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WP 3 - Scenarios and modelling of policy implementation for resource efficiency

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Contributors: Dr. Frédéric Reynès

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Key word list

CGE model, water demand, land use

Definitions and acronyms

Acronyms	Definitions
CGEM	Computational General Equilibrium model
IO	Input-output

1. Introduction

Resource use is intrinsically related to human economic activities, in particular since the industrial revolution. The development of detailed input-output (IO) database extended with environmental account such as GTAP database (www.gtap.agecon.purdue.edu) or EXIOBASE – www.exiobase.eu, Tukker et al. (2009) – helps better understanding and quantifying the link between resource use and economic activity – see Tukker and Dietzenbacher (2013). In particular, these regional databases can be used to develop Computational General Equilibrium Model (CGEM) able to cover most regions of the world economy. Examples of these models are GTAP, EXIOMOD, GINFORS, NEMESIS.

Using the technical coefficients derived from the IO databases and eventually assuming some technical efficiency, CGEM can directly derive the impact of each economic activity on the use of various resources such water, land, mineral, etc[1]. This representation has however the drawback to be demand driven in the sense that the limit of the resource is often not or imperfectly taken into account into the economic model. Often scenarios implicitly assume that the supply of the resource will be able to follow the demand, and (at the most) the modeler controls a posteriori if the resource stock is not exceeded within the time frame of the simulation. But the effect of the deterioration of the stock does not have any impact on the economy. If the simulation horizon is sufficiently short, one could argue that this approach provides a good approximation, since the negative economic impacts of the overuse of the resources may not be perceived or anticipated by agents. However, for a long horizon, it is unlikely that economic agents do not react to the deterioration of the resource stock, especially if physical effects (such as resource constraint, damages, pollution, etc.) become directly perceivable.

Certain CGEMs incorporate the resource constraint by assuming that the resource is an input of the production function – Calzadilla et al. (2010), Calzadilla et al. (2010). The supply of the resource is exogenous and the assumption of perfect flexibility of prices insure that the demand for the resource is equal to the supply at every period. This approach interprets the resource constraint as an exogenous productivity shock. When the resource is lacking, the productivity of the other production factors is lower. One need to use more of these production factors to produce the same level of production as before the shock. Therefore the average cost of production is higher because of the standard hypothesis of a production function that is homogenous of decree 1 (constant returns-to-scale). The main drawback is that the supply of the resource is exogenous and that demand is set to this level because prices are perfectly flexible. The possibility that the demand for the resource is lower than the resource constraint is a priori excluded. In many cases of resource constraint including land or water, this assumption is not satisfactory since it is completely possible for the demand at a given point in time to be lower than the supply constraint.

This weakness of most CGEM comes from their difficulties to model consistently the effect of the degradation of the resource stock on prices and the role for anticipation and rational

[1] An alternative approach to CGEM is the use of partial equilibrium model: e.g. Mannaerts (2000) for references. The main drawback of these models is that they only consider the material markets and do not account for feedback effects on the rest of the economy. There are therefore not reviewed in the present study.

economic behavior in a context of large uncertainty about the future. One important issue is that the taking into account of these dimensions hugely increase the complexity of the algebraic and computational resolution since it requires the use of intertemporal maximization resolution techniques. Examples of these approaches can be found in the literature related to the neoclassical model of (non-)renewable resources. But these are often in partial equilibrium concentrating on one resource (e.g. Okullo and Reynès (2011) for oil market). The transposition into a general equilibrium framework with a large number of sectors and economic regions would be very tedious, and therefore (to the best of our knowledge) has not been tempted so far. Other examples are the neoclassical models involving a social planner such as the DICE model which can account for uncertainty (e.g. Hwang et al. (2013). Unfortunately there is no social planner in reality and these models provide an analysis at a very aggregate level. This makes them little suited for practical purposes at country level.

It should be noted that the complexity of this transposition may not be the main issues preventing modelers from incorporating these approaches into a CGEM. Another important issue is that inter-temporal neoclassical approaches are far from being exempt from critics and weaknesses. Indeed, methods using inter-temporal maximization approach rely on bold assumptions relative to the agents' knowledge of the future, the length of their inter-temporal horizon, their risk aversion, the level of the discount rate. This makes them have properties largely at odd with reality. For these reasons, modelers are reluctant using these approaches to better account for the impact of supply in CGEM.

We use here an intermediary approach by modelling the shadow price of the resource, that is the price someone would have to charge so that consumers do not overuse the resource. This approach allows two cases: (1) the case where the resource constraint is inactive because the limit of the supply is not reached; (2) the case where the resource constraint is active, that is when the supply limit is reached. Technically, this amount in conducting 2 simulations. The first one assumes the absence of resource constraint. If the implied demand is lower than the actual supply (case 1), the algorithm is stoped here and there is no need to conduct a second simulation. But if the implied demand is higher than the actual supply, we conduct a second simulation where the shadow price of the resource adjusts to insure that the demand is equal to the supply (case 2).

Moreover, in order to increase the realism of the model, EXIOMOD will be linked to by the biophysical model LPJmL – see BONDEAU et al. (2007) – that will model the resource supply constraint for water and land use. The consistency between the two models will be insured through an iterative process. EXIOMOD will define the demand relative to water and land use that will be used as an input for LPJmL. LPJmL will define the supply constraint for water and land use. An adjustment in the (shadow) prices of water and land use in EXIOMOD will insure the consistency between supply and demand.

This report describes the way water demand and land use is modeled in EXIOMOD. Section 2 describes the methodological approach: Sub-section 2.1 gives a short description of EXIOMOD; Sub-section 2.2 describes how the modelling of water demand and land use in EXIOMOD; Section 2.3 explains the interaction between LPJmL and EXIOMOD. Section 3 concludes and describes the future steps. Section 4 gives the publications plan resulting from the work described.

2. Methodological approach

2.1. Short presentation of EXIOMOD

The EXIOMOD is a large scale and highly detailed world model built on the detailed Input-output database EXIOBASE. It is a macro-economic CGEM model that divides the global economy in 43 countries and a Rest of World, and 163 industry sectors per country. The model includes 5 types of households, a representation of 29 types GHG and non-GHG emissions, different types of waste, land use and use of material resources (80 types). Moreover, it includes a physical (in addition to the monetary) representation for each material and resource use per sector and country. The model is presently calibrated on the data for 2007. A technical description is provided in Appendix A (Chap. 6),

CGEMs (and in particular EXIOMOD) are the class of simulation tools that use large datasets of real economic data in combination with complex computational algorithms in order to assess how the economy reacts to changes in governmental policy, technology, availability of resources and other external macro-economic factors. EXIOMOD model consists of (1) the system of non-linear equations, which describes the behavior of various economic actors and (2) very detailed database of economic, trade, environmental and physical data. The core part of the model database is the Social Accounting Matrix, which represents in a consistent way all annual economic transactions.

A CGE model accounts for the interaction/feedbacks (a) between price and demand/supply quantities and (b) between economic agents at the macro and sectorial level. Therefore, it gives the economic relations between all industry sectors via their intermediate use. For example, it shows how much of different materials, products and services are used by the construction sector depending on the assumptions about its production technology. In case the efficiency of material use in the construction sector is improving over time, the model will calculate (1) direct effects: change in material use per unit of output of the sector and (2) indirect or rebound effects: the change in price of construction services as well as the change in the total output of the construction sector over time. The later outcome is translated in EXIOMOD into the change in physical materials use and extraction as well as changes in generated emissions and waste.

Production technology of each sector is mathematically formulated in a form of production function. It provides information on how many units of the composite output of a sector is technologically possible to produce using the given amount of labor, capital and intermediate inputs. In accordance with their production technology, sectors have substitution possibilities between different intermediate inputs and production factors. The production technology is modeled as a nested Constant Elasticity of Substitution functions. The nesting structure allows to introduce different substitution possibilities between different groups of inputs. Figure 1 illustrates the general nesting structure of EXIOMOD. At the first level, land and resources are separated from the other inputs (labor, capital, energy and material). Therefore the economic impact of water and land constraints will transit through the nest land/resource. In this nest, we assume fixed shares of its constituents with no substitution possibilities. This implies use of

Leontief production technologies, which is a special case of CES function with the value of elasticity of substitution approaching zero.

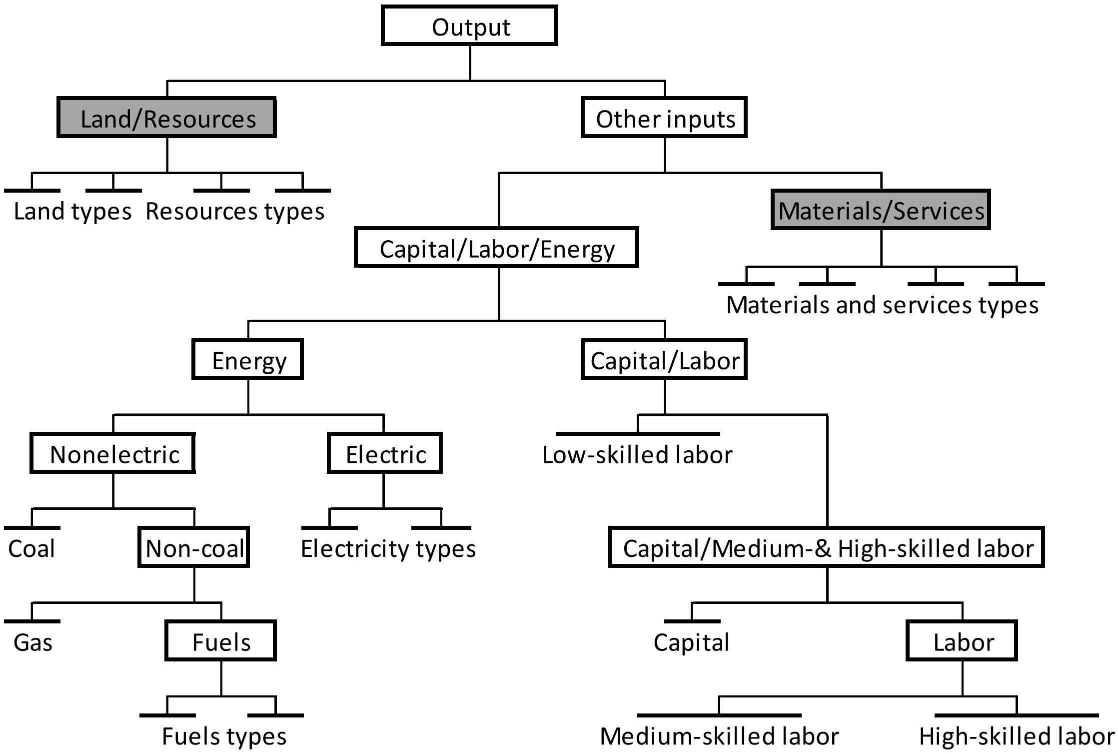

Figure 1. Production function - nested Constant Elasticity of Substitution (CES)

2.2. Modelling of water demand and land use in EXIOMOD

In the current version, water consumption and land use are defined by the level of production. In general, an increase of 1% in the level of production leads to an increase of 1% in resource use. The high level of detail allows for tracking the use by each economic agent (economic activities and consummers) of each resource both in terms of economic flows and physical quantities. We can therefore reconstruct the change in stock for any resource over a certain period. But the impact of the limit of the availability of a resource on the economy is insufficiently taken into account. Indeed, the model implicitly assumes that the supply for water and land use can always follow the quantity demanded by economic agents. The demand is never contrained by the supply of the resource. This is a bold hypothesis given the alarming information of many experts regarding the negative impact of human economic activities on the use of natural resources.

The main objective of this research is to overcome this weakness in the case of water and land use. Given the current state-of-the-art regarding the modelling of resource constraints, finding a generic solution to this issue for every resource is particularly difficult because of the specificity of each resource. Therefore, as a first step, we concentrate on land and water use. To do so, EXIOMOD will be extended with water demand and land use decisions. The land and water constraints will be explicitelly taken into account in the production function. Instead of assuming simply that the supply follows the demand, we will “endogenize” the supply of water and land by coupling EXIOMOD with the biophysical model LPJmL. General equilibrium mechanisms and iterations between the simulations of EXIOMOD and LPmL will insure the equilibrium between supply and demand. In particular this equilibrium will be ensured by price adjustments at several levels: the (shadow) price of the resource itself, the price of the resource intensive commodities, etc.

One of the difficulties in modelling the water and land constraints is that the equilibrium between the demand and supply for a resource cannot always be achieved by the adjustment of its price. The reason is that there is not always a market for natural resources. Oxigen is free, part of the water is free. A part of the land is owned and it is there difficult to define precisely the revenues generated by the land and their direct beneficiaries. In these cases, the resource constraint should be modeled more as a productivity shock than a price shock. More elegantly, it can be modeled as an increase in the shadow price of the resource, that is the price someone would have to charge so that the consumer do not overuse the resource. The shadow price approach has the advantage to generalize two cases:

(1) the case where the supply is determined by the demand, that is where the unconstrained economic demand for the resource is actually lower than the resource constraint. This case is equivalent to the traditional modelling that assumes that the supply of the resource follow the demand. In mathematical terms, the resource constraint is said inactive, and its Langrange multiplier (or shadow price) is zero.
(2) the case where the demand is determined by the supply, that is where the unconstrained economic demand for the resource would be higher than the resource constraint. This case could be modeled as an exogenous decrease in productivity that increases the price of all the commodities using the resource in their production process. The productivity shock approach has the desavantage to exclude a priori case 1, that is the possibility that the unconstraint demand for the resource is lower than the resource constraint. A equivalent interpretation is to model this effect is an increase in the shadow price of the resource. In mathematical terms, the resource constraint is said active, and its Langrange multiplier (or shadow price) is non-zero. The tighter the constraint, the higher its shadow price.

In order to distinguish the marketed from non marketed water, we will modify the production function as in Figure 2. The marketed water is an intermediary consumption in the production process like any marketed material. Marketed water uses as an input in its production process free blue water resource. In agriculture, rain fall may be substituted to irrigation. The latter may use as an input both marketed and blue waters, both being substitutable to a certain extent.

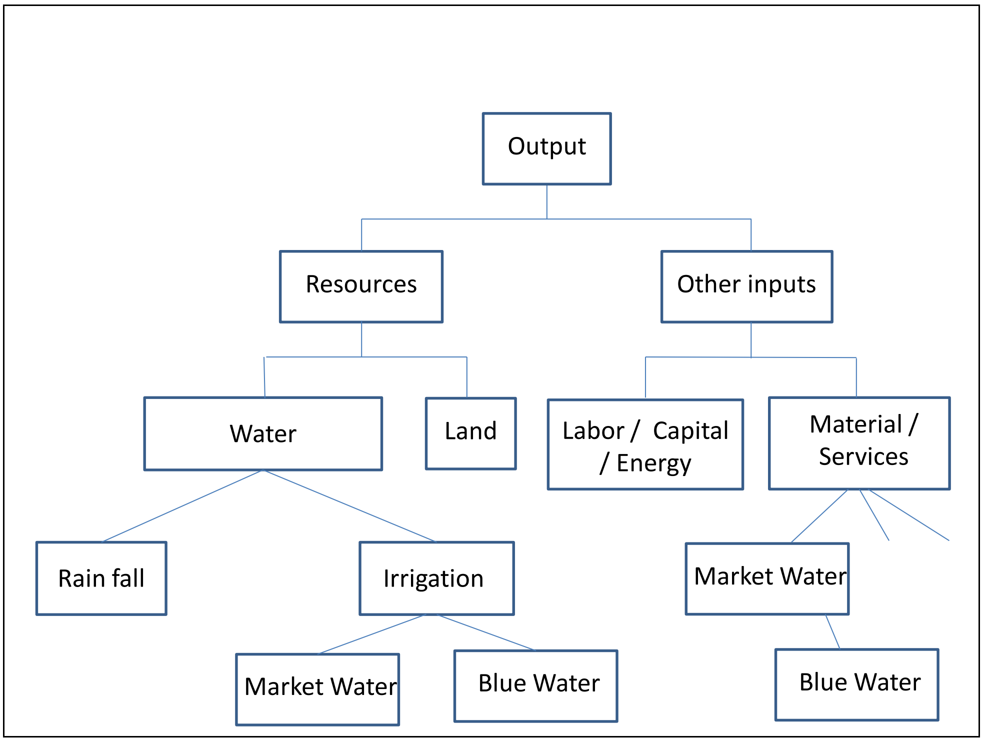

Figure 2. Modification of the production function in EXIOMOD

2.3. Interaction between LPJmL and EXIOMOD

In order to model more precisely the economic impact of water and land constraints, EXIOMOD will be hard linked with the ecological model. On one hand, EXIOMOD is a global multicountry/multisector model and therefore allows for a comprehensive analysis of the economic pressures on the environment. In particular, it can provide the demand for water and land use of each economic agent. CO2 trajectories will be linked to climate change through an existing scheme of fast-linking emission trajectories to IPCC climate model patterns. On another hand, the biophysical model LPJmL proceeds from climate, atmospheric CO2 concentrations and land use patterns/scenarios to compute in deep regional and product detail the supply of biomass for agricultural, energetic and other uses, the supply of water and use of land. It models biomass and water supply under given environmental constraints and economic demands in a spatially explicit manner.

The output of EXIOMOD simulations will provide the economic demand for water and land use to LPJmL. It corresponds to the resource demand that economic sector would like to achieve at the current prices if the resource was unlimited. In other word, it defines how demand may constrain the supply. Of course, regarding resource use, the contrary is more likely to happen at least in the long run since we expect that the supply will constrain the demand. The output of LPJmL allows for considering this case too. The resource supply constraint computed by LPJmL will be used by EXIOMOD to calculate the set of (shadow and commodities) prices that allows the economy to respect the limit of the resource. Environmental policies could eventually be used to reach this sustainable equilibrium. Constraints in supply of biomass and/or water with consequences for the economic system may be due to true environmental constraints (e.g. water scarcity) as well as competing objectives (e.g. environmental conservation, maintaining natural habitats, etc.). In either case, the environmental resource available to industrial processes is quantified in a biogeochemically consistent manner.

The main challenge is to make sure that both models provide a consistant story, that is the constraints the two models impose on each other are well taken into account at every period of time. To do so, an algorithm of simulation that iterates between the two models has to be define. As a starting point, the step of the simulations would be as follows:

1. Simulation of EXIOMOD without resource constraint
   - Output: data for the biophysical model LPJmL
2. Simulation of LPJmL
   - Output: data relative to water and land use constraint
3. Simulation of EXIOMOD with resource constraint
   - Output: data for the biophysical model LPJmL
4. Simulation of LPJmL
   - Output: data relative to water and land use constraint
   - If resource constraint (4) = resource constraint (3), STOP
   - If not, GO TO step 3.

The input and output data for EXIOMOD are given in Table 1. LPJmL will use as an input the output of EXIOMOD whereas its output will be used as an input in EXIOMOD.

Table 1. Input/output data for EXIOMOD

	Variables
Input	Land constraint, Water constraint
Output	Production per type of crops, and per country

3. Conclusions and future steps

This report presents the modelling of water demand and land use in EXIOMOD and defines how EXIOMOD can be linked with LPJmL. It also points the modelling improvement this brings compared to the existing approaches published in the literature.

The next step is to implement and test this procedure in the case of water and land use. This will imply to overcome several technical issues as previously discussed with GWS and PIK such as data exchange or models consistancy relative to the areas covered. Then the result obtain with EXIOMOD will be compared with the one obtained with GINFORS by GWS. In particular, a comparison of key indicators, such as land footprint and water footprint, could be performed.

4. Publications resulting from the work described

- Technical paper on the modelling approach implemented in the project to be submitted in an international peer-reviewed computational journal such as Economic modelling, Environmental Modelling & Software or Environmental and Resource Economics.
- A policy paper on the results obtained with modeling approach presented to be submitted international peer-reviewed in a policy journal such as Environmental Science & Policy or Ecological Economics

We intend to present the drafts of these papers in international conferences such as the conference on Water resource and environmental research or of the European Association of Environmental and Resource Economists (EAERE).

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6. APPENDIX A: Description of EXIOMOD

6.1. Summary

This document represent detailed technical description of the EXIOMOD model. Computable General Equilibrium (CGE) framework is the basis of EXIOMOD. This framework takes as a basis the notion of the Walrasian equilibrium. Walrasian equilibrium is one of the foundations of the modern micro economics theory. CGE models are a class of economic models that use actual economic data to estimate how an economy might react to changes in policy, technology or other external factors. The model consists of (a) equations describing model variables and (b) a database (usually very detailed) consistent with the model equations.

The EXIOMOD model utilizes the notion of the aggregate economic agent. They represent the behavior of the whole population group or of the whole industrial sector as the behavior of one single aggregate agent. It is further assumed that the behavior of each such aggregate agent is driven by certain optimization criteria such as maximization of utility of the households or cost-minimizing behavior by producers and average-cost pricing.

The EXIOMOD model includes the representation of the micro-economic behavior of the following economic agents: several types of households differentiated by 5 income quintiles, production sectors differentiated by 200 classification categories developed in CREEA project; investment agent; federal government and external trade sector.

The document is structured as follows. Firstly, the overview and the general framework of the EXIOMOD model is given. Secondly, we describe all the representative agents and markets included in the in the model. Further, we discuss the possibilities for future development and applications of the model. And at last the model database is described.

6.2. Overview of EXIOMOD model

The model incorporates the representation of 43 main countries of the world. It includes an individual representation of EU27 countries and candidate member states. It also includes the largest emitters such as US, Japan, Russia, Brazil, India and China. The EXIOMOD model is a dynamic, recursive over time, model, involving dynamics of capital accumulation and technology progress, stock and flow relationships and adaptive expectations.

EXIOMOD combines economic, environmental and social domains in an efficient and flexible way:

1. Social effects: includes the representation of three education levels, ten occupation types and households grouped into five income classes. One can trace the effects of specific policy on income redistribution and unemployment.
2. Economic effects: the model captures both direct and indirect (wide-economic and rebound) effects of policy measures. EXIOMOD allows for calculation of detailed sector-level impacts at the level of 163 economic sectors.
3. Environmental effects: the model includes representation of all GHG and non-GHG emissions, different types of waste, land use and use of material resources.

6.3. General framework of the model

Traditional computable general equilibrium (CGE) models as well as macro-models have ignored uncertainty, possibility to go beyond the rational behavior of households and proper treatment of expectations. Most of them also treat technological progress as exogenous to the model which makes it difficult to use such models for long-term policy analysis.

The use of CGE as a main structure of EXIOMOD allows for:

- Capturing intra-regional and inter-regional effects.
- Full representation of inter-sectoral spillovers.
- Efficient incorporation of all main resource constraints.
- Proper treatment of unemployment and under-utilization of capital stock.

By combining various methodological approaches EXIOMOD framework allows for:

- Dynamic analysis with endogenous investment decisions and development of capital stock, human capital and RTD stock
- Addressing uncertainty and provide confidence interval for policy affects by means by formal sensitivity analysis using a Monte-Carlo simulations
- Incorporation of uncertainty and irrationality into the behavior of economic agents via adaptive expectations
- Semi-endogenous technological progress

6.4. Production

Each sector within a country produces primary and a number of by-products. A similar good or a service produced by different sectors is considered to be a unique variety of this type of commodity. Behavior of the sectors is based on the minimization of the production costs for a given output level under the sector's technological constraint. Production costs of each sector in the EXIOMOD model include labor costs by type of labor, rents paid for the use of physical capital, land natural resources and the costs of intermediate inputs. In this section we consider the production technologies and optimizing behavior of the sectors. The way in which unique varieties of commodities produced by different sectors are combined and delivered to the consumers is described in the section on trade.

6.4.1. Production function

Production technology of each sector is mathematically formulated in a form of production function. It provides information on how many units of the composite output of a sector is technologically possible to produce using the given amount of labor, capital and intermediate inputs. In accordance with their production technology, sectors have substitution possibilities between different intermediate inputs and production factors. In the EXIOMOD model the producers are assumed to work in the regime of full capacity utilization and always reach the maximum of their technological possibilities.
The production technology is modeled as a nested Constant Elasticity of Substitution functions. The nesting structure allows to introduce varying substitution possibilities between different groups of inputs. Typically one would expect lower substitution possibilities on a higher level of the nested structure, e.g. between factor inputs and intermediate inputs, than on a lower level, e.g. between labor with different levels of education. We employ the similar nested structure for all the sectors, but the values of substitution elasticity could vary across the sectors. Figure 3 illustrates the general nesting structure. The presented production technology gives an opportunity for a very detailed of various energy products. The introduced level of detailing is very important in modeling environmental effects, the topic is discussed in one of the subsequent chapters. Furthermore, explicit distinction between fossil fuels, gas, electricity from coals, electricity from renewable sources and etc. allows to consider long-term scenarios in the context of technology shifts and climate change policies. On the capital-labor side, treatment of low-skilled labor as a separate from the other types of labor nest reflects low substitution possibilities between in a real production process between workers with tertiary education and workers with primary education.

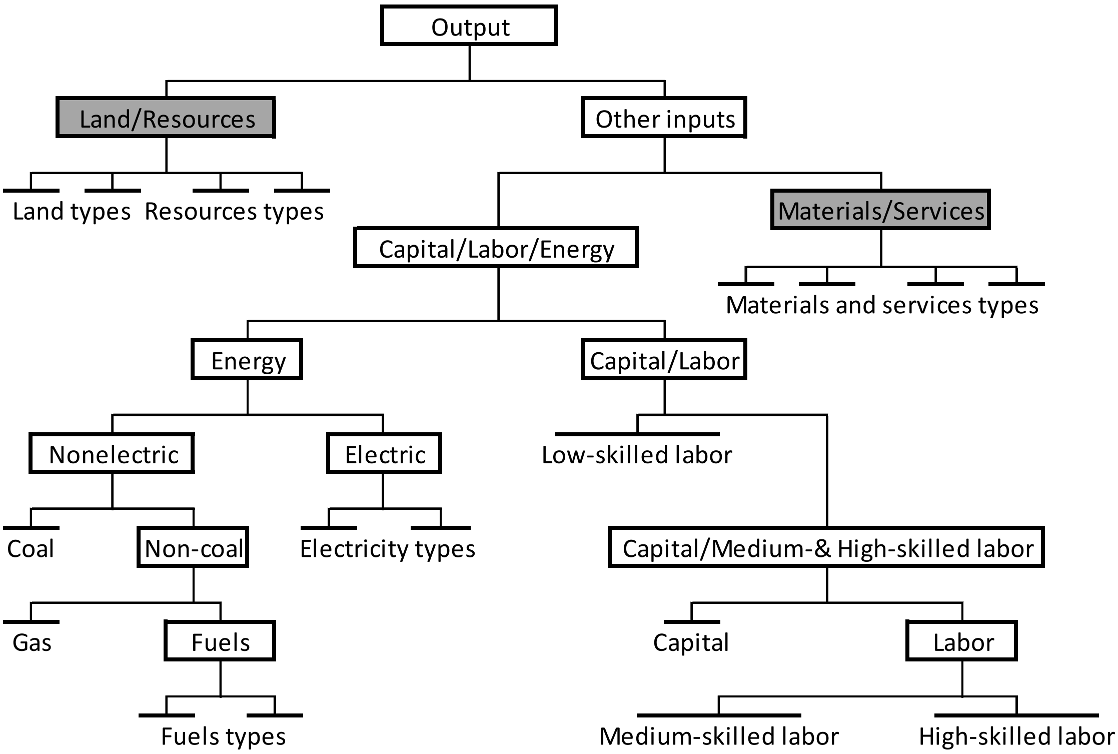

Figure 3. Production function - nested Constant Elasticity of Substitution (CES)

Two of the nests, Land/Resources and Materials/Services, require to use the fixed shares of its constituents with no substitution possibilities. This implies use of Leontief production technologies in these two nest, which is a special case of CES function with the value of elasticity of substitution approaching zero.
An example of CES technology is given by equation (1) for one the lowest nest showing the combination of different fuels[2]. Substitution possibilities between different fuel types Fi are represented by σ_F and γ_{Fi} stands for the share parameter of a specific fuel type. The values of the share parameters are between zero and one and in each nest sum up to one.

$$FUELS = a_F \cdot \left(\sum_{Fi} \gamma_{Fi} \cdot IO_{Fi}^{\frac{\sigma_F - 1}{\sigma_F}} \right)^{\frac{\sigma_F}{\sigma_F - 1}} \qquad (1)$$

Using unit costs minimization principle we derive the prices for all the nested bundle aggregates moving bottom-up in the structure. For the fuel bundle the price expression takes the following form:

$$P_{FUELS} = \frac{1}{a_F} \cdot \left(\sum_{Fi} \gamma_{Fi}^{\sigma_F} \cdot \left(P_{Fi} \cdot (1 + trm_{F1}) \cdot (1 + tc_{Fi}) \right)^{1-\sigma_F} \right)^{\frac{1}{1-\sigma_F}} \qquad (2)$$

As it follows, the unit price of a higher nest depends on the market value of the lower nests. The only exception here in the capital, since not only the market rent should be taken into account, but also the costs of replacing depreciated capital.

[2] In equation (1) and all the subsequent equation of this chapter we omit sector subscript s, but it is assumed that all the parameters, prices and volumes are sector-specific.

The producers in the EXIOMOD model take prices of all the intermediate and factor inputs and of their final product as given. Combining the information on these prices, unit costs of bundles in CES production function and the output at a higher nest level, we are determining production factor demand in each nest going from the top to the bottom of the structure. In the highest level the output is set to be equal to the demand at given prices. If we know, for example, that $KLEM$ in the number of units of 'Other inputs' needed to satisfy the demands to the final output, the demand function for 'Capital/Labor/Energy' and 'Materials/Services' would be the following:

$$KLE = KLEM \cdot \left(\frac{\gamma_{KLE}}{P_{KLE}} \right)^{\sigma_{KLEM}} \cdot P_{KLEM}^{\ \ \sigma_{KLEM}} \cdot a_{KLEM}^{\ \ \sigma_{KLEM}-1} \quad (3)$$

$$MS = KLEM \cdot \left(\frac{\gamma_{MS}}{P_{MS}} \right)^{\sigma_{KLEM}} \cdot P_{KLEM}^{\ \ \sigma_{KLEM}} \cdot a_{KLEM}^{\ \ \sigma_{KLEM}-1} \quad (4)$$

For the Leontief nest of 'Materials/Services' the demand function is taking form:

$$IO_c = ioc_c \cdot MS \quad (5)$$

The similar form is used in the 'Land/Resources' nest.

6.4.2. Commodities' output

The production technology presented above describes how various intermediate commodities and factor inputs are combined in order to produce composite sector output. The total composite output is further split into separate commodities. We assume that each sector produce one main product and a number of by-products. Distribution shares are taken to be constant over time:

$$XDD_c = iop_c \cdot XD \quad (6)$$

The possibility of one sector produce several products and one product being produced by several sectors allows us to use a complete set of supply and use tables in the model database instead of square input-output tables. It also increases the model's flexibility to be used with different databases, including the ones where a number of commodities is different from a number of sectors in the economy. For further details on the model database see the corresponding section.

6.4.3. Calibration

Such an elaborate production technology requires knowledge of a large number of parameters. For each of the nest there three types of parameters: substitution elasticity σ, shares of the inputs γ and technology level a. In the nests modeled using Leontief technology only technology parameters ioc are required. At the current stage of the model development the values of elasticity of substitution are taken from the literature research; share are technology parameters are obtained via calibration procedure using the data for the base year. The following values for substitution are employed:

Nest	σ
Output	1.8
Other inputs	1.6
Capital/Labor/Energy	1.5
Capital/Labor	1.3
Capital/M- and H-skilled labor	1.2
Labor	0.5

Energy	1.2
Electric	0.5
Non-electric	0.8
Non-coal	0.6
Fuels	0.5

Inclusion of sector- and region- specific substitution possibilities would be beneficial for the model. Unfortunately due to limitations of real data we cannot introduce different elasticity values for all the 129 sectors and 43 countries included in the model. At the later stage, for a number of aggregated sector groups and country blocks we will introduce specific values of elasticity substitution, based on combination of econometric estimates and engineering data.

6.5. Labor market

In the current version of EXIOMOD labor market representation is rather simplistic. In each region supply of labor per each education attainment level is a function of the population (pop_{ed}) with corresponding education level and the real wage rate (w_{ed}/P), where w_{ed} is the skill-specific nominal wage and P is the region-wide consumer price index. The equation reads the following:

$$LS_{ed} = B_{ed} \cdot pop_{ed} \cdot \left(w_{ed}/P \right)^{\sigma_{ed}} \qquad (7)$$

The equation reflects positive relation between the level of real wage rate and percentage of population participating in the labor force.
The unemployment rate in each region is exogenously set to zero, reducing the labor market to the situation of perfect competition with labor mobile between sectors. From the cost-minimization problem of firms we know the sector specific demand for labor has a functional form similar to the one in equations (3) and (4). Total demand for labor of specific skills level is given as an aggregation of demands over all sectors:

$$LD_{ed} = \sum_{s} LD_{ed,s} \qquad (8)$$

Labor supply should be equal labor demand:

$$LS_{ed} = LD_{ed} \qquad (9)$$

Both labor demand and labor supply are functions of the rate w_{ed} , equation (9) defines equilibrium condition of labor market.
In the current representation the labor market exhibits perfect competition properties with labor supply mobile across sectors, but immobile across regions. Migration flows are not explicitly modeled, but they are implicitly incorporated in the exogenous path of the population pop_{ed} . The elasticity of labor supply σ_{ed} is taken as 0.15 and equal between education levels. Scaling parameter B_{ed} is obtained via calibration procedure.

6.6. Consumption, savings and social effects

In the EXIOMOD model consumers are grouped into 5 categories, one for each income quintile. Each population group is described by one representative household in each country. Each of the representative consists of the individuals differentiated by three types of education levels. Although the individuals with

the different levels of education contribute unevenly to the total budget of the household, the consumption decisions are made in such a way, so it maximizes the satisfaction level of the household as a whole.
The total income of a representative household in each population category is calculated as the sum of its labor and capital rent:

$$Y_i = \sum_{ed} shL_{ed,i} \cdot LS_{ed} \cdot w_{ed} + shK_i \cdot \left(\sum_s K_s \cdot r_s + K^{land} \cdot r^{land} + K^{resource} \cdot r^{resource} \right) \qquad (10)$$

The labor income consists of total wages received by individuals with each level of education. It is assumed that the return to physical capital used by all sectors located in the country and the return on land and natural resource in the country are allocated to the local households. The return on each type of capital is calculated the corresponding capital input multiplied by the specific rate of return. Share coefficients $shL_{ed,i}$ and shK_i are based on the extensive socio-economic dataset.

Besides from wages and capital income, the households receive transfers from federal government, as well as transfers from abroad corrected for the level of exchange rate. The money received by the household are spent on payment of income taxes, current consumption of goods and services and savings for future consumption. The EXIOMOD model does not involve inter-temporal optimization, and the level of savings is determined by a marginal propensity to save applied to the total disposable income:

$$SH_i = mps_i \cdot \left(Y_i \cdot (1 - ty) + TRF_i + HTRROW_i \cdot ER \right) \qquad (11)$$

The marginal propensity to save mps_i is calculated during the calibration procedure.

The amounts of goods and services bought by the representative households are determined according to the utility-maximization principle. The household's utility is associated with the level ad structure of its consumption. In the current version of EXIOMOD a household in each income category maximizes the following Cobb-Douglas utility function:

$$U_i = \prod_c C_{i,c}^{\alpha_{i,c}^H} \qquad (12)$$

Subject to its budget constraint. Representation of households' behavior via this type utility function allows to reflect the differences in consumption structures of the households with different income levels. On the other hand, this functional form does not allow to capture variations of substitution possibilities between different (sub-groups) of commodities. One of the following steps in the model development is to include CES-utility representation with the special attention paid to substitution possibilities in the nests of transportation services, electricity and other energy types. Maximization of the utility problem (12) yields the following optimal consumption levels:

$$C_{i,c} = \alpha_{i,c}^H \cdot \frac{Y_i \cdot (1 - ty) + TRF_i - SH_i + HTRROW_i \cdot ER}{P_c \cdot (1 + trm_c) \cdot (1 + tc_c)} \qquad (13)$$

Due to inclusion of representation of three education levels and households grouped into five income quintile classes one can trace the effects of a specific policy on income redistribution and distinguish between measures that lead to increased and decreased income inequality in each specific country.

6.7. Trade

The formulation of trade flows of the EXIOMOD model is based on the Armington assumption of heterogeneity between the goods and services produced by different sectors and by different countries. According to this assumptions, similar commodities produced by different producers represent unique

varieties which fall into the same category of goods or services specified in the model, and there is a demand for each of these unique varieties. The Armington specification is used in order to explain why one country would export and import at the same type commodities from the same category.
One can imagine that all the trade of each commodity type in the country is coordinated by one trading agent, who doesn't bear any additional cost and doesn't require any commission. The trading agent operates in three steps. Firstly, he combines the commodities produced by different sector into one composite domestically produced product. Secondly, he determines the shares of this composite product which will be sold domestically and which will go on export. And lastly, he combines the domestic product with imported varieties and delivers the final product for intermediate consumption, consumption of government and households and for fixed capital formation.

6.7.1. Varieties of domestic sectors

As it was mentioned before , the similar types of commodities can be produced simultaneously by several sectors. For one sector this commodity would be the main product and for other just one of their by-products. It is assumed that there is a demand for each of the produced varieties. The substitution possibilities between the commodities produced by different sectors are described by the CES function, according to which the products with different specification are used in a certain proportion in order to produce a composite domestic commodity. The exact proportions depend on the value of elasticity of substitution and relative prices of each of the unique varieties. If the total amount of composite domestic commodity equals to XXD and the price of each variety is PDD_s then the cost-minimizing demand for a sector-specific variety is calculated using the following formula:

$$XDD_s = XXD \cdot \left(\frac{\gamma_{B,s}}{PDD_s} \right)^{\sigma_B} \cdot PDDE^{\sigma_B} \cdot a_B^{\sigma_B - 1} \qquad (14)$$

The price of the composite domestic commodity $PDDE$ is derived as the weighted average of the prices of the commodities bought from different sectors:

$$PDDE \cdot XXD = \sum_s PDD_s \cdot XDD_s \qquad (15)$$

6.7.2. Export

The composite domestic commodity should be further distributed between domestic and international markets. The generic commodity cannot be delivered to a market right away and should undergo some modification to meet the demands of the specific consumers. The modification process is modeled via Constant Elasticity of Transformation (CET) production function. Firstly, the composite domestic commodity XXD is transformed into the one for the domestic market $XDDE$ and the one for the international market E. Further, the international commodity is modified to each specific country E_{cnt} and for the rest of the world E_{ROW}. The economy of the rest of the world is not explicitly modeled in the EXIOMOD and the exports and imports to/from that region are effectively used only in order to ensure the balance in the global trading system. The amount of product delivered to each specific market is derived using cost-minimization principle and depends on parameters of CET function and the prices offered at the domestic and international markets. The total of export takes form:

$$E = XXD \cdot \left(\frac{\gamma_T}{PE} \right)^{\sigma_T} \cdot PDDE^{\sigma_T} \cdot a_T^{\sigma_T - 1} \qquad (16)$$

The bi-lateral flow are derived in a similar way.

6.7.3. Import

The final product delivered to the domestic market is a combination of commodities which are produced domestically and imported from other countries. Here we again use Armingron assumption about heterogeneity of products from different origins. Substitution possibilities are described using the CES functional form and all the equation for prices and volumes are similar to the ones when dealing with specific varieties produced by different domestic sectors. The only difference is that first the products imported from different countries M_{cnt} and the rest of the world M_{ROW} are combined into a composite imported commodity M, which is then in combination with the domestic production $XDDE$ given the final product for the consumers X. The demand for domestic commodity $XDDE$ is calculate using the formula:

$$XDDE = X \cdot \left(\frac{\gamma_A}{PXDDE} \right)^{\sigma_A} \cdot P^{\sigma_A} \cdot {a_A}^{\sigma_A - 1} \qquad (17)$$

The demand for composite import and for bi-lateral trade are calculated using similar formulas. The price of the composite final commodity delivered to consumers P is derived as the weighted average of the prices of the commodities bought from different origins:

$$P \cdot X = PXDDE \cdot XDDE + \sum_{cnt} PM_{cnt} \cdot M_{cnt} + PM_{ROW} \cdot M_{ROW} \qquad (18)$$

6.7.4. Armington elasticity

In each of the three trading phases the values of elasticity of substitution σ_B, σ_T and σ_A are very important equilibrium on all the markets. A lot of econometric studies have been conducted in order to estimate these values and how they differ between different commodities. At the current stage of the development, the EXIOMOD model uses rather high values for substitution possibilities. The exact numbers are given in the following table:

Substitution between	σ
Varieties produced in different sectors	5
Products for domestic use and for export	-1.5
Exports for different countries	-8
Varieties produced in different other countries	8
Domestic production and composite import	1.5

6.8. Energy, environment and welfare analysis

All production and consumption activities in the EXIOMOD model are associated with emissions and environmental damage. This is in particular true for the transportation. The model incorporates the representation of all major greenhouse gas and non-greenhouse gas emissions. Emissions in the EXIOMOD model are associated either with the use of different energy types by firms and households or with the overall level of the firms' output.

The EXIOMOD model includes the following types of emissions: nitrous oxide (N_2O), mono-nitrogen oxides (NO_x), hexachlorobenzene (HCB), carbon dioxide (CO_2), lead (Pb), mercury (Hg), Nickel (Ni), Copper (Cu), Arsenic (As), indeno(1,2,3-cd)pyrene, benzo(b)fluoranthene, benzo(k)fluoranthene, cadmium (Cd), zinc (Zn), Benzo(a)pyrene, carbon monoxide (CO), sulfur oxides (SO_x), methane (CH_4), ammonia (NH_3), selenium (Se), chromium (Cr), dioxins, non-methane volatile organic compounds (NMVOC), polycyclic aromatic hydrocarbon (PAH), polychlorinated biphenyl (PBCs), particulates (PM10, PM2.5), trisodium phosphate (TSP).

Emissions are measured in tones of CO_2 equivalent and are modeled as the fixed shares of production energy inputs of households' energy consumption:

$$EMIS_{s,em} = emc_{s,em} \cdot \sum_{c \in energy} IO_{c,s} \quad (19)$$

$$EMIS\_HH_{em} = emc\_hh_{em} \cdot \sum_{c \in energy} C_c \quad (20)$$

Environmental quality is one of the main factors in measuring households' utility levels. Changes in the levels of emissions have a direct impact upon the utilities of the households. Different income classes in the model are influenced differently by the changes in emission levels of local pollutants. Each emission type represented in the model is associated with the monetary value. The overall monetary value of emissions in the economy is equal to emissions of the households and emissions of the firms. The monetary evaluation of emissions by each household group depends on its willingness-to-pay. It is assumed that the willingness-to-pay is closely correlated with the income of the household. Rich households put a higher value to the emissions than the poor ones. When income-specific monetary coefficients are introduced, the welfare of each of the five population category in the EXIOMOD model can be calculated with the environmental quality incorporated in an additive way.

6.9. Government sector

The EXIOMOD model incorporates the representation of the federal government. The government sector is responsible for collecting taxes, paying subsidies and making transfers to households, production sectors and to the rest of the world. The total tax revenue consists of net taxes on production, net taxes on products, where total consumption is calculated as households' consumption, investments, government consumption and intermediate inputs for production, and, finally, income taxes:

$$TAXR = \sum_s txd_s \cdot XD_s \cdot PD_s + \sum_c tc_c \cdot P_c \cdot (1 + trm_c) \cdot (C_c + I_c + CG_c + \sum_s IO_{c,s}) + ty \cdot Y \quad (21)$$

The federal government consumes a number of commodities, where the optimal government demand is determined according to the maximization of the government consumption utility function subject to budget constraint. According to this constraint the total government tax revenues from equation (21) are spent on transfers to households and to/from the abroad, governmental savings and consumption. The consumption budget of the federal government is distributed between the consumption of various regional commodities according to the Cobb-Douglas demand function:

$$CG_c \cdot P_c \cdot (1 + trm_c) \cdot (1 + tc_c) = \alpha_c^G \cdot (TAXR - TRF - SG + TRROW \cdot ER) \quad (22)$$

6.10. Investment demand

We have considered how the commodities which are domestically produced and/or imported in a country are used as intermediate input into various production processes, for final consumption of the households and the government and for export. The EXIOMOD model also incorporates investment and capital formation decisions in the economy. These decisions are handled by an artificial national investment agent, who is responsible for buying capital goods for physical investments in all the domestic sectors. The investment agent, as well as the trading agents, don't carry any additional cost and just acts as a central coordinator of investment flows.

Buying of the capital goods is financed by the savings made by different agents in the economy. The total savings consists of the savings made by the households, government, the rest of the world and the producing sectors. The savings of the sectors are assumed to be equal to their depreciation costs, which depend on the depreciation rate δ_s and the unit cost of physical capital PI. The total savings accumulated at each period of time are corrected for the total net changes in inventories. Then the total budget available for investments is taking the form:

$$IT = SH + SG + \sum_s \delta_s \cdot K_s \cdot PI + SROW \cdot ER - \sum_c SV_c \cdot P_c \quad (23)$$

The investment is spend on buying different types of capital goods such as machinery, equipment and buildings. The different commodities are combined into one composite physical capital K. The exact mixture of the different capital goods for physical investment is determined by the maximization of the Cobb-Douglas utility function of the investment agent. Therefore the demand for capital goods for investment purposes takes the following form:

$$I_c = \frac{\alpha_{I,c} \cdot IT}{P_c \cdot (1 + trm_c) \cdot (1 + tc_c)} \quad (24)$$

The unit price of the composite physical capital can be derived using the formula:

$$PI = \prod_c \left(\frac{P_c \cdot (1 + trm_c) \cdot (1 + tc_c)}{\alpha_{I,c}} \right)^{\alpha_{I,c}} \quad (25)$$

The investment agent is also responsible for distribution of composite physical capital good between the domestic productive sectors which is further described in the Recursive dynamics section.

6.11. Model closure

Being a CGD-type model, EXIOMOD is formulated as a system of equations, where each equation represents either derived first order conditions or balance conditions. The model is solved as a mixed complementarity problem (MCP), where each of the equations is associated with one endogenous variable.

The balance conditions include income balances and market clearance conditions. Under income balance it is required that is each agent in the economy spends its total income on consumption, transfers and savings. For a producer it implies zero-profit conditions, i.e. their total revenue is spent on purchasing of intermediate inputs, payment for labour and capital cost and transfers in the form of taxes and subsidies to and from the government:

$$(1 - tdx) \cdot \sum_c PDD_c \cdot XDD_c = K \cdot r + K \cdot \delta \cdot PI + \sum_{ed} L_{ed} \cdot PL_{ed} + \sum_c IO_c \cdot P_c \cdot \left(1 + trm_c\right) \cdot (1 + tc_c) \quad (26)$$

Each representative household spends its total factor earnings plus receipts from the government either on paying taxes, consumption or savings:

$$Y + TRF + HTRROW \cdot ER = Y \cdot ty + SH + \sum_c C_c \quad (27)$$

The government budget is also balanced in each period of time. Finally, the model includes the trade balance constraint, according to which the value of the country's exports plus net governmental transfers to the rest of the world are equal to the value of country's imports.

The market clearing conditions imply that the sum of demand for a particular commodity is equal to the sum of its supplies. Each agent in the economy is a price-taker and the markets are cleared through adjustment of the price vector and the demand and supply quantities are in the equilibrium. Labour market clearing condition is given by equation (9) implying existence of only voluntary unemployment in the economy. The total population is given exogenously in the model and the equilibrium wage as defined by the wage curve ad in equation (7). The sector-specific capital in each period of time is fixed and defined by the depreciation rate and the investment decisions made in the previous periods (see section Recursive dynamics for more details). Therefore the capital market is cleared via adjustment of the sectoral return to capital r, where capital demand is calculated using the formula:

$$K = KL \cdot \left(\frac{\gamma_K}{r + \delta \cdot PI} \right)^{\sigma_{KL}} \cdot P_{KL}{}^{\sigma_{KL}} \cdot a_{KL}{}^{\sigma_{KL}-1} \qquad (28)$$

All the regions in EXIOMOD are linked between each other and with the Rest of the World (RoW) region through trade and international transfers. The RoW region doesn't have its own production and consumption structure and its relations with other regions in the model are regulated by the exogenously fixes transfers and exchange rates. For the producing regions all the lump-sum transfers between the government, household and other regions, as well as government savings, are also set exogenously. For the bi-lateral trade flows import and export prices are equal to prices in other countries multiplied by the exchange rate.

6.12. Recursive dynamics

EXIOMOD has a recursive dynamic structure composed of a sequence of static equilibria. The equilibria are connected to each other via capital accumulation. We assume that capital stocks cannot adjust instantaneously between two time periods, but need to adjust slowly over time based on accumulation of investments. Decisions regarding investment in the composite physical capital good within a specific sector in the current period ($INV_{s,t}$) influence the level of capital stock in the consecutive period ($K_{s,t+1}$). The full capital motion equation takes the form:

$$K_{s,t+1} = (1 - \delta_s) \cdot K_{s,t} + INV_{s,t} \qquad (29)$$

The investment market clears in each time periods. This means that total volume of capital accumulation in the economy is equal to the total investment budget, given by equation (23), divided by the unit price of the composite capital good, given by (25):

$$\sum_s INV_{s,t} = \frac{IT_t}{PI_t} \qquad (30)$$

Due to the model's assumption on an exogenously define savings rate for households, public and international savings, total investments are determined by household income and by the price level of the products constituting the composite capital good. In the EXIOMOD model the investment agent assigns investments to each sector based on the rate of return in the current time period. Firstly, we define the average return on investment (the price that producers pay for the use of capital in their production process) as a weighted average of rates of return in each sector:

$$RGD_t = \frac{\sum_s r_{s,t} \cdot K_{s,t}}{\sum_s K_{s,t}} \qquad (31)$$

The share of total amount of available capital good for investment assigned to a specific sector depends on the existing level of capital stock in the sector, the sector-specific return to capital, compared to the average return on investment, exogenous expectation of growth of the economy (g) and depreciation rate:

$$INV_{s,t} = \frac{IT_t}{PI_t} \cdot \frac{K_{s,t} \cdot e^{\eta_{s,t}}}{\sum_s K_{s,t} \cdot e^{\eta_{s,t}}} \quad (32)$$

,where

$$\eta_{s,t} = (\frac{r_{s,t}}{RGD_t} - 1) + g \cdot \frac{r_{s,t}}{RGD_t} + \delta_s \quad (33)$$

6.13. Model database

The unique database of the EXIOMOD model comes from two European projects: EXIOPOL and CREEA. The project EXIOPOL (A New Environmental Accounting Framework Using Externality Data and Input-Output Tools for Policy Analysis) had as a key goal to produce a Multi-Regional Environmentally Extended Supply and Use Table (MR EE SUT) for the whole world. The EXIOPOL database (EXIOBASE) has a unique detail and covers 30 emissions, around resource extractions, given specifically for 130 sectors and products by 43 countries making up 95% of global GDP, plus a Rest of World. A follow-up project of 3.5 Mio Euro under the EU's FP7 program, called Compiling and Refining Environmental and Economic Accounts (CREEA), will expand this database with improved extensions for water, land use and other resources, but above all to create an additional layer with physical information in the (economic) SUT in the EXIOPOL database (in short: EXIOBASE). For the first time this will produce a global, integrated Multi Regional Environmentally Extended Economic and Physical Supply and Use Table (MR EE E&PSUT).
In EXIOPOL project, the following steps were taken:

1. Harmonizing and detailing SUT
   a. Gathering SUT from the EU27 via Eurostat, and other SUT and IOT from 16 other countries (covering in total 95% of the global GDP). Gap filling of missing European SUT via 'same country assumption'. Converting IOT into SUT by assuming a diagonal Supply table.
   b. Constructing Use tables in basic prices via reversed engineering
   c. Harmonizing and detailing SUT with auxiliary data from FAO and a European AgriSAMS for agriculture, the EIA database for energy carriers and electricity, various resource databases for resources, etc.
2. Harmonizing and estimating extensions
   a. Allocating available resource extraction data (e.g. FAOSTAT, Aquastat) to industry sectors
   b. Allocating the International Energy Agency database for 60 energy carriers to sectors of use. Estimating emissions on the basis of energy and other activity data and TNOs TEAM model
3. Linking the country SUT via trade
   a. Splitting of Import Use tables and allocating imports to countries of exports using UN COMTRADE trade shares
   b. Confronting the resulting implicit exports with exports in the SUT, adjusting differences and rebalancing via RUGs GRAS procedure

6.14. Model applications

The EXIOMOD model, with its extensive representation of production structure of the world economy, variation of consumption patterns among social classes and environmental extensions, allows for a wide range of scenarios studies and policy-oriented analysis.
Scenarios analysis considers alternative future development lines and is a source of baseline trajectories for further policy simulations. One can vary exogenous parameters of the model in order to see how different future trends in demography, economy, society, technology, environment and (geo-)politics can produce different baseline scenarios. And one can see how the efficiency and efficacy of specific policy measures depends on the chosen baseline development path. Possible policy-oriented applications with EXIOMOD include assessment of impacts of energy, climate change and resource efficiency policies on the EU and world-wide scales.

6.15. Further model development

The EXIOMOD model is being constantly developed and adapted to the new arising policy questions. Among the upcoming improvements in the model are inclusion of endogenous technological progress and energy/materials efficiency, vintage physical and human capital stocks, integration of both physical and monetary data.
Specifically, the specification of endogenous growth in the model will be based on models of economic growth and catch-up that are widely used in the literature on a leader-follower context of economic development. In this framework, total factor productivity growth, i.e. of combined capital and labour inputs, is generated through own innovations, knowledge spillovers and technology adoption (catching-up). The greater this distance and the higher the absorptive capacity, the greater is the potential for growth through technology transfer. These properties imply that we can classify the growth equation as a semi-endogenous growth model.
Some of the existing CGE models consider gradual efficiency improvement of energy and materials use in the production process, but they assume these improvements to be autonomous and exogenously set by the modelers. We foresee to include the endogenous development of energy and material productivity in the EXIOMOD model in the same fashion as the semi-endogenous catch-up model of the total factor productivity.
In the neoclassical growth theory capital is assumed homogeneous and technical progress disembodied, meaning that all capital units equally benefit from any techno-logical improvement. The disembodied nature of technical progress looks unrealistic, as many if not most innovations need to be embodied in new kinds of durable equipment before they can be made effective. We will further include a vintage capital structure in the EXIOMOD model, meaning that machines and equipment belonging to separate generations have different productivity or face different depreciation schedules. EXIOMOD does not only takes into account the different productivity of each vintage of physical capital but also different productivity of each vintage of human capital and the depreciation of knowledge over time. Explicit representation of human capital vintages is important for understanding and representation of technology diffusion and inequality.
Integration of physical and monetary flows allows one to take proper account on the physical restrictions on consumption and production activities as well as to provide a full analysis of sustainability issues. The EXIOMOD database already includes both monetary and physical units in a consistent way and allows for their integration in a unified modeling framework. Physical dimension provides the representation of all main resource constraints in the global economy.

6.16. Geographical coverage

The model incorporates the representation of 43 main countries of the world. Countries which are not represented separately in EXIOMOD are grouped together into 5 Rest of the world regions.

Countries represented in EXIOMOD
EU27 (each country separately)
United States
Japan
China
Canada
South Korea
Brazil
India
Mexico
Russia
Australia
Switzerland
Norway
Turkey
Taiwan
Indonesia
South Africa
RoW Asia and Pacific
RoW America
RoW Europe
RoW Africa
RoW Middle East

6.17. Activity and commodity coverage

The EXIOMOD model includes 163 types of activities and 200 types of commodities. The classification is based on 59 2-digit NACE rev1.1 (CPA 2002) classification for activities (commodities). A number of sectors was detailed further. These sectors include agriculture, mining, food, energy products, mineral products, transport. The full classification list is given in the tables below.

N	Name of production sector	Code
1	Cultivation of paddy rice	i01.a
2	Cultivation of wheat	i01.b
3	Cultivation of cereal grains nec	i01.c
4	Cultivation of vegetables, fruit, nuts	i01.d
5	Cultivation of oil seeds	i01.e
6	Cultivation of sugar cane, sugar beet	i01.f
7	Cultivation of plant-based fibers	i01.g
8	Cultivation of crops nec	i01.h
9	Cattle farming	i01.i
10	Pigs farming	i01.j
11	Poultry farming	i01.k
12	Meat animals nec	i01.l
13	Animal products nec	i01.m
14	Raw milk	i01.n
15	Wool, silk-worm cocoons	i01.o
16	Manure treatment (conventional), storage and land application	i01.w.1
17	Manure treatment (biogas), storage and land application	i01.w.2

N	Name of production sector	Code
18	Forestry, logging and related service activities (02)	i02
19	Fishing, operating of fish hatcheries and fish farms; service activities incidental to fishing (05)	i05
20	Mining of coal and lignite; extraction of peat (10)	i10
21	Extraction of crude petroleum and services related to crude oil extraction, excluding surveying	i11.a
22	Extraction of natural gas and services related to natural gas extraction, excluding surveying	i11.b
23	Extraction, liquefaction, and regasification of other petroleum and gaseous materials	i11.c
24	Mining of uranium and thorium ores (12)	i12
25	Mining of iron ores	i13.1
26	Mining of copper ores and concentrates	i13.20.11
27	Mining of nickel ores and concentrates	i13.20.12
28	Mining of aluminium ores and concentrates	i13.20.13
29	Mining of precious metal ores and concentrates	i13.20.14
30	Mining of lead, zinc and tin ores and concentrates	i13.20.15
31	Mining of other non-ferrous metal ores and concentrates	i13.20.16
32	Quarrying of stone	i14.1
33	Quarrying of sand and clay	i14.2
34	Mining of chemical and fertilizer minerals, production of salt, other mining and quarrying n.e.c.	i14.3
35	Processing of meat cattle	i15.a
36	Processing of meat pigs	i15.b
37	Processing of meat poultry	i15.c
38	Production of meat products nec	i15.d
39	Processing vegetable oils and fats	i15.e
40	Processing of dairy products	i15.f
41	Processed rice	i15.g
42	Sugar refining	i15.h
43	Processing of Food products nec	i15.i
44	Manufacture of beverages	i15.j
45	Manufacture of fish products	i15.k
46	Manufacture of tobacco products (16)	i16
47	Manufacture of textiles (17)	i17
48	Manufacture of wearing apparel; dressing and dyeing of fur (18)	i18
49	Tanning and dressing of leather; manufacture of luggage, handbags, saddlery, harness and footwear (19)	i19
50	Manufacture of wood and of products of wood and cork, except furniture; manufacture of articles of straw and plaiting materials (20)	i20
51	Re-processing of secondary wood material into new wood material	i20.w
52	Pulp	i21.1
53	Re-processing of secondary paper into new pulp	i21.w.1
54	Paper	i21.2
55	Publishing, printing and reproduction of recorded media (22)	i22
56	Manufacture of coke oven products	i23.1
57	Petroleum Refinery	i23.2
58	Processing of nuclear fuel	i23.3
59	Plastics, basic	i24.1
60	Re-processing of secondary plastic into new plastic	i24.1.w
61	N-fertiliser	i24.2
62	P- and other fertiliser	i24.3

N	Name of production sector	Code
63	Chemicals nec	i24.4
64	Manufacture of rubber and plastic products (25)	i25
65	Manufacture of glass and glass products	i26.a
66	Re-processing of secondary glass into new glass	i26.w.1
67	Manufacture of ceramic goods	i26.b
68	Manufacture of bricks, tiles and construction products, in baked clay	i26.c
69	Manufacture of cement, lime and plaster	i26.d
70	Re-processing of ash into clinker	i26.d.w
71	Manufacture of other non-metallic mineral products n.e.c.	i26.e
72	Manufacture of basic iron and steel and of ferro-alloys and first products thereof	i27.a
73	Re-processing of secondary steel into new steel	i27.a.w
74	Precious metals production	i27.41
75	Re-processing of secondary preciuos metals into new preciuos metals	i27.41.w
76	Aluminium production	i27.42
77	Re-processing of secondary aluminium into new aluminium	i27.42.w
78	Lead, zinc and tin production	i27.43
79	Re-processing of secondary lead into new lead	i27.43.w
80	Copper production	i27.44
81	Re-processing of secondary copper into new copper	i27.44.w
82	Other non-ferrous metal production	i27.45
83	Re-processing of secondary other non-ferrous metals into new other non-ferrous metals	i27.45.w
84	Casting of metals	i27.5
85	Manufacture of fabricated metal products, except machinery and equipment (28)	i28
86	Manufacture of machinery and equipment n.e.c. (29)	i29
87	Manufacture of office machinery and computers (30)	i30
88	Manufacture of electrical machinery and apparatus n.e.c. (31)	i31
89	Manufacture of radio, television and communication equipment and apparatus (32)	i32
90	Manufacture of medical, precision and optical instruments, watches and clocks (33)	i33
91	Manufacture of motor vehicles, trailers and semi-trailers (34)	i34
92	Manufacture of other transport equipment (35)	i35
93	Manufacture of furniture; manufacturing n.e.c. (36)	i36
94	Recycling of waste and scrap	i37
95	Recycling of bottles by direct reuse	i37.w.1
96	Production of electricity by coal	i40.11.a
97	Production of electricity by gas	i40.11.b
98	Production of electricity by nuclear	i40.11.c
99	Production of electricity by hydro	i40.11.d
100	Production of electricity by wind	i40.11.e
101	Production of electricity by petroleum and other oil derivatives	i40.11.f
102	Production of electricity by biomass and waste	i40.11.g
103	Production of electricity by solar photovoltaic	i40.11.h
104	Production of electricity by solar thermal	i40.11.i
105	Production of electricity by tide, wave, ocean	i40.11.j
106	Production of electricity by Geothermal	i40.11.k
107	Production of electricity nec	i40.11.l
108	Transmission of electricity	i40.12
109	Distribution and trade of electricity	i40.13
110	Manufacture of gas; distribution of gaseous fuels through mains	i40.2
111	Steam and hot water supply	i40.3
112	Collection, purification and distribution of water (41)	i41
113	Construction (45)	i45

N	Name of production sector	Code
114	Re-processing of secondary construction material into aggregates	i45.w
115	Sale, maintenance, repair of motor vehicles, motor vehicles parts, motorcycles, motor cycles parts and accessoiries	i50.a
116	Retail sale of automotive fuel	i50.b
117	Wholesale trade and commission trade, except of motor vehicles and motorcycles (51)	i51
118	Retail trade, except of motor vehicles and motorcycles; repair of personal and household goods (52)	i52
119	Hotels and restaurants (55)	i55
120	Transport via railways	i60.1
121	Other land transport	i60.2
122	Transport via pipelines	i60.3
123	Sea and coastal water transport	i61.1
124	Inland water transport	i61.2
125	Air transport (62)	i62
126	Supporting and auxiliary transport activities; activities of travel agencies (63)	i63
127	Post and telecommunications (64)	i64
128	Financial intermediation, except insurance and pension funding (65)	i65
129	Insurance and pension funding, except compulsory social security (66)	i66
130	Activities auxiliary to financial intermediation (67)	i67
131	Real estate activities (70)	i70
132	Renting of machinery and equipment without operator and of personal and household goods (71)	i71
133	Computer and related activities (72)	i72
134	Research and development (73)	i73
135	Other business activities (74)	i74
136	Public administration and defence; compulsory social security (75)	i75
137	Education (80)	i80
138	Health and social work (85)	i85
139	Incineration of waste: Food	i90.1.a
140	Incineration of waste: Paper	i90.1.b
141	Incineration of waste: Plastic	i90.1.c
142	Incineration of waste: Metals and Inert materials	i90.1.d
143	Incineration of waste: Textiles	i90.1.e
144	Incineration of waste: Wood	i90.1.f
145	Incineration of waste: Oil/Hazardous waste	i90.1.g
146	Biogasification of food waste, incl. land application	i90.3.a
147	Biogasification of paper, incl. land application	i90.3.b
148	Biogasification of sewage slugde, incl. land application	i90.3.c
149	Composting of food waste, incl. land application	i90.4.a
150	Composting of paper and wood, incl. land application	i90.4.b
151	Waste water treatment, food	i90.5.a
152	Waste water treatment, other	i90.5.b
153	Landfill of waste: Food	i90.6.a
154	Landfill of waste: Paper	i90.6.b
155	Landfill of waste: Plastic	i90.6.c
156	Landfill of waste: Inert/metal/hazardous	i90.6.d
157	Landfill of waste: Textiles	i90.6.e
158	Landfill of waste: Wood	i90.6.f
159	Activities of membership organisation n.e.c. (91)	i91
160	Recreational, cultural and sporting activities (92)	i92
161	Other service activities (93)	i93

N	Name of production sector	Code
162	Private households with employed persons (95)	i95
163	Extra-territorial organizations and bodies	i99

N	Name of product	Code
1	Paddy rice	p01.a
2	Wheat	p01.b
3	Cereal grains nec	p01.c
4	Vegetables, fruit, nuts	p01.d
5	Oil seeds	p01.e
6	Sugar cane, sugar beet	p01.f
7	Plant-based fibers	p01.g
8	Crops nec	p01.h
9	Cattle	p01.i
10	Pigs	p01.j
11	Poultry	p01.k
12	Meat animals nec	p01.l
13	Animal products nec	p01.m
14	Raw milk	p01.n
15	Wool, silk-worm cocoons	p01.o
16	Manure (conventional treatment)	p01.w.1
17	Manure (biogas treatment)	p01.w.2
18	Products of forestry, logging and related services (02)	p02
19	Fish and other fishing products; services incidental of fishing (05)	p05
20	Anthracite	p10.a
21	Coking Coal	p10.b
22	Other Bituminous Coal	p10.c
23	Sub-Bituminous Coal	p10.d
24	Patent Fuel	p10.e
25	Lignite/Brown Coal	p10.f
26	BKB/Peat Briquettes	p10.g
27	Peat	p10.h
28	Crude petroleum and services related to crude oil extraction, excluding surveying	p11.a
29	Natural gas and services related to natural gas extraction, excluding surveying	p11.b
30	Natural Gas Liquids	p11.b.1
31	Other Hydrocarbons	p11.c
32	Uranium and thorium ores (12)	p12
33	Iron ores	p13.1
34	Copper ores and concentrates	p13.20.11
35	Nickel ores and concentrates	p13.20.12
36	Aluminium ores and concentrates	p13.20.13
37	Precious metal ores and concentrates	p13.20.14
38	Lead, zinc and tin ores and concentrates	p13.20.15
39	Other non-ferrous metal ores and concentrates	p13.20.16
40	Stone	p14.1
41	Sand and clay	p14.2
42	Chemical and fertilizer minerals, salt and other mining and quarrying products n.e.c.	p14.3
43	Products of meat cattle	p15.a
44	Products of meat pigs	p15.b

N	Name of product	Code
45	Products of meat poultry	p15.c
46	Meat products nec	p15.d
47	products of Vegetable oils and fats	p15.e
48	Dairy products	p15.f
49	Processed rice	p15.g
50	Sugar	p15.h
51	Food products nec	p15.i
52	Beverages	p15.j
53	Fish products	p15.k
54	Tobacco products (16)	p16
55	Textiles (17)	p17
56	Wearing apparel; furs (18)	p18
57	Leather and leather products (19)	p19
58	Wood and products of wood and cork (except furniture); articles of straw and plaiting materials (20)	p20
59	Wood material for treatment, Re-processing of secondary wood material into new wood material	p20.w
60	Pulp	p21.1
61	Secondary paper for treatment, Re-processing of secondary paper into new pulp	p21.w.1
62	Paper and paper products	p21.2
63	Printed matter and recorded media (22)	p22
64	Coke Oven Coke	p23.1.a
65	Gas Coke	p23.1.b
66	Coal Tar	p23.1.c
67	Motor Gasoline	p23.20.a
68	Aviation Gasoline	p23.20.b
69	Gasoline Type Jet Fuel	p23.20.c
70	Kerosene Type Jet Fuel	p23.20.d
71	Kerosene	p23.20.e
72	Gas/Diesel Oil	p23.20.f
73	Heavy Fuel Oil	p23.20.g
74	Refinery Gas	p23.20.h
75	Liquefied Petroleum Gases (LPG)	p23.20.i
76	Refinery Feedstocks	p23.20.j
77	Ethane	p23.20.k
78	Naphtha	p23.20.l
79	White Spirit & SBP	p23.20.m
80	Lubricants	p23.20.n
81	Bitumen	p23.20.o
82	Paraffin Waxes	p23.20.p
83	Petroleum Coke	p23.20.q
84	Non-specified Petroleum Products	p23.20.r
85	Nuclear fuel	p23.3
86	Plastics, basic	p24.a
87	Secondary plastic for treatment, Re-processing of secondary plastic into new plastic	p24.a.w
88	N-fertiliser	p24.b
89	P- and other fertiliser	p24.c
90	Chemicals nec	p24.d
91	Charcoal	p24.e
92	Additives/Blending Components	p24.f
93	Biogasoline	p24.g

N	Name of product	Code
94	Biodiesels	p24.h
95	Other Liquid Biofuels	p24.i
96	Rubber and plastic products (25)	p25
97	Glass and glass products	p26.a
98	Secondary glass for treatment, Re-processing of secondary glass into new glass	p26.w.1
99	Ceramic goods	p26.b
100	Bricks, tiles and construction products, in baked clay	p26.c
101	Cement, lime and plaster	p26.d
102	Ash for treatment, Re-processing of ash into clinker	p26.d.w
103	Other non-metallic mineral products	p26.e
104	Basic iron and steel and of ferro-alloys and first products thereof	p27.a
105	Secondary steel for treatment, Re-processing of secondary steel into new steel	p27.a.w
106	Precious metals	p27.41
107	Secondary preciuos metals for treatment, Re-processing of secondary preciuos metals into new preciuos metals	p27.41.w
108	Aluminium and aluminium products	p27.42
109	Secondary aluminium for treatment, Re-processing of secondary aluminium into new aluminium	p27.42.w
110	Lead, zinc and tin and products thereof	p27.43
111	Secondary lead for treatment, Re-processing of secondary lead into new lead	p27.43.w
112	Copper products	p27.44
113	Secondary copper for treatment, Re-processing of secondary copper into new copper	p27.44.w
114	Other non-ferrous metal products	p27.45
115	Secondary other non-ferrous metals for treatment, Re-processing of secondary other non-ferrous metals into new other non-ferrous metals	p27.45.w
116	Foundry work services	p27.5
117	Fabricated metal products, except machinery and equipment (28)	p28
118	Machinery and equipment n.e.c. (29)	p29
119	Office machinery and computers (30)	p30
120	Electrical machinery and apparatus n.e.c. (31)	p31
121	Radio, television and communication equipment and apparatus (32)	p32
122	Medical, precision and optical instruments, watches and clocks (33)	p33
123	Motor vehicles, trailers and semi-trailers (34)	p34
124	Other transport equipment (35)	p35
125	Furniture; other manufactured goods n.e.c. (36)	p36
126	Secondary raw materials	p37
127	Bottles for treatment, Recycling of bottles by direct reuse	p37.w.1
128	Electricity by coal	p40.11.a
129	Electricity by gas	p40.11.b
130	Electricity by nuclear	p40.11.c
131	Electricity by hydro	p40.11.d
132	Electricity by wind	p40.11.e
133	Electricity by petroleum and other oil derivatives	p40.11.f
134	Electricity by biomass and waste	p40.11.g
135	Electricity by solar photovoltaic	p40.11.h
136	Electricity by solar thermal	p40.11.i
137	Electricity by tide, wave, ocean	p40.11.j
138	Electricity by Geothermal	p40.11.k
139	Electricity nec	p40.11.l
140	Transmission services of electricity	p40.12
141	Distribution and trade services of electricity	p40.13

N	Name of product	Code
142	Coke oven gas	p40.2.a
143	Blast Furnace Gas	p40.2.b
144	Oxygen Steel Furnace Gas	p40.2.c
145	Gas Works Gas	p40.2.d
146	Biogas	p40.2.e
147	Distribution services of gaseous fuels through mains	p40.2.1
148	Steam and hot water supply services	p40.3
149	Collected and purified water, distribution services of water (41)	p41
150	Construction work (45)	p45
151	Secondary construction material for treatment, Re-processing of secondary construction material into aggregates	p45.w
152	Sale, maintenance, repair of motor vehicles, motor vehicles parts, motorcycles, motor cycles parts and accessoiries	p50.a
153	Retail trade services of motor fuel	p50.b
154	Wholesale trade and commission trade services, except of motor vehicles and motorcycles (51)	p51
155	Retail trade services, except of motor vehicles and motorcycles; repair services of personal and household goods (52)	p52
156	Hotel and restaurant services (55)	p55
157	Railway transportation services	p60.1
158	Other land transportation services	p60.2
159	Transportation services via pipelines	p60.3
160	Sea and coastal water transportation services	p61.1
161	Inland water transportation services	p61.2
162	Air transport services (62)	p62
163	Supporting and auxiliary transport services; travel agency services (63)	p63
164	Post and telecommunication services (64)	p64
165	Financial intermediation services, except insurance and pension funding services (65)	p65
166	Insurance and pension funding services, except compulsory social security services (66)	p66
167	Services auxiliary to financial intermediation (67)	p67
168	Real estate services (70)	p70
169	Renting services of machinery and equipment without operator and of personal and household goods (71)	p71
170	Computer and related services (72)	p72
171	Research and development services (73)	p73
172	Other business services (74)	p74
173	Public administration and defence services; compulsory social security services (75)	p75
174	Education services (80)	p80
175	Health and social work services (85)	p85
176	Food waste for treatment: incineration	p90.1.a
177	Paper waste for treatment: incineration	p90.1.b
178	Plastic waste for treatment: incineration	p90.1.c
179	Intert/metal waste for treatment: incineration	p90.1.d
180	Textiles waste for treatment: incineration	p90.1.e
181	Wood waste for treatment: incineration	p90.1.f
182	Oil/hazardous waste for treatment: incineration	p90.1.g
183	Food waste for treatment: biogasification and land application	p90.2.a
184	Paper waste for treatment: biogasification and land application	p90.2.b
185	Sewage sludge for treatment: biogasification and land application	p90.2.c

N	Name of product	Code
186	Food waste for treatment: composting and land application	p90.3.a
187	Paper and wood waste for treatment: composting and land application	p90.3.b
188	Food waste for treatment: waste water treatment	p90.4.a
189	Other waste for treatment: waste water treatment	p90.4.b
190	Food waste for treatment: landfill	p90.5.a
191	Paper for treatment: landfill	p90.5.b
192	Plastic waste for treatment: landfill	p90.5.c
193	Inert/metal/hazardous waste for treatment: landfill	p90.5.d
194	Textiles waste for treatment: landfill	p90.5.e
195	Wood waste for treatment: landfill	p90.5.f
196	Membership organisation services n.e.c. (91)	p91
197	Recreational, cultural and sporting services (92)	p92
198	Other services (93)	p93
199	Private households with employed persons (95)	p95
200	Extra-territorial organizations and bodies	p99

6.18. Land use coverage

N	Land use type name
1	Arable Land - rice
2	Arable Land - wheat
3	Arable Land - other cereals
4	Arable Land - roots and tubers
5	Arable Land - sugar crops
6	Arable Land - pulses
7	Arable Land - nuts
8	Arable Land - oil crops
9	Arable Land - vegetables
10	Arable Land - fruits
11	Arable Land - fibres
12	Arable Land - other crops
13	Arable Land - fodder crops
14	Permanent Pasture
15	Forest Area

6.19. Representation of physical inputs and outputs

N	Type of flow	Physical product
1	Gross Energy Use	Anthracite
2	Gross Energy Use	Coking Coal
3	Gross Energy Use	Other Bituminous Coal
4	Gross Energy Use	Sub-Bituminous Coal
5	Gross Energy Use	Lignite/Brown Coal
6	Gross Energy Use	Peat
7	Gross Energy Use	Patent Fuel
8	Gross Energy Use	Coke Oven Coke
9	Gross Energy Use	Gas Coke
10	Gross Energy Use	Coal Tar

N	Type of flow	Physical product
11	Gross Energy Use	BKB/Peat Briquettes
12	Gross Energy Use	Gas Works Gas
13	Gross Energy Use	Coke Oven Gas
14	Gross Energy Use	Blast Furnace Gas
15	Gross Energy Use	Oxygen Steel Furnace Gas
16	Gross Energy Use	Elec/Heat Output from Non-spec. Manuf. Gases
17	Gross Energy Use	Industrial Waste
18	Gross Energy Use	Municipal Waste (Renew)
19	Gross Energy Use	Municipal Waste (Non-Renew)
20	Gross Energy Use	Primary Solid Biomass
21	Gross Energy Use	Biogas
22	Gross Energy Use	Biogasoline
23	Gross Energy Use	Biodiesels
24	Gross Energy Use	Other Liquid Biofuels
25	Gross Energy Use	Charcoal
26	Gross Energy Use	Natural Gas
27	Gross Energy Use	Crude Oil
28	Gross Energy Use	Natural Gas Liquids
29	Gross Energy Use	Refinery Feedstocks
30	Gross Energy Use	Additives/Blending Components
31	Gross Energy Use	Other Hydrocarbons
32	Gross Energy Use	Refinery Gas
33	Gross Energy Use	Ethane
34	Gross Energy Use	Liquefied Petroleum Gases (LPG)
35	Gross Energy Use	Motor Gasoline
36	Gross Energy Use	Aviation Gasoline
37	Gross Energy Use	Gasoline Type Jet Fuel
38	Gross Energy Use	Kerosene Type Jet Fuel
39	Gross Energy Use	Kerosene
40	Gross Energy Use	Gas/Diesel Oil
41	Gross Energy Use	Residual Fuel Oil
42	Gross Energy Use	Naphtha
43	Gross Energy Use	White Spirit & SBP
44	Gross Energy Use	Lubricants
45	Gross Energy Use	Bitumen
46	Gross Energy Use	Paraffin Waxes
47	Gross Energy Use	Petroleum Coke
48	Gross Energy Use	Non-specified Petroleum Products
49	Gross Energy Use	Heat Output from non-specified comb fuels
50	Gross Energy Use	Nuclear
51	Gross Energy Use	Hydro
52	Gross Energy Use	Geothermal
53	Gross Energy Use	Solar Photovoltaics
54	Gross Energy Use	Solar Thermal
55	Gross Energy Use	Tide, Wave and Ocean
56	Gross Energy Use	Wind
57	Gross Energy Use	Other sources
58	Gross Energy Use	Electricity
59	Gross Energy Use	Heat
60	Gross Energy Use	Dissipative Energy Losses
61	Gross Energy Supply	Anthracite

N	Type of flow	Physical product
62	Gross Energy Supply	Coking Coal
63	Gross Energy Supply	Other Bituminous Coal
64	Gross Energy Supply	Sub-Bituminous Coal
65	Gross Energy Supply	Lignite/Brown Coal
66	Gross Energy Supply	Peat
67	Gross Energy Supply	Patent Fuel
68	Gross Energy Supply	Coke Oven Coke
69	Gross Energy Supply	Gas Coke
70	Gross Energy Supply	Coal Tar
71	Gross Energy Supply	BKB/Peat Briquettes
72	Gross Energy Supply	Gas Works Gas
73	Gross Energy Supply	Coke Oven Gas
74	Gross Energy Supply	Blast Furnace Gas
75	Gross Energy Supply	Oxygen Steel Furnace Gas
76	Gross Energy Supply	Elec/Heat Output from Non-spec. Manuf. Gases
77	Gross Energy Supply	Industrial Waste
78	Gross Energy Supply	Municipal Waste (Renew)
79	Gross Energy Supply	Municipal Waste (Non-Renew)
80	Gross Energy Supply	Primary Solid Biomass
81	Gross Energy Supply	Biogas
82	Gross Energy Supply	Biogasoline
83	Gross Energy Supply	Biodiesels
84	Gross Energy Supply	Other Liquid Biofuels
85	Gross Energy Supply	Charcoal
86	Gross Energy Supply	Natural Gas
87	Gross Energy Supply	Crude Oil
88	Gross Energy Supply	Natural Gas Liquids
89	Gross Energy Supply	Refinery Feedstocks
90	Gross Energy Supply	Additives/Blending Components
91	Gross Energy Supply	Other Hydrocarbons
92	Gross Energy Supply	Refinery Gas
93	Gross Energy Supply	Ethane
94	Gross Energy Supply	Liquefied Petroleum Gases (LPG)
95	Gross Energy Supply	Motor Gasoline
96	Gross Energy Supply	Aviation Gasoline
97	Gross Energy Supply	Gasoline Type Jet Fuel
98	Gross Energy Supply	Kerosene Type Jet Fuel
99	Gross Energy Supply	Kerosene
100	Gross Energy Supply	Gas/Diesel Oil
101	Gross Energy Supply	Residual Fuel Oil
102	Gross Energy Supply	Naphtha
103	Gross Energy Supply	White Spirit & SBP
104	Gross Energy Supply	Lubricants
105	Gross Energy Supply	Bitumen
106	Gross Energy Supply	Paraffin Waxes
107	Gross Energy Supply	Petroleum Coke
108	Gross Energy Supply	Non-specified Petroleum Products
109	Gross Energy Supply	Heat Output from non-specified comb fuels
110	Gross Energy Supply	Nuclear
111	Gross Energy Supply	Hydro
112	Gross Energy Supply	Geothermal

N	Type of flow	Physical product
113	Gross Energy Supply	Solar Photovoltaics
114	Gross Energy Supply	Solar Thermal
115	Gross Energy Supply	Tide, Wave and Ocean
116	Gross Energy Supply	Wind
117	Gross Energy Supply	Other sources
118	Gross Energy Supply	Electricity
119	Gross Energy Supply	Heat
120	Gross Energy Supply	Dissipative Energy Losses
121	Emission-relevant Energy Use	Anthracite
122	Emission-relevant Energy Use	Coking Coal
123	Emission-relevant Energy Use	Other Bituminous Coal
124	Emission-relevant Energy Use	Sub-Bituminous Coal
125	Emission-relevant Energy Use	Lignite/Brown Coal
126	Emission-relevant Energy Use	Peat
127	Emission-relevant Energy Use	Patent Fuel
128	Emission-relevant Energy Use	Coke Oven Coke
129	Emission-relevant Energy Use	Gas Coke
130	Emission-relevant Energy Use	Coal Tar
131	Emission-relevant Energy Use	BKB/Peat Briquettes
132	Emission-relevant Energy Use	Gas Works Gas
133	Emission-relevant Energy Use	Coke Oven Gas
134	Emission-relevant Energy Use	Blast Furnace Gas
135	Emission-relevant Energy Use	Oxygen Steel Furnace Gas
136	Emission-relevant Energy Use	Elec/Heat Output from Non-spec. Manuf. Gases
137	Emission-relevant Energy Use	Industrial Waste
138	Emission-relevant Energy Use	Municipal Waste (Renew)
139	Emission-relevant Energy Use	Municipal Waste (Non-Renew)
140	Emission-relevant Energy Use	Primary Solid Biomass
141	Emission-relevant Energy Use	Biogas
142	Emission-relevant Energy Use	Biogasoline
143	Emission-relevant Energy Use	Biodiesels
144	Emission-relevant Energy Use	Other Liquid Biofuels
145	Emission-relevant Energy Use	Charcoal
146	Emission-relevant Energy Use	Natural Gas
147	Emission-relevant Energy Use	Crude Oil
148	Emission-relevant Energy Use	Natural Gas Liquids
149	Emission-relevant Energy Use	Refinery Feedstocks
150	Emission-relevant Energy Use	Additives/Blending Components
151	Emission-relevant Energy Use	Other Hydrocarbons
152	Emission-relevant Energy Use	Refinery Gas
153	Emission-relevant Energy Use	Ethane
154	Emission-relevant Energy Use	Liquefied Petroleum Gases (LPG)
155	Emission-relevant Energy Use	Motor Gasoline
156	Emission-relevant Energy Use	Aviation Gasoline
157	Emission-relevant Energy Use	Gasoline Type Jet Fuel
158	Emission-relevant Energy Use	Kerosene Type Jet Fuel
159	Emission-relevant Energy Use	Kerosene
160	Emission-relevant Energy Use	Gas/Diesel Oil
161	Emission-relevant Energy Use	Residual Fuel Oil
162	Emission-relevant Energy Use	Naphtha
163	Emission-relevant Energy Use	White Spirit & SBP

N	Type of flow	Physical product
164	Emission-relevant Energy Use	Lubricants
165	Emission-relevant Energy Use	Bitumen
166	Emission-relevant Energy Use	Paraffin Waxes
167	Emission-relevant Energy Use	Petroleum Coke
168	Emission-relevant Energy Use	Non-specified Petroleum Products
169	Emission-relevant Energy Use	Heat Output from non-specified comb fuels
170	Emission-relevant Energy Use	Nuclear
171	Emission-relevant Energy Use	Hydro
172	Emission-relevant Energy Use	Geothermal
173	Emission-relevant Energy Use	Solar Photovoltaics
174	Emission-relevant Energy Use	Solar Thermal
175	Emission-relevant Energy Use	Tide, Wave and Ocean
176	Emission-relevant Energy Use	Wind
177	Emission-relevant Energy Use	Other sources
178	Emission-relevant Energy Use	Electricity
179	Emission-relevant Energy Use	Heat
180	Emission-relevant Energy Use	Dissipative Energy Losses
181	Domestic Extraction Used - Primary Crops	Rice
182	Domestic Extraction Used - Primary Crops	Wheat
183	Domestic Extraction Used - Primary Crops	Other cereals
184	Domestic Extraction Used - Primary Crops	Roots and tubers
185	Domestic Extraction Used - Primary Crops	Sugar crops
186	Domestic Extraction Used - Primary Crops	Pulses
187	Domestic Extraction Used - Primary Crops	Nuts
188	Domestic Extraction Used - Primary Crops	Oil crops
189	Domestic Extraction Used - Primary Crops	Vegetables
190	Domestic Extraction Used - Primary Crops	Fruits
191	Domestic Extraction Used - Primary Crops	Fibres
192	Domestic Extraction Used - Primary Crops	Other crops
193	Domestic Extraction Used - Primary Crops	Straw
194	Domestic Extraction Used - Primary Crops	Other crop residues
195	Domestic Extraction Used - Primary Crops	Fodder crops
196	Domestic Extraction Used - Primary Crops	Biomass harvested from grasslands
197	Domestic Extraction Used - Grazing	Grazing
198	Domestic Extraction Used - Wood	Timber
199	Domestic Extraction Used - Wood	Other extractions
200	Domestic Extraction Used – Animals	Marine fish
201	Domestic Extraction Used – Animals	Inland water fish
202	Domestic Extraction Used – Animals	Other aquatic animals
203	Domestic Extraction Used – Animals	Hunting
204	Domestic Extraction Used - Metal Ores	Iron ores
205	Domestic Extraction Used - Metal Ores	Bauxite and aluminium ores
206	Domestic Extraction Used - Metal Ores	Copper ores
207	Domestic Extraction Used - Metal Ores	Lead ores
208	Domestic Extraction Used - Metal Ores	Nickel ores
209	Domestic Extraction Used - Metal Ores	Tin ores
210	Domestic Extraction Used - Metal Ores	Uranium and thorium ores
211	Domestic Extraction Used - Metal Ores	Zinc ores
212	Domestic Extraction Used - Metal Ores	Precious metal ores
213	Domestic Extraction Used - Metal Ores	Other metal ores
214	Domestic Extraction Used - Non-Metallic Minerals	Chemical and fertilizer minerals

N	Type of flow	Physical product
215	Domestic Extraction Used - Non-Metallic Minerals	Clays and kaolin
216	Domestic Extraction Used - Non-Metallic Minerals	Limestone, gypsum, chalk, dolomite
217	Domestic Extraction Used - Non-Metallic Minerals	Salt
218	Domestic Extraction Used - Non-Metallic Minerals	Slate
219	Domestic Extraction Used - Non-Metallic Minerals	Other industrial minerals
220	Domestic Extraction Used - Non-Metallic Minerals	Building stones
221	Domestic Extraction Used - Non-Metallic Minerals	Gravel and sand
222	Domestic Extraction Used - Non-Metallic Minerals	Other construction minerals
223	Domestic Extraction Used - Fossil Fuels	Hard coal
224	Domestic Extraction Used - Fossil Fuels	Lignite/brown coal
225	Domestic Extraction Used - Fossil Fuels	Crude oil
226	Domestic Extraction Used - Fossil Fuels	Natural gas
227	Domestic Extraction Used - Fossil Fuels	Natural gas liquids
228	Domestic Extraction Used - Fossil Fuels	Peat for energy use
229	Unused Domestic Extraction - Primary Crops	Rice
230	Unused Domestic Extraction - Primary Crops	Wheat
231	Unused Domestic Extraction - Primary Crops	Other cereals
232	Unused Domestic Extraction - Primary Crops	Roots and tubers
233	Unused Domestic Extraction - Primary Crops	Sugar crops
234	Unused Domestic Extraction - Primary Crops	Pulses
235	Unused Domestic Extraction - Primary Crops	Nuts
236	Unused Domestic Extraction - Primary Crops	Oil crops
237	Unused Domestic Extraction - Primary Crops	Vegetables
238	Unused Domestic Extraction - Primary Crops	Fruits
239	Unused Domestic Extraction - Primary Crops	Fibres
240	Unused Domestic Extraction - Primary Crops	Other crops
241	Unused Domestic Extraction - Primary Crops	Straw
242	Unused Domestic Extraction - Primary Crops	Other crop residues
243	Unused Domestic Extraction - Primary Crops	Fodder crops
244	Unused Domestic Extraction - Primary Crops	Biomass harvested from grasslands
245	Unused Domestic Extraction - Grazing	Grazing
246	Unused Domestic Extraction - Wood	Timber
247	Unused Domestic Extraction - Wood	Other extractions
248	Unused Domestic Extraction – Animals	Marine fish
249	Unused Domestic Extraction – Animals	Inland water fish
250	Unused Domestic Extraction – Animals	Other aquatic animals
251	Unused Domestic Extraction – Animals	Hunting
252	Unused Domestic Extraction - Metal Ores	Iron ores
253	Unused Domestic Extraction - Metal Ores	Bauxite and aluminium ores
254	Unused Domestic Extraction - Metal Ores	Copper ores
255	Unused Domestic Extraction - Metal Ores	Lead ores
256	Unused Domestic Extraction - Metal Ores	Nickel ores
257	Unused Domestic Extraction - Metal Ores	Tin ores
258	Unused Domestic Extraction - Metal Ores	Uranium and thorium ores

N	Type of flow	Physical product
259	Unused Domestic Extraction - Metal Ores	Zinc ores
260	Unused Domestic Extraction - Metal Ores	Precious metal ores
261	Unused Domestic Extraction - Metal Ores	Other metal ores
262	Unused Domestic Extraction - Non-Metallic Minerals	Chemical and fertilizer minerals
263	Unused Domestic Extraction - Non-Metallic Minerals	Clays and kaolin
264	Unused Domestic Extraction - Non-Metallic Minerals	Limestone, gypsum, chalk, dolomite
265	Unused Domestic Extraction - Non-Metallic Minerals	Salt
266	Unused Domestic Extraction - Non-Metallic Minerals	Slate
267	Unused Domestic Extraction - Non-Metallic Minerals	Other industrial minerals
268	Unused Domestic Extraction - Non-Metallic Minerals	Building stones
269	Unused Domestic Extraction - Non-Metallic Minerals	Gravel and sand
270	Unused Domestic Extraction - Non-Metallic Minerals	Other construction minerals
271	Unused Domestic Extraction - Fossil Fuels	Hard coal
272	Unused Domestic Extraction - Fossil Fuels	Lignite/brown coal
273	Unused Domestic Extraction - Fossil Fuels	Crude oil
274	Unused Domestic Extraction - Fossil Fuels	Natural gas
275	Unused Domestic Extraction - Fossil Fuels	Natural gas liquids
276	Unused Domestic Extraction - Fossil Fuels	Peat for energy use
277	Water Consumption Blue - Agriculture	Rice
278	Water Consumption Blue - Agriculture	Wheat
279	Water Consumption Blue - Agriculture	Other cereals
280	Water Consumption Blue - Agriculture	Roots and tubers
281	Water Consumption Blue - Agriculture	Sugar crops
282	Water Consumption Blue - Agriculture	Pulses
283	Water Consumption Blue - Agriculture	Nuts
284	Water Consumption Blue - Agriculture	Oil crops
285	Water Consumption Blue - Agriculture	Vegetables
286	Water Consumption Blue - Agriculture	Fruits
287	Water Consumption Blue - Agriculture	Fibres
288	Water Consumption Blue - Agriculture	Other crops
289	Water Consumption Blue - Agriculture	Fodder crops
290	Water Consumption Green - Agriculture	Rice
291	Water Consumption Green - Agriculture	Wheat
292	Water Consumption Green - Agriculture	Other cereals
293	Water Consumption Green - Agriculture	Roots and tubers
294	Water Consumption Green - Agriculture	Sugar crops
295	Water Consumption Green - Agriculture	Pulses
296	Water Consumption Green - Agriculture	Nuts
297	Water Consumption Green - Agriculture	Oil crops
298	Water Consumption Green - Agriculture	Vegetables
299	Water Consumption Green - Agriculture	Fruits
300	Water Consumption Green - Agriculture	Fibres
301	Water Consumption Green - Agriculture	Other crops

N	Type of flow	Physical product
302	Water Consumption Green - Agriculture	Fodder crops
303	Water Consumption Blue - Livestock	Dairy cattle
304	Water Consumption Blue - Livestock	Non-dairy cattle
305	Water Consumption Blue - Livestock	Pigs
306	Water Consumption Blue - Livestock	Sheep
307	Water Consumption Blue - Livestock	Goats
308	Water Consumption Blue - Livestock	Buffaloes
309	Water Consumption Blue - Livestock	Camels
310	Water Consumption Blue - Livestock	Horses
311	Water Consumption Blue - Livestock	Chicken
312	Water Consumption Blue - Livestock	Turkeys
313	Water Consumption Blue - Livestock	Ducks
314	Water Consumption Blue - Livestock	Geese
315	Water Consumption Blue - Manufacturing	Food products, beverages and tobacco
316	Water Consumption Blue - Manufacturing	Textiles and textile products
317	Water Consumption Blue - Manufacturing	Pulp, paper, publishing and printing
318	Water Consumption Blue - Manufacturing	Chemicals, man-made fibres
319	Water Consumption Blue - Manufacturing	Non-metallic, mineral products
320	Water Consumption Blue - Manufacturing	Basic metals and fabrication of metals
321	Water Consumption Blue - Manufacturing	Other manufacturing
322	Water Consumption Blue - Electricity	Tower
323	Water Consumption Blue - Electricity	Once-through
324	Water Withdrawal Blue - Manufacturing	Food products, beverages and tobacco
325	Water Withdrawal Blue – Manufacturing	Textiles and textile products
326	Water Withdrawal Blue – Manufacturing	Pulp, paper, publishing and printing
327	Water Withdrawal Blue – Manufacturing	Chemicals, man-made fibres
328	Water Withdrawal Blue – Manufacturing	Non-metallic, mineral products
329	Water Withdrawal Blue – Manufacturing	Basic metals and fabrication of metals
330	Water Withdrawal Blue - Manufacturing	Other manufacturing
331	Water Withdrawal Blue – Electricity	Tower
332	Water Withdrawal Blue - Electricity	Once-through
332	Water Withdrawal Blue - Electricity	Once-through

6.20. Coverage of emissions

N	Name of pollutant	Discharge
1	CO2	air
2	N2O	air
3	CH4	air
4	HFCs	air
5	PFCs	air
6	SF6	air
7	NOX	air
8	SOx	air
9	NH3	air
10	NMVOC	air
11	CO	air
12	CFCs	air
13	HCFCs	air

N	Name of pollutant	Discharge
14	Pb	air
15	Cd	air
16	Hg	air
17	As	air
18	Cr	air
19	Cu	air
20	Ni	air
21	Se	air
22	Zn	air
23	Aldrin	air
24	Chlordane	air
25	Chlordecone	air
26	Dieldrin	air
27	Endrin	air
28	Heptachlor	air
29	Hexabr.-biph.	air
30	Mirex	air
31	Toxaphene	air
32	HCH	air
33	DDT	air
34	PCB	air
35	dioxin	air
36	PM10	air
37	PAH	air
38	Benzene	air
39	1,3 Butadiene	air
40	Formaldehyd	air
41	PM2.5	air
42	Furans	air
43	Benzo-[a]-pyrene	air
44	PBDEs	air
45	Benzo-[b]-fluoranthene	air
46	Benzo-[k]-fluoranthene	air
47	Indeno-[1,2,3-cd]-pyrene	air
48	HCB	air
49	PCDD/F (dioxins and furans)	air
50	TSP (total suspended particulate)	air
51	N	water
52	P	water
53	BOD	water
54	N	soil
55	P	soil
56	Cd	soil
57	Cu	soil
58	Zn	soil
59	Pb	soil
60	Hg	soil
61	Cr	soil
62	Ni	soil