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# CONSTRUCTION OF THE ENERGY SOCIAL ACCOUNTING MATRIX FOR IRELAND

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## ACRONYMS

ATS	Air transportation sector
BEUS	Business Energy Use Survey
CSO	Central Statistics Office
CT	Carbon tax
DT	Direct tax
EB	Energy balance
EGS	Electricity and gas supply sector
EU ETS	European Union Emissions Trading System
FISIM	Financial intermediation services indirectly measured
HBS	Household Budget Survey
HH	Households
HSL	High-skilled labour
LFS	Labour Force Survey
LSL	Low-skilled labour
MQE	Mining, quarrying, and extraction
MSL	Medium-skilled labour
NACE	Nomenclature of economic activities
ONM	Non-metallic mineral sector
PFOM	Petroleum, furniture and other manufacturing (PFOM)
PRT	Production tax
QAIS	Quarterly Accounts of Institutional Sectors
RHG	Representative household groups
RoW	Rest of the world account
SAM	Social accounting matrix
SEAI	Sustainable Energy Authority of Ireland
S-I	Saving–investment
SILC	Survey on Income and Living Conditions
ST	Sales tax
SUT	Supply and use table

## EXECUTIVE SUMMARY

A Social Accounting Matrix (SAM) represents the basis of a computable general equilibrium (CGE) model in terms of data. The matrix presents a snapshot of the economy for a given period of time, usually one year. This paper provides details concerning the data collection process to construct a SAM for the Ireland Environment, Energy and Economy (I3E) model. Due to the energy focus of the I3E model, the SAM is extended to construct an Energy SAM (ESAM). The ESAM includes several energy sectors and commodities and their concomitant carbon emissions. To this end, several data sources are used to disaggregate already available sectors and commodities into subsectors.

# 1 Introduction

A computable general equilibrium (CGE) model reproduces the structure of the economy in its entirety including productive sectors, goods, households, factor inputs, trade and the government, where the nature of all existing economic transactions among diverse economic agents is quantified. To calibrate the CGE model parameters, a Social Accounting Matrix (SAM) is needed. A SAM can be defined as an organised matrix representation of all transactions and transfers between different production activities (sectors), goods (commodities), factors of production (labour, capital, and land), and institutions (households, corporate sector, government, and enterprises) within an economy and with respect to the rest of the world. A SAM is thus a comprehensive accounting framework within which the full circular flow of an economy (where households use their disposable income for consumption, which creates income for production, which creates income for factors of production which are owned by households, which creates income for households who again devote their income to consumption) is captured.

This paper explains the data collection process and balancing procedure of the ESAM as used in the I3E model in detail. The next section explains the basic structure of a typical SAM. Section 3 summarises the data sources utilised to construct firstly the SAM and then the ESAM for the Irish economy. Section 4 is devoted to explaining both the construction steps of the aggregated version of the Irish SAM and the relationships across the economic agents, as defined in the I3E model. Section 5 summarises the disaggregation of the energy sectors and commodities and the construction process of the ESAM, whereas Section 6 explains the disaggregation of the household sector into different household groups. Appendix A explains the relations between different prices and valuations used in the input–output tables. Appendix B provides the lists of activities and commodities defined in the I3E model and finally, the mapping of the Household Budget Survey (HBS) consumption items to the I3E commodities can be found in Appendix C.

## 2 Basic SAM Structure

A typical SAM depicts all the transactions in the economy in the form of a symmetric matrix. Each economic agent is represented as both a row and a column account. The number of agents represented depends on the nature of the analysis. If a researcher wishes to explore the distributive effects of a policy change, there would be more than one households group. Each row of the SAM gives receipts of an account while the column gives the expenditure. An entry in row  $i$  and column  $j$  represents the receipts of account  $i$  from account  $j$ . The total of each row has to be equal to the total of the corresponding column. The logic behind this rule is simple: an expenditure of one agent is the income of another agent, and an agent's income should be equal to its expenditure.

As a SAM is formed to calibrate the model parameters, the structure of a SAM is determined by the structure of the CGE model regarding the number of agents and commodities represented in the model. As summarised by Pyatt (1988), a SAM brings together data from many various sources to describe

the structural characteristics and is a very good way of displaying information concerning the structural interdependence in an economy at both the macro and meso levels. Round (2003) describes the SAM as a meso-level framework, noting that it operates as a functional bridge between a macro framework and markets and institutions that have a more detailed description.

### 3 Data Sources

Generally, Input–Output (IO) tables are used to construct SAMs and are constructed based on the Supply and Use Tables (SUTs). The SUTs provide the most detailed data on the sources of supply and demand of commodities, including exports and imports, the cost of production, the composition of gross value added and taxes and subsidies on products. Industries are on the rows of SUTs while products are on the columns. The supply table provides information on which sectors produce which commodities, imports by commodities, trade margins, taxes, and subsidies on products. The use table, by contrast, is formed by using four different tables: domestic use table (usage of domestically produced products), import use table (usage of imported products), net tax table (tax minus subsidies) on products, and lastly trade margins table. Trade and transportation services measured by trade and transportation margins which are necessary to deliver commodities from factories and docks to markets. They are one of the basic components of the valuation process.<sup>1</sup>

Each national statistical office produces an IO table by applying either the product technology or the industry technology assumption to the SUTs.<sup>2</sup> Regardless of the choice of conversion, the resulting IO will assume that each industry is associated with the production of a single product. In other words, IO tables restrict the information provided by SUTs, and do not allow industries to produce multiple products and do not allow commodities to be produced by multiple activities. However, secondary and tertiary products may play an essential role in some industries and should, therefore, be included. The latter restriction leads to ignorance concerning differentiated products produced by domestic industries.

In order to avoid the restrictions introduced by IO tables, a SAM can be constructed by directly using the SUTs. In this case, the domestic production can be represented more accurately, although several complexities emerge such that each industry has to determine the level of production of each product.

As a SAM records incomes and expenditures, which are flow variables, it provides a snapshot of the economy for a period of time. Choosing a year for which a SAM is constructed, the base-year, in other words, has important implications. By definition, a SAM depicts the economy in an *accounting equilibrium* where total expenditure is equal to total income for each agent. However, *economic equilibrium* requires that each agent does not tend to and has no incentive to change her/his behaviour. In other words, the decisions of agents are stable, which, in turn, requires stability of prices including commodity prices and factors of production prices since the latter determines income (cost of production) of house-

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<sup>1</sup> A brief explanation is provided on Appendix A. For further details, an interested reader is advised to see UN (1999); EURO-STAT (2008, 2013).

<sup>2</sup> Details of these assumptions are beyond the focus of this document. Details can be found in the manuals mentioned above.



holds (firms) and the former determines the consumption profiles of the agents. Therefore, selecting an appropriate base-year requires choosing a year in which prices are *relatively* stable.

Another essential restriction in choosing the base year is the availability of all required data, where the latest available data would be preferred. The latest SUTs for the Irish economy are available for the year 2015 in which there is a significant increase (of 26%) in the gross domestic product due to relocated balance sheets in the reporting procedure, which are mainly dominated by intellectual property products (CSO, 2017). Since this updated process has no impacts on prices, disposable income, consumption or energy demand, the year 2014 is chosen as the base year as the relation between all economic variables were more consistent to each other in 2014.

As the data provided by the SUTs is not sufficient to construct a SAM, additional data at a macro-economic level, including for example government transfers to households, government savings, and net factor income from the rest of the world are retrieved from government and national accounts.

To be able to analyse policy impacts via the energy system, several of the energy-related sectors in the SAM need to be further disaggregated to the desired level of detail creating a so-called Energy SAM (ESAM). An ESAM expands the SAM to include energy inputs explicitly and the concomitant emissions from energy use; in other words fuel combustion. Several energy-related sectors of the SAM are disaggregated into specific carbon commodities and industries. This process involves distributing the total value of the original sector over the newly created subsectors for the activity and commodity rows and columns in the SAM. The disaggregation process requires not only obtaining information on production activities intermediate input demand composition and the composition of value added by factors of production but also distribution of final consumption across private (household) consumption, public consumption, consumption by investment purposes (investment by origin) and exports.

Although the I3E model mainly focuses on the energy–economy interaction, the SUTs for the Irish economy are quite restrictive regarding the level of details for the energy-related sectors due to data confidentiality concerns. For instance, as there is only one refinery in the country, the Central Statistical Office (CSO) merges the petroleum sector with the furniture and other manufacturing sector, and provides highly aggregated data on the merged sector. The commodities produced by these quite distinct sectors are also provided in aggregate figures. The same aggregation is also a problem for the mining and quarrying sector, which produces peat and coal and extracts natural gas, which are commodities with different carbon contents affecting their emissions and the taxation policy applied to them. As explained in Section 5, extensive use is made of EUROSTAT and EXIOBASE datasets, as well as Energy Balance (EB) from the Sustainable Energy Authority of Ireland (SEAI) and the Business Energy Use Survey of CSO.

Lastly, in order to analyse the distributional impacts of policy changes, the private household sector is disaggregated into 10 distinct representative household groups (RHGs, five in rural areas and five in urban areas) based on disposable income. The total labour force is also disaggregated into low-, medium-, and high-skilled labour based on attained level of education. In the disaggregation process of the households, the HBS, the Survey on Income and Living Conditions (SILC) and the Labour Force Survey (LFS) are used extensively. Details of the disaggregation procedure are discussed in Section 6.

## 4 Aggregated Social Accounting Matrix

This section is devoted to explaining the construction of the Irish ESAM; see Table 1 for an aggregated version. In the following subsections, the details of each account and the relationship between the agents are summarized.

The SUTs for Ireland consist of 58 industries and 58 products. These production sectors are firstly merged into 29 sectors based on their shares in total value added, employment and emissions. Subsequently, as explained in detail in Section 5, three sectors are further disaggregated, and the total number of sectors / activities in the I3E model reaching 32. The products are merged into 39 commodities based on their economic or environmental importance. Out of 39 commodities, 37 are domestically produced in Ireland while two of them (crude oil and coal) are imported in their entirety. The list of activities and commodities in the SAM can be found in Appendix B.

Notice that the columns of a SAM show the expenditures of the account whereas the rows consist of the incomes of the account. For the sake of simplicity, the notation  $(x,y)$  will be used where  $x$  stands for the row account and  $y$  stands for the column account.

### 4.1 Activities – ACT

The account Activities (ACT) produces commodities by using commodities as intermediate inputs and factors of production, and pays a production tax over the value of the production. Total domestic production, which is equal to the sum of the Supply Table is consumed by the Commodities (COM) account. In other words, the account COM buys all products from the ACT account, and this comprises the income of the ACT account. Thus, this value appears in the cell  $(ACT,COM)$ .

The column of the ACT account shows the cost structure of the production sectors. The total value of intermediate input demand, which is the income of the COM account, appears in the cell  $(COM,ACT)$ . The sectors make payments to the factors of production, which are capital  $(CAP,ACT)$ , low-skilled labour  $(LSL,ACT)$ , medium-skilled labour  $(MSL,ACT)$  and high-skilled labour  $(HSL,ACT)$ . The figure in the cell  $(CAP,ACT)$  directly comes from the Use Table's corresponding row sum. The sum of the payments to the labour types, which is also directly available in the Use Table, is disaggregated into payments to types of labour by using the Survey on Income and Living Conditions (SILC).<sup>3</sup>

The only information not available in the Use Table is the activities' payments to the rest of the world account (RoW), which corresponds to half of the cost of the European Union Emission Trading System (EU-ETS). In the current legislation, around half of the cost of the ETS is paid to the government and the remainder goes to the EU Commission. Half of the total cost of the ETS (around €80 million) is put in the cell  $(RoW,ACT)$  and this amount is deducted from the original 'Net taxes (taxes minus subsidies) on production' in the Use Table, and the remaining value, the cell  $(PT,ACT)$ , is the production tax payments of the activities.

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<sup>3</sup> See Section 4.4 for further details.

## 4.2 Commodities (COM) and Margins (MAR)

The row of the account of Commodities (COM) shows the components of total demand; the intermediate input demand (COM,ACT), trade and transportation margin demand (COM,MAR), government demand (COM,GOV), household (including Non-profit Institutions Serving Households-NPISH) demand (COM,HH), investment demand including changes in inventories (COM,S-I) and, finally, export demand (COM,RoW). All these values come from the corresponding columns of the Use Table. In the national accounts, in-kind transfers from the government to households are excluded from household consumption but included in public consumption. In the SAM, the value of in-kind transfers retrieved from the government accounts is added (subtracted) to (from) private (public) consumption.

Trade and transportation services are necessary to deliver commodities from factories and docks to markets. Producer prices do not comprise the cost of these margins since these are not part of the production process. These costs are paid by final users of commodities and are included in purchaser prices. On the Supply Table, the values in the column of margins are entered as negative for trade and transportation activities and they are positive for all other activities; the column sum is equal to zero. The reason for this is that trade and transportation activities are the producers of these intermediation services while the other sectors demand these services. The sum of margin demands – the sum of positive values on the margin column of the Supply table – appears in the cell (COM,MAR). The sum of negative values of the same column appears in the cell (MAR,COM) as these services are demanded by commodities, since a commodity is produced by several activities and the cost of margins is paid by consumers.

The column of the account of COM shows the sources of supply; the domestic production (ACT,COM), margin demand (MAR,COM), sales / value added tax on the total domestic demand (ST,COM), carbon tax collected on the domestic demand of the energy commodities (CT,COM) and, finally, import demand (RoW,COM).

## 4.3 Capital – CAP

The Capital account collects gross payments to capital, which equal the sum of net operating surplus and the consumption of fixed capital in the Use Table. Since this is the income of the Capital account, the value is in the cell (CAP,ACT).

The account pays a direct tax to the account of DT (DT,CAP), which is equal to the corporate tax collection of the government. This value is calculated as a residual by subtracting income tax collection from the sum of the total direct tax and capital tax revenue of the government. In other words, it includes capital acquisitions tax, capital gains tax, corporation tax, local property tax, other current direct taxes, and capital taxes. The net-of-tax capital income goes to the account of Enterprises (ENT,CAP), which is the owner of all production activities. The reason for introducing such an account is to simplify some details of the model; this solves the issue of a lack of sector-specific data such as corporate tax payments.

#### **4.4 Labour Types – LSL, MS� and HSL**

The accounts of different labour types collect gross wage income from the activities (L,ACT) and pay the wage income tax to the account of Direct Tax (DT,L), where  $L$  stands for each labour account, LSL, MS� and HSL. The net-of-tax amount goes to households as net wage income (HH,L). The total value of direct tax income of labour types is equal to the income tax revenue of the government.

These labour types are created by using the SILC data based on attained level of education. For instance, individuals with no formal/ primary or lower secondary education are assumed to be low-skilled, individuals who have an upper secondary, post Leaving Certificate or third level without a degree are assumed to be medium-skilled, and lastly, individuals with a third-level degree or above are assumed to be high-skilled. Then, for each type of household defined in the model, the composition of wage income by skills is retrieved: the share of labour income of each type of labour in total wage income of each RHG. In this analysis, individuals under age 16 or without information concerning attained education are excluded.

The SILC also provides the economic sector of employment by NACE codes for each working individual, but the sectoral classification of the survey is quite restrictive, especially for manufacturing and transportation sectors. To have more accurate results on the sectoral wage costs, the Labour Force Survey (LFS) is utilised by using the same mapping of the attained level of education and the skill types defined in the model. Then, the share of each type of labour in the total sectoral employment can be estimated.

#### **4.5 Enterprises – ENT**

As mentioned before, the account is the owner of all production activities. It collects the net capital income from the capital account (CAP,ENT) and transfers from the government. The value of government transfers is calculated as residual to ensure the government account is in equilibrium. The value, on the other hand, is quite close to the sum of the following items in the government accounts: other current transfers, capital transfers and net acquisition of non-financial assets.

Total income is split between payments to households as net-of-tax capital income (HH,ENT) in the form of dividends and corporate savings (S-I,ENT). The corporate savings are collected from the Quarterly Accounts of Institutional Sectors (QAIS). Payments to households are calculated as a residual.

#### **4.6 Government – GOV**

All tax accounts pay their revenues to the government account (GOV,T), where  $T$  stands for each tax account, PRT, ST, CT, and DT.

Government expenditure consists of public demand of commodities (COM,GOV), transfers to enterprises (ENT,GOV), unilateral welfare and pension transfer to households (HH,GOV) and interest payments over the outstanding foreign debt stock to the rest of the world (RoW,GOV).

The difference between total government income and expenditure represents public saving, which is equal to operating surplus / deficit value in the government accounts appears in the cell (S-I,GOV).

**Table 1: Aggregated SAM of Ireland  
for the year 2014, €billion**

	ACT	COM	MAR	CAP	LSL	MSL	HSL	PRT	ST	CT	DT	ENT	GOV	HH	S-I	RoW	Total
ACT		417.95															417.95
COM	240.95		25.46										26.24	87.08	45.16	216.90	641.79
MAR		25.46															25.46
CAP	102.99																102.99
LSL	7.72																7.72
MSL	29.46																29.46
HSL	36.06																36.06
PRT	0.74																0.74
ST		17.14															17.14
CT		0.39															0.39
DT				8.10	0.72	10.40	17.02										36.24
ENT				94.89									5.95				100.85
GOV								0.74	17.14	0.39	36.24						54.51
HH					7.00	19.06	19.05					56.71	28.08			-29.72	100.17
S-I												44.14	-7.10	13.09		-4.97	45.16
RoW	0.04	180.85											1.33				182.21
Total	417.95	641.79	25.46	102.99	7.72	29.46	36.06	0.74	17.14	0.39	36.24	100.85	54.51	100.17	45.16	182.21	

**ACT:** Activities; **COM:** Commodities, **CAP:** Capital; **LSL:** Low-skilled labour; **MSL:** Medium-skilled labour; **HSL:** High-skilled labour; **MAR:** Trade and transportation margins; **PRT:** Production tax; **ST:** Sales tax; **CT:** Carbon tax; **DT:** Direct tax; **GOV:** Government; **HH:** Households; **ENT:** Enterprises; **S-I:** Saving–Investment; **RoW:** Rest of the world.

The value of interest payments to the rest of the world is calculated by subtracting the change in the foreign debt stock of the government (retrieved from the National Treasury Management Agency) from the interest payments (excluding financial intermediation services indirectly measured – FISIM) of the government. Accordingly, the government foreign debt stock increased by €6.3 billion between 2014 and 2013, while the its interest payment was €7.6 billion in 2014. The net payment of the government to the rest of the world is positive and appears in the cell (RoW,GOV). As all information comes from the government accounts, the cell (ENT,GOV) is used as a residual account to balance the government accounts.

It should be noted that the total revenue of the government in the SAM is less than its realised value in 2014 by around €11 billion. The reasons for this difference can be explained as follows. First, the total amount of indirect taxes (taxes on production and consumption) is €18.27 billion in the SUTs while it is €21.21 billion in the government accounts. The difference of €2.94 billion can be attributed to subsidies on production and commodities. The remaining difference, €8.5 billion, is equal to the sum of the following items in the government account: sales of goods and services, investment income, current transfer revenue, and capital transfer revenue. The recipient of sales of goods and services is the activity of public services, which is defined as a separate production activity (sector) in the I3E model. The remaining items are ignored as the I3E model does not have specific agents that are payers or recipients of these income items. In order to ensure the balance of the government account, the total expenditure is set to equal the total of revenue and the transfer to enterprises is used as a residual account.

#### **4.7 Households – HH**

Households have net-of-tax wage income from the labour accounts (HH,L) where *L* stands for the labour types, dividend income from the enterprises (HH,ENT), transfer (including pension income) from the government (HH,GOV), and net factor income from the rest of the world (HH,RoW). The value of the last item is readily available in the national accounts. The sum of these items yields household disposable income as all items are in net-of-tax terms. Households devote their disposable income to private consumption (COM,HH) or to saving (S-I,HH), which is calculated as residual to hold the balance of the account of HH. The HBS is used extensively in the calibration process of household-level parameters. For further information, see Section 6.

#### **4.8 Rest of the World – RoW**

As in the case of all single-country CGE models, all countries except Ireland are assumed to be a single unit referred to as the ‘rest of the world’. All monetary flows between the rest of the world and Ireland are traced within the rest of the world (RoW) account. Since all transactions related to this account are assumed to be denominated in a foreign currency, an exchange rate adjustment takes place. In the case of Ireland, although there is no exchange rate discrepancy for the transactions within the EU, almost two-thirds of the value of foreign trade consists of trade flows between Ireland and the United States and

Ireland and the United Kingdom. As there is no distinction between these trade partners within the I3E model, the exchange rate movements also play an important role.

The account receives half of the cost of ETS permits paid to the European Commission (RoW,ACT), imports of commodities (RoW,COM), and the government interest payments over the outstanding foreign debt stock (RoW,GOV). The account's expenditures consist of exports of commodities (COM,RoW) and net factor income of households (HH,RoW). The difference between the row sum and the column sum yields the net foreign exchange demand of an economy – the current account balance. Its positive value indicates that the country runs a current account deficit. In the case of Ireland, this value is -€4.97 billion, which means that the country has a current account surplus. In other words, the value is negative since the current account is the net outflow of savings abroad.

The realised value of the current account surplus for the year of 2014 was €6.8 billion. As explained in Section 4.6, the model has to ignore some income streams because the data used to construct the SAM come from different sources, and there are some discrepancies across these.

#### **4.9 Savings-Investment – S-I**

The receipts of the account of Savings–Investment are corporate savings (S-I,ENT), private savings (S-I,HH), government savings (S-I,GOV) and the foreign savings (S-I,RoW). Since the total amount of savings is used to finance the investment expenditures in the economy, the only expenditure item of the account is commodity demand for investment purposes (COM,S-I). Since all other accounts are in equilibrium, the value of foreign savings also equilibrates the saving / investment balance.

## **5 Energy Sector Disaggregation Process**

To be able to analyse impacts via the energy system, several of the energy-related sectors (activities and commodities) in the CSO SUTs need to be further disaggregated to the desired level of detail. The disaggregation entails creating multiple sectors from a single sector including: Mining, Quarrying, and Extraction (MQE – NACE 5-9), Petroleum, Furniture and Other Manufacturing (PFOM – NACE 19, 31, 32) and Electricity and Gas Supply (EGS – NACE 35).

In the case of MQE, a distinction needs to be made between crude oil, peat, coal, natural gas and other mining sectors. Other mining includes metal ore, stone, sand, and clay. PFOM has been aggregated to avoid data confidentiality issues. This sector needs to be disentangled from furniture and other manufacturing and further disaggregated into diesel, gasoline, kerosene, fuel oil, LPG and other petroleum products. EGS needs to be disaggregated into electricity services and gas services.

The disaggregation process involves distributing the total value of the original sector over the newly created subsectors for the activity and commodity rows and columns in the SUTs. The disaggregation process requires not only obtaining information on production activities, including, intermediate input demand composition and the composition of value added by factors of production, but also distribution

of final consumption across private (household) consumption, public consumption, consumption by investment purposes (investment by origin), and exports.

The disaggregation relies heavily on two data sources: the 2014 Irish Energy Balance (EB) published by the SEAI and the 2014 Business Energy Use Survey (BEUS) published by the CSO. The EB presents national energy statistics on energy production and consumption in Ireland. The flow of energy from production, transformation and the energy sectors' own use through to final consumption in different sectors of the economy is given in energy units (ktoe). These energy units are converted into tonnes and monetary units using different fuel prices derived from the SEAI domestic and commercial fuel costs archives and the IEA fuel costs data for Ireland. The BEUS is an annual survey conducted by the CSO that collects information about energy use by businesses in Ireland. This survey presents both the energy use of different fuels and sectors in energy units as well as in monetary costs. The BEU provides the latest data concerning business energy use and will be used in the future to update the EB.

Once the energy sector is disaggregated, the I3E will be able to explicitly include carbon commodities (peat, coal, natural gas, gasoline, gas oil, fuel oil, kerosene, and other petroleum products), which are used by the various production sectors or consumed directly by final users. In this way, carbon and carbon emissions can be tracked through the various production and consumption channels.

In what follows, we discuss the disaggregation process of each energy-related sector in turn.

## 5.1 Petroleum and Furniture

In the SUTs for Ireland, the petroleum sector (NACE 19) is combined with the furniture and other manufacturing sector (NACE 31 and 32) to create the PFOM sector. This has been done to avoid data confidentiality issues, where the petroleum sector is dominated by a single firm. CSO data from 2011 concerning output and value added are used as well as EUROSTAT data, to disaggregate these sectors.

### 5.1.1 Supply Table disaggregation

The CSO does provide data for 2011 for the petroleum and chemicals sectors (NACE 19, 20) and the furniture and other manufacturing sector (NACE 31 and 32) separately concerning market output, intermediate consumption, gross value-added and taxes on product less subsidies. Using the 2011 supply table data for the chemical sector (NACE 20), the level of these variables for the petroleum sector can be estimated. Where output for the petroleum sector is given as:

$$X_{pet} = X_{pch} - X_{ch} \quad (1)$$

where  $X_{pch}$  represents the output for the combined petroleum and chemicals sector (as given in the 2011 CSO output data),  $X_{ch}$  is the output for the chemicals sector (obtained from the 2011 SUTs) and  $X_{pet}$  is the estimated output for the petroleum sector.



For gross value added, intermediate consumption and taxes on product less subsidies, the same approach is used:

For gross values added:

$$VA_{pet} = VA_{pch} - VA_{ch} \quad (2)$$

For intermediate consumption:

$$IC_{pet} = IC_{pch} - IC_{ch} \quad (3)$$

$$IC_{pet} = \sum_c Z_{cpet} \quad (4)$$

and for taxes on product less subsidies (net tax on production):

$$TAX_{pet} = TAX_{pch} - TAX_{ch} \quad (5)$$

We later use these estimated variables to capture the relative sizes of the petroleum and furniture and other manufacturing sectors in Ireland compared to other EU countries.

EUROSTAT provides supply tables for various EU countries and the EU27 and EA19, the monetary union.<sup>4</sup> Comparing the energy balances of the various EU countries, the EU27 and EA19 with that of Ireland, we believe that the EA19 best represents the energy structure of Ireland. For the disaggregation process, it is assumed that the EA19 flows can approximate the Irish relative flows within the economy from and to the petroleum and furniture and other manufacturing. In other words, for example 50% of PFOM commodities in the EA19 are used (for example, manufacturing chemicals), it is assumed that 50% of the Irish petroleum commodities are also used in the manufacturing of chemicals. Moreover, if in the EA19, 20% of total commodities produced by the petroleum sector are chemicals, 20% of commodities produced by the petroleum sector in Ireland are assumed to be chemical products.

Concerning the estimation of product sales in the supply table, to distinguish the share of each commodity produced by the activity PFOM that is designated as being produced by petroleum, both the estimated output of the petroleum and furniture and other manufacturing sectors and the share of each commodity's production in total production (output) in each sector in the EA19 are used. The share of each commodity in total production by the petroleum activity is referred to here as the supply table commodity share and is calculated as follows:

$$scs_{EUpetc} = \frac{X_{EUpetc}}{\sum_c X_{EUpetc}} \quad (6)$$

where  $X_{EUpetc}$  represents the value of commodity  $c$  produced by the activity petroleum, given in the EUROSTAT EA19 supply table for 2014. The share for furniture and other manufacturing is calculated in the same way.

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<sup>4</sup> Austria, Belgium, Cyprus, Estonia, Finland, France, Germany, Greece, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Portugal, Slovakia, Slovenia, and Spain.

The share of each commodity produced by the activity PFOM that is designated as being produced by petroleum is then given by:

$$ss_{petc} = \frac{X_{pet} scs_{petc}}{X_{petc} scs_{EU_{petc}} + X_{fm} scs_{EU_{fmc}}} \quad (7)$$

where  $X_{fm}$  and  $X_{pet}$  represent the output for the furniture and other manufacturing and petroleum sectors respectively in 2011, as calculated above.  $scs_{EU_{fmc}}$  represents the supply table commodity share for the furniture and other manufacturing sector. In this way, we weight the EA19 shares by the relative magnitudes of the furniture and other manufacturing and petroleum sectors in Ireland.

The remainder is designated as furniture and other manufacturing:

$$ss_{fmc} = 1 - ss_{petc} \quad (8)$$

The share of the PFOM commodities produced by the different activities that is designated as petroleum commodities (in the supply table rows) is calculated similarly by first calculating the EA19 supply table activity share:

$$sas_{EU_{apet}} = \frac{X_{EU_{apet}}}{\sum_a X_{EU_{apet}}} \quad (9)$$

The share of the PFOM commodities produced by the different activities that is designated as petroleum commodities is then calculated as follows:

$$ss_{apet} = \frac{X_{pet} sas_{EU_{apet}}}{X_{pet} sas_{EU_{apet}} + X_{fm} sas_{EU_{afm}}} \quad (10)$$

The remainder is designated as furniture and other manufacturing:

$$ss_{afm} = 1 - ss_{apet} \quad (11)$$

For the case of flows from petroleum and furniture and other manufacturing to themselves and each other, the share is calculated differently as follows, where for example the share of the PFOM produced by the petroleum activity is estimated by first estimating the EA19 share:

$$sas_{EU_{petpet}} = \frac{X_{EU_{petpet}}}{X_{EU_{petpet}} + X_{EU_{petfm}} + X_{EU_{fmm}} + X_{EU_{fmpet}}} \quad (12)$$

$$ss_{EU_{petpet}} = \frac{X_{pet} sas_{EU_{petpet}}}{X_{pet} (sas_{EU_{petpet}} + sas_{EU_{petfm}}) + X_{fm} (sas_{EU_{fmm}} + sas_{EU_{fmpet}})} \quad (13)$$

Note that the bulk of production in each activity falls in the corresponding commodity: almost all of the production of activity petroleum concerns the commodity petroleum.

The trade margins for the commodities are not given for the EA19. In this case, we have used data for the EA19 countries for which data are available.<sup>5</sup> First the shares of trade margins in total supply for each sector is calculated:

$$sm_{EU\ pet} = \frac{M_{EU\ pet}}{Z_{EU\ pet}} \quad (14)$$

$$sm_{EU\ fm} = \frac{M_{EU\ fm}}{Z_{EU\ fm}} \quad (15)$$

where  $M_{EU\ pet}$  is the sum of the payments of EA19 countries by the petroleum commodity to margins, and  $Z_{EU\ pet}$  represents the sum of the EA19 countries' total supply.

The share of total trade margins for PFOM that is designated to the petroleum commodity is then:

$$sm_{pet} = \frac{X_{pet} sm_{EU\ pet}}{X_{pet} sm_{EU\ pet} + X_{fm} (sm_{EU\ fm})} \quad (16)$$

The imports of and sales taxes on petroleum products are directly calculated based on the 2014 EB and CSO trade data, where the remainder of the PFOM totals are designated as pertaining to the furniture and other manufacturing sector. This is described in more detail in the next section.

### 5.1.2 Use Table disaggregation

For disaggregating the use table, we use the same approach as in the case of the supply table. EUROSTAT, however, does not provide the use table at purchaser prices but at basic prices: purchaser prices are the sum of basic prices, net taxes on products, trade and transport margins and non-deductible VAT. This use table needs to be converted from basic to purchaser prices. To do this, the data concerning the use table in both basic and purchaser prices for the EA19 countries for which these data are available are collected.<sup>6</sup> A basic-to-purchaser multiplier is calculated for each of these countries (given by N) for each commodity and activity combination for the petroleum sector and furniture and manufacturing sectors. The example of the petroleum sector is shown here, where the basic-to-purchaser price multiplier is given as:

For the activity petroleum:

$$bpm_{ncpet} = \frac{ZPP_{ncpet}}{ZBP_{ncpet}} \quad (17)$$

where  $ZPP_{ncpet}$  are the values in the use table for country  $n$  commodity  $c$  for activity petroleum at purchaser prices and  $ZBP_{ncpet}$  at basic prices.

We then take the average multiplier by dividing the sum of these by the number of countries for which there is data (N):

$$bpm_{EU\ pet} = \frac{\sum_n bpm_{ncpet}}{N} \quad (18)$$

<sup>5</sup> Austria, Belgium, Cyprus, Estonia, Finland, France, Germany, Greece, Italy, Luxembourg, Netherlands, Portugal, Slovakia, Slovenia, and Spain.

<sup>6</sup> Estonia, France, Italy, Netherlands, Portugal, Slovenia.

For the commodity petroleum:

$$bpm_{npeta} = \frac{ZPP_{npeta}}{ZBP_{npeta}} \quad (19)$$

We then take the average multiplier by dividing the sum of these by the number of countries:

$$bpm_{EU\,pet} = \frac{\sum_n bpm_{npeta}}{N} \quad (20)$$

Using these multipliers, the EUROSTAT EA19 use table at basic prices is converted to purchaser prices. Finally, these multipliers are adjusted such that the relative shares of intermediate consumption for the petroleum and furniture and other manufacturing sectors hold (as calculated using 2011 CSO data):

$$ics_{pet} = \frac{IC_{pet}}{IC_{pet} + IC_{fm}} \quad (21)$$

This is done by multiplying each multiplier for each sector by the same factor; in other words all petroleum multipliers are multiplied by the same factor. Following this, this converted EUROSTAT use table in purchaser prices is applied to disaggregate the CSO use table for the PFOM sector.

Concerning the estimation of intermediate demand, the share of each commodity used by the activity PFOM that is designated as being used by the activity petroleum is calculated by first calculating the EA19 use table (in purchaser prices) activity share of intermediate consumption, which represents the share of commodity  $c$  in total intermediate demand by activity petroleum, and given by:

$$uc_{SEU\,c\,pet} = \frac{Z_{EU\,c\,pet}}{\sum_c Z_{EU\,c\,pet}} \quad (22)$$

where  $Z_{EU\,c\,pet}$  represents the value of commodities used by the activity petroleum in the converted EUROSTAT EA19 use table for 2014.

These shares are then weighted by the relative shares of the petroleum and furniture and other manufacturing sectors in intermediate consumption in 2011 given by the CSO. The share of commodities used by the PFOM sector that is designated as being used by petroleum is hence calculated as follows:

$$us_{c\,pet} = \frac{IC_{pet} \, uc_{SEU\,c\,pet}}{IC_{pet} \, uc_{SEU\,c\,pet} + IC_{fm} \, uc_{SEU\,c\,fm}} \quad (23)$$

The remainder is designated as furniture and other manufacturing:

$$us_{c\,fm} = 1 - us_{c\,pet} \quad (24)$$

The share of the PFOM commodities used by the different activities that is designated as petroleum commodities is similarly estimated by first estimating the EA19 use table activity share of intermediate consumption, which represents the share of activity  $a$  in total intermediate demand of the petroleum commodity:

$$uas_{EU\ pet a} = \frac{Z_{EU\ pet a}}{\sum_a Z_{EU\ pet a}} \quad (25)$$

$$us_{\ pet a} = \frac{IC_{\ pet} \ uas_{EU\ pet a}}{IC_{\ pet} \ uas_{EU\ pet a} + IC_{\ fm} \ uas_{EU\ fm a}} \quad (26)$$

The remainder is designated as furniture and other manufacturing:

$$us_{\ fm a} = 1 - us_{\ pet a} \quad (27)$$

For the case of flows from petroleum and furniture and other manufacturing to themselves and each other, the share is calculated differently as follows, where for example the share of the PFOM used by the petroleum activity is given by:

$$us_{\ pet\ pet} = \frac{IC_{\ pet} \ uas_{EU\ pet\ pet}}{IC_{\ pet} (uas_{EU\ pet\ pet} + uas_{EU\ pet\ fm}) + IC_{\ fm} (uas_{EU\ fm\ pet} + uas_{EU\ fm\ fm})} \quad (28)$$

Concerning the shares of value-added, total gross value added (GVA) of PFOM is directly divided across the petroleum and furniture and other manufacturing sectors based on their gross value added provided for 2011. The share of the petroleum sector is then given as:

$$vas_{\ pet} = \frac{VA_{\ pet}}{VA_{\ pet} + VA_{\ fm}} \quad (29)$$

The operating surplus, net taxes, and consumption of fixed capital – the elements of GVA are also divided based on the levels of GVA for each sector.

Total final uses are calculated as the total uses (which is total supply in the supply table) minus total inter-industry demand (which is the sum of intermediate consumption over products). Total final uses (*fu*) are then divided among the final uses (consumption of households, NPISH, government consumption, gross fixed capital formation, change in inventories, and exports) based on their shares in total final uses for the EA19.

$$FU_{\ fu\ pet} = \frac{TFU_{\ pet} \ FU_{EU\ fu\ pet}}{TFU_{EU\ pet}} \quad (30)$$

Some of the final use elements are later adjusted when disaggregating petroleum products if more reliable data are available. This is discussed in the next section.

## 5.2 Petroleum products

The petroleum sector represents a single activity or industry. The petroleum commodities, however, need to be further disaggregated into gasoline, kerosene, fuel oil, LPG, diesel and other petroleum products. This is done based on the Irish EB published by the SEAI and the CSO's BEUS.

**Table 2: IEA fuel costs data for Ireland**

Fuel type	Price (€/toe, excl. taxes)	Source	Emissions coefficient (tCO <sub>2</sub> /TJ)	Source
Gasoline	783.3	IEA	70.0	SEAI
Kerosene	741.1	IEA & SEAI	71.4	SEAI
Fuel Oil	771.4	IEA	73.3	SEAI
LPG	657.8	IEA & SEAI	63.7	SEAI
Diesel	1,048.0	IEA	73.3	SEAI

We convert the EB into tonnes and monetary units using different fuel prices derived from the SEAI domestic and commercial fuel costs archives and the IEA fuel costs data for Ireland. In Table 2, the prices for each fuel type used and the source are given, as well as the conversion factors used to calculate the fuel-specific CO<sub>2</sub> emissions.

Disaggregating the supply table, we first disaggregate the supply of petroleum products produced by the petroleum sector. The above-calculated share of petroleum commodity produced by petroleum ( $ss_{petpet}$ ) is divided among the different petroleum products (given by  $pp$ ). This is based on the estimated monetary values of the EB of transformation output of refineries, calculated by:

$$TS_{pp} = p_{pp} SOR_{pp} \quad (31)$$

where  $p_{pp}$  is the price of the petroleum product  $pp$  in €/ktoe and  $SOR_{pp}$  is the quantity of supply by oil refineries in ktoe of  $pp$ . The supply share for each petroleum product is given as:

$$ss_{petpp} = \frac{SOR_{pp}}{\sum_{pp} SOR_{pp}} \quad (32)$$

For disaggregating the supply of petroleum commodities by other activities (which is extremely small), we apply the EXIOBASE dataset (Version 2.2.2). EXIOBASE is a global, detailed Multi-regional Environmentally Extended Supply and Use / Input-Output database. It was developed by harmonising and detailing SUTs for a large number of countries. This dataset focus on resources and includes a detailed disaggregation of the petroleum sector for Ireland. We calculate the share of each petroleum product in supply by:

$$ss_{app} = \frac{S_{app}}{\sum_a S_{app}} \quad (33)$$

where  $S_{app}$  is the supply of the petroleum product by activity  $a$  in EXIOBASE.

To disaggregate the use table, we use the same approach but apply the BEUS data to determine which activities use which petroleum products. We divide the total use of petroleum products across the various products assuming the same shares as in the BEUS monetary data. Where our estimates of total petroleum product use differ significantly from those of the BEUS, our petroleum/furniture and other manufacturing shares are adjusted to replicate the BEUS estimates.

Total intermediate uses are used to divide the total share:

$$us_{app} = \frac{I_{app}}{\sum_{pp} IU_{app}} \quad (34)$$

where  $IU_{app}$  represents intermediate uses in monetary terms for each activity by petroleum product.

Imports are estimated based on both the EB and CSO import data, which give the value of imports for different product types defined using the Standard International Trade Classification (SITC, Rev 4). The aggregated CSO import data concerning petroleum, petroleum products and related material (SITC 33) are shared among the various petroleum products based on the monetary EB estimates.<sup>7</sup> Taxes on petroleum products are taken from the Revenue Commissioners' tax receipt data, which give carbon and other taxes on the different petroleum products.

### 5.3 Mining and quarrying

The MQE sector composes of various mining activities. It needs to be disaggregated into other mining, peat, coal, natural gas and crude oil. To disaggregate the different mining sectors, the EXIOBASE dataset (Version 2.2.2) and the 2007 CSO SUTs are utilised. In earlier CSO SUTs (up to 2007), a distinction was made 'mining' (coal, peat, crude oil, natural gas and metal ore extraction) and 'ther mining' (any other mining). EXIOBASE data display the same relative split between mining and other mining as the CSO data. These data are adjusted based on the EB to account for the relative decrease in natural gas production between 2007 and 2014. As will be discussed in the description of the EGS further on, it is assumed that natural gas used by activities is directly supplied by the natural gas extraction sector here. Furthermore, natural gas imports are also accounted for in the MQE sector.

#### 5.3.1 Supply Table disaggregation

Coal and crude oil are not extracted in Ireland; hence these sectors do not have a share in MQE domestic supply. All supply is imported. Coal and crude oil do not represent an activity and are only disaggregated as commodities. We define the different mining activities and commodities are defined as *min*; these are coal, crude oil, peat, natural gas and other mining (though coal and crude oil are omitted in the supply case).

The supply table is disaggregated by assuming the same relative shares as EXIOBASE and the EB. The share of each commodity produced by MQE activity that is designated as being produced by each activity *min* is given by:

$$ss_{minc} = \frac{X_{Exiominc}}{\sum_{min} X_{Exiominc}} \quad (35)$$

where  $X_{Exiominc}$  represents the value of commodity *c* produced by activity *min* given by EXIOBASE.

<sup>7</sup> Note that this category also includes crude oil, which falls under the mining sector and hence is excluded here.

The share of MQE commodities produced by the different activities that is designated as being each *min* commodity (in the supply table) is similarly given by:

$$SS_{amin} = \frac{X_{Exioamin}}{\sum_{min} X_{Exioamin}} \quad (36)$$

Regarding the case of flows from the mining sectors to themselves (hence the supply of mining commodities by mining activities), the CSO 2007 split between energy mining (natural gas and peat) and other mining is applied first to determine their relative sizes. Here, EXIOBASE is used to subtract metal ore mining from the CSO-defined mining to obtain energy mining and then add it to other mining. Energy mining is then split between natural gas and peat by applying the EB data, which give the most accurate estimate of the domestic supply of peat and natural gas for 2014.

The estimated monetary values of domestic production of peat and natural gas as given by the EB are calculated. The total supply in monetary terms ( $TS_{min}$ ) is calculated based on the 2014 EB as follows:

$$TS_{min} = p_{min} QI_{min} \quad (37)$$

where  $p_{min}$  is the price of the commodity *min* given by the SEAI in €/ktoe and  $QI_{min}$  is the quantity of intermediate use in ktoe of *min*.

Where the total supply of energy mining are used to divide the total share of energy mining supply:

$$SS_{minmin} = \frac{T_{min}}{\sum_{min} TS_{min}} \quad (38)$$

### 5.3.2 Use Table disaggregation

The use table disaggregation follows a similar methodology as the supply table, where the share of each commodity used by MQE activity that is designated as being used by *min* is given by:

$$SU_{cmin} = \frac{Z_{Exiocmin}}{\sum_{min} Z_{Exiocmin}} \quad (39)$$

where  $Z_{Exiocmin}$  represents the value of commodities *c* used by the mining sector *min* given in EXIOBASE or BEUS. For the sectors/commodities for which they are available, we have used BEUS 2014 data as they are more up-to-date and reliable.

The share of MQE commodities used by the different activities that is designated as *min* commodities is similarly given by:

$$SU_{mina} = \frac{Z_{Exiomina}}{\sum_{min} Z_{Exiomina}} \quad (40)$$

or the case of flows from mining activities to themselves and each other the share is calculated as follows, where the share of mining and quarrying commodities produced by mining that is designated as energy mining is similarly given by:



$$su_{minmin} = \frac{Z_{Exiominmin}}{\sum_{min} Z_{Exiominmin}} \quad (41)$$

Finally, the total value-added of the MQE needs to be distributed between peat, natural gas, and other mining activities. Value-added consists of four components: compensation of employees; net operating surplus; consumption of fixed capital; and net taxes on production (the term *vac* refers to these components). The total of these are shared between the activities based on their relative shares in the EXIOBASE data (adjusted for a decrease in natural gas production using the EB) and using CSO 2007 value-added data:

$$va_{vac} = \frac{VA_{Exiovaca}}{\sum_{vac} Z_{Exiovaca}} \quad (42)$$

where  $VA_{Exiovaca}$  represents the value of the value-added component *vac* for the sector *a* given in EXIOBASE. The same approach is used to disaggregate the final demand.

## 5.4 Electricity and Gas

The EGS (NACE 35) is disaggregated into separate gas and electricity sectors. In the SUTs, natural gas is represented both in the MQE and EGS sectors. Examining the data, it is assumed that activities are supplied with natural gas directly from the natural gas extraction sector (within MQE). Furthermore, natural gas is imported in the MQE sector. The gas supply service sector provides gas supply services, such as the transmission and distribution of gas. This sector also supplies natural gas to households and the government.

### 5.4.1 Supply Table disaggregation

The EGS sector is separated into gas and electricity using the EXIOBASE data, the BEUS data and the EB data of 2014 and price data from the SEAI.

The supply of EGS commodities by EGS is disaggregated using the same relative shares as in the EB data. Total supply in monetary terms for natural gas and electricity ( $TS_{gas}$  and  $TS_{el}$ ) are calculated based on the 2014 EB. We show the calculations for gas, where the same approach is used for electricity, as follows:

$$TS_{gas} = p_{gas} QS_{gas} \quad (43)$$

where  $p_{gas}$  is the price of the natural gas in €/ktoe and  $QS_{gas}$  the quantity of supply in ktoe.

The gas supply commodity that is produced by the gas supply is a share of the EGS supply:

$$ss_{gas} = \frac{T_{gas}}{TS_{gas} + TS_{el}} \quad (44)$$

The small amounts of supply from other sectors is shared among gas supply and electricity supply using the EXIOBASE shares. Imports are split using the CSO import data.

### 5.4.2 Use Table disaggregation

EGS use is split into gas supply and electricity use. To disaggregate the column – use by the EGS sector – EXIOBASE data are used, where the same shares as in the EXIOBASE data are used. The EGS row – the use by other activities of EGS – is split using the BEUS data using the monetary values. Value added is split using the EXIOBASE value-added shares. Final demand is split using the EB.

### 5.5 Carbon Tax

Carbon taxes are estimated using the Revenue Commissioners’ data on tax receipts. These data give both carbon tax and other excises on solid fuels, electricity and the various oils and fuels such as gasoline, diesel, LPG. The volumes of petroleum products taxed are also compared with estimations to ensure consistency.

## 6 Household Disaggregation

In the current version of the model, 10 different household groups are defined based on their disposable income. In the HBS, the CSO provides disposable income quantiles (20 groups) separately for urban and rural areas. These households are merged into five groups in rural areas and five groups in urban areas. Following this, the HBS income items are aggregated into four groups as follows.

**Table 3: Aggregation Key of the HBS Income Items to the I3E Income Items**

HBS Code	Definition	Income Item
HE054	Employees-wages/salaries	Wage
HE055	Self-employed	Wage
HE057	Investment income	Capital/Asset
HE058	Property income	Capital/Asset
HE059	Own garden/farm produce (valued at retail prices)	Capital/Asset
HE060	Other direct income	Capital/Asset
HE056	Retirement pensions	Pension
HE063	Older people pensions	Pension
HE064	Widows, widowers and guardian payments	Pension
HE062	Child benefit	Transfer
HE065	Other long term social protection payments	Transfer
HE066	Job-seekers payments (including farm assist)	Transfer
HE067	Carers’ payments	Transfer
HE068	Education grants/scholarships/back to education allowance	Transfer
HE069	Other state transfers	Transfer

Following this, the share of each household group in each income item (wage, asset, welfare transfer, and pension) is calculated, and these parameters are used to disaggregate the figures across households on the HH row in Table 1. The sum of income items for each household yields the disposable income of the household group – the row sum of the respective HH columns.

In the disaggregation of the column items on the HH column in Table 1, the only required information is the distribution of commodity  $c$ 's consumption across household groups. To obtain the parameters to perform this disaggregation, each consumption item in the HBS is mapped to a commodity defined in the I3E model, as shown in Appendix C. In this way, total household consumption demand of each commodity can be allocated across the household types. Ensuring an accounting balance of the household accounts requires that the sum of consumption demand of each household be subtracted from the disposable income of the respective household group to get the household level private savings (S-I,HH).

## 7 Emissions Trading System

The Emissions Trading System (ETS) is the main climate policy applied in the European Union (EU). The system constructs an EU-wide carbon emission allowance market in which emission permits are traded via auctioning.<sup>8</sup> Each installation (a production unit), except those which operate in the energy production sector, has an amount of free allowances, which is determined for the period of 2013–2020 in Phase III of the ETS. Installations for which emissions exceed their free allowances must buy additional allowances in the EU-wide allowance market at the EU-ETS price. On the other hand, if the installation emits less than its free allowance, it can sell its unused allowances on the ETS market at the EU-ETS price. In this regard, the ETS serves as either a cost or a revenue item depending on changes in the behaviour of installations concerning their carbon-intensive energy commodity demand.

Free ETS allowances cover two types of emissions; emissions related to fuel combustion and process emissions. In the I3E model, the former is calculated by multiplying the carbon content of energy commodity and the volume of intermediate demand. The latter, however, is calculated as a fixed fraction of the volume of output as the process emissions rise in the production process of other non-metallic minerals (ONM). For the air transportation sector (ATS), the other ETS emissions emerge due to the fact that the aviation emissions and the energy demand of the sector are inconsistent in the EB of Ireland. This is because the aviation firms purchase a fraction of their fuels outside of Ireland, although the entire emissions of the installations are included in the total Irish emissions.

The ETS also plays a crucial role in the I3E framework. As explained in detail in the technical document, all activities for which the sectoral emissions are fully or partially covered by the ETS internalise the cost of the ETS in their energy demand decisions. To have an accurate representation of the ETS in the I3E model, the installation-based free allowance figures and NACE codes of installations provided by the Environment Protection Agency (EPA) of Ireland are utilised. Following this, each installation is

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<sup>8</sup> In the EU-ETS terminology; the terms allowance and emission permits are used interchangeably.

**Table 4: ETS Figures, 2014**

	Sector	Emissions		Allowance		Cost
		Total	ETS	Free	Purchased	
<b>Energy Demand Related Emissions</b>	PET	0.77	0.77	0.25	0.52	3.10
	ATS	3.07	3.07	2.13	0.94	5.65
	ONM	0.46	0.42	0.39	0.03	0.18
	CHE	0.14	0.10	0.03	0.07	0.45
	BPP	0.15	0.11	0.54	-0.43	-2.57
	BFM	0.70	0.53	0.89	-0.35	-2.11
	FBT	0.78	0.60	0.42	0.18	1.06
	HHS	0.28	0.01	0.00	0.01	0.04
	SER	0.69	0.02	0.00	0.02	0.10
	HTP	0.08	0.06	0.01	0.05	0.32
	NGS	1.63	1.20	0.04	1.15	6.92
	OTM	0.84	0.65	0.08	0.56	3.39
	ELC	8.54	8.54	0.00	8.54	51.22
	<b>Process Emissions</b>	ATS		4.60	3.19	1.41
ONM			2.32	2.38	-0.07	-0.39
<b>Total</b>		18.11	22.98	10.34	12.64	75.83
<b>Realized Values</b>			23.29	9.73	13.56	

*Note:* All emission figures are in million tonne equivalent CO<sub>2</sub>. The cost is in million Euro terms.

mapped to an I3E sector, and their free allowances are aggregated. Table 4 shows free allowance, ETS emissions calculated in the I3E, amount of purchased allowance and cost of ETS for each activity.

## Appendix A Valuation

Trade and transportation margins and net taxes on products (taxes minus subsidies) comprise one of the basic components of the valuation process. [EUROSTAT \(1995\)](#) distinguishes between two main valuation concepts of the flows of goods and services: purchaser prices and basic prices.

- **Purchaser prices** is the price the purchaser actually pays for the products. It includes any taxes less subsidies on the products (but excluding deductible taxes like a value-added tax (VAT) on the products); and any transport charges paid separately by the purchaser to take delivery at the required time and place. Since final consumers confront that price in the market, it also corresponds to the commodity's retail price.
- **Basic prices** is the price receivable by the producer from the purchaser for a unit of a good or service produced. It is output minus any tax payable on that unit as a consequence of its production or sale (taxes on products), plus any subsidy receivable on that unit as a consequence of its production or sale (subsidies on products). It excludes any transport charges invoiced separately by the producer. It includes any transport margins charged by the producer on the same invoice, even when they are included as a separate item on the invoice.

The difference between these two basic valuation concepts relates therefore to 'trade and transport margins' on the one hand, and to 'taxes less subsidies' on products on the other. Producer prices were the main valuation concept in the former system of national accounts. When we also introduce the concept of producer prices, the difference between these two valuation concepts can be attributed to the two factors.

- **Producer prices** is the amount receivable by the producer from the purchaser for a unit of a good or service produced as output minus any value added tax invoiced to the purchaser. It excludes any transport charges invoiced separately by the producer.

Thus, the relationship between the different types of prices can be shown as follows:

Purchaser price (excluding any deductible VAT)

- Non-deductible VAT
- Trade and transport margins

= Producer price

- Taxes on products (excl. VAT)
- + Subsidies on products

= Basic price

Producer prices do not include the cost of margins, since these are not part of the production process. These costs are paid by final users of commodities and are included in purchaser prices. Since a commodity is produced by several activities and the cost of margins is paid by consumers, margins are demanded by commodities, and they are reported as a part of the use table.

## Appendix B Activities and Commodities in the I3E Model

**Table B.1: Activities**

<b>Abbreviation</b>	<b>Name</b>	<b>NACE Codes</b>
ACC	Accommodation and hotel services	55–56,79
AGR	Agriculture	1-3
ATS	Air transportation	51
BFM	Basic metal manufacturing	24–25
BPP	Basic pharmaceutical products	21
CHE	Chemicals and chemical products	20
CON	Construction	41–43
EDU	Education sector	85
ELC	Electricity	
FBT	Food, beverage and tobacco	10–12
FSR	Financial services	64–66,77
HHS	Health sector	86–88
HTP	High-technology products	26–28
LTS	Land transportation	49
NGS	Natural gas supply	
OIN	Other industrial products	17,18,33
OMN	Other mining products	
ONM	Other non-metallic products	23
OTM	Other manufacturing	31–32
PEA	Peat	
PET	Petroleum	
PUB	Public sector	84
RES	Real estate services	68
RUP	Rubber and plastic products	22
SER	Other services	remaining*
TEL	Telecommunication services	61
TEX	Textile	13–15
TRD	Trade	45–47
TRE	Transportation equipment	29–30
WAT	Water and sewerage	36,37–39
WTS	Water transportation	50
WWP	Wood and wood products	16

\*: It excludes NACE codes 5-9 (Mining, Quarrying and Extraction), 19 (Petroleum Products), and 35 (Electricity and Gas Supply).

*Note:* The activities without NACE codes are further disaggregated sectors.

**Table B.2: Commodities**

AGR	Agriculture	BFM	Basic metal manufacturing
PEA	Peat	HTP	High-technology products
COA	Coal	TRE	Transportation equipment
CRO*	Crude oil	ELC	Electricity
OMN*	Other mining products	NGS	Natural gas supply
FBT	Food, beverage and tobacco	WAT	Water and sewerage
TEX	Textile	CON	Construction
WWP	Wood and wood products	TRD	Trade
OIN	Other industrial products	LTS	Land transportation
GAL	Gasoline	WTS	Water transportation
KRS	Kerosene	ATS	Air transportation
FUO*	Fuel oil	ACC	Accommodation and hotel services
LPG	Liquid petroleum gas	TEL	Telecommunication services
DIE	Diesel	FSR	Financial services
OPP	Other petroleum products	RES	Real estate services
OTM	Other manufacturing	PUB	Public services
CHE	Chemicals and chemical products	EDU	Education sector
BPP	Basic pharmaceutical products	HHS	Health sector
RUP	Rubber and plastic products	SER	Other services
ONM	Other non-metallic products		

\*: Not subject to private consumption.

## Appendix C Mapping of HBS Consumption to the I3E Model

<b>HBS</b>	<b>Definition</b>	<b>I3E</b>
H01_01_16	Takeaway food brought/delivered to home	ACC
H01_02	Meals away from home (incl. take-out tea/coffee)	ACC
H08_06_01	Delivery charges (e.g. for takeaways) and other transport services	ACC
H09_09_03	Holidays in the ROI (accommodation)	ACC
H09_09_04	Holidays abroad (including accommodation)	ACC
H09_09_01	Package holidays in the ROI	ACC
H09_09_02	Package holidays abroad	ACC
H09_09_05	Money spent on holidays when abroad	ACC
H09_19_02	Catering services (e.g. for wedding)	ACC
H09_19_04	Room hire (e.g. function room)	ACC
H01_01_10	Total fish	AGR
H01_01_11	Fruit and nuts	AGR
H01_01_12	Vegetables	AGR
H08_06_02	Air travel within ROI	ATS
H08_06_03	International air travel	ATS
H07_17	Cutlery	BFM
H07_18	Kitchen utensils	BFM
H07_20	Small tools (e.g. hammer, spanner, saw)	BFM
H06_08	Hair products	BPP
H06_09	Cosmetics and related accessories	BPP
H06_10	Baby toiletries/accessories (e.g. nappies)	BPP
H09_01_01	Prescription medication	BPP
H09_01_02	Over the counter (OTC) medicines	BPP
H09_01_03	Other medical products (plasters, bandages, etc.)	BPP
H09_01_10	Spectacles and lenses (including accessories and repairs)	BPP
H09_13	Plants, flowers, seeds, fertilisers and insecticides	BPP
H06_01	Detergents, washing up liquid and washing powder	CHE
H06_02	Disinfectants, polishes and other cleaning materials	CHE
H06_03	Non-durable small household articles	CHE
H06_04	Toilet paper	CHE
H06_05	Toiletries - disposable (e.g. toothpaste)	CHE
H06_06	Toilet soap, liquid soap, shower gel, etc.	CHE
H06_07	Toilet requisites (e.g. toothbrush and comb)	CHE
H05_15	Other materials for the maintenance and repair of the dwelling	CON



H05_17	Services for maint. and repair of the dwelling (e.g. electrician, painter)	CON
H05_19	Capital improvements contractor (e.g. extension and room conversion)	CON
H08_02_02	Diesel	DIE
H09_07	Education and training	EDU
H04_01	Electricity	ELC
H01_01_01	Bread	FBT
H01_01_02	Flour	FBT
H01_01_03	Pastries and biscuits	FBT
H01_01_04	Breakfast cereals	FBT
H01_01_05	Milk, cream yoghurt and cheese	FBT
H01_01_06	Butter, fats and cooking oil	FBT
H01_01_07	Eggs	FBT
H01_01_08	Pasta, pizza, quiche and grains	FBT
H01_01_09	Meat	FBT
H01_01_13	Sugars, confectionery and snacks	FBT
H01_01_14	Other food items	FBT
H01_01_15	Non-alcoholic beverages	FBT
H02	Total drink and tobacco	FBT
H09_12_07	Bank service charges	FSR
H09_12_08	Bank and Post Office counter charges	FSR
H09_12_09	Fees and service charges of brokers/investment consultants	FSR
H08_03_01	Vehicle insurance	FSR
H08_03_02	Travel insurance	FSR
H09_10	Insurance/pension premiums	FSR
H05_06	Second dwelling - mortgage and home insurance	FSR
H05_08	Primary dwelling insurance	FSR
H08_02_01	Petrol	GAL
H09_01_04	Doctor (not consultant)	HHS
H09_01_05	Dentist	HHS
H09_01_06	Specialist practice (including consultant, orthodontist)	HHS
H09_01_07	Physiotherapy and other paramedical services/fees	HHS
H09_01_08	Services of medical analysis labs	HHS
H09_01_09	Hospital services	HHS
H09_18_05	Charitable donations and subscriptions	HHS
H09_19_01	Present - not specified	HHS
H07_23	Audio equipment	HTP
H07_24	Accessories for audio equipment	HTP

H07_25	Television sets	HTP
H07_26	DVD and digital media players	HTP
H07_27	Satellite dish purchase	HTP
H07_28	TV/video/audio/computer - spare parts	HTP
H07_29	Cameras, camcorders and accessories	HTP
H07_30	Optical instruments (e.g. binoculars)	HTP
H07_31	Computers (including media tablets, laptops)	HTP
H07_32	Printers, ink cartridges, calculators and computer accessories	HTP
H07_33	Consoles for computer games	HTP
H07_36	DVD and CD (pre recorded and blank)	HTP
H07_37	Film/memory card, hard drives and memory sticks	HTP
H07_40	Major durables for indoor recreation	HTP
H09_02_01	Telephone, answering and fax machine - purchase and repair	HTP
H09_02_02	Mobile phone/car phone purchase	HTP
H07_05	Fridges and freezers	HTP
H07_06	Washing machines, spin and tumble dryers	HTP
H07_07	Dishwasher	HTP
H07_08	Gas cooker	HTP
H07_09	Electric cooker and combined electric/gas (including microwave)	HTP
H07_10	Other major household appliances (including rental)	HTP
H07_11	Heaters/air conditioners/shower units etc.	HTP
H07_12	Cleaning equipment (e.g. vacuum)	HTP
H07_13	Small electric household appliances	HTP
H07_14	Gas/electric appliances spare parts	HTP
H07_19	Electrical tools for house and garden	HTP
H07_21	Electrical consumables (e.g. batteries, bulbs)	HTP
H07_22	Lighting equipment	HTP
H07_45	Electrical items for personal care (e.g. hair dryer)	HTP
H07_39	Musical instruments (purchase and hire)	HTP
H07_44	Lawn mowers	HTP
H09_01_11	Therapeutic equipment - non optical items (e.g. wheelchair)	HTP
H09_08_02	Equipment for sport, camping and open-air recreation (purc., rep., hire)	HTP
H09_08_03	Other items for games and sports	HTP
H09_15_01	Jewellery, clocks and watches	HTP
H09_16	Baby equipment	HTP
H04_03	Liquid Fuels (e.g. heating oil)	KRS
H08_05	Bus, Luas, rail and taxi	LTS

H08_06_04	Other purchased transport services	LTS
H04_02	Gas	NGS
H05_18	Central heating installation	OIN
H09_06	Reading materials	OIN
H07_16	Glassware, china and pottery	ONM
H07_46	Fancy and decorative goods (e.g. mirrors)	ONM
H08_02_03	Other fuels and lubricants for personal transport	OPP
H05_23	Carpets and rugs	OTM
H07_01	Household furniture	OTM
H07_42	Garden furniture	OTM
H04_04	Solid Fuels	PEA
H09_12_10	Passport fees	PUB
H09_12_11	Birth/death/marriage certificate fees	PUB
H05_12	Other services relating to dwelling	RES
H09_12_04	Conveyancing, estate agents and surveyors	RES
H05_04	Mortgage payment (primary dwelling)	RES
H05_05	Purchase (including deposit) on primary dwelling	RES
H05_07	Purchase (including deposit) on second dwelling	RES
H05_01	Rent paid for primary dwelling	RES
H05_02	Ground rent and other rentals paid by tenants	RES
H05_03	Second dwelling rent	RES
H05_24	Hard floor coverings	RUP
H05_14	Equipment hire and small material purchase (e.g. sandpaper)	RUP
H05_20	Double glazing, kitchen units, sheds, etc.	RUP
H05_21	Purchase of materials for capital improvements	RUP
H05_22	Bathroom fittings	RUP
H05_16	Central heating maintenance	SER
H09_19_05	Postage (e.g. stamps and registered mail)	SER
H09_12_03	Trade union and professional organisation contributions	SER
H09_11	Pet costs	SER
H09_19_06	Photographic services	SER
H09_19_10	Other services (e.g. photocopying and newspaper advert)	SER
H07_34	Computer games/software	SER
H07_35	Downloads, streaming, apps and other internet services n.e.c	SER
H07_43	Garden accessories	SER
H09_03	Internet, telephone and television subscriptions	SER
H09_04	Admission and subscription charges - sports and leisure	SER

H09_05	Betting and lotteries	SER
H09_08.01	Games and toys	SER
H09_19.11	Celebration articles	SER
H07_02	Furniture recovering and repairs	SER
H07_15	Repairs and insurance for household appliances	SER
H07_38	Repairs and/or insurance of TV, video, audio, DVD and computer	SER
H07_41	Repair and maintenance of other major durables for recreation	SER
H09_19.07	Cleaning of clothing	SER
H09_19.08	Cleaning of clothing	SER
H09_19.09	Footwear repair and hire	SER
H09_12.01	Legal fees paid to solicitors	SER
H09_12.12	Other licences	SER
H09_14	Hairdressing and personal grooming	SER
H09_15.03	Repair to personal goods	SER
H09_15.04	Personal goods not otherwise specified	SER
H09_17	Care, domestic and household services	SER
H09_19.03	Funeral expenses	SER
H09_02.03	Telephone account payment	TEL
H09_02.04	Mobile phone account payments	TEL
H09_02.05	Mobile phone top-up and other payments	TEL
H03	Total clothing and footwear	TEX
H07_03	Bedroom textiles	TEX
H07_04	Other household textiles	TEX
H09_15.02	Leather and travel goods	TEX
H08_04	Vehicle maintenance and other costs	TRD
H08_01.01	Motor cars – new	TRE
H08_01.02	Motor cars – second hand	TRE
H08_01.03	Motor cycles	TRE
H08_01.04	Bicycles purchase	TRE
H08_01.05	Other vehicles	TRE
H05_10	Water charges	WAT
H05_11	Refuse/sewage collection and skip hire	WAT
H05_13	Paint, wallpaper, timber and plaster	WWP

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