ELECTRO_COUP

Electrification of heating and mobility: Socioeconomic impacts of non-ETS policies with sector coupling and sectoral linkages

WORKING PAPER 1

The LEEM Model

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Content:

Introduction

The EU climate policy architecture distinguishes non-ETS from ETS sectors and defines GHG targets for the non-ETS in the member states. Strategies of decarbonization focus on electrification of end-use energy purposes accompanied by expanding electricity supply from renewables, nuclear and fossil fuels with carbon capture technologies. That implies shifting the burden of decarbonization to the electricity sector that is covered by the ETS. Several studies have already highlighted the potential overlapping in EU climate policy and the problems arising from that (Böhringer et al., 2008, and Böhringer, 2014). In the worst case, large part of carbon reduced in one part of the energy system reappears in another part (Eichner and Pethig, 2018), a phenomenon known as leakage. For this purpose, the analysis must focus on the linkages between different sectors. These linkages must cover sector coupling in the energy system between electricity production, distribution and storage on the one hand and other energy sources (heat, gas) on the other hand (Bloomberg Finance L.P., 2020). Jarke and Perino (2017, 2019) have set up an economic modelling framework that allows for integrating important feedbacks of this kind (sectoral leakage and sector coupling). Their modeling approach works on a relatively aggregate level and does not incorporate the feedback of a switch to electricity on aggregate energy efficiency.

In this paper, a modelling framework that fully integrates the energy system and explicitly deals with different types of linkages, is applied. These linkages comprise: (i) input-output (IO) linkages in production (quantities and prices) and (ii) energy demand linkages between ETS and non ETS. The model therefore disaggregates the most important sectors from the perspective of climate policy: several energy intensive industries (ETS), electricity and heat generation (ETS), non-energy intensive industries (non ETS), household transport (non ETS), freight transport (non ETS), and heating of households and service industries (non ETS). The full integration of the energy system into a macroeconomic IO model guarantees that all changes in the energy system have a consistent impact in the economy, both at the level of quantities as well as at the level of costs and prices. Energy technologies are based on bottom-up datasets in the buildings and the transport sector.

The model describes the national economy of an EU country (Austria) aiming at emission targets for the non ETS using a policy mix. The permit price in the ETS is exogenous (small country assumption), but costs for permits depend on national excess permit demand and are an important component in price setting of electricity generation. Electricity prices are described by a stylized merit-order price model that incorporates the emission cap and permit costs. Domestic carbon leakage takes place, when energy demand in the non ETS shifts from fossil fuels to electricity.

1. The IO Framework

The macroeconomic IO model integrates the standard input-output (IO) linkages in production, as well as the energy demand linkages between ETS and non ETS. The model therefore disaggregates the most important sectors from the perspective of climate policy: several energy intensive industries (ETS), electricity and heat generation (ETS), non-energy intensive industries (non ETS), and services. The other main non ETS part are households (transport and heating) and freight transport. The IO model is based on a system of supply/use tables (SUT) and covers 26 industries and 38 goods that are defined as aggregates from NACE 2-digits. The industry classification is identical with the sectors for which final energy demand is available in the energy balance (Statistik Austria, for details see the Appendix).

The philosophy of LEEM for energy modelling is the parallel and consistent accounting of the (monetary) IO model and of the energy system. One option for integrating is the hybrid IO model (Miller and Blair, 2009) with measuring the non-energy part in monetary units and the energy part in physical units. That also implies a correct representation of energy transformation processes (Kratena and Schleicher, 1999)and is fully consistent with the energy balance concepts of 'final energy demand' and 'energy transformation (input and output)', as Guevara (2017) has shown. On the other hand, in the model in hybrid units, at some stages all physical flows need to be converted into monetary flows using the implicit prices following from a simple division. These conversions are not always one to one, due to conceptual differences, which makes a full conversion impossible. Therefore, a model with two layers is applied in LEEM, where the production system in monetary units is solved by the corresponding IO model in monetary terms (based on the SUT 2017) and the energy transformation system in physical units is solved by the corresponding IO model in physical terms (based on the Energy Balance 2017).

The matrices and vectors that constitute the IO model (monetary and physical) are:

(i) the supply table (industries * goods) V with column sum equal to the vector of output by goods, q(g). The row sum of this matrix is defined as the vector of output by industries, **q**,

(ii) the domestic use table for intermediates (goods * industries) $\mathbf{U^d}$ with row sum equal to the vector of output by goods, **q**(**g**), and

(iii) the imports use table for intermediates (goods * industries) $\mathbf{U^{im}}$ with row sum equal to the vector of intermediate imports by goods.

(iv) the matrices of final demand $\mathbf{F^d}$ and $\mathbf{F^{im}}$ (goods * final demand components), comprising domestic (d) and imported (im) goods.

Total imports im are the sum of intermediate and final imports. The supply and use tables are converted into coefficients matrices for setting up the IO model. The 'market shares matrix' **D** is derived by dividing the matrix elements of **V** through the column sum, **q**(**g**). This matrix links the output by industries **q** to the output by goods **q**(**g**): **q** = **D** **q**(**g**). The domestic 'technical coefficients matrix' $\mathbf{B}^d$ is derived by dividing the domestic use table Ud through the vector of total output by industries, **q**. The elements xdij/qj of $\mathbf{B}^d$ define the domestic input *i* in the production of one unit of industry *j*, therefore they determine domestic intermediate demand xd as a function of output by industries **q**: $\mathbf{x}^d = \mathbf{B}^d \mathbf{q}$.

The two main equations of the IO model are:

$$\mathbf{q} = \mathbf{D}\,\mathbf{q}(\mathbf{g}) \tag{1}$$

$$\mathbf{q}(\mathbf{g}) = \mathbf{B}^{\mathrm{d}}\mathbf{q} + \mathbf{cp}^{\mathrm{d}} + \mathbf{cf}^{\mathrm{d}} + \mathbf{f}^{*\mathrm{d}} \tag{2}$$

In (2), the domestic part of the final demand categories that are endogenous, private consumption (**cp**) and capital formation (**cf**) are separated from the exogenous parts of final demand (public consumption, stock changes, and exports).

A similar IO model is set up for energy transformation, where final energy demand and some other components of the energy balance (transport losses, non-energy consumption, stock changes) constitute the final components. This IO model is also based on the SUT framework, where the 'industries' are the eight transformation processes τ and the goods are the 26 types of energy *k* (for details of the classification, see the Appendix).

$$\mathbf{q} = \mathbf{D}(\mathbf{k})\,\mathbf{q}(\mathbf{k},\mathbf{T}) \tag{3}$$

$$\mathbf{x}(\mathbf{k}) = \mathbf{B}_{\mathrm{k},\tau}\mathbf{q} + \mathbf{fe} + \mathbf{ex} + \mathbf{f}^{*,\mathrm{k}} \tag{4}$$

$$\mathbf{q}(\mathbf{k}) = \mathbf{x}(\mathbf{k}) - \mathbf{im} \quad ; \quad \mathbf{q}(\mathbf{k},\mathbf{T}) = \mathbf{T}_{\mathrm{P,T}}\,\mathbf{q}(\mathbf{k}) \tag{5}$$

Equation (3) links the output by transformation processes τ (**q**) to the output (secondary production) by types of energy *k* (**q**(**k**,**T**)) and equation (4) defines total demand (**x**(**k**)) by energy *k* as the sum of transformation input, defined by the coefficient matrix $\mathbf{B}_{k,\tau}$, final energy **fe**, exports **ex**, and a rest $\mathbf{f}^{*,k}$ (transport losses, stock changes, non-energetic use). Total demand minus imports gives total output **q**(**k**), that contains some types of energy that are supplied directly from nature (primary production) as – for example - crude oil and natural gas, as well as others (secondary production) that stem from transformation, like steam and electricity. A matrix mostly containing one and zero elements, $\mathbf{T}_{P,T}$, is applied to derive output from secondary production (**q**(**k**,**T**)) from total output **q**(**k**).

2. Production and prices

The SUT framework is also applied for the price system of the economy and in analogy to output by industries ($\mathbf{q}$) and output by goods ($\mathbf{q}(\mathbf{g})$), in the case of prices we have domestic goods prices ($\mathbf{p}^{d\prime}$) and output prices ($\mathbf{p}'$). Import prices ($\mathbf{p}^{im\prime}$) are exogenously given.

The 'market shares matrix' transforms output prices by industry into goods prices:

$$\mathbf{p}^{d\prime} = \mathbf{p}'\,\mathbf{D} \tag{6}$$

The output prices by industry are determined by mark-up pricing, combined with a unit cost function of labor and intermediate inputs. The mark up μ is levied upon marginal cost, i. e. the cost of labor and intermediates combined in the fixed aggregate input coefficient b_{LM} with the corresponding composite price p_{LM}. That defines the vector $[p_{LM}b_{LM}(1+\mu)]'$:

$$\mathbf{p}' = [p_{LM}b_{LM}(1+\mu)]' + \mathbf{t}_q' \tag{7}$$

The input bundle of intermediate inputs and labor input per unit of output in industry *j* is the element $b_{LM,j} = \lambda_{L,j} + \mathbf{i}'\mathbf{b}_j^d + \mathbf{i}'\mathbf{b}_j^{im}$ with $\mathbf{b}_j^d$ as the vector of domestic input coefficients in *j* and $\mathbf{b}_j^{im}$ as the vector of domestic input coefficients in *j*. The sum of the second and the third term is the total intermediate input coefficient per unit of output, $m_j = \mathbf{i}'\mathbf{b}_j^d + \mathbf{i}'\mathbf{b}_j^{im}$. The coefficients b_{LM} are assumed to be constant.

Applying a CES cost function with constant returns to scale, the composite price for industry *j*, $p_{LM,j}$ is:

$$p_{LM,j} = \left(d_{L,j}p_{L,j}^{1-\sigma_j} + (1-d_{L,j})p_{M,j}^{1-\sigma_j}\right)^{1/(1-\sigma_j)} \tag{8}$$

The CES function has become the main workhorse in CGE modeling (Burfisher, 2017), as it is more flexible than Cobb-Douglas in the sense that it allows different own price elasticity values than – 1. The factor demand equations in industry *j* with substitution elasticity s_j are:

$$s_{L,LM,j} = d_{L,j}\left(\frac{p_{LM,j}}{p_{L,j}}\right)^{\sigma_j} \quad ; \quad s_{M,LM,j} = (1-d_{L,j})\left(\frac{p_{LM,j}}{p_{M,j}}\right)^{\sigma_j} \tag{9}$$

The *nominal* factor shares ($d_{L,j}$) are kept constant in the comparative setting of this model. The $s_{L,LM}$ and $s_{M,LM}$ are the real shares within the *L,M* – bundle, so that the aggregate IO coefficients $\mathbf{i}'\mathbf{b}_j^d + \mathbf{i}'\mathbf{b}_j^{im}$ are defined as:

$$\lambda_{L,j} = s_{L,LM,j}\,b_{LM,j} \quad ; \quad \mathbf{i}'\mathbf{b}_j^d + \mathbf{i}'\mathbf{b}_j^{im} = m_j = s_{M,LM,j}\,b_{LM,j} \tag{10}$$

The total input coefficient (per output) of intermediates plus labor b_{LM} is constant, whereas the factor input shares within this total input (equation (9)) are flexible and change according to changes in the factor prices (vectors $\mathbf{p}_L$ and $\mathbf{p}_M$). The elements of $\mathbf{p}_L$ are derived by dividing the wage rate in each industry *j* by the base case wage rate, w_0, $p_{L,j} = w_j/w_{j,0}$. The change in the factor input shares, in turn, changes the input coefficients $\lambda_{L,j}$ and m_j. The latter is the column sum of the domestic and the import technical coefficients matrix, as defined in (10).

The structure within these matrices is constant and defined by 'use structure' matrices $\mathbf{S}_M^d$ and $\mathbf{S}_M^{im}$. Each element of these matrices is defined as the share of intermediate input of good *i* in industry *j* (x_{ij}) in total intermediate inputs of industry *j* (x_j). The use structure matrices are applied for integrating the IO loop in the price model:

$$\mathbf{p}_M' = \mathbf{p}^{d\prime}\mathbf{S}_M^d + \mathbf{p}^{im\prime}\mathbf{S}_M^{im} \tag{11}$$

The price of labor $\mathbf{p}_L$ is determined in the labor market module of the model and the price of intermediate inputs $\mathbf{p}_M$ via equation (11).

The domestic use structure matrix $\mathbf{S}_M^d$ is further applied for the feedback of the change in the total intermediate input coefficient *m* on the technical coefficients-matrix $\mathbf{B}^d$. Note that each technical coefficient b_{ij}^d can be defined as the product of an element of matrix $\mathbf{S}_M^d$ with the total input coefficient: $b_{ij}^d = s_{ij}^d m_j$. Therefore, the technical coefficients in matrix $\mathbf{B}^d$ are endogenous, according to $b_{ij}^d = s_{ij}^d m_j$, and this represents important feedbacks from prices to IO linkages in equation (2).

The total technical coefficients for energy goods in final energy demand of all industries j and of transformation energy demand in the electricity and in the steam sector (b_{ij} with i = energy goods) are determined from functions in the energy module (section 4). The link between the coefficients defined in section 4 and the technical coefficients in the IO framework is based on 'implicit prices' that convert physical units into monetary units at constant prices.

$$\boldsymbol{\pi}' = \mathbf{p}' - [p_{LM} b_{LM}]' - \mathbf{t}_q' \tag{12}$$

In (12), the capital income coefficient per unit of output is derived as the difference between the output price and the unit cost for labor and intermediates.

Gross fixed capital formation by industry is defined by a simple equation that contains depreciation (linked to the capital stock in t – 1) plus a constant term. Capital formation in t adds to the capital stock in t +1, according to the capital accumulation equation. It is then converted into the vector of capital formation by goods (**cf**), by applying an investment matrix $\mathbf{B}_{cf}$ that links both dimensions and has column sum equal to one. The vector **cf** is then split up into a vector of domestic goods ($\mathbf{cf}^d$) that feeds back to equation (2) and another vector of imported investment goods ($\mathbf{cf}^{im}$).

3. Consumer Demand

The components of disposable income are determined in the production and price module. The row vector of wages (**w**') is defined as the product of nominal labor coefficients (equation (10), net of taxes $[\lambda(1 - t_Y)]'$, where $[\lambda(1 - t_Y)]' = (\lambda_1(1 - t_Y), \lambda_2(1 - t_Y), \dots \lambda_n(1 - t_Y))$, with the diagonalized matrix of output ($\hat{\mathbf{q}}$), and the row vector of profits ($\boldsymbol{\pi}'$ in equation (12)) is the product of nominal profit coefficients, net of taxes $[\kappa(1 - t_Y)]'$ with the diagonalized matrix of output ($\hat{\mathbf{q}}$). The total sum of profits $\boldsymbol{\pi}'\mathbf{i}$ comprises non-distributed profits and profits distributed to households that are part of disposable household income. The share of total profits accruing to disposable household income is defined as s_Y. The income tax rate t_Y is defined as a net tax rate by relating the balance of public transfers to households and deductions from household income (social security contributions plus income taxes) to wage and profit income of households ($\mathbf{w}' + s_Y \boldsymbol{\pi}'$). That yields the household vector of primary income $\mathbf{y}' = [\lambda(1 - t_Y)]'\hat{\mathbf{q}} + [s_Y\kappa(1 - t_Y)]'\hat{\mathbf{q}}$. Total disposable household income is **yd**, which besides the income generated in production (**y**) also contains the other income sources, namely profit income and net foreign transfers, Y_p.

Aggregate private consumption is therefore a function of real disposable income YD/PC, where YD is the sum of $\mathbf{y}'\mathbf{i}$ as defined above and other income, Y_p:

$$YD = \mathbf{y}'\mathbf{i} + Y_p \tag{13}$$

Aggregate real private consumption CP becomes a function of output and prices with c_Y as the average propensity of consumption:

$$CP = c_Y[\mathbf{y}'\mathbf{i} + Y_p]/PC \tag{14}$$

The consumer price PC is defined as an aggregate Divisia price index of three expenditure aggregates: (i) energy en (heating), (ii) personal transport tr, and (iii) non-energy consumption nen:

$$\ln(PC) = w_{en,cp}\ln(p_{en,cp}) + w_{tr,cp}\ln(p_{tr,cp}) + w_{nen,cp}\ln(p_{nen,cp}) \tag{15}$$

The budget shares $w_{en,cp}$, $w_{tr,cp}$ and $w_{nen,cp}$ are constant, implying Cobb-Douglas preferences of households and the real consumption expenditure of goods within energy and personal transport are calculated from converting the energy demand from the bottom-up models and functions of households into expenditure at constant prices (applying 'implicit prices'). The two aggregate prices $p_{en,cp}$ and $p_{tr,cp}$ are defined as simple indices with quantity shares s_i and consumption good prices, $p_{i,cp}$: $\Sigma_i s_i p_{i,cp}$. The consumption goods prices are given as weighted prices of each consumption good i (CPA): $p_{i,cp} = im_{i,cp} p^{im} + (1 - im_{i,cp}) p^d$, where the $im_{i,cp}$ are the import shares of the good in the consumption vector.

Assuming full separability between energy and transport consumption on the one hand and non-energy consumption on the other hand, yields non-energy consumption as the difference:

$$CP_{nen} = CP - CP_{en} - CP_{tr} \tag{16}$$

This aggregate non-energy consumption comprises 23 COICOP categories, out of which five are durables or linked to durable consumption (that is relevant for energy consumption): rents, maintenance of dwellings, household appliances, purchases of vehicles and transport services. These are also determined (partly in physical units, e.g.: vehicles) in the bottom-up models and functions of households. We assume Cobb-Douglas preferences for the 23 as well as for the 18 COICOP categories of non-durable, non-energy consumption, so that budget shares $w_{i,nen}$ are constant within both aggregates. The consumer price vector in 23 COICOP classification ($\mathbf{p}_{nen}$)' is the product of the consumer price vector in CPA (($\mathbf{p}_{CP}$)' with elements $p_{i,cp}$) with a bridge matrix for consumption $\mathbf{B}_{cp}$ (CPA * COICOP) with column sum equal to unity:

$$\mathbf{p}_{\mathrm{nen}}' = \mathbf{p}_{\mathrm{CP}}' \mathbf{B}_{\mathrm{cp}} \tag{17}$$

The quantity expenditure shares within non-durable non-energy consumption are derived by dividing the budget shares $w_{i,nen}$ by the consumption price for the corresponding good ($p_{i,nen}$) and multiplying with the aggregate price (($\mathbf{p}_{nen}$)'$\mathbf{i}$). Consumption at constant prices of non-energy categories therefore is given with:

$$cp_{nen} = \left[(w_{i,nen} \frac{p_{i,nen}}{\mathbf{p}_{\mathbf{nen}}' \mathbf{i}}) Q_{nen} \right] \tag{18}$$

The vector $\mathbf{cp}_{nen}$ resultimg from that has the dimension of 23 COICOP (CC) categories and is measured at purchaser prices. It is in a subsequent first step converted to the industry classification of the SUT and in a second step to basic prices by subtracting net taxes and redistributing trade and transport margins. The first step is carried out by applying the bridge matrix for consumption $\mathbf{B}_{cp}$ (CPA * COICOP). The resulting vector **cp** can then be split up into a vector of domestic goods ($\mathbf{cp}^{d}$) that enters into equation (2) and another vector of imported consumption goods ($\mathbf{cp}^{im}$).

4. Energy

Total final energy demand is a common variable to the IO model (monetary units) and to the IO model of energy transformation (physical units) in LEEM. This variable is determined in physical units either in the IO model or in the bottom-up approaches and then transferred to the IO model of energy transformation. The input structure of electricity generation is the other common variable to the IO model (monetary units) and to the IO model of energy transformation (physical units). This structure will be determined in the energy transformation model and changes in the input structure are proportionally transferred to the electricity sector column vector in the IO model.

4.1 Final energy demand for heating and private transport

The model linkage between bottom-up approaches of energy demand in the Non-ETS and the LEEM model comprises final energy for heating (buildings) and private as well as freight transport.

Heating energy demand of households (physical units) stems from the Invert/EE-Lab model and is classified in the 26 types of energy *k* (for details of the classification, see the Appendix) of the energy IO model. This energy demand becomes part of final energy **fe** (equation (4)) and is converted into monetary expenditure (in the classification of energy goods in the IO model) by applying 'implicit prices'. The resulting expenditure becomes part of CP_{en} in equation (16). Other results from the Invert/EE-Lab model simulation are used for determining some energy relevant durable expenditure, for example dwelling area, investment in heating appliances, and investment in thermal insulation. The physical data for dwelling area are linked to the consumption expenditure for actual and imputed rents (yielding an implicit renting price per m2) and the expenditure data (maintenance of dwellings, appliances) are directly linked to the corresponding categories of private consumption.

Private transport demand (physical units) is taken from different scenarios with the NEMO transport model, which is based on a bottom-up dataset. This dataset covers vehicle purchases and stocks by drive, technical efficiency of the stocks and 'service demand' (km driven). Besides (exogenous) changes in the modal split between different types of public transport and car transport, the share of drives (gasoline, diesel, electricity) in vehicle purchases changes over time. The main Kaya type equation for energy demand for different types of energy *k* (gasoline, diesel, electricity) is:

$$E_k = \frac{E_k}{K_k}\frac{K_k}{K}K \qquad \text{with } K = \sum_k K_k \tag{19}$$

The vehicle stocks of different drives are simply determined by the accumulation equation:

$$K_{k,t} = (1-d)K_{k,t-1} + CF_{k,t-1} \tag{20}$$

Gross capital formation (CF) adds to the last period's stock and depreciation with fixed depreciation rate δ is subtracted from last period's stock. Equation (20) determines the second ($\frac{K_k}{K}$) and the last term (K) in equation (19). The first term is the average energy consumption of each vehicle fleet, determined by efficiency and service demand.

Energy demand by type of energy of non-ETS industries is modelled by applying a similar equation to (19), but with outoput by process (Q_k) and specific energy intensity by process ($\frac{E_k}{Q_k}$), which together determine, $\frac{E_k}{Q}$. Different from private transport, where all physical stock data are available, for the non-ETS industries only total Q is known, but not the specific output (Q_k) for fuel specific processes. This needs to be estimated and the model needs to be calibrated simultaneously, meeting plausible ranges for the relationship between efficiencies of different technologies, ($\frac{E_k}{Q_k}$). The energy input equation is defined with: $\frac{E_k}{Q} = \frac{E_k}{Q_k}\frac{Q_k}{Q}$. For heating in non-ETS industries, the results for households are adjusted and used. For other purposes of energy in non-ETS industries, the two components of $\frac{E_k}{Q}$ are simply extrapolated, but not explicitly modelled. The coefficient $\frac{E_k}{Q}$ is directly converted into the corresponding technical coefficient of the IO model, applying implicit prices.

4.2 Transformation energy demand

In LEEM the input coefficients in the two transformation processes 'Electricity plants' and 'Autoproducer electricity plants' are endogenous, the input coefficients of the other six processes are fixed. The input coefficients in electricity production are modelled in a similar way as the final energy intensities in the production sectors. The coefficients (physical units) are the product of technology (= type of energy *k*) specific input coefficients (for example coal input per unit of output from electricity from coal) $\frac{E_k}{Q_k}$, and the shares of these technologies in total electricty production (physical units), $\frac{Q_k}{Q}$. Again, the resulting coefficient $\frac{E_k}{Q}$ is directly converted into the corresponding technical coefficient in the electricity sector of the IO model, applying implicit prices.

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Appendix

The industries in LEEM are identical with those in the sectoral disaggregation of final energy in the Austrian Energy Balance. The definition of these industries via NACE 2 and 3 digits has been provided by Statistics Austria.

Table A1: Industries in LEEM and corresponding NACE definitions (2 and 3-digits)

01, 02, 03	Agriculture, forestry, fishing
05-07	Mining
10,11-12	Food/beverages/tobacco production
13-15	Textiles and leather
16	Wood production
17-18	Paper production
19	Cokery, refining of oil
20, 21	Chemical industry
23	Other non-m,etallic mineral production
24	Iron & Steel, non-ferrous metals
25-28	Machinery, equipment
29, 30	Transport equipment
22, 31-33	Other manufacturing
351	Electricity
352	Natural gas
353	Steam
41	Construction of buildings
42	Civil engineering
43	Specialized construction
491 - 492	Rail transport
493	Other passenger transport
494	Road freight transport
495	Transport via pipeline
50	Water transport
51	Air transport
Rest	Public and private services

The classification of goods in LEEM is identical with the industry classification, except for energy mining products (= primary energy, CPA 05-07) and for products from coke oven and refinery (CPA 19). The splitting up of 05-07 started from those issues, where a 1:1 assignment was possible: crude oil to refineries, gas to natural gas (351) and metal ores to Iron&steel, non-ferrous metals (24). All other inputs along the row of the two input tables (use table in IO, final energy use in energy balance) have been assigned to coal.

For splitting up 19, information of the energy balance (physical units) has been plugged in and converted into a first estimate in monetary units applying prices from Statistics Austria. This was adjusted to the totals of row 19 in the use table (monetary units). For slitting up the total use in domestic and imported products, the corresponding import shares of the energy balance for each product have been taken as a starting point. The resulting first estimate has been adjusted to the total imports of row 19 from the use table and to imports by product in the energy balance.

Table A2: Goods in LEEM and corresponding NACE definitions (2 and 3-digits)

01, 02, 03	Agriculture, forestry, fishing
05-07	Coal and lignite
05-07	Crude petroleum
05-07	Natural gas
05-07	Metal ores
08-09	Other mining
10,11-12	Food products, beverages, tobacco
13-15	Textiles and leather
16	Wood, products of wood
17-18	Paper and paper prducts
19	Coke
19	Gasoline
19	Kerosine
19	Diesel
19	Gasoil
19	Fuel oil
19	Liquid gas
19	Other oil products
19	Refinery gas
20, 21	Chemicals
23	Other non-m,etallic mineral products
24	Iron & Steel, non-ferrous metals
25-28	Machinery, equipment
29, 30	Transport equipment
22, 31-33	Other manufacturing
351	Electricity
352	Natural gas
353	Steam
41	Construction of buildings
42	Civil engineering
43	Specialized construction
491 - 492	Rail transport
493	Other passenger transport
494	Road freight transport
495	Transport via pipeline
50	Water transport
51	Air transport
Rest	Public and private services

The transformation processes and the types of energy in the energy IO model in LEEM represent the maximum level of detail that is available in the Austrian Energy Blance (Statistics Austria).

Table A3: Transformation processes in LEEM

Coke Oven
Blast Furnace
Refinery
Char Coal Production
Electricity Plants
Autoproducer Electricity Plants
Steam Plants
Autoproducer Steam Plants

Table A4: Types of energy in LEEM

Coal
Lignite
Lignite briquette
Peat
Coke
Crude oil
Other refinery input
Gasoline
Kerosine
Diesel
Gasoil
Fuel oil
Liquid gas
Other oil products
Refinery gas
Natural gas
Blast furnace gas
Coke oven gas
Fuelwood
Waste
Biofuels
Ambient heat
Hydro power
Wind, PV
District heat
Electricity