			Total use by product
Value added	Value added by component and by homogeneous units of production						
Imports for similar products	Total imports by product						
Supply	Total supply by homogeneous units of production			Total final uses by category			

Source: Eurostat Manual of Supply, Use and Input-Output Tables, ISSN 1977-0375

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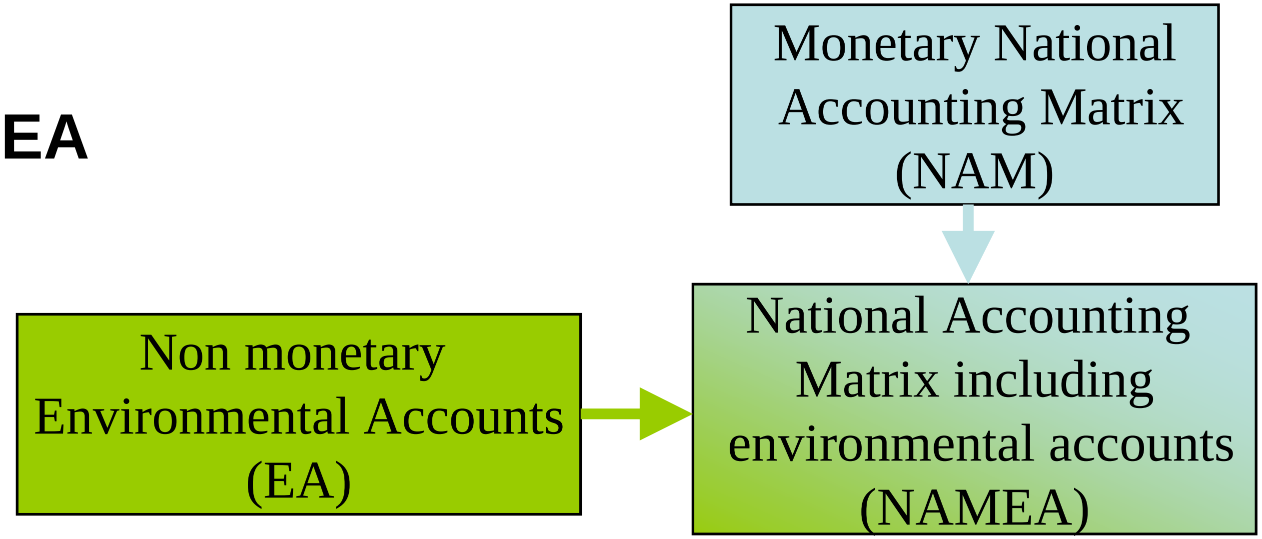
Environmental extensions

> **NAMEA**



> **Current extensions concern Air and Water emissions**

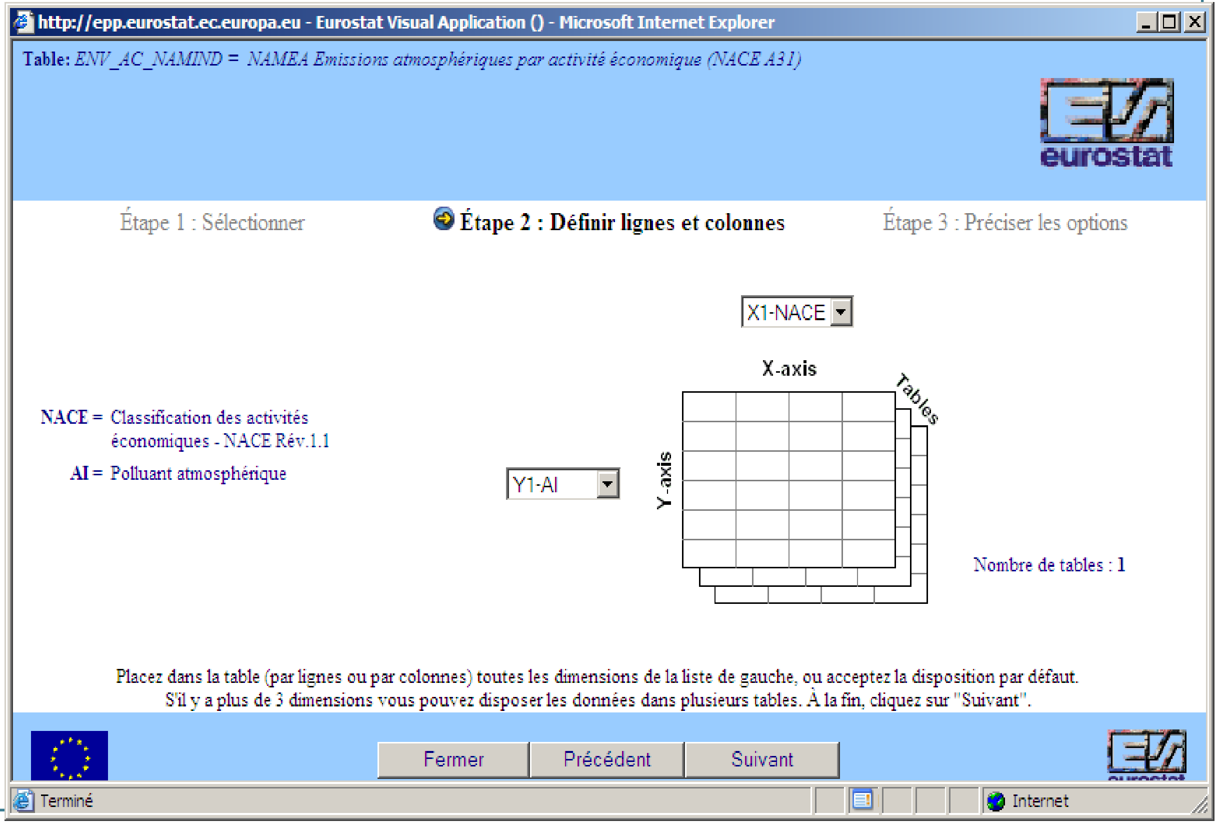
- Generally, total emissions per industry are added to the SUTs
- Interpreted within the IOT as emissions per unit (Euro) of final demand

NAMEA data

> NAMEA

- Use of **IO framework** (European System of Accounts 95)
- Extended with satellite accounts: presently air and water emissions

> IO Tables available at Eurostat size 59*59



Problems with waste

> **Waste occur at all stages of the life-cycle of materials**

- Waste from stocks (after the use phase of products) may appear several years after the production
- Different types of waste must be included in the list of “products” (even for households for example)
- Different types of waste treatment must be included in the list of “industries”
- Recycling displaces primary materials: this obliges to consider the **physical** flows of recycled materials within the economy

Accounting for waste

- Waste quantities arise from all sectors of the economy, final consumption, stock degradation and waste treatments
- The monetary I/O tables in Eurostat are based on the “2 digits” level of the NACE
  - waste management is poorly described by 3 activities: “recycling”, “waste treatments” and “waste water treatment”
- Two problems
  - Making waste flows appear in the I/O framework
  - Calculating waste flows

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Arrangements of SUTs in Forwast

> **We disaggregate the waste management sector**
>
> - collection, treatment and disposal of wastes and sewage by public and private enterprises, main potential provider of secondary resources, avoiding the use of primary resources

> **We disaggregate industries providing different types of waste and using recycled materials**

Disaggregation - example

> **Disaggregate activities to include recycling**

- 3 activities around the Point of substitution

Original Product Categories	NACE Code	NEW Product Categories (FORWAST 134)
Basic metals	27.1(disaggr.)	Iron basic, virgin
Basic metals	27.1(disaggr.)	Iron basic, recycled
Basic metals	27.42(disaggr.)	Aluminium basic, virgin
Basic metals	27.42(disaggr.)	Aluminium basic, recycled
Basic metals	27.44(disaggr.)	Copper basic, virgin
Basic metals	27.44(disaggr.)	Copper basic, recycled
Basic metals	27.4(disaggr.)	Metals basic, n.e.c., virgin
Basic metals	27.4(disaggr.)	Metals basic, n.e.c., recycled
Basic metals	27.2(disaggr.)+27.3(disaggr.)+27.5(disaggr.)	Iron, after first processing
Basic metals	27.2(disaggr.)+27.3(disaggr.)+27.5(disaggr.)	Aluminium, after first processing
Basic metals	27.2(disaggr.)+27.3(disaggr.)+27.5(disaggr.)	Copper, after first processing
Basic metals	27.2(disaggr.)+27.3(disaggr.)+27.5(disaggr.)	Metals n.e.c., after first processing

1 product in Eurostat 59*59 IOTs

⇨ This leads to 127*127 matrices in Forwast

Including waste recycling and treatment

> **We disaggregated 12 sectors/industries**

- to account for different types of waste
- to account for different management routes of these waste
  - Recycling of waste: wood, paper, oils, plastics, glass+mineral wool+ceramic, slags&ashes, concrete+asphalt+minerals, bricks, iron, aluminium, copper, other metals
  - Treatments: Incineration, Manure treatment, Biogasification, Composting of food waste, Waste water treatment, Landfill, Land application of waste, Unexpected waste
- See the list

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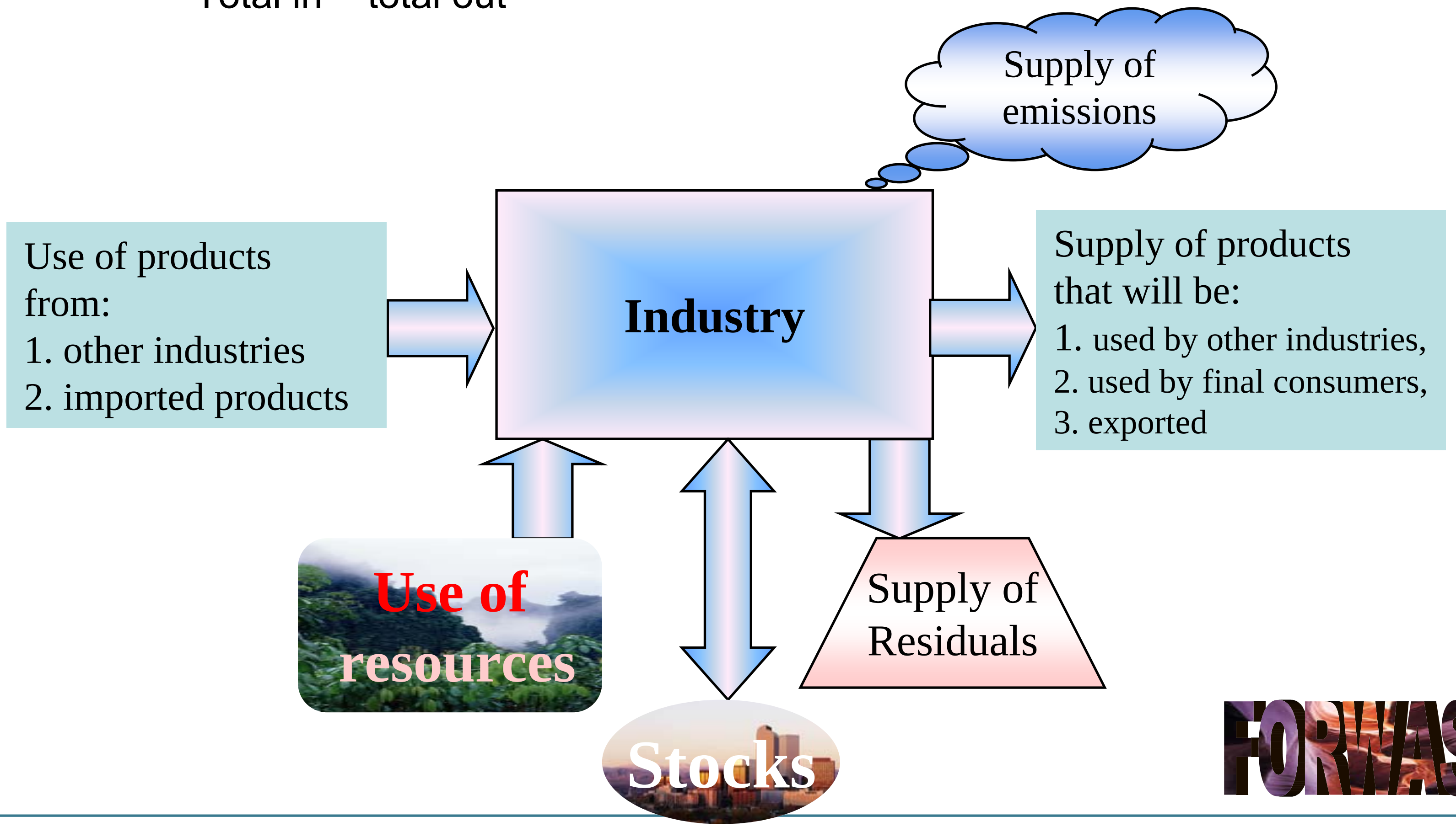
Principle of the Forwast mass balance per activity

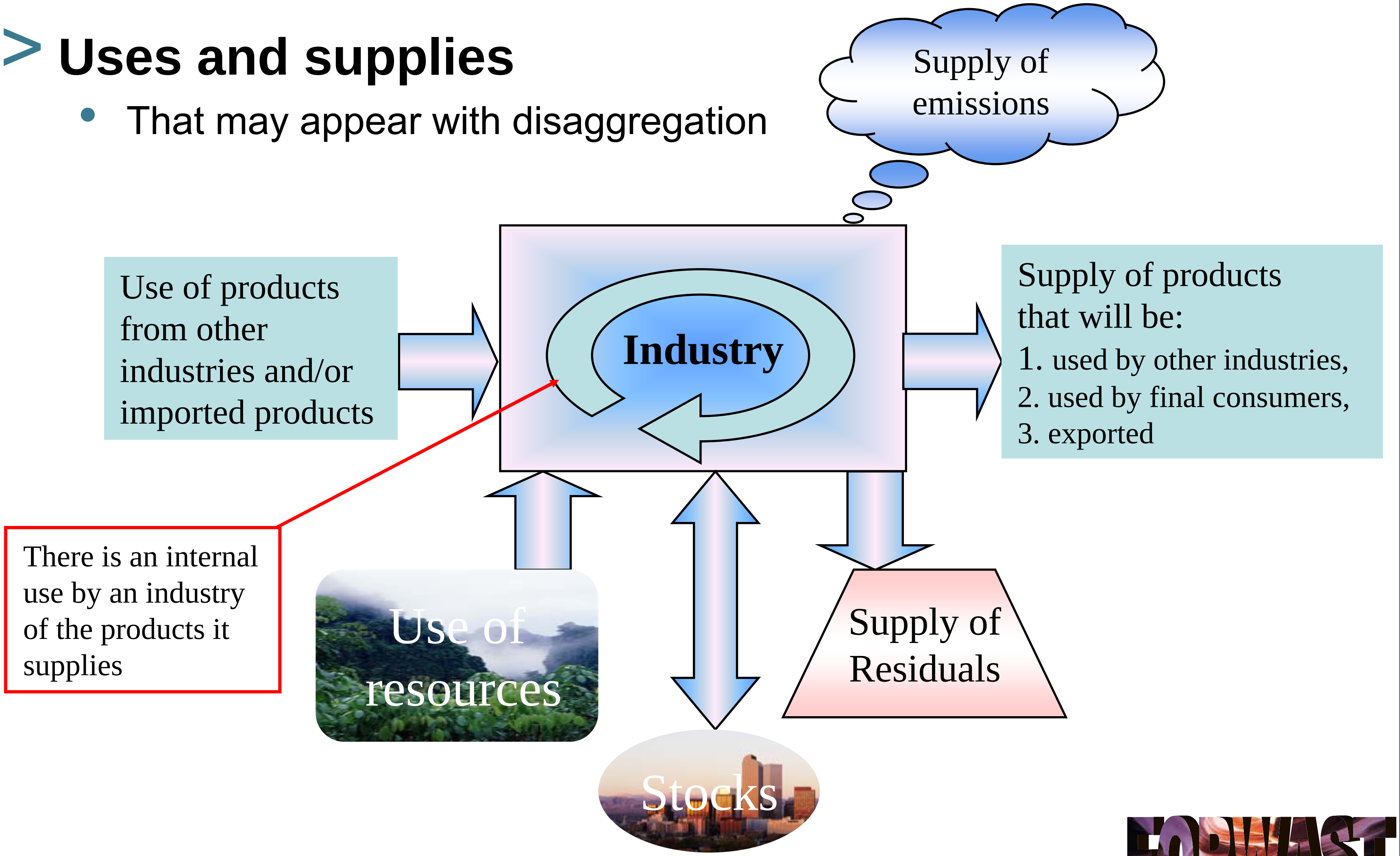
- **The “economy” is divided in activities**
  - 59 activities in Eurostat “National Accounts”
- **Material flows used and supplied by each activity**
  - Total in = total out



Principle of the Forwast mass balance per sector/ industry

> Uses and supplies

- That may appear with disaggregation



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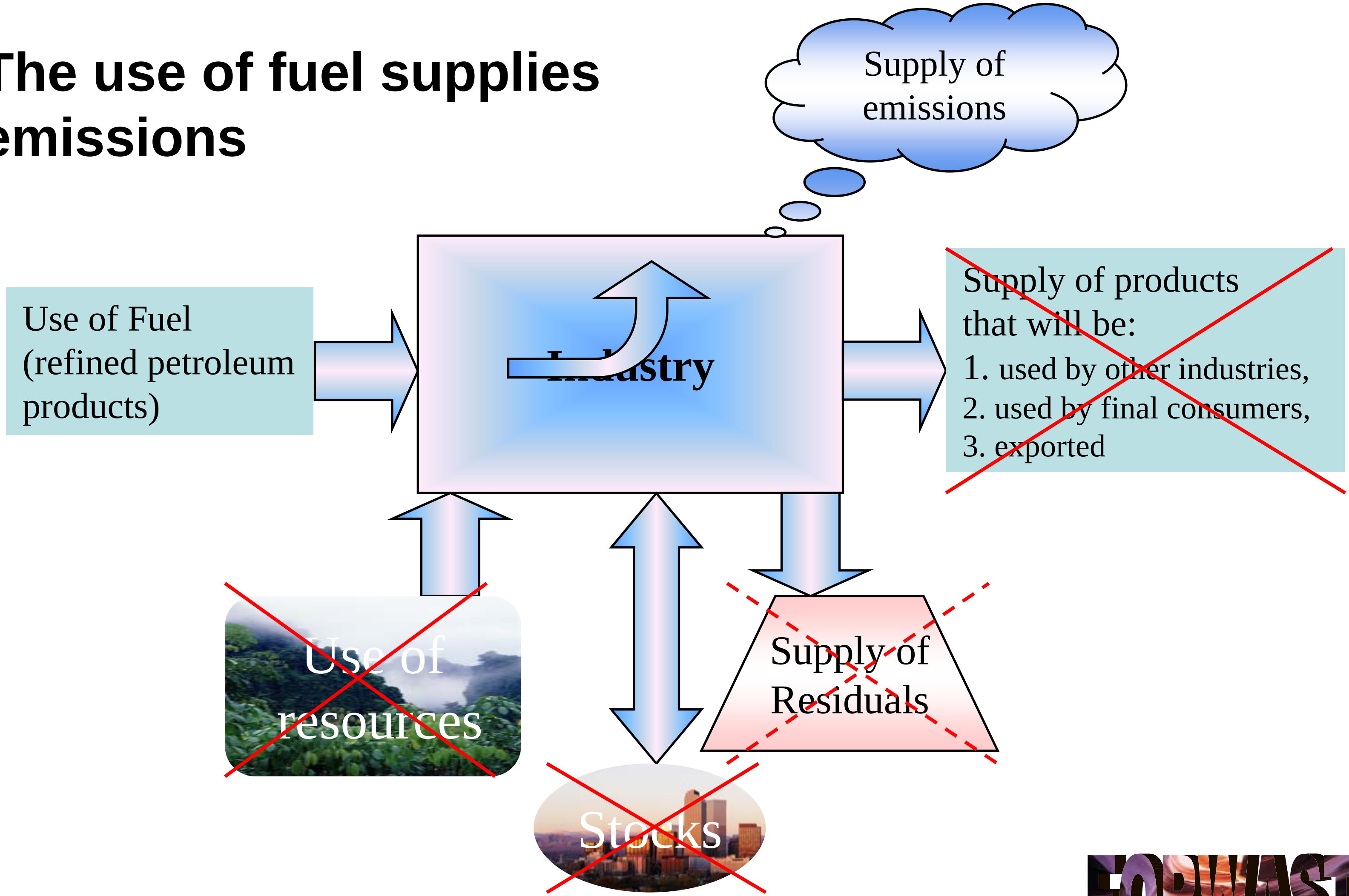
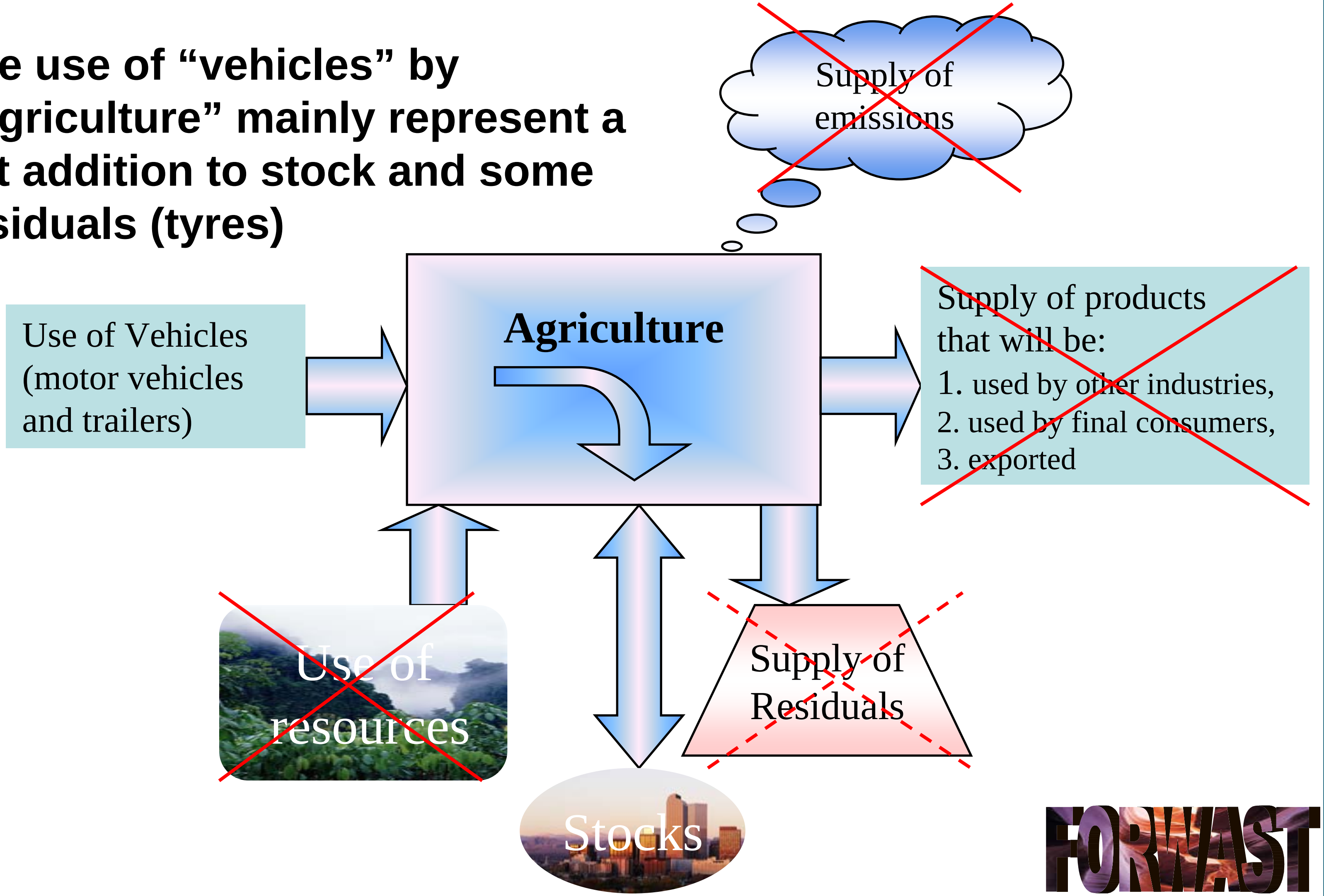
Mass balance per industry – Fuels

> **The use of fuel supplies emissions**



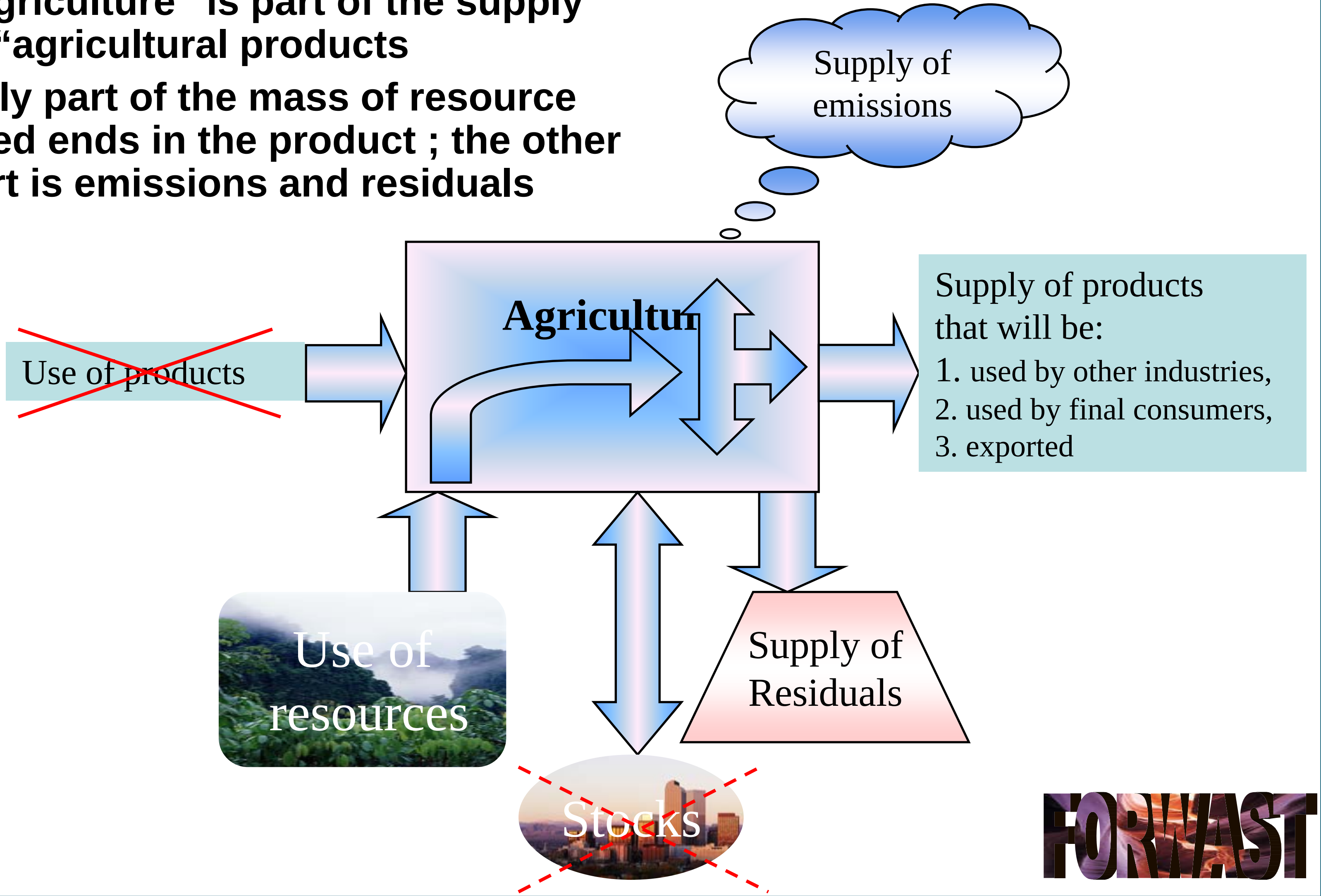
Mass balance per industry – use of products that are not part of the supplied products

- **The use of “vehicles” by “Agriculture” mainly represent a net addition to stock and some residuals (tyres)**



Mass balance per industry – use of resources

- **The use of “resources” by “Agriculture” is part of the supply of “agricultural products**
- **Only part of the mass of resource used ends in the product ; the other part is emissions and residuals**



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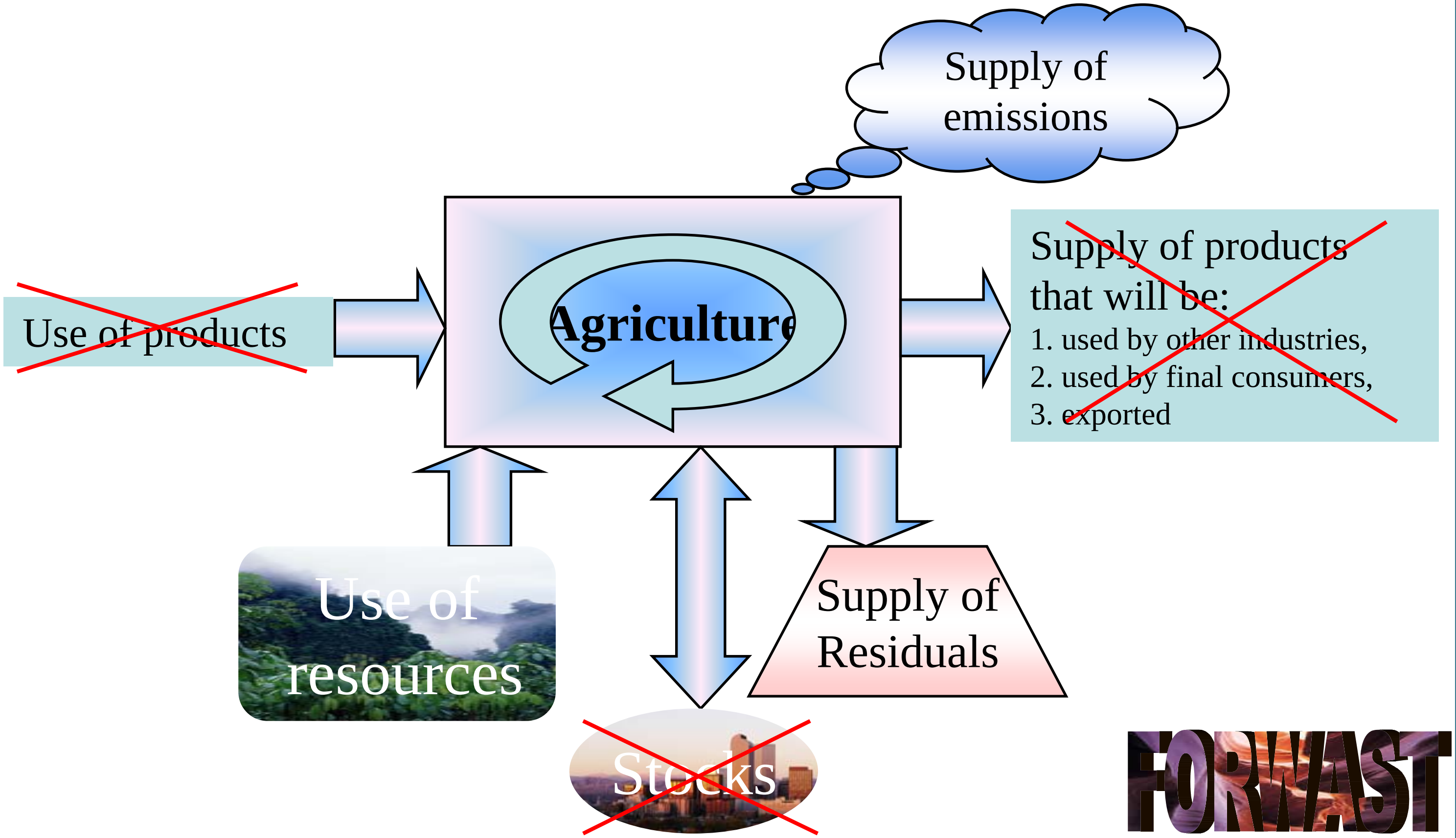
Mass balance per industry – internal flows

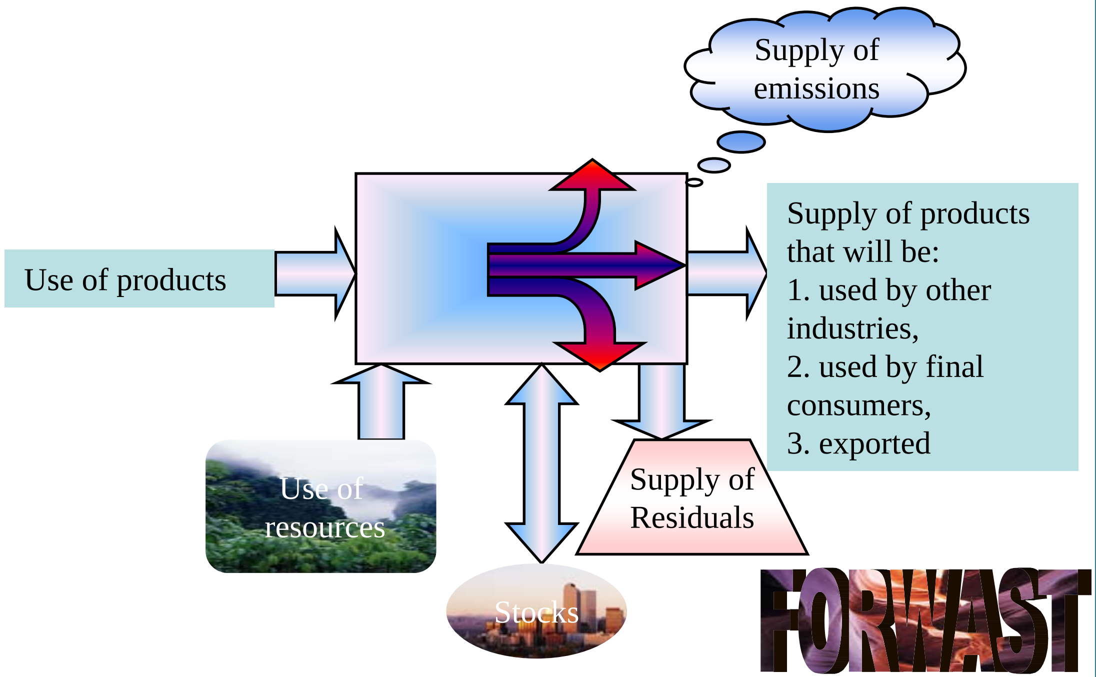
- When disaggregated, “Agriculture” uses “grain crops” to feed “bovines”
- These crops do not appear in the “supply”, neither in the “use” of “Agriculture”
- They are an “internal flow”, which causes the use of resources, the supply of residuals and emissions



Mass balance per industry – transfer coefficients

> Uses partly transferred in supplied products

- The part of the resources used by an industry that ends up in the product it supplies is defined by a “resource transfer coefficient”
- The part of the products used by an industry that ends up in the product it supplies is defined by a “product transfer coefficient”
- Some products used are not transferred at all in the product supplied



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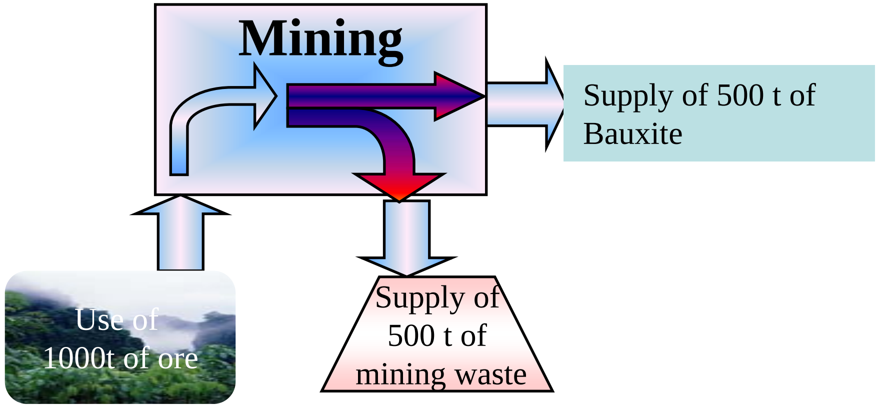
Mass balance – transfer coefficients example 1

> Use of resources by “mining”

- The industry “bauxite from mine” exploits natural ore to produce bauxite (Al_2O_3 + impurities).
- The part of the ore which is not “bauxite” (mining waste) generally remains on the production site.
- Mining waste can be dealt with the “resource transfer coefficient” adapted to the composition of the ore.
- Example:

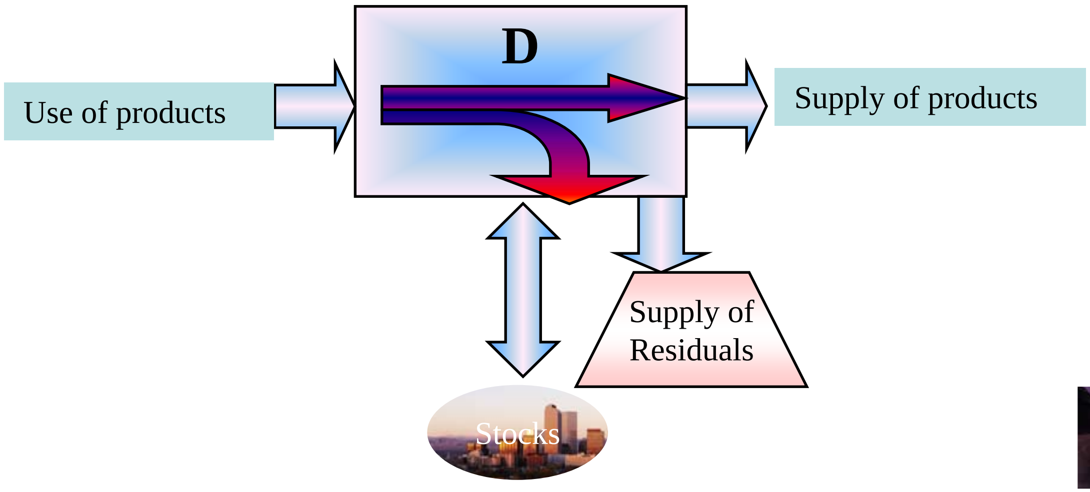


- The “resource transfer coefficient” is 50%

Mass balance - transfer coefficients example 2

> Manufacture of furniture

- Uses many products of which:
  - Those entering in the composition of furniture (wood planks, screws, plastic parts,…)
  - Those not entering in the product supplied (machinery, tools, electricity,…)
- The transfer of matter from used products to supplied product (unless known specifically) is calculated as:
  - D = (mass of output)/(mass of all inputs entering in the output)
- D shows a “matter transfer” efficiency of all industries



Forwast Physical balance of flows

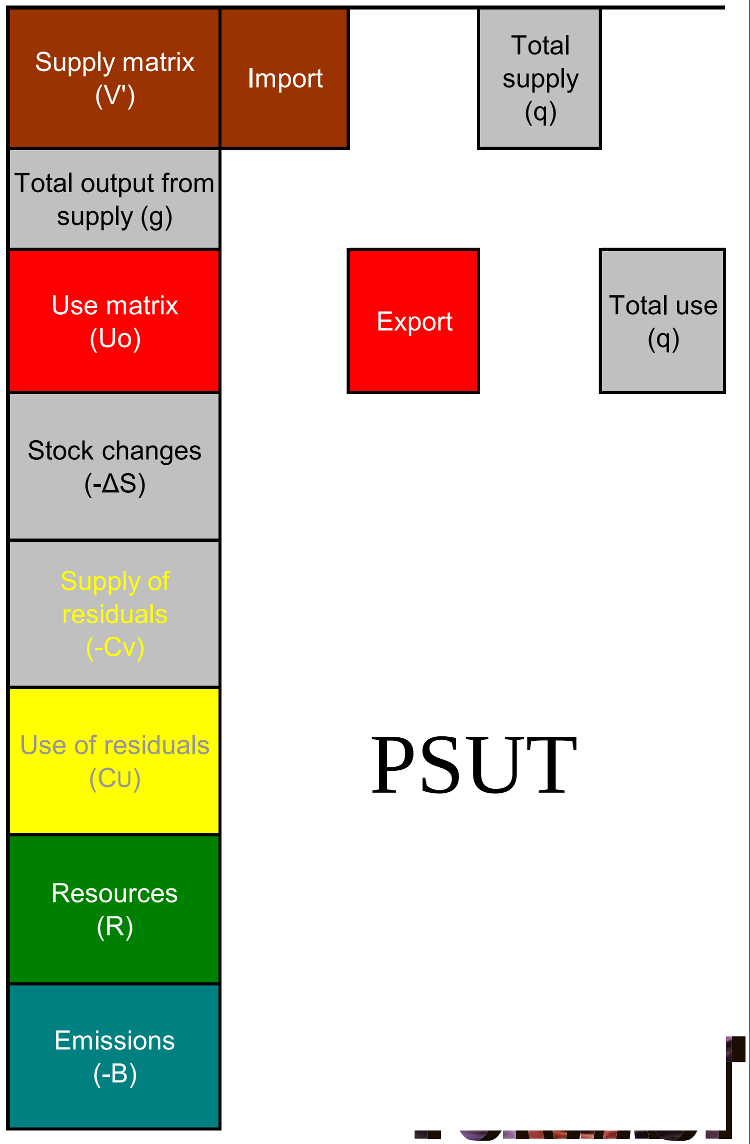
> **Complete Physical SUT system**

- Per activity:

Supply + waste + stock change + emissions	=	Use + Resources + use of waste

- Per product:

Supply + Import	=	Use + Export



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Calculating waste flows

> **Waste are "supplied" from activities**

- Waste are calculated as:
  - the total uses (of resources and products)
  - that do not end up as products, stocks or emissions
- When the supplied products have a lifetime < 1 year, these products become waste in the year
- Else, these products appear as "stocks" and become waste according to the distribution of their lifetime

> **Supplied waste of the different products are distributed between waste management activities**

- % of "wood waste" being recycled, composted, biogasified, incinerated,…

> **Waste management activities in turn supply new products and new waste**

- Waste are also distributed between waste management activities

> **Until reaching a "final" destination in landfill or soil**

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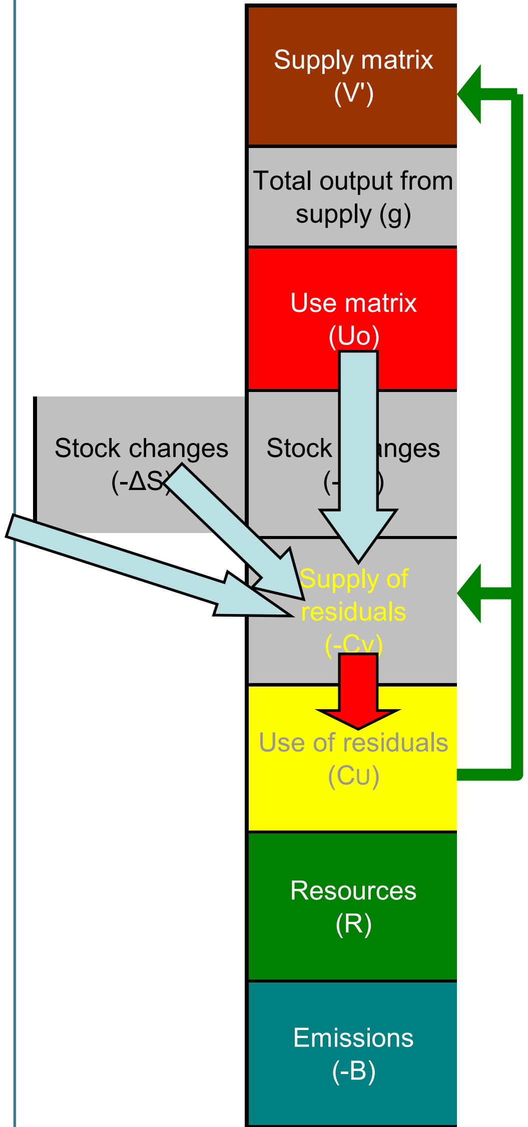
The materials cycles



- The “Supply of residuals” is fed from “Use” and stocks from previous years
- Residuals are distributed by an additional matrix (not shown) in the different waste treatment activities that will “Use these residuals”
- These activities will supply new products (recycling, composting) and new residuals
- …until final disposal

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Accounting for stocks

- **The model calculates a “stock variation” for each year**
  - As a result of the mass balance of the economy,
  - taking into account the different products and materials (resources included in products)
- **The problem is to determine**
  - The accumulation of the stock
  - The initial and/or present actual stock
- **Starting with the flows and stocks of the economy in 2003, a time series is implemented on a yearly basis.**
- **When possible, stocks calculation is validated with existing MFA data**

The estimation of the initial stock

> **A methodology to figure the initial stock at one date is given**

- Review of main “products” making the stocks
- This includes main technological changes in the past (for construction and vehicles)

> **The initial stock is given by**

- Historical stock change * life time of materials involved
- This is reviewed for all industries participating to the building of the stock
- Main uncertainties come from buildings and infrastructure

The waste generated from stocks

> **The waste generated from stocks is calculated using the distribution of life time of the products constituting the stock**
  - This causes a problem for “multi-components” products (as buildings, vehicles)
  - The glass of the windows do not have the same life time as the frames of the windows, which have not the same life time as the internal walls, which have not the same life time as the structural walls
  - We have the same problem for vehicles (considering glass, tyres, lights,…)

> **For these main products (buildings, vehicles) of the stock, we consider the life time of each individual component, thus getting to a more reliable estimation of the waste generated than considering a “mean” life time of these products.**
  - Problem: the waste are not located at the “assembling” activity but at the “components producing” activities
  - As a whole, it does not change the material balance but has to be kept in mind for policies focusing on these activities (C&D waste, EoL vehicles)

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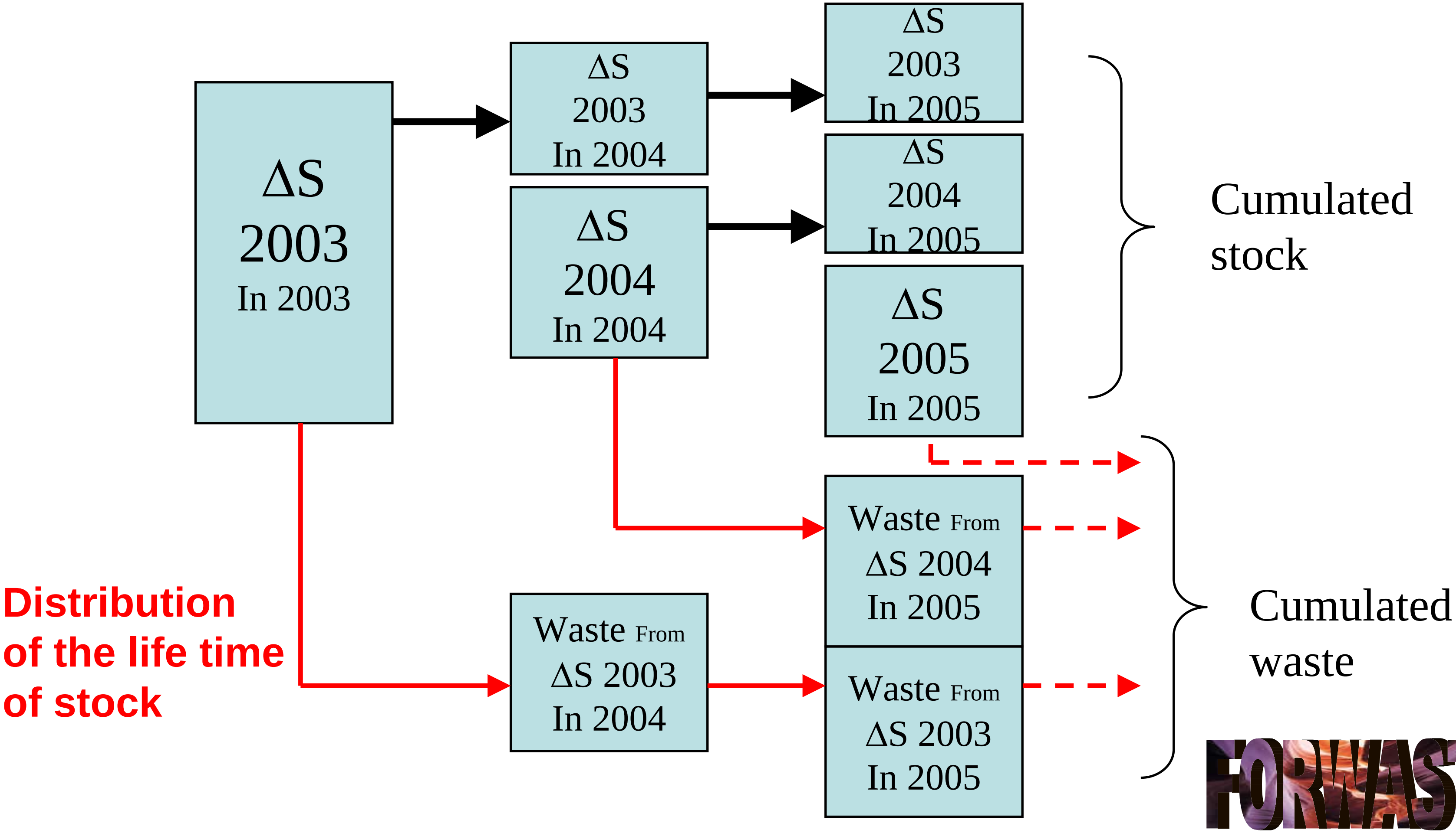
Stocks depreciation

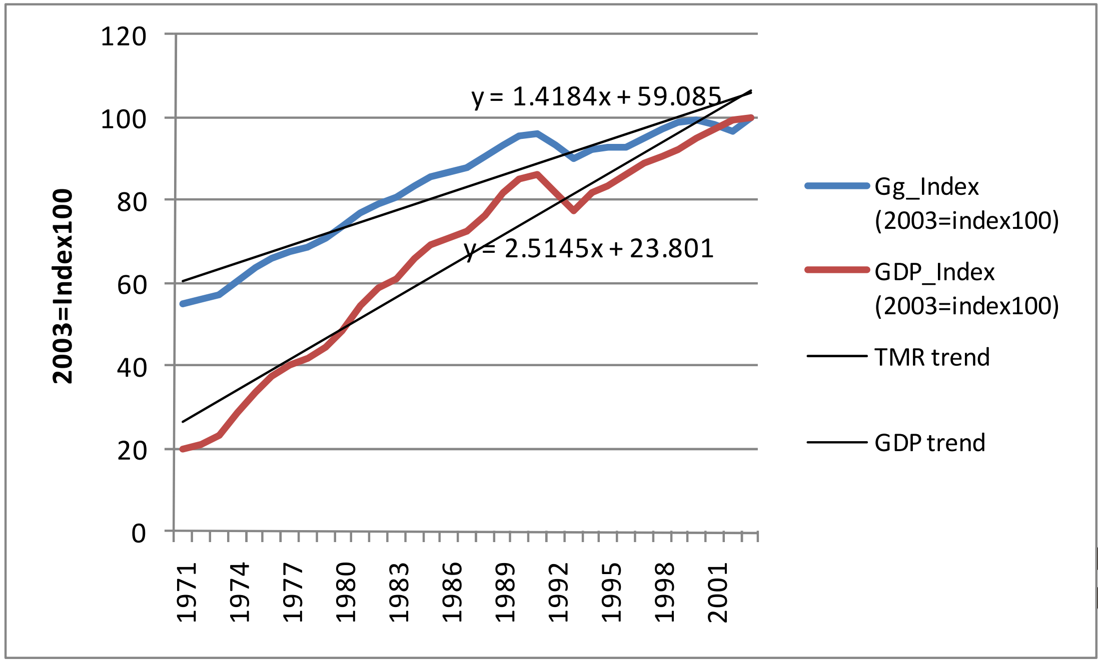
> **Time series of accumulated stock and waste**



The evolution of stocks in time

> **The stock is assessed via simulations summed over a time series of 30 past years**

- The stock variations of past years is approximated using GDP…
  - no SUT tables available before 98, and for a limited number of countries
- …and accounting for the evolution of technologies (i.e. car built 30 years ago contain more % of metals, but were lighter; inverse for buildings) through the TMR (total material requirement) index



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- National accounting – Supply and Use Tables, Input/Output Table
- Environmental extensions – accounting for waste - disaggregation
- Principle of the Forwast Mass balance per activity
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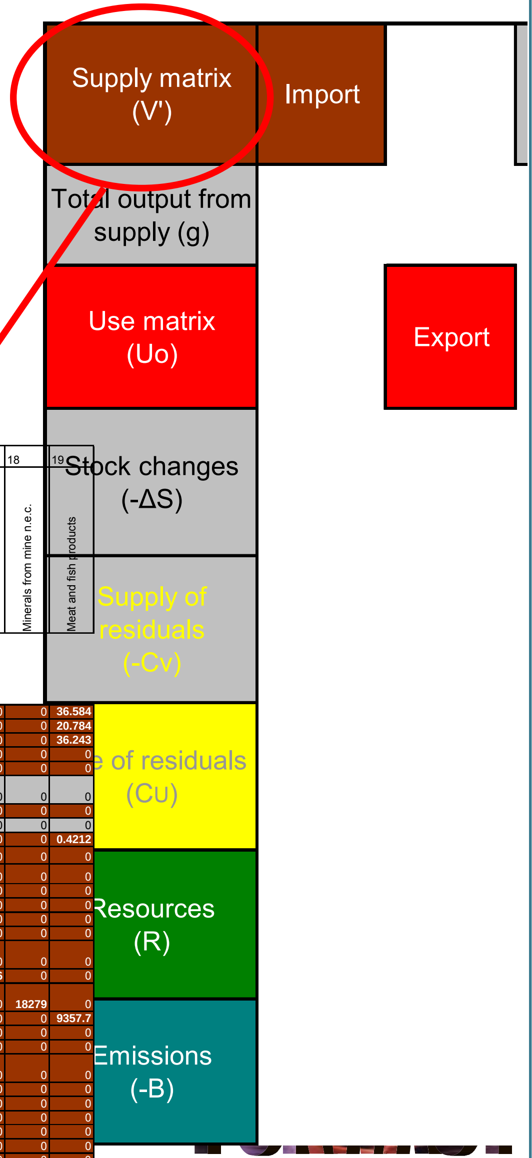
- Feeding the SUTs – a tour on available databases
- How the model work? - summary

Feeding the model

> Huge Data mining

- 127*127 matrices
- 27 countries
  - 4 countries in detail (F, D, A, DK)
  - 23 countries less detailled
- Historical data

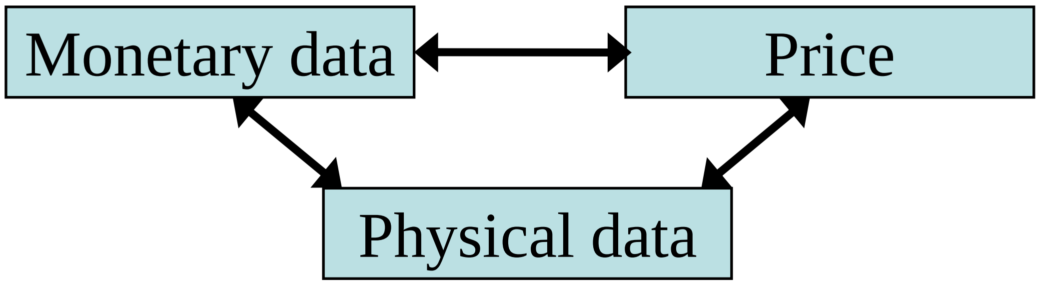


Supply Table (V'_T)

NACE No.	Product No.	Activity No. / Activities / Products	1 Bovine meat and milk	2 Pigs	3 Poultry and animals n.e.c.	4 Grain crops	5 Crops n.e.c.	6 Agricultural services n.e.c.	7 Forest products	8 Recycling of waste wood	9 Fish	10 Coal, lignite, peat	11 Crude petroleum and natural gas	12 Iron ores from mine	13 Bauxite from mine	14 Copper from mine	15 Metals from mine n.e.c.	16 Sand, gravel and stone from quarry	17 Clay and soil from quarry	18 Minerals from mine n.e.c.	19 Meat and fish products
1.21	1	Bovine meat and milk	4117	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	36.584
1.23	2	Pigs	0	2339	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	20.784
01.24+01.25	3	Poultry and animals n.e.c.	0	0	4078.9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	36.243
01.1(disaggr.)	4	Grain crops	0	0	0	82166	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
01.1(disaggr.)	5	Crops n.e.c.	0	0	0	0	72202	0	0	0	0	0	0	0	0	0	0	0	0	0	0
01(disaggr.)+01.4+01.5	6	Agricultural services n.e.c.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2 (disaggr.)	7	Forest products	0	0	0	0	0	0	30268	0	0	0	0	0	0	0	0	0	0	0	0
2 (disaggr.)	8	Recycling of waste wood	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5	9	Fish	0	0	0	0	0	0	0	0	948.15	0	0	0	0	0	0	0	0	0	0.4212
10	10	Coal, lignite, peat	0	0	0	0	0	0	0	0	0	2243	0	0	0	0	0	0	0	0	0
11	11	Crude petroleum and natural gas	0	0	0	0	0	0	0	0	0	0	2687	0	0	0	0	0	0	0	0
13.1	12	Iron ores from mine	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
13.2(disaggr.)	13	Bauxite from mine	0	0	0	0	0	0	0	0	0	0	0	0	670	0	0	0	0	0	0
13.2(disaggr.)	14	Copper from mine	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
13.2(disaggr.)	15	Metals from mine n.e.c.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.002	0	0	0	0
14.1+14.21	16	Sand, gravel and stone from quarry	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	382870	0	0	0
14.22	17	Clay and soil from quarry	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	37896	0	0
14.3+14.4+14.5	18	Minerals from mine n.e.c.	0	0	0	0	0	0	0	0	0	166.11	1295.7	0	0	0	0	0	0	18279	0
15.1+15.2	19	Meat and fish products	411.2	69.41	140.03	0	0	16.231	0	0	0	0	0	0	0.1663	0	2E-06	0	0	0	9357.7
15.5	20	Dairy products	815.1	0	0	0	0	32.18	0	0	0	0	0	0	0.2213	0	3E-06	0	0	0	0
15.3	21	Fruits and vegetables, processed	0	0	0	105.28	134.38	5.5452	0	0	0	0	0	0	0.064	0	8E-07	0	0	0	0
15.4	22	Vegetable and animal oils and fats	55.74	9.41	18.984	41.776	53.326	2.2005	0	0	0	0	0	0	0.0474	0	6E-07	0	0	0	0
15.6	23	Flour	207.1	34.96	70.528	155.21	198.12	8.1752	0	0	0	0	0	0	0.176	0	2E-06	0	0	0	0
15.83	24	Sugar	0	0	0	196.5	250.84	10.351	0	0	0	0	0	0	0.1195	0	2E-06	0	0	0	0
15.7	25	Animal feeds	502.9	84.91	171.29	376.94	481.16	19.855	0	0	0	0	0	0	0.4275	0	6E-06	0	0	0	0
15.8(ext.)	26	Food preparations n.e.c.	112.3	18.96	38.256	84.187	107.46	4.4344	0	0	0	0	0	0	0.0955	0	1E-06	0	0	0	0
15.9	27	Beverages	653.2	0	0	489.59	624.95	25.788	0	0	0	0	0	0	0.4684	0	6E-06	0	0	0	0
16	28	Tobacco products	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
17	29	Textiles	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
18	30	Wearing apparel and furs	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
19	31	Leather products, footwear	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

From monetary to physical flows

- Using the triangulation where relevant data can be found



- And adding physical data from other sources

Visit through the Forwast databases

> Have a look at SUTs…

- D3.2 Databases of material flows and stocks in the four countries
- D4.2 Databases of material flows and stocks for EU-27

> …and documentation

- D3.1 for DE, DK, AU, FR
- D4.1 for other countries

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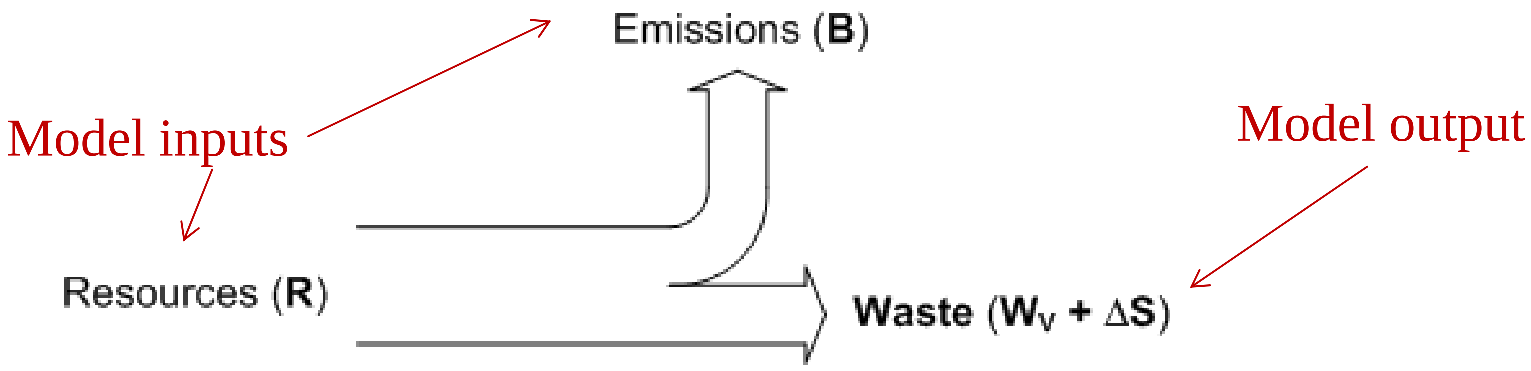
How does the model work?

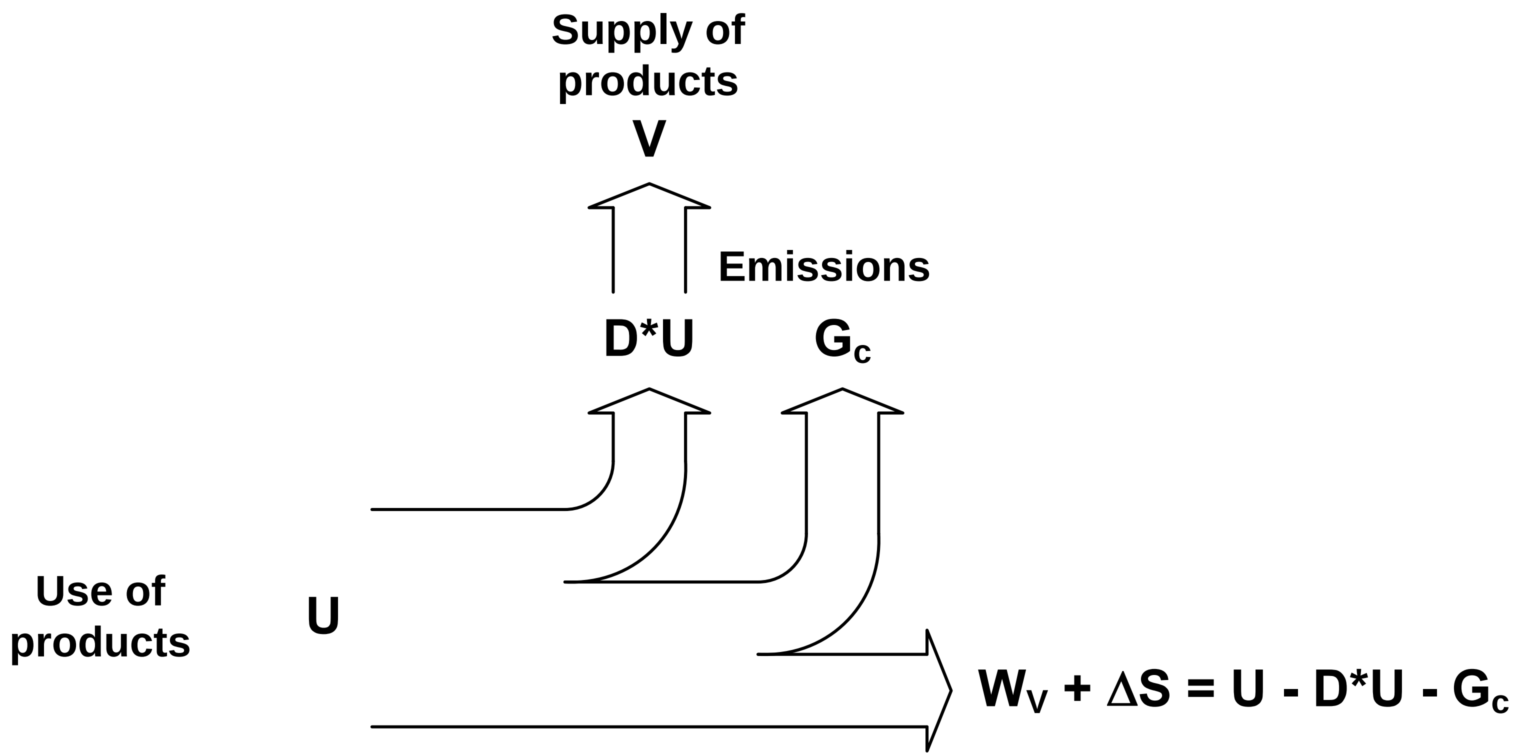
> **Model outputs**

- Waste generation in years 2003-2035
- Accumulated stocks in years 2003-2035
- Environmental impact of EU27 production and consumption (calculated from Emissions and Waste)



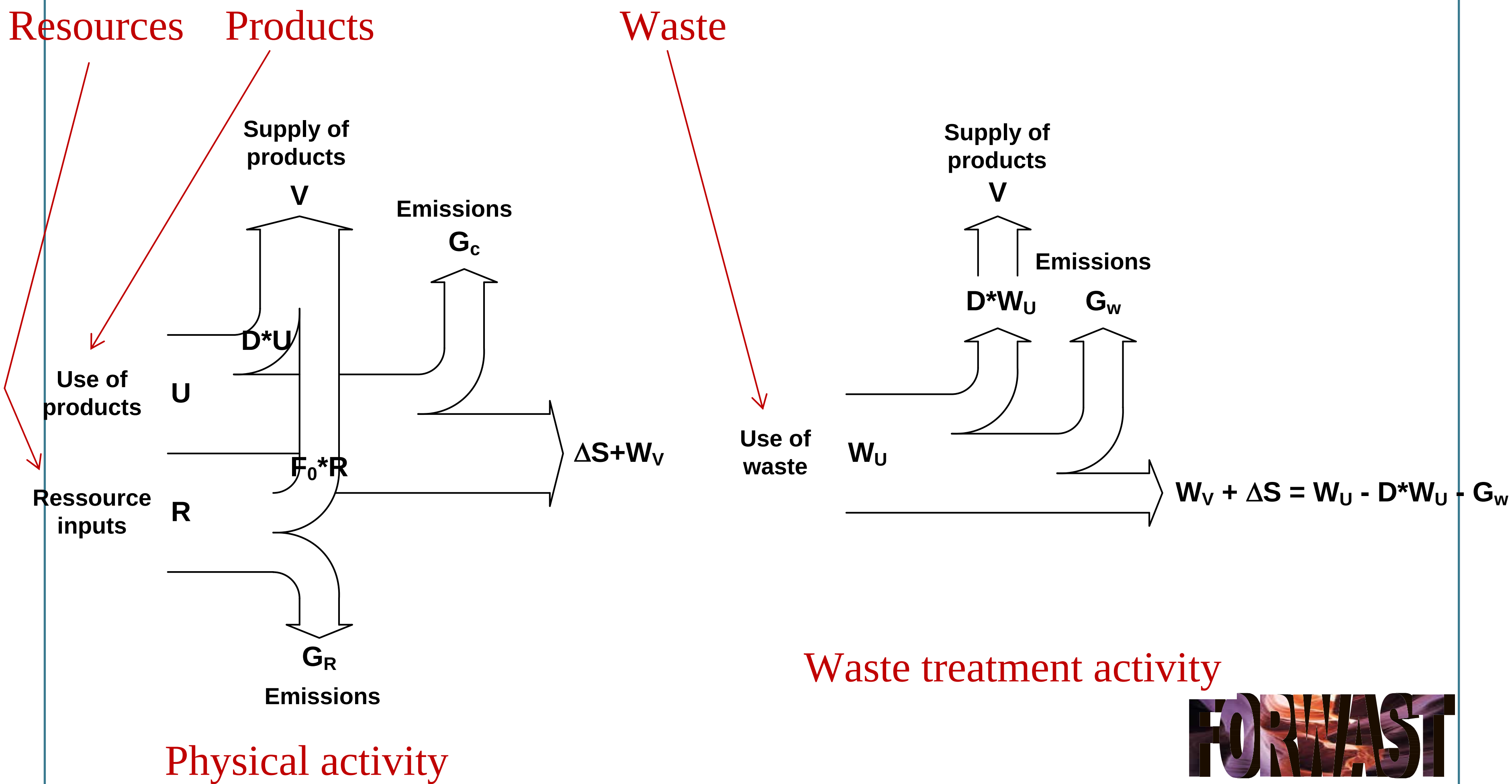
Calculation of waste generation

> **Inputs of products become products, emissions and waste**



Calculation of waste generation

> **Three types of inputs**



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Distiction between waste and stock addition

1 kg waste + stock addition (**Wv**+Δ**S**)

Stock degradation

Year \ Products	Printed matter and recorded media
1	0.04
2	0.08
3	0.12
4	0.16
5	0.2
6	0.16
7	0.12
8	0.08
9	0.04
10	0
11	0

- Gives in 1 year after

0.04 kg waste ($\mathbf{W_V}$) +

0.96 kg stock addition (Δ**S**)

Modelling of waste treatment in the IO model

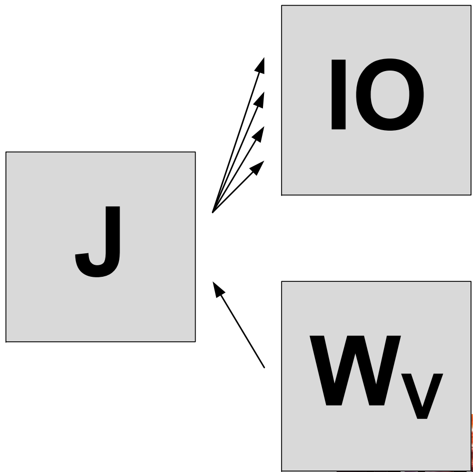
Specification of treatment for each waste type (**J**)

Calculated waste output from activity (**W_v**)

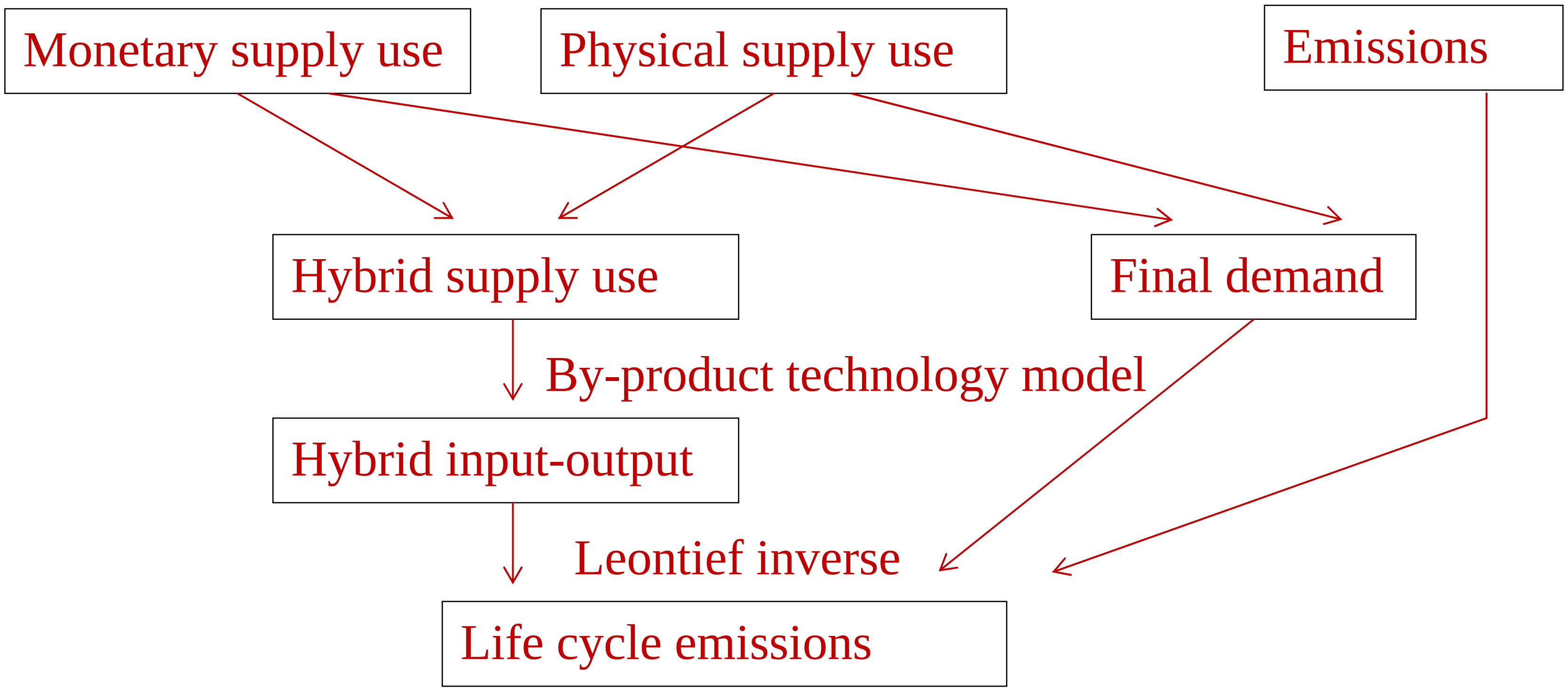
102 waste types → **34 waste types**

- waste from 58 physical produts in SUT
- waste from 44 waste treatment activities

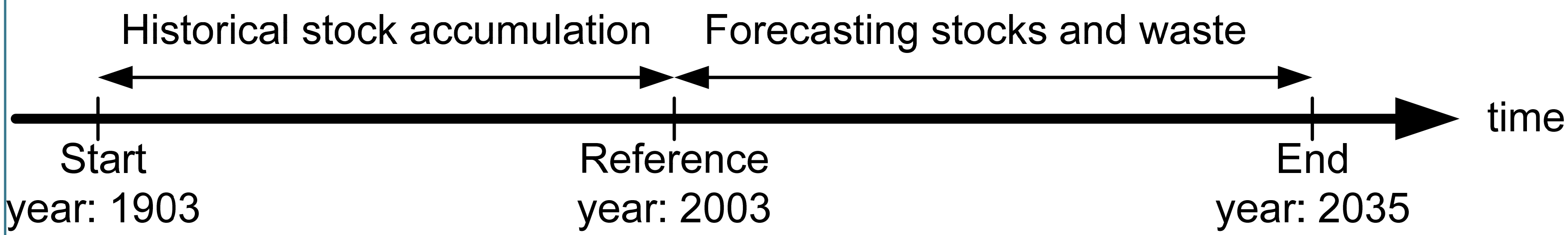
Hybrid units in IO-table:
Waste treatment services are measured in kg treated waste →



Model output: Environmental impact



Time series: calculation of waste and stocks



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Model output: Accumulated waste generation

> **For each year, e.g. 2003, we have:**

2003

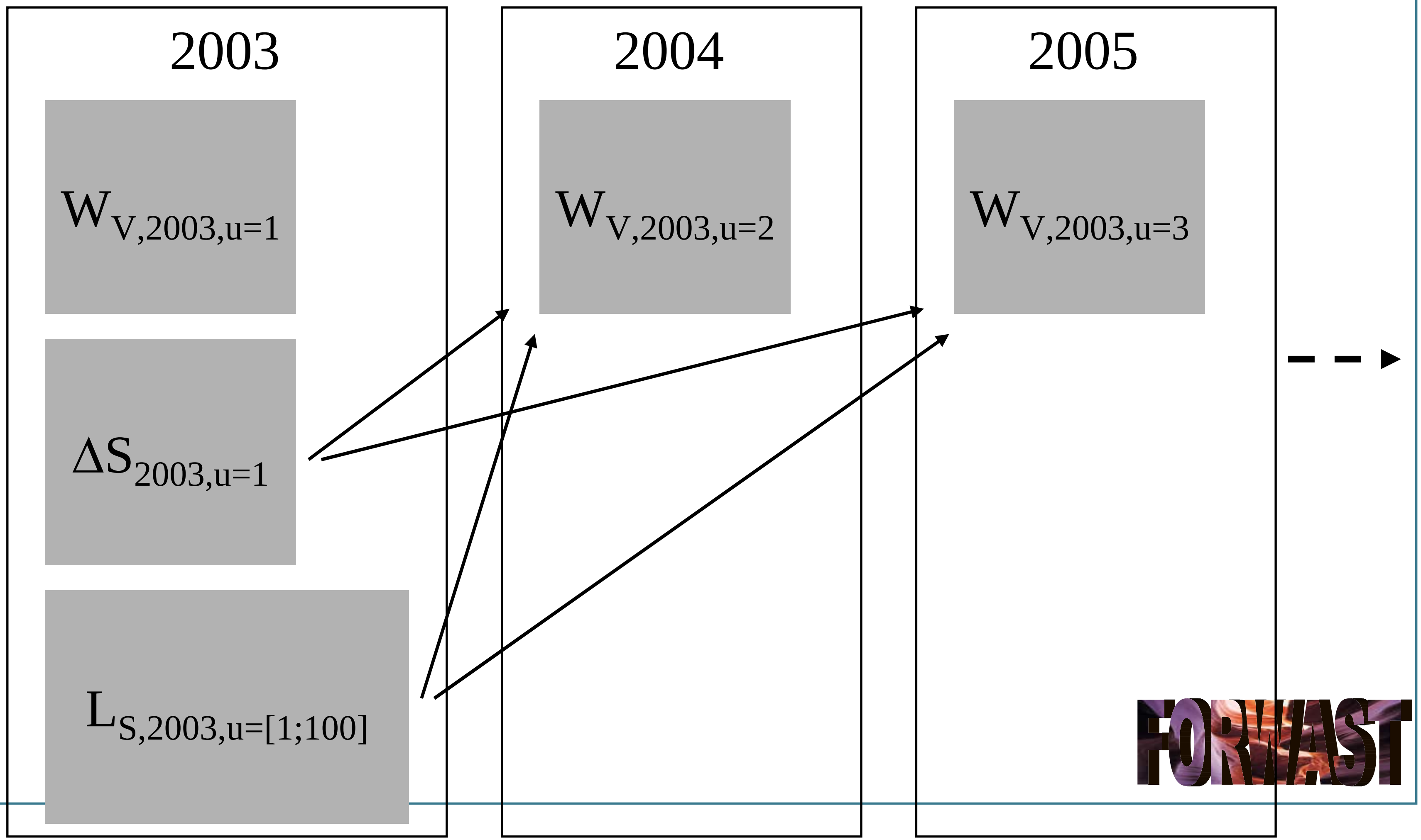
$W_{V,2003,u=1}$

$\Delta S_{2003,u=1}$

$L_{S,2003,u=[1;100]}$

Model output: Accumulated waste generation

> **We can calculate waste from $\Delta S_{2003,u=1}$ for the subsequent years:**



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Model output: Accumulated waste generation

> **We can do the same for all years, and then sum up the waste for each year originating from several years:**

2003	2004	2005
$W_{V,2003,u=1}$	$W_{V,2003,u=2}$	$W_{V,2003,u=3}$
	$W_{V,2004,u=1}$	$W_{V,2004,u=2}$
		$W_{V,2005,u=1}$
$\Sigma W_{V,2003}$	$\Sigma W_{V,2004}$	$\Sigma W_{V,2005}$

Model output: Accumulated stocks (S)

> **For each year, e.g. 2003, we have:**

2003

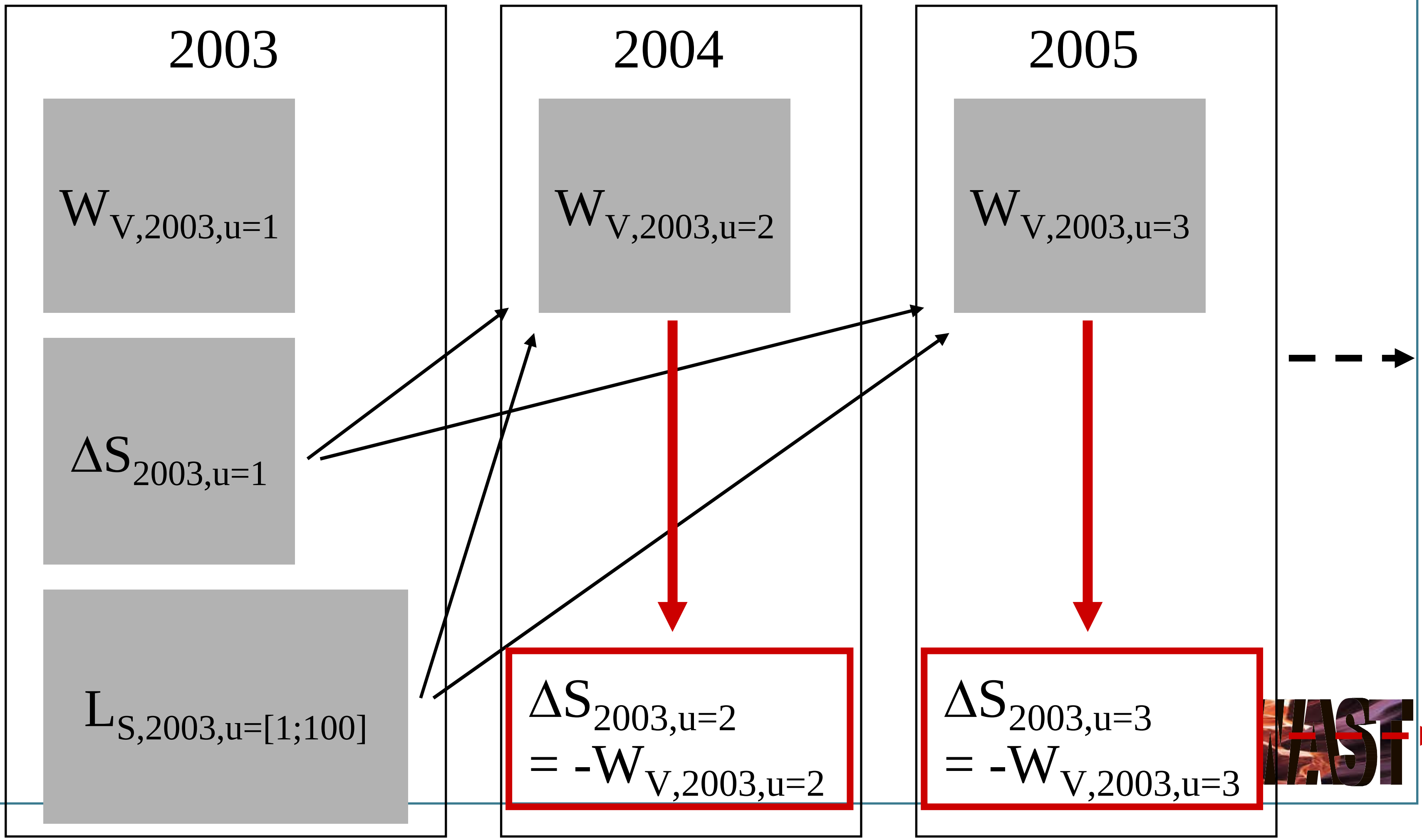
$W_{V,2003,u=1}$

$\Delta S_{2003,u=1}$

$L_{S,2003,u=[1;100]}$

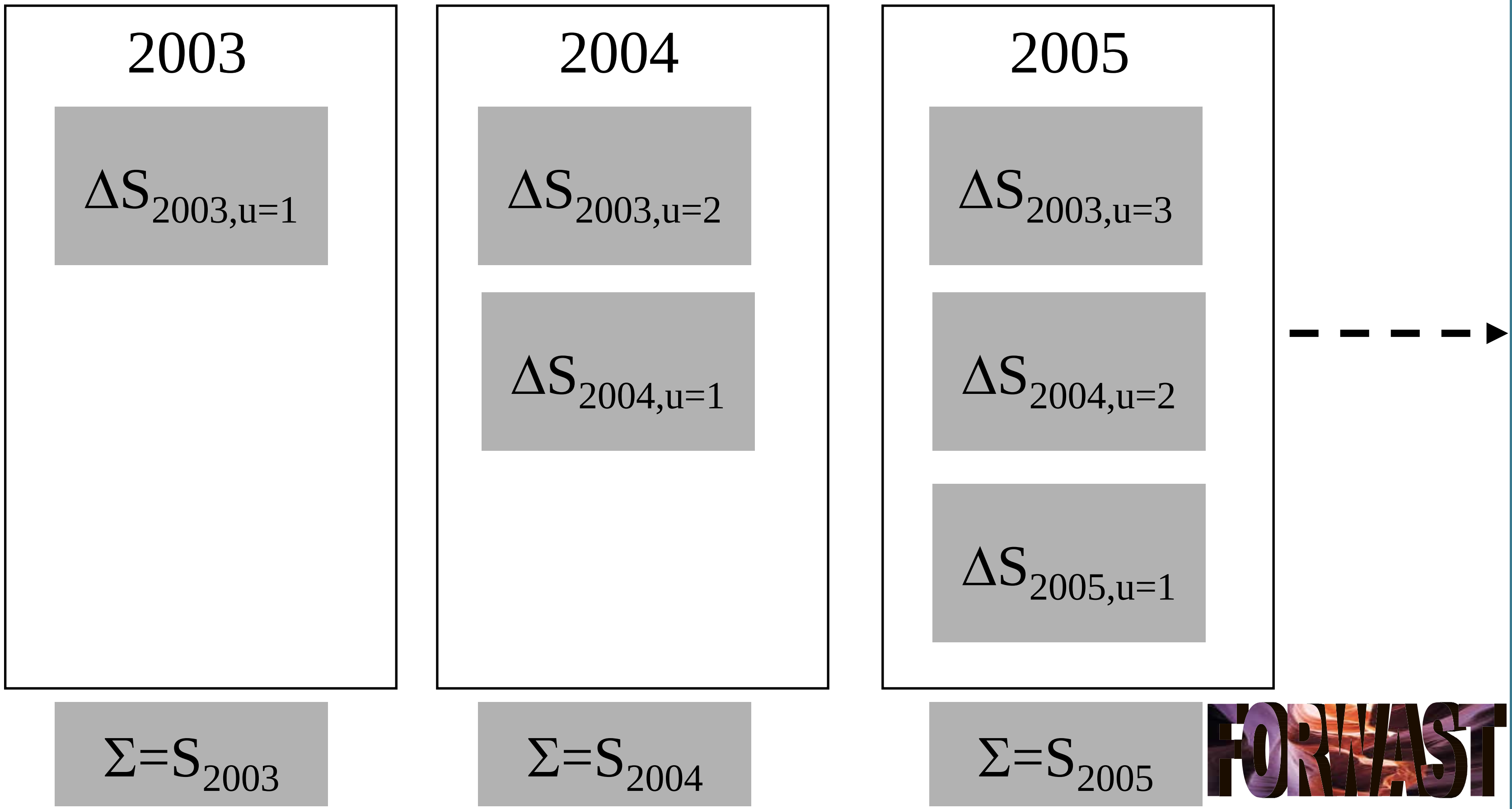
Model output: Accumulated stocks (S)

> **We can calculate** $\Delta S_{2003,u=2...endyear}$ **for the subsequent years:**



Model output: Accumulated stocks (S)

> **We can do the same for all years, and then sum up the stock changes for each year originating from several years:**



The model is...

- **Self-validating; Mass balance checks (activities and products)**
- **Overall model outputs (wastes and stocks) are:**
  - only affected by uncertainties in resource and emission data
  - all other uncertainties are allocation uncertainties
- **State-of-art IO-model**
  - Hybrid unit model (easy to use for hybrid LCA)
  - Waste is correctly modelled: Virgin/recycled, and several treatments

More: Have a look at D6.4

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Model building for mapping of physical flows and stocks of resources

Scenarios for forecasting future waste quantities

Model's results: Life-cycle environmental stakes of waste recycling and prevention

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Forecasting waste quantities in the next 25 years - topic

> The forecasting exercise is based on the definition of scenarios that drive the year by year changes of the economy and of waste management.

> The scenarios are defined according to:
- **Hypothesis on the evolution of the macro-economic situation (3 scenarios),**
- **Hypothesis on the waste management options that could be the result of waste policies (3 scenarios).**

> This chapter reviews the building of these scenarios and their implementation in the model

> As a result, waste forecasts for the next 25 years are provided.

Building scenarios

> A litterature review of recent macro-economic scenarios leads to the choice of a baseline scenario presented in the *European Energy and transport: trends to 2030.*

> The IPAT equation is used for identifying parameters that affect the level of environmental impact associated with anthropogenic activity.

- Environmental impact = Population*Affluence*Technology
  - Population projections
  - Affluent population consumes more materials
  - Environmental impact intensity of the applied technology
- Affluence (linked to GDP) and Technology (Eco-efficiency) are considered the main drivers to build Forwast scenario (EU27, horizon 2035)

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Macro-economic scenarios

> Selection of variants

- Selection of “plausible” scenarios, by opposition to scenarios that would imply large fundamental changes to the current world economic and political paradigm
- “better than the baseline”: high level of affluence with great emphasis on the development of new eco-efficient technologies (high growth scenario, as in *IPCC A1T* and *B1*)
- “worse than the baseline”: low level of affluence with little emphasis on the development of new eco-efficient technologies (low growth scenario, as in *IPCC A2*)

> Description of the scenarios

- Deliverable 5.1: review of recent scenarios
- Deliverable 5.2: chosen scenarios

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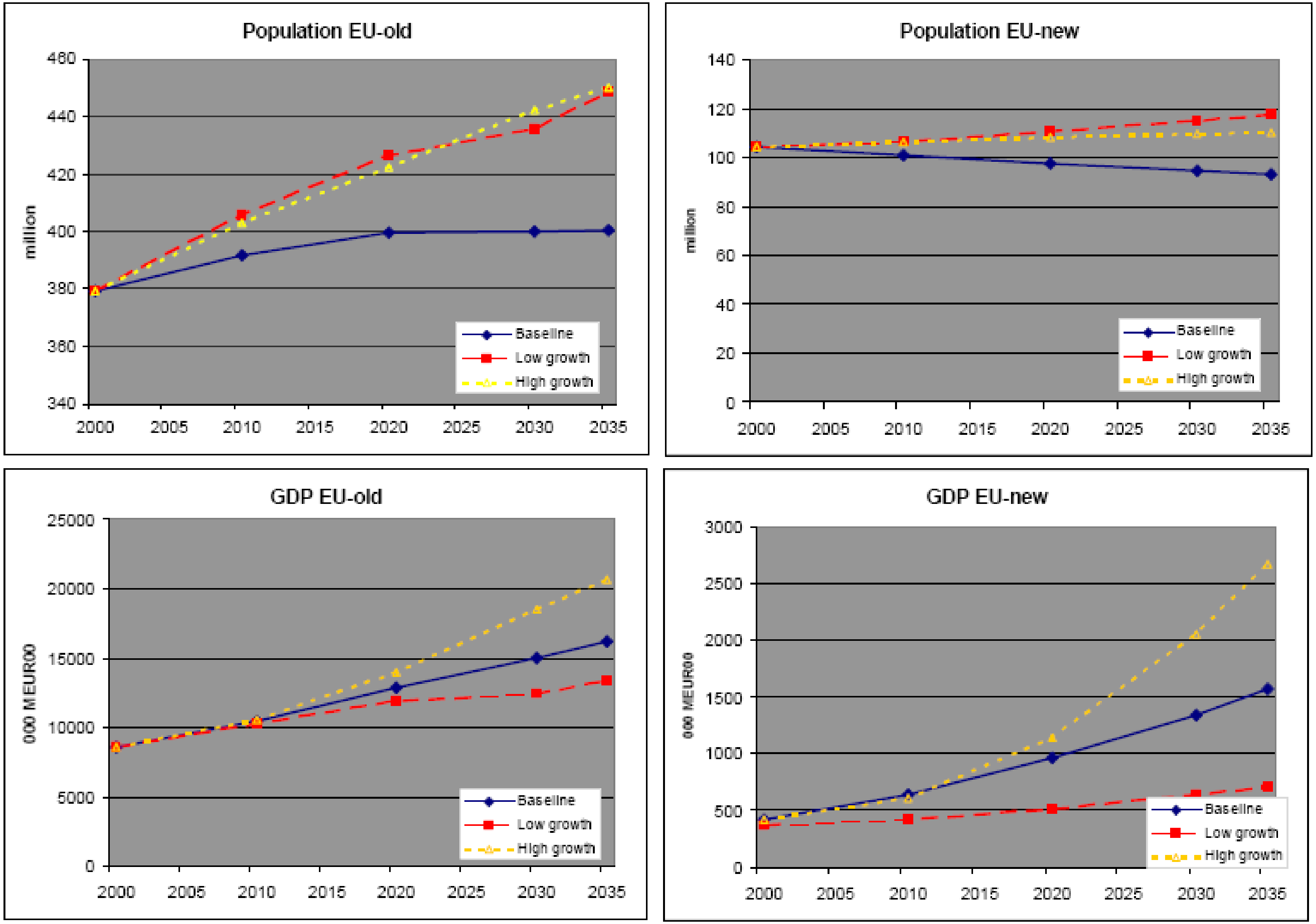
Chosen inputs: population and GDP



Waste management senarios: prevention

> Strategies for the reduction of waste
  - **ecodesign and technological innovation**
  - **better planning and organisational changes,**
  - **changes in attitude**
  - **substitution.**

> Application to waste streams with the highest potential in waste prevention

Activity	Changed parameter		2003	2015	2035
Household	Use	Meat use	100	85	81
	Use	Flour use	increased correspondingly by dry mass		
Food industry	Use, waste	Fruit and veg. Use & waste	100	85	81
	Use, waste	Grain crops & waste	100	97.6	97
	Use, waste	Crops nec & waste	100	85	81
Beverages	Use, waste	Use of plastic & waste	100	90	88
	Use, waste	Use of glass & waste	100	90	88
Household	Use, waste	Textiles, wearing and apperal, leather & waste	100	94	93
All, except household	Use, waste	Printed matter	100	92	90
All, except refinery industry	Use, waste, emissions	Use of refined petroleum, waste, and emissions	100	94	93
All, except machinery product activities	Use, waste	Machinery and equipment n.e.c.	100	94	93
	Use, waste	Office machinery and computers	100	94	93
	Use, waste	Electrical machinery n.e.c.	100	94	93
	Use, waste	Radio, television and communication equipment	100	94	93
	Use, waste	Instruments, medical, precision, optical, clocks	100	94	93

Waste management senarios: recycling

- **Recycling of different products is analysed from the point of view of technological development**
  - Paper
  - Copper,
  - Plastic
  - Construction and demolition waste
  - Biological waste
- **Different strategies are derived**

Waste management senarios: recycling

> Scenario implementation

Activity	Changed parameter		2003	2015	2035
Beveages industry	Waste to recycling	paper and paper products	20%	30%	50%
		Plastic and rubber products	25%	70%	85%
		Glass	60%	90%	95%
		Fabricated metal products	59%	80%	90%
Construction industry	Waste to recycling	Sand, gravel and stone	15%	40%	80%
		Forest products and wood products	15%	20%	40%
		Plastic and rubber products	3%	7%	14%
		Bricks	15%	40%	70%
		Fabricated metal products	20%	85%	95%
Agriculture	Waste to biogas	Manure	0%	70%	70%
All	Waste to biogas	Food waste	0%	40%	60%
All	Waste to recycling	Paper waste	59%	67%	77%
Motor vehicles and trailers	ELV to recycling	Iron waste	95%	95%	95%
		Alu waste	95%	95%	95%
		Copper waste	61%	61%	61%
		Metals nec waste	61%	61%	61%
		Fabricated metal products, except machinery waste	60%	95%	95%
		Machinery and equipment n.e.c. waste	60%	95%	95%
All	WEEE waste to trecycling	Office machinery and computers waste	24%	75%	90%
		Radio, television and communication equipment waste	25%	75%	90%
		Instruments, medical, precision, optical, clocks waste	20%	75%	90%

Waste management senarios: waste treatments

> Waste treatment activities included in this scenario were

- **mechanical-biological treatment**
- **Incineration**
- **landfilling**

> Considering the BAT

Activity	Changed parameter		2003	2015
Agriculture	Waste to biogas	Manure	0%	100%
All	Waste to incineratin	Food waste	43%	80%
		Textile waste	55%	80%
		Paper waste	15%	35%
All	Waste to recycling	Inert waste	1%	5%
All	Waste to recycling	Iron waste	46%	52%
		Alu waste	41%	50%
		Copper waste	40%	50%
		Metals nec waste	41%	50%

- Deliverable 5.3: three what-if scenarios

Implementing scenarios

- **Macro economic scenarios combine through IPAT the economic growth and the level of environmental protection**
  - High growth with high level
  - Baseline
  - Low growth with low level
- **Waste management scenarios are described by targets (prevention, recycling) to be met at specific dates**
  - Targets for 2015
  - Targets for 2035
- **To implement WM scenarios within macro economic contexts at different levels of environmental protection,**
  - The targets are met 2 years earlier in the high growth scenario
  - The targets are met 2 years later in the low growth scenario

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Forecasts

> **As a result of scenarios simulations, three types of data are provided:**

- Stocks
- Waste generated
- Environmental impact

> **These are calculated for the reference year (2003) and the 9 scenarios**

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Data coverage and pre-conditions

- Data collection coverage
  - Covers 38% of EU27 economy (missing Gemany, Austria, Slovenia, UK, Ireland, Spain, Italy)
  - Assumption: EU27 = EU20 / 0.38 (GDP representation)
- Historical time series
  - 1971-2003: GDP (Eurostat), Physical flows (Relationship between GDP and TMR)
  - 1903-1970: Extrapolation (exponential) of 1971-1990
- Life cycle emissions from imported products
  - Assumed that rest of world (ROW) is equal to EU27

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Stocks

> **EU27, 2003**

- Stocks are presented as
  - Stocks in use in the economy (infrastructure, buildings, machinery, vehicles,…
  - Stocks not in use (ie, in landfills)
- By type of material,
- By sector contributing.

> **+/- 160 000 million tons in the economy**

> **+/- 250 000 million tons in landfills**

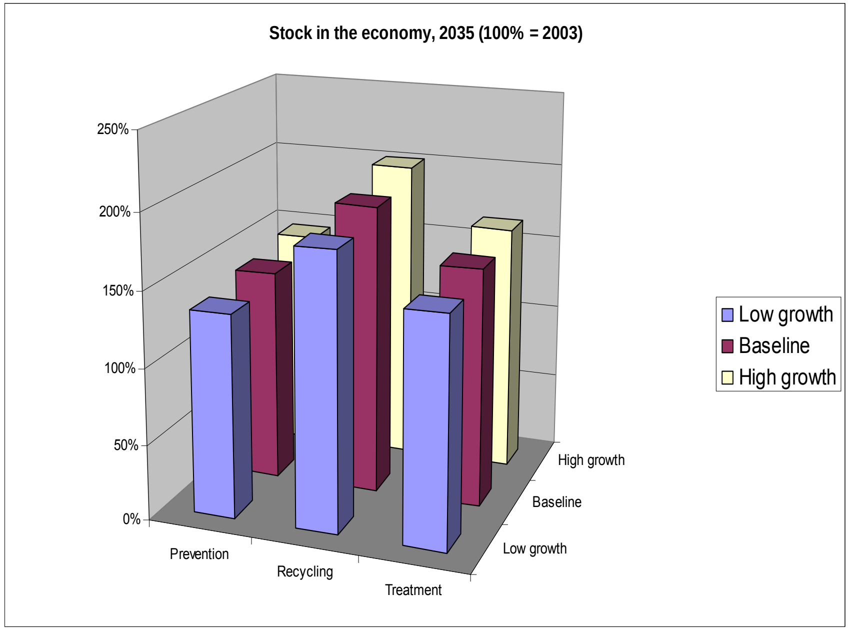
Stocks

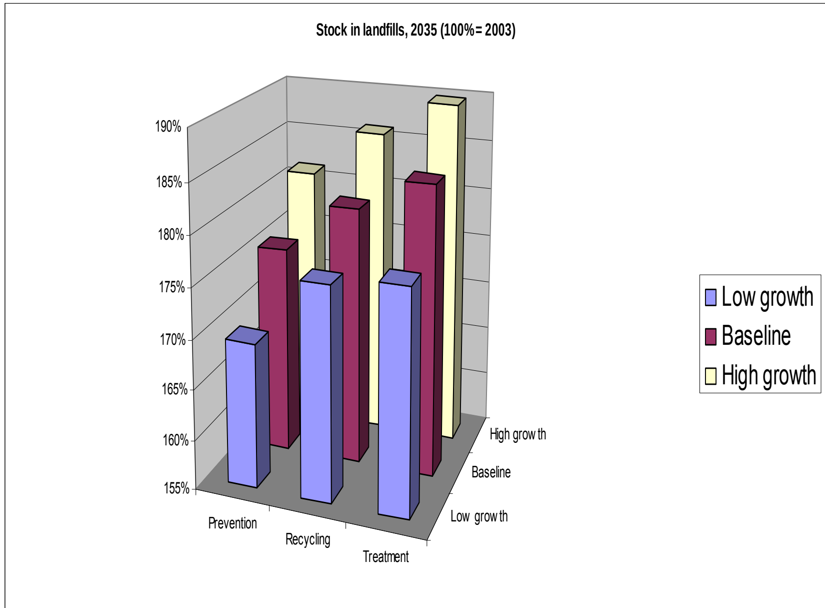
Stock category		Quantity, dry weight (Million t)	Sector											
			Agriculture and fishery	Forestry	Ressource extraction	Food industry	Industry	Construction	Refineries and gas	Electricity and heat	Service	Waste treatment	Household	All sectors
Stocks in the economy														
Construction materials	Sand, stone, clay	116 345	1%	0%	6%	1%	19%	52%	0%	0%	11%	7%	1%	100%
	Concrete, asphalt	30 647	0%	0%	0%	2%	6%	80%	0%	0%	5%	2%	5%	100%
	Bricks	3 086	0%	0%	0%	0%	8%	73%	0%	0%	8%	2%	8%	100%
Textile	Textile, wearing apperel, footwear	105	1%	0%	0%	1%	24%	3%	0%	0%	13%	2%	57%	100%
Wood	Wood products	3 280	2%	0%	0%	2%	29%	40%	0%	1%	12%	2%	10%	100%
Paper products	Paper and printed/recorded media	210	0%	0%	0%	4%	15%	1%	0%	0%	45%	4%	29%	100%
Plastic	Plastic and rubber products	139	2%	0%	0%	7%	25%	19%	1%	0%	18%	2%	24%	100%
Glass	Glass products	558	2%	0%	2%	27%	22%	23%	0%	0%	12%	6%	5%	100%
Metal products	Iron products	948	0%	0%	1%	1%	64%	26%	0%	0%	6%	1%	1%	100%
	Aluminium products	39	0%	0%	0%	3%	74%	16%	0%	0%	4%	1%	0%	100%
	Copper products	21	0%	0%	0%	2%	86%	9%	0%	0%	2%	0%	1%	100%
	Metals nec products	11	0%	0%	0%	2%	70%	15%	0%	0%	10%	2%	1%	100%
	Fabricated metal products, except mach	624	1%	0%	1%	4%	29%	27%	1%	0%	18%	12%	7%	100%
	Machinery and equipment n.e.c.	723	6%	0%	2%	4%	32%	9%	1%	0%	27%	5%	14%	100%
	Office machinery and computers	5	0%	0%	0%	1%	13%	1%	0%	0%	63%	7%	15%	100%
	Electrical machinery n.e.c.	335	1%	0%	0%	1%	26%	19%	1%	1%	29%	3%	18%	100%
	Radio, television and communication equ	69	0%	0%	0%	0%	31%	2%	0%	1%	37%	2%	26%	100%
	Instruments, medical, precision, optical,	30	0%	0%	0%	0%	16%	3%	0%	1%	48%	1%	30%	100%
	Furniture and other manufactured goods	408	0%	0%	0%	0%	10%	2%	0%	0%	24%	3%	60%	100%
Total		**157 583**												
Stocks not in use														
Stock in landfill	Landfill of waste: Food	5 922	0%	0%	0%	0%	0%	0%	0%	0%	0%	100%	0%	100%
	Landfill of waste: Paper	1 317	0%	0%	0%	0%	0%	0%	0%	0%	0%	100%	0%	100%
	Landfill of waste: Plastic	1 247	0%	0%	0%	0%	0%	0%	0%	0%	0%	100%	0%	100%
	Landfill of waste: Metals	2 249	0%	0%	0%	0%	0%	0%	0%	0%	0%	100%	0%	100%
	Landfill of waste: Glass/inert	186 695	0%	0%	0%	0%	0%	0%	0%	0%	0%	100%	0%	100%
	Landfill of waste: Mine waste	3 954	0%	0%	0%	0%	0%	0%	0%	0%	0%	100%	0%	100%
	Landfill of waste: Textiles	223	0%	0%	0%	0%	0%	0%	0%	0%	0%	100%	0%	100%
	Landfill of waste: Wood	2 568	0%	0%	0%	0%	0%	0%	0%	0%	0%	100%	0%	100%
	Landfill of waste: Oil/Hazardous waste	8 665	0%	0%	0%	0%	0%	0%	0%	0%	0%	100%	0%	100%
	Landfill of waste: Slag/ash	32 550	0%	0%	0%	0%	0%	0%	0%	0%	0%	100%	0%	100%
Total		**245 388**												

Stocks

> **Have a look at xls results file**

- To results file:
- Make your own sheets and graphs





Waste generation

> **EU27, 2003**

- Quantity of waste generated
- By type of waste,
- By sector contributing.

> **+/- 5 000 million tons in 2003**

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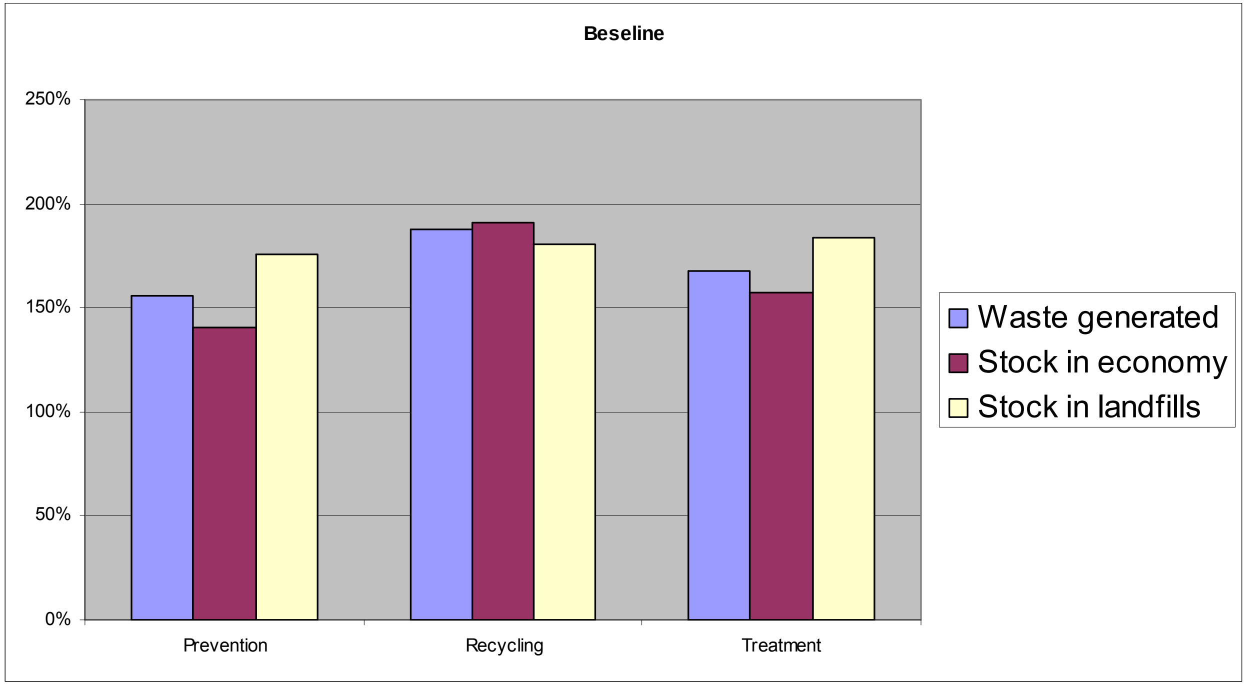
Waste generated

Waste category	Waste fraction	Quantity, dry weight (Million t)	Sector											
			Agriculture and fishery	Forestry	Ressource extraction	Food industry	Industry	Construction	Refineries and gas	Electricity and heat	Service	Waste treatment	Household	All sectors
Organic	Food waste	526	4%	0%	0%	32%	3%	0%	0%	0%	11%	1%	50%	100%
	Food waste to WWT	4	0%	0%	0%	1%	2%	0%	0%	0%	18%	0%	77%	100%
	Manure	157	100%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	100%
	Wood waste	82	1%	12%	1%	2%	25%	21%	0%	11%	9%	2%	16%	100%
Textile	Textile waste	18	1%	0%	0%	1%	16%	2%	0%	0%	11%	2%	68%	100%
Paper	Paper waste	113	0%	0%	0%	8%	27%	1%	0%	0%	39%	3%	20%	100%
Plastic	Plastic waste	167	2%	0%	0%	8%	24%	24%	1%	0%	19%	3%	19%	100%
Glass	Glass waste	60	2%	0%	2%	27%	22%	23%	0%	0%	12%	6%	5%	100%
Construction and inert	Sand, stone, clay	1 657	1%	0%	6%	1%	23%	50%	0%	0%	10%	6%	2%	100%
	Cement, concrete, asphalt	566	0%	0%	0%	2%	10%	75%	0%	0%	5%	2%	5%	100%
	Bricks waste	38	0%	0%	0%	0%	8%	73%	0%	0%	8%	2%	8%	100%
	Ash and slag waste	762	0%	0%	1%	0%	3%	0%	1%	7%	2%	83%	2%	100%
	Metal ore waste	90	0%	0%	3%	0%	80%	2%	0%	0%	14%	1%	0%	100%
Metal	Iron waste	218	2%	0%	1%	2%	46%	19%	1%	0%	16%	5%	9%	100%
	Aluminium waste	20	2%	0%	1%	3%	44%	17%	1%	0%	17%	5%	10%	100%
	Copper waste	6	1%	0%	0%	2%	53%	12%	0%	0%	18%	3%	11%	100%
	Metals nec waste	7	2%	0%	1%	2%	38%	16%	1%	0%	21%	6%	12%	100%
	Other materials (non metal)	34	0%	0%	0%	1%	17%	7%	0%	1%	30%	3%	42%	100%
Special fractions	Special fractions	378	11%	0%	0%	1%	28%	2%	17%	0%	12%	2%	26%	100%
Total		**4 904**												

Waste generated

> **Have a look at xls results file**

- To file
- Make your own graphs

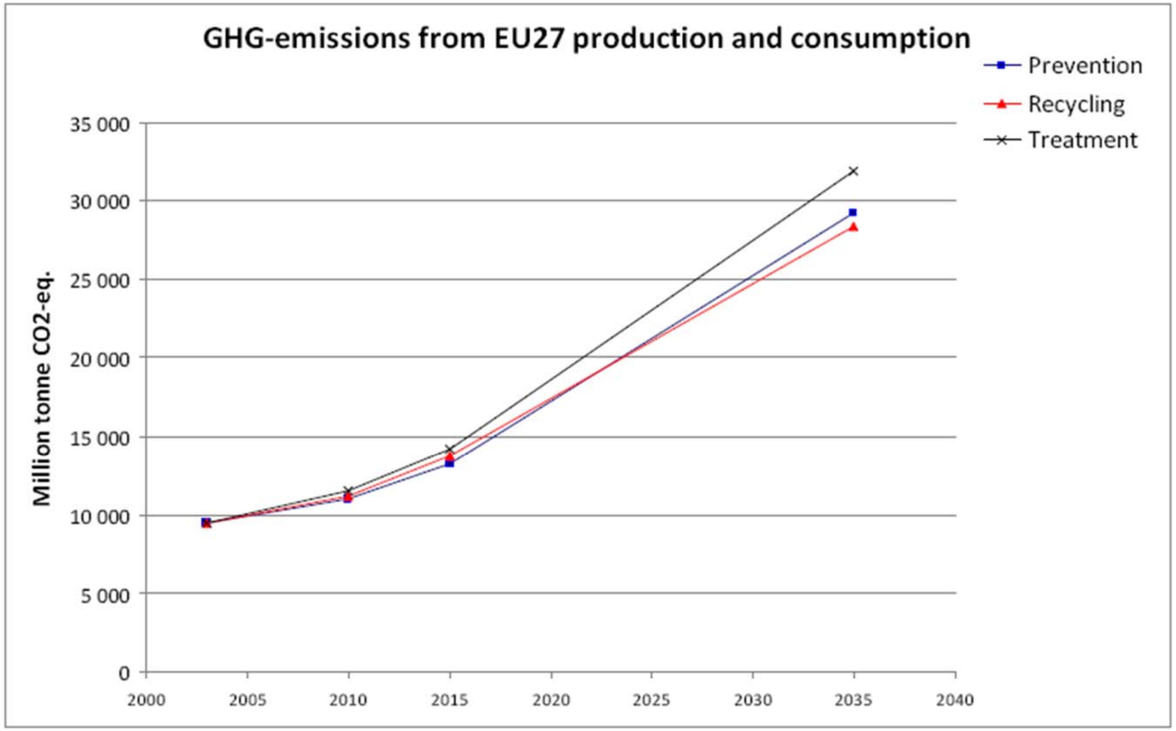


Environmental impact

> GHG emissions – baseline scenario

Life cycle GHG-emissions related to EU27 production and consumption

million t CO2-eq.	2003	2010	2015	2035
Prevention	9 467	11 002	13 218	29 213
Recycling	9 467	11 184	13 765	28 395
Treatment	9 467	11 494	14 195	31 891



See model outputs - emissions

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Advice, training: contact the closest Forwast team member

Geoscience for a sustainable Earth

brgm

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- **And find more info through partners's web sites on http://forwast.brgm.fr**

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