# Renewable and Non-Renewable Energy Embodied in International Trade[1]


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**Resumo**

No contexto da expansão da integração econômica global e da fragmentação mundial da produção ocorrida a partir da década de 1980, torna-se progressivamente mais complexo identificar e responsabilizar de forma imparcial os principais atores globais na geração de externalidades ambientais. Nesse cenário, a presente pesquisa considera que uma avaliação das energias renováveis e não renováveis utilizadas setorialmente nos principais países e regiões envolvidos no comércio internacional pode contribuir para essa identificação. Especificamente, foi realizada uma análise da intensidade energética das energias renováveis e não renováveis a nível setorial em países e regiões, bem como uma investigação do comércio virtual destas energias em todo o mundo. Com este objetivo, foi utilizada a base de dados EORA26 para 1996 e 2016, que foi agregada para fornecer informações para 14 países e 16 regiões. Os principais resultados mostraram que a energia renovável e não renovável embutida no comércio internacional encontrava-se maioritariamente no hemisfério norte. Adicionalmente, percebeu-se que, para melhor compreender a respetiva responsabilidade, é necessário não só realizar uma avaliação global dos principais exportadores líquidos de energias virtuais, bem como considerar, em termos de dimensão, as diferenças nos padrões de exportação setoriais dos países e regiões em estudo, assim como a intensidade energética desses setores e, com base nessa informação, ponderar as exportações desses países para então alcançar uma compreensão mais ampla dos principais atores responsáveis pelas disparidades ambientais em todo o mundo.



**Abstract**

In the context of the expansion of global economic integration and the worldwide fragmentation of production which has occurred since the 1980s, it is becoming increasingly difficult to identify and attribute unbiased liability to the main global players in the generation of environmental externalities. In this scenario, the present research considers that an assessment of renewable and non-renewable energy used at a sectoral level in the main countries and regions engaged in international trade can contribute to this identification. Specifically, an analysis was conducted of the energy intensity of renewable and non-renewable energies at a sectoral level in countries and regions, as well as an investigation of the virtual trade in these energies around the world. For this purpose, the EORA26 database for 1996 and 2016 was used, which was aggregated to provide information for 14 countries and 16 regions. The main results showed that the renewable and non-renewable energy embodied in international trade was mostly in the northern hemisphere. In addition, it was realized that in order to better understand their responsibility, it is necessary not only to conduct a global assessment of the main net exporters of virtual energies, but also to consider, in terms of size, the differences in the sectoral export patterns of the countries and regions under study, as well as the energy intensity of these sectors and, based on this information, weight the exports of



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these countries and then achieve a wider understanding of the main actors behind environmental disparities around the world.
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## 1 – Introduction

International trade has experienced substantial transformations from the end of the 20th century to the beginning of the 21st century. These changes are largely due, firstly, to advances in information technology, which have reduced the relevance of geographical distance to the organization of production, as well as to changes in tariffs in many countries on trade in intermediate goods. As a result, industries that previously required proximity for the organization of the production chain began to benefit from greater mobility of the segments of this chain. Thus, a capital-intensive line, in this new context, could easily be set up in a region with a lower cost of capital, while another labor-intensive line could be located where labor was cheaper.

This reorganization has led to the fragmentation of production chains, where, for example, an industry originally from one country, such as Germany, now has production segments spread across other countries, such as Eastern Europe. The core of the production chain tends to remain in the country of origin, but production segments are distributed globally in order to minimize costs, even if this geographical distribution is limited by transport costs and other barriers, such as legal and tax learning costs in other countries. Thus, Global Value Chains (GVCs) were formed, even if they present a regional trend (North America, Europe and Southeast Asia), as observed in UNCTAD (2013) and Corrêa (2016).

The advance of production has changed the global trade pattern. From the mid-1980s to the end of the second decade of the 21st century, international trade grew significantly, not only due to the increase in production, but also to the fragmentation of production, which represents an increase in exports of intermediate products, as pointed out by Veiga and Rios (2017) and Carneiro (2017). With this transition, environmental responsibility for the production of goods has expanded beyond the borders of the final producing country to include the countries where the production chains originate.

Economic and ecological systems have a complex relationship, where the first, contained in the second, uses resources from the second and generates residues and emissions for the latter. The main problems arise when the economic system puts excessive pressure on the ecological system, leading to the scarcity of non-renewable resources, as well as the excessive use of renewable resources in a way that does not allow them to be renewed in the necessary proportion, and also when the capacity to absorb the residues and pollution generated is exceeded, as described in detail by Machado, Schaeffer and Worrel (2001). In this context, sustainable development, as defined by Güney (2019), is fundamental to ensuring that current needs are met without compromising the needs of future generations.

In the framework of global value chains, international trade can be used to transfer production links to other countries in order to reduce environmental costs. This practice can intensify market failures in developing countries, aggravating regional and, consequently, global environmental damage. In this sense, it is possible that, intentionally or not, developed countries preserve their own ecosystems by exploiting other systems, as can be seen from the study by Machado, Schaeffer and Worrel (2001).

The use of international trade to transfer environmental damage, without clear accountability, makes the issue complex. The integration of global economic and ecological systems means that a country's environmental degradation can be attributed to multiple actors.

Therefore, international cooperation is crucial to solving market failures and mitigating environmental damage, as noted in Nordstrom et al. (1999).

Furthermore, as explained by Peters and Hertwich (2007), there is a compatibility between developed countries in environmental agreements and undeveloped countries outside these agreements, which are used as a low-cost alternative for unclean production segments in developed countries. This can lead to conflicts of interest, as developed countries can oppose the participation of certain countries in certain agreements[4] because they have an interest in maintaining cheap possibilities for some of the productive links in their production chains. International trade has two major externalities: the facilitation of economic development and growth (positive) and the possible exploitation of the decoupling[5] of production and consumption (negative), which can deepen market failures and local environmental problems.

The function of an international environmental/trade agreement should be to mitigate negative externalities without harming positive ones, through assertive regulatory measures. This requires mutual understanding and not unilateral impositions. The interruption of a trade agreement should not be justified based on the argument of avoiding the negative externality, since trade and interactions between countries have the positive potential to develop the industries of a polluting country, reducing the discrepancies between its industries and international ones in relation to environmental market failures. This can reduce the length of time that polluting characteristics remain in developing countries, reducing the total environmental impact generated in the long term.

It is worth noting that studies such as Shafiei and Salim (2014) and Dogan and Seker (2016) state that the increasing use of renewable energy is associated with a reduction in CO2 emissions, while non-renewable energy is linked to an increase in these emissions. The study by Adams, Klobodu and Apio (2018), indicates that energy is associated with economic growth, with renewable energy having a smaller impact compared to non-renewable energy. However, developed countries often use non-renewable energy to a larger extent, while at the same time putting pressure on developing countries to use renewable energy.

Unfortunately, no study was found that evaluated renewable and non-renewable energy embodied in international trade. However, there were studies that analyzed greenhouse gas emissions, the consumption of other energies (solar, fossil, total energy, etc.) embodied in international trade and virtual water trade. All of which use a similar methodology, but for different types of markets. For example, Lenzen (1998) investigated primary energy and greenhouse gases embodied in Australia's final demand, while Machado, Schaeffer and Worrel (2001) evaluated the impact of international trade on energy consumption and carbon emissions embodied in Brazil's exports and imports. Weber and Matthews (2007) studied environmental emissions and energy in the international trade of the United States using an MRIO containing information from 7 other economies[6]. Tang et al. (2013) analyzed the fossil[7] energy embodied in the UK's international trade.

Wiedmann et al. (2007) emphasize the relevance of multi-regional models in this type of assessment and discuss global climate policy options to reduce the impact of trade on climate. Peters and Hertwich (2007), examined the CO2 embodied in international trade using a GTAP MRIO for 2001, identifying the net exporters and importers of CO2.

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[4] Not only environmental agreements, but also other agreements, like economic ones, which have environmental implications.

[5] Decoupling means that in order to serve a consumer market in developed country A, the latter can transfer part of its production to country B, because that country has no environmental regulations that could increase the production cost of the link in question.

[6] Canada, China, Mexico, Japan, Germany, the United Kingdom and South Korea with data for 1997, 2002 and 2004.

[7] From oil, natural gas and coal.

Su et al. (2010), evaluating China and Singapore, presented analyses of the carbon emissions embodied in the countries' international trade. Zhou and Yang (2011) carried out a study on carbon emissions embodied in China's international trade, which found that China is a net exporter of carbon, but the main suggestion is that part of the responsibility for emissions should also be attributed to the countries that consume this production. Also studying China, Su and Ang (2013) discuss two methodological approaches to dealing with the emissions embodied in a country's imports, single-region and multi-region, using data from China.

Feng et al. (2013) investigated CO2 emissions embodied in trade between regions in China and the rest of the world, highlighting the disparity between developed and developing regions. Su and Ang (2014) combined the methodological approaches of hybrid emission embodied in trade (HEET) and step-wise distribution of emissions embodied in trade (SWD-EET) to study how interregional and international trade affect the emissions of Chinese regions. Ren et al. (2014) in addition to questioning the emissions embodied in Chinese trade, evaluated the impact of foreign direct investment on CO2 emissions in China.

There have also been studies focused on evaluations of embodied energy in sectors of a particular country. Liu et al. (2018) studied the consumption of embodied energy in the Chinese construction industry, measuring it in the industry's imports and exports and identifying its level of dependence on international trade. The study used the input-output matrices provided by WIOD for a 15-year period (1995-2009), with 40 regions. Similarly, using the WIOD database, for the same time period, the study by Cortés-Borda et. al (2015) quantifies the amount of solar energy embodied in trade, using environmentally extended input-output models. Although the research was limited to solar energy, it succeeded in covering international trade to various regions.

Studies with the same purpose, but for the evaluation of water embodied in trade, have also been developed. As in Lenzen et al. (2013.a), who differentiated water scarcity in virtual trade using a global database, the Eora Global Multi-Region Input-Output. In regional studies, Zhao et al. (2015) measured the transfer of physical and virtual water at provincial level in China. While Zhang and Anadon (2014), examined virtual water trade in China and also carried out a footprint assessment.

It is important to note that a detailed analysis of these studies reveals the importance of multi-regional models for understanding the complex interactions between economic and ecological systems. The databases made available by EORA, as set out in Lenzen et al. (2012), present a detailed mapping of the global economy. This allows for a comprehensive assessment of the virtual energy trade, providing detailed structural information on the distribution of renewable and non-renewable energy and enabling a greater ability to understand global environmental responsibility.

Considering this, it is necessary to use an evaluation method that takes into account not only the environmental problems arising from a given country's production, but also the environmental problems generated by countries' indirect ways in international trade. A hybrid multi-regional input-output (MRIO) model, containing input-output information and energy use (renewable and non-renewable) by economic sector, can provide the basis for this type of energy-economic analysis.

Specifically, for this study, a regional aggregation is made in which, from 189 countries, the EORA26 matrix presented in Lenzen et al. (2013.b), the EORA26-30 model is formed, with 14 countries and 16 regions, in which the sectors are maintained as in the original, adding to the matrix information on energy consumption in terajoules (TJ) per sector for each country. Using this base, it is possible to evaluate virtual energy trade, capturing the effects of changes in consumption patterns on virtual energy trade between regions over time. Through this analysis, it is plausible to provide greater clarity for accountability for the use of non-renewable embodied energy, as well as for recognition in the case of greater use of renewable embodied energy, whether in the country's imports or exports.

The second section describes the database and the methodology used for the evaluation. The third section provides the results of the virtual market for renewable and non-renewable energies. Finally, the fourth section presents the main conclusions of the work.

## 2 – Database and Methodology

Firstly, the database used, EORA26, and the transformations made are presented. Then, in the second section, the basic structure of an input-output model is presented, in which product flows between economic sectors in a single region are considered. The third section presents the generalization needed to understand a multi-regional model. The fourth section presents the concept of Energy Intensity and the methodology for estimating energy use using the production and consumption approach. Finally, the methodology needed to evaluate the net energy exports/imports of the regions under evaluation is demonstrated.

### 2.1 – Database

The multi-regional input-output matrix made available by the Eora global supply chain database provided all the data needed to prepare the input-output matrix used in this assessment. EORA26 which consists of a multi-regional input-output matrix at basic prices for 189 countries containing 26 sectors, was utilized. In addition, the database provides information on environmental accounts for all sectors in all countries.

The academic license used provided access to data within the time series from 1990 to 2016 and two time periods were chosen, 1996 and 2016. For the environmental assessment, we used 9 satellite accounts provided by Eora in terajoules, 4 of which are non-renewables and 5 renewables, so adding them up in the respective order results in two column vectors (one renewable and the other non-renewable), with information by sector for the 189 countries, with n = 4914 elements, as shown in the table 2.1.

| | Nonrenewable Energy | | Renewable Energy |
|---|---|---|---|
| 1 | Natural Gas | 1 | Hydroelectric Electricity |
| 2 | Coal | 2 | Geothermal Electricity |
| 3 | Petroleum | 3 | Wind Electricity |
| 4 | Nuclear Electricity | 4 | Solar, Tide and Wave Electricity |
| | | 5 | Biomass and Waste Electricity |

**Table 2.1 –** Energy (Non-renewable and Renewable)

In order to carry out the research, it became necessary to aggregate the matrices to a smaller number of regions, prioritizing the fifteen largest economies of 2020 (Table 2.2), given the special case of the United Kingdom, which was added to Ireland to form the British Isles region.

Further aggregations were made to form other regions, resulting in an input-output model with 30 regions (Table 2.3) and 26 sectors (Table 2.4), named EORA26-30. The countries contained in each EORA26-30 region are shown in Annexes I, II and III.

| | cod | Countries | GDP |
|---|---|---|---|
| 1 | USA | United States | 21.060,50 |
| 2 | CHN | China | 14.687,70 |
| 3 | JPN | Japan | 5.048,79 |
| 4 | DEU | Germany | 3.889,67 |
| 5 | GBR | United Kingdom | 2.704,61 |
| 6 | IND | India | 2.671,60 |
| 7 | FRA | France | 2.639,01 |
| 8 | ITA | Italy | 1.897,21 |
| 9 | CAN | Canada | 1.647,60 |
| 10 | KOR | Korea, Rep. | 1.644,31 |
| 11 | RUS | Russian Federation | 1.493,08 |
| 12 | BRA | Brazil | 1.476,11 |
| 13 | AUS | Australia | 1.326,94 |
| 14 | ESP | Spain | 1.276,96 |
| 15 | MEX | Mexico | 1.090,51 |

**Table 2.2 –** 15 Biggest Economies of 2020 in Billions of Dollars

| | Regions |
|---|---|
| 1 | Northern Europe |
| 2 | British Isles |
| 3 | France |
| 4 | Germany |
| 5 | Rest of Western Europe |
| 6 | Rest of Eastern Europa |
| 7 | Russia |
| 8 | Italy |
| 9 | Spain |
| 10 | Rest of Southern Europe |
| 11 | Canada |
| 12 | Mexico |
| 13 | USA |
| 14 | Central America, Caribbean and Rest of Northern America |
| 15 | Brazil |
| 16 | Rest of South America |
| 17 | Northern Africa |
| 18 | Western Africa, Central Africa and Eastern Africa |
| 19 | Southern Africa |
| 20 | Central Asia |
| 21 | China |
| 22 | Japan |
| 23 | South Korea |
| 24 | Rest of East Asia |
| 25 | Middle East |
| 26 | India |
| 27 | Rest of South Asia |
| 28 | Southeast Asia |
| 29 | Australia |
| 30 | Rest of Oceania |

| | Industries |
|---|---|
| 1 | Agriculture |
| 2 | Fishing |
| 3 | Mining and Quarrying |
| 4 | Food & Beverages |
| 5 | Textiles and Wearing Apparel |
| 6 | Wood and Paper |
| 7 | Petroleum, Chemical and Non-Metallic Mineral Products |
| 8 | Metal Products |
| 9 | Electrical and Machinery |
| 10 | Transport Equipment |
| 11 | Other Manufacturing |
| 12 | Recycling |
| 13 | Electricity, Gas and Water |
| 14 | Construction |
| 15 | Maintenance and Repair |
| 16 | Wholesale Trade |
| 17 | Retail Trade |
| 18 | Hotels and Restraurants |
| 19 | Transport |
| 20 | Post and Telecommunications |
| 21 | Finacial Intermediation and Business Activities |
| 22 | Public Administration |
| 23 | Education, Health and Other Services |
| 24 | Private Households |
| 25 | Others |
| 26 | Re-export & Re-import |

**Table 2.3 –** Regions EORA26-30 e **Table 2.4 –** Industries EORA26-30

## 2.2 – The Basic Input-Output Model

As described by Miller and Blair (2009), a basic input-output model is built using observed information on product flows from each economic sector $i$ (as producer/seller) in a single economic area (country, region, state, etc.) to each of the sectors $j$ (as buyers), including itself, which is recognized as inter-sector or inter-industry flows ($z_{ij}$).

These flows are measured for a particular period (usually quarterly or annually) and in monetary terms (usually in dollars), normally collected from national or regional statistics, such as those provided by the Social Accounting Matrices (SAMs). Note that transactions are presented in monetary rather than physical terms, due to the difficulty of numerically relating the production of one sector to another in physical units.

In this region, economic activity is separated into a number $n$ of productive sectors (called sectors or industries). The transactions from each sector $i$ to each sector $j$ (including to the same, when $j = i$), are designated as $z_{ij}$ (also recognized as intermediate consumption). Pointing out that according to the structure of an input-output matrix, $i$ represents the rows (the sales of the sectors) and $j$ represents the columns (the purchases of the sectors), meaning that $z_{11}$ represents the sales made by sector 1 to the buyer sector 1.

In addition, there are also sales to buyers who are external to the region's industrial sectors, which constitute final demand, such as household consumption, government spending and foreign trade. These are determined in a way that is unrelated to the production performed by the sectors (exogenous). The total final demand for production in sector $i$ is represented by $y_i$, i.e. sector $i$'s sales to final demand. By developing a simple accounting equation that shows how each sector $i$ distributes its production through sales to other sectors and to final demand, we arrive at $x_i$, which represents the total production of sector $i$, intermediate consumption plus final demand, as shown below:

$$x_i = z_{i1} + \cdots + z_{ij} + \cdots + z_{in} + y_i = \sum_{j=1}^{n} z_{ij} + y_i \quad (1)$$

Based on this equation, the total production of each sector can be identified, as shown below:

$$\begin{aligned} x_1 &= z_{11} + \cdots + z_{1j} + \cdots + z_{1n} + y_1 \\ &\vdots \\ x_i &= z_{i1} + \cdots + z_{ij} + \cdots + z_{in} + y_i \\ &\vdots \\ x_n &= z_{n1} + \cdots + z_{nj} + \cdots + z_{nn} + y_n \end{aligned} \quad (2)$$

Which can be reorganized as follows:

$$\boldsymbol{X} = \begin{bmatrix} x_1 \\ \vdots \\ x_n \end{bmatrix}, \quad \boldsymbol{Z} = \begin{bmatrix} z_{11} & \cdots & z_{1n} \\ \vdots & \ddots & \vdots \\ z_{n1} & \cdots & z_{nn} \end{bmatrix}, \quad \boldsymbol{Y} = \begin{bmatrix} y_1 \\ \vdots \\ y_n \end{bmatrix} \quad (3)$$

Usually, lower-case letters are used for vectors and upper-case letters for matrices, but we chose to use the same notation presented in Cortés-Borda et. al (2015). We have $\boldsymbol{X}$ and $\boldsymbol{Y}$ as column vectors with $n$ rows and $\boldsymbol{Z}$ as a matrix with dimension $n^2$. Knowing that $\boldsymbol{i}$ is a column vector of dimension $n$ where all its elements have a value of 1, equation (3) can be presented in matrix notation:

$$\boldsymbol{X} = \boldsymbol{Zi} + \boldsymbol{Y} \quad (4)$$

Post-multiplication of $\boldsymbol{Z}$ by $\boldsymbol{i}$ is used because the result is a column vector that represents the sum of all the rows of the matrix $\boldsymbol{Z}$[8].

Furthermore, the sectors' demand will be related to the sector's production in the same period (inputs to production), as pointed out by Miller and Blair (2009), a fundamental assumption is that the intersectoral flows from $i$ to $j$, in a given period, depend entirely on the total produced by sector $j$ for the same period, as shown below:

$$a_{ij} = \frac{z_{ij}}{x_j} = \frac{value\ of\ i\ purchased\ by\ j\ in\ the\ period}{value\ produced\ by\ j\ in\ the\ period} \quad (5)$$

The above equation is known in the input-output literature as the representation of the technical coefficients, which are determined by production technology. It is assumed that $a_{ij}$ is constant[9] in the short term, manifesting a fixed relationship between the output and the input of

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[8] $\boldsymbol{i}'$ is a row vector with dimension $n$ where all elements are 1. Pre-multiplying $\boldsymbol{Z}$ by $\boldsymbol{i}'$ results in a row vector whose elements represent the sum of the columns of $\boldsymbol{Z}$. For more information, it is recommended to consult Miller and Blair (2009).

[9] It is assumed to be constant over the period portrayed by the input-output model, thus economies of scale in production are ignored. In other words, the assumption determines constancy in the short term (in the period evaluated).

a sector, in which the Leontief system operates, characterized by constant returns to scale. Introducing the same matrix generalization into equation 5, we have that:

$$\boldsymbol{A} = \begin{bmatrix} a_{11} & \cdots & a_{1n} \\ \vdots & \ddots & \vdots \\ a_{n1} & \cdots & a_{nn} \end{bmatrix} \tag{6}$$

Understanding the definition of the technical coefficients in (5), equation (4) can be rewritten as follows:

$$\boldsymbol{X} = \boldsymbol{A}.\boldsymbol{X} + \boldsymbol{Y} \tag{7}$$

Recognizing $\boldsymbol{I}$ as an identity matrix of dimension $n^2$, we have that the final demand $\boldsymbol{Y}$ can be represented by:

$$(\boldsymbol{I} - \boldsymbol{A})\boldsymbol{X} = \boldsymbol{Y} \tag{8}$$

From this, we reach the final equation of the basic input-output model:

$$\boldsymbol{X} = (\boldsymbol{I} - \boldsymbol{A})^{-1}\boldsymbol{Y} \tag{9}$$

This final equation contains the so-called Leontief Inverse (first component on the right).

### 2.3 – Multi-Regional Input-Output Model

Input-output models usually contained only one region described, with the aim of evaluating sectoral aspects of that region. However, more sophisticated models that include more than one region are increasingly common, allowing comparative assessments between different regions, known as multi-regional input-output models (MRIO). As stated by Miller and Blair (2009), the central point in the development of these models is the consideration of transactions between different regions and their sectors. A multi-regional model contains $p$ individual regions, each with $n$ sectors.

Similarly to using the subscript $i$ and $j$ to designate sectors, in this paper we use the superscript $r$ and $r'$ to designate the region. Thus, as $x_i$ denotes the total production of sector $i$, $x^r$ denotes the total production of region $r$, and therefore $x_i^r$ denotes the total production of sector $i$ in region $r$. Following this nomenclature and replicating the development made by Cortes-Borda et al. (2015), matrix $\boldsymbol{A}$ is broken down into $p^2$ sub-matrices $\boldsymbol{A}^{rr'}$, which describe the economic transactions between regions $r$ (in a row) and $r'$ (in a column), as shown below:

$$\boldsymbol{A} = \begin{bmatrix} \boldsymbol{A}^{11} & \cdots & \boldsymbol{A}^{1p} \\ \vdots & \ddots & \vdots \\ \boldsymbol{A}^{p1} & \cdots & \boldsymbol{A}^{pp} \end{bmatrix}, \qquad \boldsymbol{A}^{rr'} = \begin{bmatrix} a_{11}^{rr'} & \cdots & a_{1n}^{rr'} \\ \vdots & \ddots & \vdots \\ a_{n1}^{rr'} & \cdots & a_{nn}^{rr'} \end{bmatrix} \tag{10}$$

Note that $a_{11}^{rr'}$ represents the same ratio seen in $a_{ij}$ in equation (5), but in a multi-regional matrix, where inter-regional and intra-regional interaction is taken into account. Note that the same can be done for $\boldsymbol{Z}$.

$$\boldsymbol{Z} = \begin{bmatrix} \boldsymbol{Z}^{11} & \cdots & \boldsymbol{Z}^{1p} \\ \vdots & \ddots & \vdots \\ \boldsymbol{Z}^{p1} & \cdots & \boldsymbol{Z}^{pp} \end{bmatrix}, \qquad \boldsymbol{Z}^{rr'} = \begin{bmatrix} z_{11}^{rr'} & \cdots & z_{1n}^{rr'} \\ \vdots & \ddots & \vdots \\ z_{n1}^{rr'} & \cdots & z_{nn}^{rr'} \end{bmatrix} \tag{11}$$

Moreover, each region $r'$ (in a column) can demand as many products from local sectors as from sectors in other regions. In this way, $\boldsymbol{Y}^{r'}$ is defined as the final demand of region $r'$ for its own sectors and the sectors of all the other regions, which is presented as a column vector of $np$ elements. The final demand of $r'$ comprises a set of $p$ vectors $\boldsymbol{Y}^{rr'}$, each of which contains $n$ elements, representing the sales of the $i$ sectors of region $r$ (row) to the final demand of region r' (column), i.e. these $n$ elements are broken down into $y_i^{rr'}$ which represents the products demanded by region $r'$ (column) by the products of the $i$ sectors of region $r$ (row). Below is the notation corresponding to $\boldsymbol{Y}^{r'}$ and $\boldsymbol{Y}^{rr'}$:

$$\boldsymbol{Y}^{r'} = \begin{bmatrix} \boldsymbol{Y}^{1r'} \\ \vdots \\ \boldsymbol{Y}^{rr'} \\ \vdots \\ \boldsymbol{Y}^{pp'} \end{bmatrix}, \qquad \boldsymbol{Y}^{rr'} = \begin{bmatrix} y_1^{rr'} \\ \vdots \\ y_i^{rr'} \\ \vdots \\ y_n^{rr'} \end{bmatrix} \tag{12}$$

In addition, we have the total final demand of the model, which consists of the sum of the column vectors of regional final demands, in which its elements represent the total final demand for the sectors of all the regions, thus being a column vector with $np$ elements.

$$\boldsymbol{Y} = \begin{bmatrix} y_1^1 \\ \vdots \\ y_i^r \\ \vdots \\ y_n^p \end{bmatrix}, \qquad \boldsymbol{Y} = \begin{bmatrix} \boldsymbol{Y}^1 \\ \vdots \\ \boldsymbol{Y}^r \\ \vdots \\ \boldsymbol{Y}^p \end{bmatrix}, \qquad \boldsymbol{Y}^r = \begin{bmatrix} y_1^r \\ \vdots \\ y_i^r \\ \vdots \\ y_n^r \end{bmatrix} \tag{13}$$

It can also be said that $\boldsymbol{Y}$ can be divided into $p$ vectors $\boldsymbol{Y}^r$ with dimension $n$, in which the total final demand by sector in region $r$ is contained.

When considering the total product in economy $\boldsymbol{X}$, the same logical approach applies, it is understood that this is divided into $p$ submatrices (column vectors) $\boldsymbol{X}^r$ corresponding to the total product by region, containing $n$ elements $x_i^r$, corresponding to the total product by sector of the country.

$$\boldsymbol{X} = \begin{bmatrix} x_1^1 \\ \vdots \\ x_i^r \\ \vdots \\ x_n^p \end{bmatrix}, \qquad \boldsymbol{X} = \begin{bmatrix} \boldsymbol{X}^1 \\ \vdots \\ \boldsymbol{X}^r \\ \vdots \\ \boldsymbol{X}^p \end{bmatrix}, \qquad \boldsymbol{X}^r = \begin{bmatrix} x_1^r \\ \vdots \\ x_i^r \\ \vdots \\ x_n^r \end{bmatrix} \tag{14}$$

### 2.4 – Energy Intensity

The definition of "Energy Intensity" is the amount of energy used per monetary unit traded in each country and sector. To find it, you need a vector of Energy Use in terajoules ($\boldsymbol{E}$), by sector and country ($e_i^r$) and perform the ratio between it and the total product ($\boldsymbol{X}$) by sector and corresponding country ($x_i^r$).

$$ei_i^r = \frac{e_i^r}{x_i^r} \tag{15}$$

As a result, it is possible to find the Energy Intensity ($\boldsymbol{EI}$) vector of dimension $np$, as shown below:

$$\boldsymbol{EI} = [ei_1^1 \quad \dots \quad ei_i^r \quad \dots \quad ei_n^p] \tag{16}$$

The notation can be expressed using $p$ regional submatrices $\boldsymbol{EI}^r$ with $n$ elements representing the sectors of the region:

$$\boldsymbol{EI} = [\boldsymbol{EI}^1 \quad \dots \quad \boldsymbol{EI}^r \quad \dots \quad \boldsymbol{EI}^p] \tag{17}$$

$$\boldsymbol{EI}^r = [ei_1^r \quad \dots \quad ei_i^r \quad \dots \quad ei_n^r] \tag{18}$$

### 2.5 – International Trade

In order to calculate the energy embodied in the transactions between region $r$ and $r'$ ($Embodied^{rr'}$), the sum of the energy embodied in the intermediate[10] sales and the portion of this energy embodied in the final demand of this region for the products of the same region[11] ($\boldsymbol{Y}^{rr'}$) is found.

$$Embodied^{rr'} = \boldsymbol{EI}^r.(\boldsymbol{Z}^{rr'}.\boldsymbol{i}) + \boldsymbol{EI}^r.\boldsymbol{Y}^{rr'} \tag{22}$$

[10] First term on the right-hand side of equation (22).

[11] Second term on the right-hand side of equation (22).

For the purpose of simplification, the $Embodied^{rr'}$ can be arranged in a square matrix, called ($\boldsymbol{EE}$) as shown in equation (23). The main diagonal elements of this matrix, where $r = r'$, show sales within the same region, while the other elements show the Energy Embodied in trade ($Energy\_\boldsymbol{T}$).

$$\boldsymbol{EE} = \begin{bmatrix} Embodied^{11} & \cdots & Embodied^{1p} \\ \vdots & \ddots & \vdots \\ Embodied^{p1} & \cdots & Embodied^{pp} \end{bmatrix} \tag{23}$$

The total Energy Embodied in international trade ($Energy\_\boldsymbol{T}$) corresponds to the sum of all the elements in the $\boldsymbol{EE}$ matrix, with the exception of the main diagonal of this matrix ($r = r'$). Below is a representation of $Energy\_\boldsymbol{T}$ and a matrix similar to $\boldsymbol{EE}$, but without the main diagonal ($\boldsymbol{EED}$). Note that the sum of the $\boldsymbol{EED}$ elements is equal to the $Energy\_\boldsymbol{T}$ value.

$$Energy\_\boldsymbol{T} = \sum_{r=1}^{p} \sum_{r=1}^{p} Embodied^{rr'} \quad \forall\, r \neq r' \tag{24}$$

$$\boldsymbol{EED} = \begin{bmatrix} 0 & \cdots & Embodied^{1p} \\ \vdots & \ddots & \vdots \\ Embodied^{p1} & \cdots & 0 \end{bmatrix} \tag{25}$$

Using the $\boldsymbol{EED}$ matrix, it is possible to study whether a given $r$ is a net importer or net exporter of the type of energy being evaluated. It should be noted that the rows of the $\boldsymbol{EED}$ matrix represent sales from $r$ to all the other[12] $r'$. In this way, the Exported Energy ($Energy\_EX$) of each region is represented by the equation below:

$$Energy\_EX = \boldsymbol{EED.i} \tag{26}$$

Consequently, $Energy\_EX$ is a column vector with $p$ elements (one for each region), expressing how much energy of that type is exported by the region. Similarly, once you know that the columns of the $\boldsymbol{EED}$ matrix represent $r'$ purchases from all the other regions, the Imported Energy ($Energy\_IMP$) of each region is represented as follows:

$$Energy\_IMP = \boldsymbol{i'.EED} \tag{27}$$

$Energy\_IMP$ is a line vector, with $p$ elements, whereby through this and $Energy\_EX$, the Net Energy Imports/Exports of the regions are found by the difference between the exports and imports of energy from the same region (and the sectors of the region). In equational terms, the difference between the $Energy\_EX$ vector and the transpose of the $Energy\_IMP$ vector must be taken, as shown below:

$$NET = Energy\_EX - Energy\_IMP' \tag{28}$$

Note that each element of the $NET$ vector represents the net import/export of energy from region $r$ ($net^r$). A region is considered a net exporter when $net^r > 0$ and a net importer when $net^r < 0$. Note that all these results are also obtained in sectoral form by region ($net_i^r$), in order to understand the proportion of each economic sector to the regional result.

## 3 – Results

### 3.1 – Results of the Virtual Non-Renewable Energy Market

For the purposes of interpreting Figures 3.1 and 3.2, the color blue represents the regions that are Net Importers of Non-Renewable Energy (NRE) and the color red represents the regions that are Net Exporters, while the intensity of the color shows the magnitude of the export or import.

[12] As the main diagonal has been removed, there are no sales from one region to itself, only to the others.

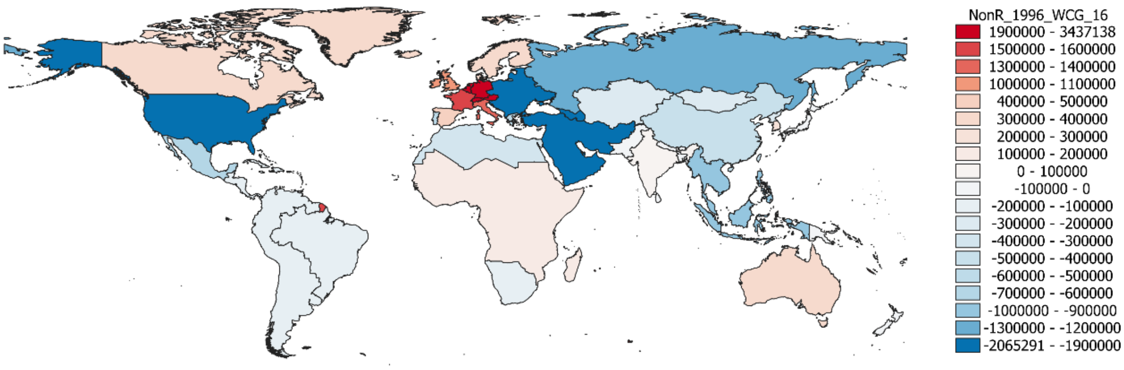


Figure 3.1: Virtual Trade in Non-Renewable Energy in 1996

Figure 3.1 shows that, in 1996, the NRE embodied in international trade originated from countries in Europe (with the exception of Eastern Europe and the rest of Southern Europe), Canada, Australia and West-Central-East Africa. The main importers were the United States, Eastern Europe, the Middle East, Russia and Southeast Asia, followed to a lesser extent by China and Mexico, with little representation from the other regions.

It is clear that although the Middle East is one of the main exporters of oil in its energy matrix, the oil used in the production of its exported goods is not large enough to at least match NRE exports with its imports. This is explained by the differentiation between the export of crude oil and its use for energy production purposes.

Observing these results in 1996, it is notable that the virtual trade in NRE was predominantly in the northern hemisphere. An interesting part of the results shows that Japan had little significance in this trade, even though it has an energy matrix composed mainly of fossil fuels, its exports and imports almost neutralize each other. The use of Southeast Asian countries as destinations for a considerable part of the links in Japanese value chains could be the explanation for this scenario[13].

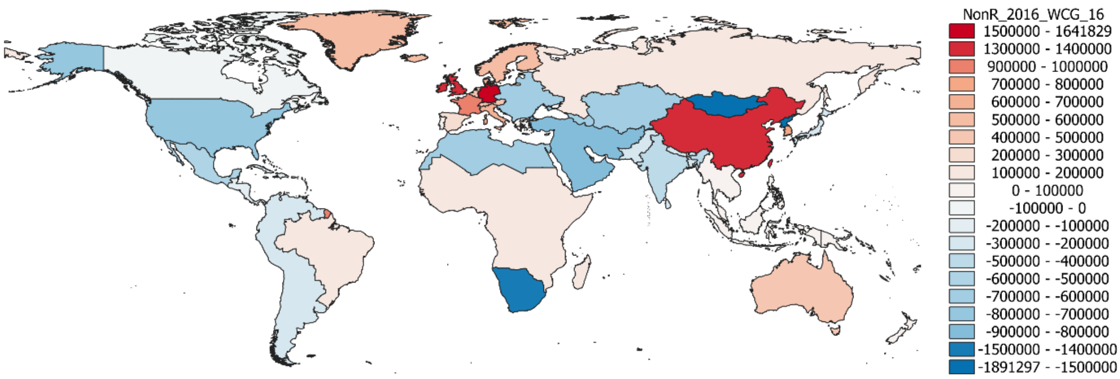


Figure 3.2: Virtual Trade in Non-Renewable Energy in 2016

Based on Figure 3.2, it can be seen that European prominence remained the same in 2016, with an increase in the prominence of exports generated by the British Isles, constancy in German prominence and a decrease in France and Italy. However, as far as Asia is considered, there has been a strong transition in China, from a medium-ranking importer to a high-ranking exporter. Other transitions in this direction have occurred in Russia and Brazil, while India and Canada have made the opposite transition, from exporters to importers.

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[13] In order to reach a conclusion on this question, it is worth investigating the level of energy intensity of these links

The ranking of imports has changed, with the United States, Eastern Europe and the Middle East remaining very important. However, regions such as the Rest of East Asia (Mongolia, North Korea, Taiwan, Hong Kong, Macao SAR), Central Asia and South Africa have become the biggest importers. The concentration of imports also shifted to other regions, such as the rest of South Asia, North Africa and India, which have gained importance as importers. On the export side, Australia and Northern Europe have gained prominence on the export side.

In order to assess which sectors are intensive in non-renewable energy, the ratio of "Non-Renewable Energy Used" to "Gross Value of Production by country sector" for 1996 and 2016 is provided in Annex IV. It can be seen that sector 13 (Electricity, Gas and Water) is one of the most intensive sectors for all countries in both periods (with the exception of Brazil), as well as having the highest proportion in several countries and in both periods, where from this perspective it has the greatest relevance, which characterizes it as a Non-Renewable Energy-intensive sector.

Another sector with great importance in countries' energy consumption (energy intensity) is sector 7 (Petroleum, Chemical and Non-Metallic Mineral Products), which shows a similar pattern to the previous one, although it does not have the highest proportion in most of the countries and periods evaluated. This is followed by sectors 3 (Mining and Quarrying), 12 (Recycling) and 19 (Transport), which have a high degree of energy intensity in most countries and periods, but to a lesser extent than the two previous sectors. The other sectors with a certain degree of non-renewable energy use are sectors 2 (Fishing), 8 (Metal Products) and 25 (Others)[14].

Furthermore, for Russia in 1996, sectors 24 (Private Households) and 25 (Others) registered exorbitant values, with both[15] reaching the exact proportion of 3771%, much higher than usual. In 2016, the proportion fell to 3.4%, showing a change[16] in the country's energy matrix.

When we examine the countries that were net exporters of NRE at sectoral level in 1996 and 2016 in Table 3.1, we see that Western Europe has a pattern of concentration of exports in sectors 7 (Petroleum, Chemical and Non-Metallic Mineral Products), 8 (Metal Products), 9 (Electrical and Machinery), 13 (Electricity, Gas and Water) and 19 (Transport). Australia has a concentration in sectors 3 (Mining and Quarrying), 7 (Petroleum, Chemical and Non-Metallic Mineral Products) and 8 (Metal Products).

Analyzing the countries that have transitioned from net importers to net exporters, in 1996 Russia had an NRE import quota with sectors 9 (Electrical and Machinery), 14 (Construction) and 25 (Others)[17] being the most important. In 2016, as a net exporter, the main sectors responsible for this transition were 3 (Mining and Quarrying), 7 (Petroleum, Chemical and Non-Metallic Mineral Products) and 8 (Metal Products) (with a quota similar to Canada's in 1996). For Brazil, the main importing sectors in 1996 were 7 (Petroleum, Chemical and Non-Metallic Mineral Products), 9 (Electrical and Machinery), 10 (Transport Equipment) and 14 (Construction); as an exporter, in 2016, the main sectors were 3 (Mining and Quarrying), 6 (Wood and Paper) and 19 (Transport).

The most influential sectors for China's imports in 1996 were sectors 8 (Metal Products), 9 (Electrical and Machinery) and 14 (Construction), while for its net exports in 2016, the most

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[14] If the German and Russian cases are ignored, this sector almost loses all its representativeness.

[15] This simultaneous and exorbitant ratio is more indicative of a weakness in the balance of the data made available by EORA, rather than a reliable result for two non-renewable energy-intensive sectors in Russia.

[16] In 2016, the proportions for both sectors remained the same, indicating the persistence of fragile energy consumption data for these sectors in Russia. It should be noted that for Russia, the same is true for sectors 15, 16 and 17 (the same is true for Canada). For Germany, this occurs in sectors 24 and 25, as well as 9 and 10. For Japan, an equality is found in sectors 20, 21 and 22.

[17] Which is more related to the database development method than to a result per se.

significant were sectors 7 (Petroleum, Chemical and Non-Metallic Mineral Products), 11 (Other Manufacturing) and 19 (Transport). When we look at the Canadian case, with the opposite transition to the previous ones, in 1996 the most relevant sectors for its exports were 3 (Mining and Quarrying), 7 (Petroleum, Chemical and Non-Metallic Mineral Products) and 13 (Electricity, Gas and Water), and in 2016, as a net importer, the most relevant sectors were 19 (Transport), 21 (Financial Intermediation and Business Activities) and 26 (Re-export & Re-import).

In contrast to the net exporters in 1996 and 2016, the net importers in both years have a more diverse agenda, indicating that they present different needs. The United States shows a constant relevance in sectors 10 (Transport Equipment), 14 (Construction), 22 (Public Administration) and 23 (Education, Health and Other Services), while Japan shows this permanence in sectors 3 (Mining and Quarrying), 4 (Food & Beverages), 13 (Electricity, Gas and Water) and 23 (Education, Health and Other Services), while the Middle East shows a standardization only in sectors 9 (Electrical and Machinery) and 23 (Education, Health and Other Services), being the case of the greatest sectoral change between 1996 and 2016. A pertinent observation is that the 7 (Petroleum, Chemical and Non-Metallic Mineral Products), 8 (Metal Products), 9 (Electrical and Machinery) and 19 (Transport) sectors are highly relevant in the global virtual trade in NRE, both in 1996 and 2016.

A notable observation is that net exports and imports follow a pattern related to the energy intensity of the sectors in most situations. However, sector 13 (Electricity, Gas and Water), the most intensive sector, is not the one which is most represented in countries' net imports and exports.

| | British Isles | | France | | Germany | | Rest of Western Europe | | Russia | | Canada | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1996 | 2016 | 1996 | 2016 | 1996 | 2016 | 1996 | 2016 | 1996 | 2016 | 1996 | 2016 |
| 1 | 0,00% | 0,00% | 0,00% | 0,00% | 0,00% | 0,61% | 0,00% | 0,00% | -2,87% | 0,00% | 0,00% | 0,00% |
| 2 | 0,10% | 0,43% | 0,00% | 0,87% | 0,01% | 0,13% | 0,02% | 0,00% | -0,39% | 0,00% | 0,00% | 0,00% |
| 3 | 2,04% | 5,01% | 1,28% | 2,37% | 0,67% | 2,50% | 1,51% | 1,43% | 0,00% | 29,88% | 50,02% | 0,00% |
| 4 | 0,00% | 0,44% | 0,00% | 0,26% | 0,00% | 0,00% | 0,00% | 0,00% | -4,39% | 0,00% | 0,00% | -0,15% |
| 5 | 0,00% | 0,00% | 0,00% | 0,16% | 0,00% | 0,00% | 0,00% | 0,00% | -2,44% | 0,00% | 0,00% | -2,66% |
| 6 | 0,00% | 1,03% | 0,00% | 0,86% | 0,32% | 0,93% | 0,00% | 0,06% | -2,55% | 0,00% | 0,00% | 0,00% |
| 7 | 93,51% | 56,82% | 90,31% | 50,33% | 85,81% | 46,79% | 91,11% | 48,17% | 0,00% | 32,69% | 43,77% | -0,49% |
| 8 | 2,45% | 6,68% | 2,11% | 6,50% | 4,68% | 11,49% | 3,38% | 8,48% | -2,34% | 18,73% | 0,00% | 0,00% |
| 9 | 1,63% | 15,74% | 1,47% | 13,45% | 4,00% | 13,18% | 2,36% | 14,91% | -11,55% | 0,00% | 0,00% | 0,00% |
| 10 | 0,00% | 0,00% | 0,00% | 0,62% | 0,00% | 1,23% | 0,00% | 0,00% | -1,68% | 0,00% | 0,00% | 0,00% |
| 11 | 0,00% | 0,40% | 0,34% | 1,79% | 0,96% | 0,96% | 0,51% | 1,64% | 0,00% | 6,42% | 0,00% | -0,58% |
| 12 | 0,00% | 0,25% | 0,00% | 0,00% | 0,05% | 0,21% | 0,06% | 0,19% | 0,00% | 4,41% | 0,00% | -2,30% |
| 13 | 0,16% | 0,40% | 2,05% | 4,77% | 2,00% | 6,90% | 0,00% | 0,00% | -1,49% | 0,00% | 5,18% | 0,00% |
| 14 | 0,00% | 0,00% | 0,00% | 0,00% | 0,00% | 0,00% | 0,00% | 0,00% | -9,44% | 0,00% | 0,00% | -3,83% |
| 15 | 0,00% | 0,00% | 0,00% | 0,00% | 0,00% | 0,00% | 0,00% | 0,00% | -0,17% | 0,00% | 0,00% | -0,09% |
| 16 | 0,00% | 0,00% | 0,00% | 0,00% | 0,00% | 0,00% | 0,00% | 0,00% | -2,23% | 0,00% | 0,00% | -1,56% |
| 17 | 0,00% | 0,00% | 0,00% | 0,00% | 0,00% | 0,00% | 0,00% | 0,00% | -4,96% | 0,00% | 0,00% | -2,49% |
| 18 | 0,00% | 0,18% | 0,00% | 0,00% | 0,00% | 0,00% | 0,00% | 0,00% | -0,77% | 0,00% | 0,00% | -0,98% |
| 19 | 0,00% | 12,61% | 2,37% | 18,01% | 1,49% | 15,69% | 0,65% | 25,10% | -6,52% | 7,86% | 1,01% | -53,83% |
| 20 | 0,00% | 0,00% | 0,00% | 0,00% | 0,00% | 0,00% | 0,00% | 0,00% | -0,82% | 0,00% | 0,00% | -3,78% |
| 21 | 0,00% | 0,00% | 0,00% | 0,00% | 0,00% | 0,00% | 0,00% | 0,00% | -8,77% | 0,00% | 0,00% | -7,24% |
| 22 | 0,00% | 0,00% | 0,00% | 0,00% | 0,00% | 0,00% | 0,00% | 0,00% | -0,37% | 0,00% | 0,00% | -4,52% |
| 23 | 0,00% | 0,00% | 0,00% | 0,00% | 0,00% | 0,00% | 0,00% | 0,00% | -8,98% | 0,00% | 0,00% | -3,19% |
| 24 | 0,10% | 0,01% | 0,05% | 0,00% | 0,00% | 0,00% | 0,29% | 0,02% | -3,71% | 0,00% | 0,00% | 0,00% |
| 25 | 0,00% | 0,00% | 0,00% | 0,00% | 0,00% | 0,00% | 0,10% | 0,00% | -23,00% | 0,00% | 0,02% | 0,00% |
| 26 | 0,00% | 0,00% | 0,00% | 0,00% | 0,00% | 0,00% | 0,00% | 0,00% | -0,56% | 0,00% | 0,00% | -12,30% |

| | USA | | Brazil | | China | | Japan | | Middle East | | Australia | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1996 | 2016 | 1996 | 2016 | 1996 | 2016 | 1996 | 2016 | 1996 | 2016 | 1996 | 2016 |
| 1 | -3,70% | 0,00% | -7,19% | 0,98% | -7,09% | 0,00% | -1,40% | -0,80% | -2,75% | -2,29% | 0,95% | 3,24% |
| 2 | 0,00% | 0,00% | -0,64% | 0,00% | -0,07% | 0,00% | -0,46% | -0,34% | -0,07% | -0,06% | 0,10% | 0,33% |
| 3 | 0,00% | 0,00% | 0,00% | 41,14% | 0,00% | 0,00% | -22,00% | -9,08% | 0,00% | 0,00% | 56,02% | 46,66% |
| 4 | -3,77% | -5,09% | -3,58% | 0,00% | -3,58% | 0,00% | -6,31% | -6,92% | -3,11% | -4,44% | 2,22% | 2,62% |
| 5 | -5,85% | -6,11% | -6,87% | 0,00% | -1,27% | 3,76% | -1,07% | -3,38% | -8,58% | -5,46% | 0,53% | 0,26% |
| 6 | -3,03% | -4,34% | -1,58% | 9,58% | -6,95% | 0,00% | -1,14% | -1,45% | -2,49% | -2,20% | 0,06% | 0,66% |
| 7 | -11,51% | 0,00% | -24,11% | 0,00% | 0,00% | 56,63% | 0,00% | 0,00% | -27,77% | 0,00% | 39,29% | 26,22% |
| 8 | 0,00% | 0,00% | -1,44% | 6,60% | -13,64% | 0,00% | -8,44% | 0,00% | -2,46% | -1,52% | 1,59% | 12,03% |
| 9 | -2,43% | -0,53% | -10,84% | 3,38% | -27,47% | 1,32% | 0,00% | 0,00% | -14,07% | -37,93% | 0,00% | 4,83% |
| 10 | -10,91% | -11,40% | -8,60% | 0,00% | -5,57% | 0,00% | 0,00% | 0,00% | -2,83% | -6,43% | 0,00% | 0,00% |
| 11 | -2,04% | -0,68% | -1,12% | 4,47% | 0,00% | 7,04% | -0,11% | -0,44% | -3,97% | -4,38% | 0,00% | 0,77% |
| 12 | 0,00% | 0,00% | -2,20% | 0,00% | 0,00% | 0,32% | 0,00% | 0,00% | -1,04% | -0,89% | 0,10% | 0,35% |
| 13 | -4,11% | -4,77% | -1,73% | 0,00% | -1,07% | 0,00% | -43,13% | -35,23% | -1,99% | -0,75% | 0,00% | 0,00% |
| 14 | -11,01% | -6,99% | -8,77% | 0,00% | -20,73% | 0,00% | -4,21% | -2,65% | -5,54% | -4,45% | 0,00% | 0,00% |
| 15 | -0,05% | -0,01% | -0,02% | 0,01% | -0,02% | 0,00% | 0,00% | 0,00% | -0,35% | -0,31% | 0,00% | 0,00% |
| 16 | -0,61% | 0,00% | -0,22% | 0,11% | -0,29% | 0,05% | 0,00% | 0,00% | -1,30% | -1,40% | 0,00% | 0,00% |
| 17 | -1,57% | -0,65% | -0,50% | 0,21% | -0,57% | 0,13% | -0,03% | 0,00% | -1,10% | -1,09% | 0,00% | 0,00% |
| 18 | -1,92% | -1,50% | -0,69% | 0,00% | -0,03% | 0,25% | -3,38% | -3,84% | -0,89% | -0,58% | 0,00% | 0,55% |
| 19 | 0,00% | 0,00% | -7,86% | 34,48% | -3,19% | 30,50% | 0,00% | 0,00% | -3,87% | 0,00% | 0,00% | 4,74% |
| 20 | -2,14% | -2,54% | -1,31% | 0,00% | -0,46% | 0,00% | 0,00% | -0,74% | -0,49% | -1,47% | 0,00% | 0,00% |
| 21 | -4,83% | -3,05% | -0,92% | 0,00% | -2,70% | 0,00% | -1,28% | -2,16% | -3,44% | -5,72% | 0,00% | 0,00% |
| 22 | -13,67% | -40,80% | -1,77% | 0,00% | -0,15% | 0,00% | -0,19% | -0,41% | -3,74% | -10,45% | 0,00% | 0,00% |
| 23 | -16,86% | -11,46% | -6,08% | 0,00% | -3,94% | 0,00% | -6,84% | -5,15% | -7,11% | -6,48% | 0,00% | 0,00% |
| 24 | 0,00% | -0,07% | 0,00% | 0,02% | 0,00% | 0,00% | 0,00% | 0,00% | 0,00% | -0,04% | 0,09% | 0,00% |
| 25 | 0,00% | 0,00% | 0,00% | 0,00% | -1,20% | 0,00% | 0,00% | -0,01% | -0,06% | -0,14% | 0,01% | 0,00% |
| 26 | 0,00% | -0,01% | -1,97% | 0,00% | 0,00% | 0,00% | 0,00% | -27,38% | -0,98% | -1,52% | 0,00% | 0,00% |

**Table 3.1 – Virtual Trade in Nonrenewable Energy at sectoral level for 1996 and 2016**

### 3.2 – Results of the Virtual Renewable Energy Market

In order to be able to understand Figures 3.3 and 3.4, it should be clear that the green color represents the regions that are Net Exporters of RE, the purple color represents the regions that are Net Importers and the relevance is indicated by the intensity of the color.


Figure 3.3: Virtual Trade in Renewable Energy in 1996

According to Figure 3.3, in 1996 virtual trade in renewable energy was mainly concentrated in North America, with the United States as the main net exporter and Canada as the main net importer. Germany, France, the British Isles and China also exported with less intensity. The remaining significant net importers include Brazil, West-Central-East Africa, Central America-Caribbean-Rest of North America, Russia, India and Southeast Asia.

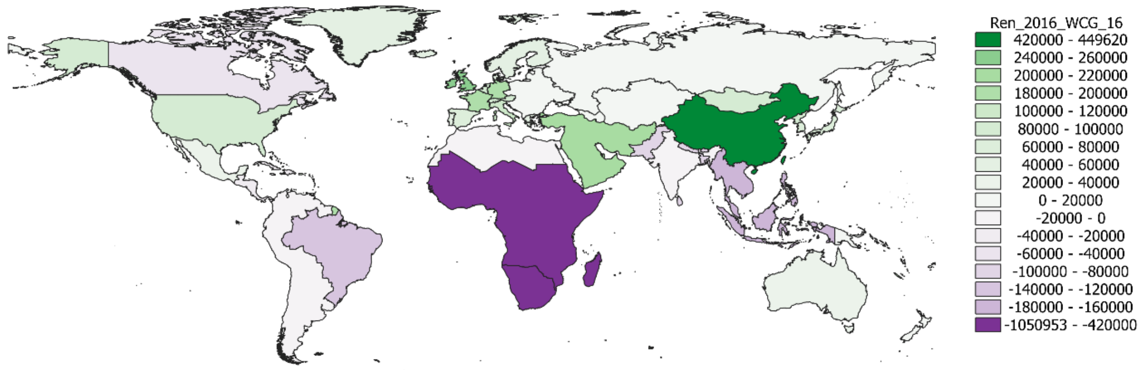


Figure 3.4: Virtual Trade in Renewable Energy in 2016

As shown in figure 3.4, the scenario in 2016 is considerably distinct. It seems that the same pattern of compensation as in 1996 persists for the United States and Canada, but at a global level, the degree of relevance of these countries has decreased significantly. Western Europe is showing noticeable growth in its exports on the trade market, with regions such as France, Italy, Spain, Northern Europe and, above all, the British Isles gaining prominence.

The Middle East is gaining relevance and is becoming a significant exporter in the market. However, this is not comparable to the case of China, which has made a notable effort to increase the use of RE in the production of exported goods, going from being a discreet importer to the largest exporter in the market.

In contrast to the decrease in net imports in Canada, West-Central-Eastern Africa has become the region with the highest level of imports, while Southern Africa has moved from the position of low relevance exporter to the second largest importer. Other regions that are significant in terms of imports are Southeast Asia, Brazil and the Rest of South Asia.

For the purpose of evaluating the sectors of countries that are intensive in renewable energy, the ratio of "Renewable Energy Used" to "Gross Value of Production by country sector" for the years 1996 and 2016 is shown in Annex V. According to this ratio, as in the case of non-renewable energy, sector 13 (Electricity, Gas and Water) is predominantly the most renewable energy-intensive sector, which characterizes this sector as energy-intensive.

Sectors 7 (Petroleum, Chemical and Non-Metallic Mineral Products) and 12 (Recycling) have maintained a degree of energy intensiveness in the case of renewables, but the relevance of sector 7 has decreased and 12 has increased, and could be considered to have surpassed the relevance of sector 7. In addition, sector 6 (Wood and Paper) has distinguished itself, gaining relevance when compared to the case of non-renewables.

Regarding sector 19 (Transport), which showed significant energy intensity in the non-renewable case, in the renewable case, it is only recognized due to the low representation of other sectors. Sector 24 (Private Households) and 25 (Others) show some representativeness, but this is practically only due to Russian use in 1996, which makes it difficult to label this sector as renewable energy intensive at a global level, regardless of the period considered.

In the virtual RE market, most of the regions shown in table 3.2 are net exporters. At a sectoral level, with the exception of Russia in 2016, all of them have sector 7 (Petroleum, Chemical and Non-Metallic Mineral Products) as their most relevant sector. Once again, there is a high concentration between sectors 6 (Wood and Paper) and 9 (Electrical and Machinery), both in terms of imports and exports. The Russian transition case, which was a net importer in 1996 with a concentration in sectors 7 (Petroleum, Chemical and Non-Metallic Mineral Products), 9 (Electrical and Machinery), 14 (Construction), 23 (Education, Health and Other Services) and 25 (Others), became a net exporter in 2016, particularly in sectors 3 (Mining and Quarrying), 6 (Wood and Paper), 8 (Metal Products) and 13 (Electricity, Gas and Water).

There are also countries that persevered in these two periods as net importers of RE. The Canadian case concentrates its imports in sectors 7 (Petroleum, Chemical and Non-Metallic Mineral Products), 22 (Public Administration) and 26 (Re-export & Re-import), with an observation for sector 19 (Transport) in 2016. Looking at Brazil, the most relevant sectors[18] in terms of imports were 7 (Petroleum, Chemical and Non-Metallic Mineral Products), 8 (Metal Products), 13 (Electricity, Gas and Water) and 19 (Transport).

As in the NRE market, the pattern of concentration in the Petroleum, Chemical and 7 (Petroleum, Chemical and Non-Metallic Mineral Products) reaffirming the energy intensity in this sector. With regard to sectors 8 (Metal Products) and 9 (Electrical and Machinery), there is a pattern occurring in 1996 and 2016, which highlights the relevance of these sectors for the virtual commerce of RE. Moreover, the 6 (Wood and Paper) and 13 (Electricity, Gas and Water) sectors were added to the total relevance of the RE market. It is worth noting that although sector 13 (Electricity, Gas and Water) is energy-intensive, in the NRE market the sector is not as important, but in the RE market the sector has considerable values. Furthermore, although sector 12 (Recycling) is intensive in RE, it does not show significant results in the virtual RE market.

[18] With observation for the unusual situation in sector 4 in 2016.

| | British Isles | | France | | Germany | | Rest of Western Europe | | Russia | | Canada | | USA | | Brazil | | China | | Japan | | Middle East | | Australia | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1996 | 2016 | 1996 | 2016 | 1996 | 2016 | 1996 | 2016 | 1996 | 2016 | 1996 | 2016 | 1996 | 2016 | 1996 | 2016 | 1996 | 2016 | 1996 | 2016 | 1996 | 2016 | 1996 | 2016 |
| 1 | 0,00% | 0,09% | 0,55% | 0,23% | 0,71% | 0,38% | 0,43% | 0,20% | -3,20% | 0,00% | -2,54% | -1,21% | 0,18% | 0,37% | -2,38% | -1,38% | 0,29% | 0,30% | 0,00% | 0,00% | 1,81% | 0,98% | 0,00% | 0,46% |
| 2 | 0,06% | 0,03% | 0,13% | 0,07% | 0,02% | 0,01% | 0,00% | 0,00% | -0,46% | 0,00% | -0,31% | -0,10% | 0,04% | 0,05% | -0,35% | -0,56% | 0,01% | 0,00% | 0,02% | 0,00% | 0,00% | 0,01% | 0,00% | 0,00% |
| 3 | 0,71% | 0,38% | 0,28% | 0,18% | 0,20% | 0,35% | 0,16% | 0,08% | 0,00% | 14,07% | -1,51% | -0,18% | 0,01% | 2,01% | -0,43% | -0,35% | 0,26% | 0,00% | 0,00% | 1,29% | 12,91% | 9,23% | 1,61% | 0,00% |
| 4 | 1,77% | 2,37% | 2,79% | 2,85% | 1,53% | 2,37% | 1,50% | 0,00% | -5,32% | 0,00% | -2,47% | -0,13% | 1,71% | 0,00% | -2,32% | -20,69% | 3,21% | 1,15% | 0,12% | 0,00% | 0,00% | 1,23% | 0,00% | 0,00% |
| 5 | 0,00% | 1,19% | 0,51% | 0,83% | 0,73% | 0,99% | 0,07% | 0,77% | -2,18% | 0,00% | -1,55% | -1,20% | 0,00% | 0,00% | -2,07% | -0,53% | 7,31% | 8,35% | 0,00% | 0,00% | 0,04% | 2,76% | 2,12% | 1,10% |
| 6 | 8,36% | 8,43% | 0,00% | 4,14% | 10,45% | 11,88% | 4,98% | 9,87% | -1,29% | 10,79% | -1,80% | 0,00% | 0,00% | 0,00% | -1,09% | 0,00% | 9,06% | 12,87% | 0,00% | 0,00% | 0,32% | 2,10% | 12,52% | 11,40% |
| 7 | 59,52% | 55,62% | 53,77% | 50,23% | 43,30% | 39,25% | 78,12% | 57,13% | -23,48% | 0,00% | -40,85% | -37,71% | 68,43% | 66,60% | -23,75% | -32,72% | 48,92% | 41,86% | 41,60% | 42,94% | 70,51% | 44,30% | 59,59% | 47,50% |
| 8 | 2,31% | 4,06% | 1,35% | 2,16% | 2,91% | 6,41% | 1,35% | 6,18% | -1,56% | 40,92% | -6,03% | -2,93% | 0,22% | 2,16% | -4,08% | -10,70% | 1,76% | 5,62% | 3,74% | 8,03% | 0,00% | 6,12% | 5,26% | 15,66% |
| 9 | 5,48% | 19,73% | 8,92% | 28,18% | 7,36% | 17,25% | 8,65% | 21,78% | -7,13% | 0,09% | -3,62% | -3,81% | 9,12% | 9,55% | -3,20% | 0,00% | 4,08% | 16,47% | 21,16% | 17,69% | 0,00% | 14,03% | 4,83% | 15,63% |
| 10 | 0,00% | 0,24% | 1,08% | 0,27% | 1,70% | 0,99% | 0,00% | 0,00% | -0,83% | 0,00% | -3,78% | -2,77% | 0,00% | 0,00% | -2,64% | -1,31% | 0,00% | 0,03% | 5,53% | 3,13% | 0,00% | 0,01% | 0,00% | 0,00% |
| 11 | 0,00% | 1,30% | 3,26% | 2,83% | 1,38% | 1,53% | 3,93% | 2,92% | -1,14% | 4,97% | -1,33% | 0,00% | 0,20% | 0,00% | -0,27% | 0,00% | 8,67% | 7,66% | 2,98% | 2,17% | 0,00% | 5,73% | 2,64% | 3,51% |
| 12 | 0,44% | 0,84% | 0,00% | 0,01% | 0,23% | 0,59% | 0,45% | 0,60% | 0,00% | 1,74% | -0,33% | -0,10% | 0,57% | 8,89% | -1,49% | -0,35% | 0,34% | 0,56% | 0,64% | 2,48% | 5,31% | 3,00% | 1,57% | 1,95% |
| 13 | 20,86% | 1,94% | 27,84% | 6,60% | 28,66% | 15,24% | 0,00% | 0,00% | 0,00% | 22,68% | -1,10% | 0,00% | 17,57% | 9,06% | -40,23% | -12,13% | 13,44% | 0,39% | 12,57% | 7,53% | 5,02% | 1,36% | 9,77% | 1,89% |
| 14 | 0,00% | 0,01% | 0,00% | 0,00% | 0,00% | 0,00% | 0,00% | 0,00% | -9,99% | 0,00% | -4,85% | -3,89% | 0,00% | 0,00% | -2,60% | -1,41% | 0,00% | 0,00% | 0,00% | 0,00% | 0,00% | 0,21% | 0,00% | 0,00% |
| 15 | 0,00% | 0,00% | 0,00% | 0,00% | 0,00% | 0,00% | 0,00% | 0,00% | -0,17% | 0,00% | -0,11% | -0,08% | 0,00% | 0,00% | -0,01% | 0,00% | 0,01% | 0,00% | 0,02% | 0,03% | 0,00% | 0,00% | 0,00% | 0,00% |
| 16 | 0,00% | 0,00% | 0,00% | 0,00% | 0,01% | 0,00% | 0,00% | 0,00% | -2,19% | 0,00% | -1,38% | -1,05% | 0,00% | 0,00% | -0,08% | -0,02% | 0,00% | 0,00% | 0,45% | 1,51% | 0,00% | 0,04% | 0,00% | 0,00% |
| 17 | 0,00% | 0,03% | 0,00% | 0,00% | 0,01% | 0,00% | 0,00% | 0,00% | -4,86% | 0,00% | -3,07% | -2,23% | 0,00% | 0,00% | -0,17% | -0,05% | 0,00% | 0,00% | 0,00% | 0,06% | 0,00% | 0,06% | 0,00% | 0,00% |
| 18 | 0,00% | 0,39% | 0,00% | 0,00% | 0,12% | 0,01% | 0,00% | 0,00% | -0,38% | 0,01% | -0,37% | -0,41% | 0,00% | 0,00% | -0,22% | -0,71% | 0,33% | 0,12% | 0,00% | 0,50% | 0,00% | 0,89% | 0,00% | 0,00% |
| 19 | 0,35% | 2,85% | 0,03% | 1,64% | 0,73% | 3,08% | 0,21% | 0,59% | -5,62% | 4,73% | -0,84% | -17,03% | 0,31% | 0,83% | -7,60% | -11,56% | 0,82% | 4,90% | 5,95% | 12,38% | 0,01% | 7,42% | 0,00% | 1,35% |
| 20 | 0,00% | 0,10% | 0,00% | 0,01% | 0,09% | 0,04% | 0,00% | 0,00% | -0,40% | 0,00% | -0,22% | -2,57% | 0,00% | 0,00% | -0,62% | -0,65% | 0,08% | 0,00% | 0,18% | 0,00% | 0,00% | 0,32% | 0,00% | 0,00% |
| 21 | 0,00% | 0,38% | 0,00% | 0,00% | 0,54% | 0,00% | 0,00% | 0,00% | -6,31% | 0,00% | -3,14% | -3,19% | 0,00% | 0,00% | -1,03% | -1,11% | 0,21% | 0,00% | 0,50% | 0,00% | 0,00% | 0,18% | 0,00% | 0,00% |
| 22 | 0,00% | 0,00% | 0,00% | 0,00% | 0,00% | 0,00% | 0,00% | 0,00% | -0,18% | 0,00% | -6,86% | -5,79% | 0,00% | 0,00% | -0,55% | -0,46% | 0,00% | 0,00% | 0,00% | 0,04% | 0,00% | 0,23% | 0,00% | 0,00% |
| 23 | 0,00% | 0,12% | 0,00% | 0,00% | 0,00% | 0,00% | 0,00% | 0,00% | -10,43% | 0,00% | -2,69% | -4,08% | 0,00% | 0,00% | -1,68% | -1,46% | 0,12% | 0,00% | 0,00% | 0,00% | 0,00% | 0,74% | 0,00% | 0,00% |
| 24 | 0,06% | 0,00% | 0,03% | 0,00% | 0,00% | 0,00% | 0,25% | 0,09% | -1,76% | 0,00% | 0,00% | 0,00% | 0,10% | 0,00% | 0,00% | 0,00% | 1,33% | 0,01% | 0,08% | 0,01% | 2,22% | 0,02% | 0,04% | 0,00% |
| 25 | 0,10% | 0,00% | 0,02% | 0,00% | 0,03% | 0,00% | 0,32% | 0,00% | -10,85% | 0,00% | 0,00% | 0,00% | 1,73% | 0,84% | -0,10% | -0,29% | 0,03% | 0,00% | 4,47% | 0,21% | 3,66% | 0,00% | 0,05% | 0,00% |
| 26 | 0,00% | 0,00% | 0,00% | 0,00% | 0,00% | 0,00% | 0,00% | 0,00% | -0,28% | 0,00% | -9,24% | -9,56% | 0,00% | 0,00% | -1,02% | -1,56% | 0,00% | 0,00% | 0,00% | 0,00% | 0,00% | 0,00% | 0,00% | 0,00% |

**Table 3.2 – Virtual Trade in Renewable Energy at sectoral level for 1996 and 2016**

## 4 – Conclusion

In 1996, the NRE embodied in international trade originated in Western Europe (with the exception of the Rest of Southern Europe), Canada, Australia and West-Central-East Africa. The main importers were the United States, Eastern Europe, the Middle East, Russia and Southeast Asia. In this way, it can be seen that the virtual trade in NRE was mainly in the northern hemisphere in these periods.

In 2016, Europe's importance remained, but as far as Asia is concerned, there was a strong transition in China, which went from being a medium-sized importer to a highly important exporter. Other transitions in this direction occurred in Russia and Brazil, while India and Canada made a transition in the opposite direction, from exporters to net importers.

The hierarchy of imports has changed, with the United States, Eastern Europe and the Middle East remaining the most important. However, regions such as the Rest of East Asia, Central Asia and South Africa have become the biggest importers.

In sectoral terms, for the years 1996 and 2016, Western Europe shows a pattern of export concentration in sectors 7 (Petroleum, Chemical and Non-Metallic Mineral Products), 8 (Metal Products), 9 (Electrical and Machinery), 13 (Electricity, Gas and Water) and 19 (Transport). In addition, when compared to the regions that remained net importers or net exporters in 1996 and 2016, those belonging to the first group have a diverse portfolio, with variations between regions and between time periods. On the other hand, the exporting regions showed stability in their sectoral concentrations in the market, which indicates differences in the needs of the exporting and importing regions.

A relevant observation is that the 7 (Petroleum, Chemical and Non-Metallic Mineral Products), 8 (Metal Products), 9 (Electrical and Machinery) and 19 (Transport) sectors proved to be of great relevance in the global virtual trade of NRE, highlighting these as NRE-intensive sectors, both in 1996 and 2016. Another notable observation is that net exports and imports follow a pattern related to the energy intensity of the sectors in the majority of cases. However, sector 13 (Electricity, Gas and Water), the most intensive sector, is barely represented in the countries' NRE net imports and exports, in contrast to the opposite scenario in the RE market. Whereas sector 12 (Recycling), despite being energy-intensive, has no significant representation in both markets.

With specific regard to Virtual Trade in Renewable Energy, in 1996 it was mainly concentrated in North America, with the United States as the main net exporter and Canada as the main net importer.

Moving forward to 2016, we see a considerably different scenario. The pattern seen for the United States and Canada in 1996 has been preserved, but with a significant loss of relevance. With regard to Western Europe, there was an increase in exports to the market, with the British Isles in particular. Looking at the Net Import results, Canada's loss of relevance in terms of market share was balanced by an increase in imports from West-Central-Eastern Africa and Southern Africa.

At a sectoral level, as in the NRE market, the concentration pattern in the 7 (Petroleum, Chemical and Non-Metallic Mineral Products), 8 (Metal Products) and 9 (Electrical and Machinery) sectors were maintained in 1996 and 2016. The 6 (Wood and Paper) and 13 (Electricity, Gas and Water) sectors were added to the total relevance of the RE market.

In the light of these results, when discussing environmental policies, before setting certain benchmarks, a careful look should be taken at the countries whose exports are mainly in the energy-intensive sectors, such as sectors 7 (Petroleum, Chemical and Non-Metallic Mineral Products), 12 (Recycling) and 13 (Electricity, Gas and Water), as well as the less energy-intensive sectors, such as 2 (Fishing), 3 (Mining and Quarrying), 6 (Wood and Paper), 8 (Metal Products) and 19 (Transport), because it is necessary to differentiate in terms of "weight" in order to assign accountability to these countries.

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# ANNEX IV

| | British Isles | | France | | Germany | | Rest of Western Europe | | Russia | | Canada | | USA | | Brazil | | China | | Japan | | Middle East | | Australia | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1996 | 2016 | 1996 | 2016 | 1996 | 2016 | 1996 | 2016 | 1996 | 2016 | 1996 | 2016 | 1996 | 2016 | 1996 | 2016 | 1996 | 2016 | 1996 | 2016 | 1996 | 2016 | 1996 | 2016 |
| 1 | 0,18% | 0,04% | 0,17% | 0,14% | 0,16% | 0,02% | 0,54% | 0,22% | 0,49% | 0,17% | 0,34% | 0,14% | 0,39% | 0,19% | 0,19% | 0,17% | 0,47% | 0,08% | 0,09% | 0,06% | 0,31% | 0,26% | 0,18% | 0,11% |
| 2 | 0,03% | 0,01% | 0,72% | 0,34% | 0,02% | 0,01% | 0,07% | 1,64% | 0,48% | 0,16% | 0,33% | 0,14% | 0,04% | 0,02% | 1,80% | 1,57% | 0,07% | 0,01% | 0,45% | 0,38% | 0,07% | 0,08% | 0,74% | 0,32% |
| 3 | 0,71% | 0,26% | 0,19% | 0,07% | 0,30% | 0,08% | 0,19% | 0,79% | 3,84% | 0,89% | 1,32% | 0,94% | 1,37% | 0,63% | 0,43% | 0,26% | 1,63% | 0,31% | 3,70% | 0,85% | 1,34% | 0,33% | 0,69% | 0,43% |
| 4 | 0,20% | 0,05% | 0,12% | 0,06% | 0,13% | 0,08% | 0,13% | 0,08% | 0,55% | 0,21% | 0,38% | 0,15% | 0,22% | 0,14% | 0,11% | 0,06% | 0,64% | 0,07% | 0,12% | 0,09% | 0,15% | 0,09% | 0,13% | 0,06% |
| 5 | 0,17% | 0,05% | 0,10% | 0,03% | 0,05% | 0,03% | 0,09% | 0,03% | 0,41% | 0,17% | 0,21% | 0,08% | 0,20% | 0,05% | 0,05% | 0,03% | 0,40% | 0,05% | 0,06% | 0,05% | 0,16% | 0,09% | 0,08% | 0,04% |
| 6 | 0,16% | 0,05% | 0,14% | 0,04% | 0,14% | 0,09% | 0,11% | 0,06% | 0,39% | 0,15% | 0,41% | 0,09% | 0,45% | 0,27% | 0,19% | 0,11% | 0,92% | 0,15% | 0,12% | 0,09% | 0,25% | 0,15% | 0,10% | 0,07% |
| 7 | 2,34% | 0,20% | 1,82% | 0,18% | 2,00% | 0,22% | 2,13% | 0,30% | 13,02% | 1,82% | 5,75% | 0,63% | 4,54% | 0,35% | 3,05% | 0,37% | 5,40% | 0,54% | 1,29% | 0,28% | 10,35% | 1,12% | 3,14% | 1,04% |
| 8 | 0,34% | 0,07% | 0,24% | 0,08% | 0,22% | 0,09% | 0,27% | 0,19% | 2,33% | 0,50% | 0,68% | 0,21% | 0,49% | 0,21% | 0,65% | 0,46% | 2,37% | 0,35% | 0,23% | 0,17% | 0,49% | 0,28% | 1,52% | 0,53% |
| 9 | 0,10% | 0,03% | 0,09% | 0,03% | 0,06% | 0,03% | 0,06% | 0,02% | 0,40% | 0,13% | 0,12% | 0,05% | 0,11% | 0,06% | 0,05% | 0,04% | 0,39% | 0,05% | 0,07% | 0,05% | 0,72% | 0,58% | 0,01% | 0,01% |
| 10 | 0,11% | 0,03% | 0,04% | 0,02% | 0,06% | 0,03% | 0,06% | 0,03% | 0,09% | 2,15% | 0,09% | 0,05% | 0,13% | 0,06% | 0,05% | 0,03% | 0,38% | 0,05% | 0,11% | 0,07% | 0,11% | 0,10% | 0,02% | 0,01% |
| 11 | 0,31% | 0,14% | 0,20% | 0,06% | 0,07% | 0,03% | 0,15% | 0,03% | 0,29% | 0,12% | 0,24% | 0,08% | 0,10% | 0,06% | 0,16% | 0,12% | 0,89% | 0,15% | 0,18% | 0,13% | 1,96% | 1,15% | 0,02% | 0,00% |
| 12 | 0,50% | 0,22% | 1,22% | 0,12% | 0,06% | 0,04% | 0,09% | 0,05% | 0,45% | 0,17% | 0,30% | 0,12% | 0,00% | 0,00% | 12,72% | 1,87% | 0,00% | 0,05% | 0,12% | 0,09% | 2,14% | 1,45% | 0,00% | 0,00% |
| 13 | 5,37% | 1,85% | 7,38% | 4,56% | 6,21% | 2,42% | 3,54% | 2,23% | 56,78% | 11,71% | 8,98% | 2,73% | 11,65% | 5,71% | 0,31% | 0,28% | 14,88% | 4,14% | 3,31% | 2,75% | 9,06% | 4,74% | 12,58% | 6,63% |
| 14 | 0,04% | 0,01% | 0,04% | 0,02% | 0,04% | 0,01% | 0,05% | 0,04% | 0,31% | 0,11% | 0,13% | 0,06% | 0,05% | 0,02% | 0,03% | 0,02% | 0,19% | 0,04% | 0,05% | 0,05% | 0,14% | 0,09% | 0,03% | 0,01% |
| 15 | 0,05% | 0,02% | 0,05% | 0,02% | 0,06% | 0,04% | 0,08% | 0,03% | 0,18% | 0,10% | 0,13% | 0,07% | 0,09% | 0,04% | 0,05% | 0,02% | 0,20% | 0,03% | 0,04% | 0,04% | 0,04% | 0,05% | 0,01% | 0,00% |
| 16 | 0,06% | 0,01% | 0,07% | 0,03% | 0,06% | 0,03% | 0,08% | 0,03% | 0,18% | 0,10% | 0,13% | 0,07% | 0,08% | 0,03% | 0,05% | 0,02% | 0,20% | 0,03% | 0,04% | 0,03% | 0,06% | 0,05% | 0,01% | 0,00% |
| 17 | 0,05% | 0,01% | 0,05% | 0,02% | 0,06% | 0,04% | 0,06% | 0,02% | 0,18% | 0,10% | 0,13% | 0,07% | 0,09% | 0,05% | 0,05% | 0,02% | 0,20% | 0,03% | 0,04% | 0,04% | 0,05% | 0,06% | 0,00% | 0,00% |
| 18 | 0,04% | 0,01% | 0,07% | 0,03% | 0,08% | 0,03% | 0,07% | 0,02% | 0,27% | 0,17% | 0,17% | 0,07% | 0,10% | 0,03% | 0,03% | 0,01% | 0,31% | 0,05% | 0,07% | 0,08% | 0,21% | 0,14% | 0,00% | 0,00% |
| 19 | 0,60% | 0,43% | 0,08% | 0,56% | 0,19% | 0,44% | 0,39% | 0,89% | 3,25% | 1,53% | 0,89% | 0,85% | 0,95% | 1,43% | 0,20% | 1,88% | 2,60% | 0,78% | 0,21% | 0,58% | 0,84% | 1,52% | 1,43% | 0,42% |
| 20 | 0,05% | 0,01% | 0,07% | 0,02% | 0,05% | 0,04% | 0,07% | 0,02% | 0,14% | 0,10% | 0,11% | 0,05% | 0,11% | 0,04% | 0,06% | 0,17% | 0,24% | 0,03% | 0,04% | 0,04% | 0,13% | 0,06% | 0,01% | 0,01% |
| 21 | 0,05% | 0,01% | 0,05% | 0,02% | 0,05% | 0,03% | 0,06% | 0,02% | 0,26% | 0,12% | 0,16% | 0,07% | 0,07% | 0,03% | 0,02% | 0,01% | 0,16% | 0,04% | 0,04% | 0,04% | 0,05% | 0,03% | 0,02% | 0,01% |
| 22 | 0,05% | 0,02% | 0,05% | 0,02% | 0,04% | 0,02% | 0,05% | 0,03% | 0,11% | 0,20% | 0,17% | 0,08% | 0,03% | 0,04% | 0,05% | 0,02% | 0,77% | 0,09% | 0,04% | 0,04% | 0,10% | 0,11% | 0,02% | 0,00% |
| 23 | 0,05% | 0,01% | 0,04% | 0,02% | 0,04% | 0,02% | 0,05% | 0,02% | 0,23% | 0,11% | 0,15% | 0,05% | 0,11% | 0,03% | 0,01% | 0,01% | 0,22% | 0,04% | 0,04% | 0,03% | 0,11% | 0,10% | 0,06% | 0,02% |
| 24 | 0,00% | 0,00% | 0,00% | 0,00% | 3,85% | 0,00% | 0,01% | 0,00% | 3771% | 3,40% | 0,00% | 0,00% | 0,09% | 0,04% | 0,00% | 0,00% | 0,14% | 0,05% | 0,03% | 0,06% | 0,09% | 0,13% | 0,01% | 0,00% |
| 25 | 1,14% | 0,28% | 0,05% | 0,36% | 3,85% | 0,00% | 0,08% | 0,22% | 3771% | 3,40% | 0,00% | 0,00% | 0,09% | 0,05% | 0,04% | 0,03% | 0,77% | 0,09% | 0,28% | 0,25% | 1,97% | 1,07% | 0,02% | 0,00% |
| 26 | 0,00% | 0,00% | 0,00% | 0,00% | 0,00% | 0,00% | 0,00% | 0,00% | 0,00% | 0,00% | 0,00% | 0,00% | 0,00% | 0,00% | 0,00% | 0,00% | 0,00% | 0,00% | 0,00% | 0,00% | 0,00% | 0,00% | 0,00% | 0,00% |

**Table 5.1 – Proportion of Nonrenewable Energy Use in relation to Gross Value of Production at sectoral level for 1996 and 2016**

# ANNEX V

| | British Isles | | France | | Germany | | Rest of Western Europe | | Russia | | Canada | | USA | | Brazil | | China | | Japan | | Middle East | | Australia | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1996 | 2016 | 1996 | 2016 | 1996 | 2016 | 1996 | 2016 | 1996 | 2016 | 1996 | 2016 | 1996 | 2016 | 1996 | 2016 | 1996 | 2016 | 1996 | 2016 | 1996 | 2016 | 1996 | 2016 |
| 1 | 0,01% | 0,01% | 0,00% | 0,00% | 0,00% | 0,00% | 0,02% | 0,00% | 0,02% | 0,00% | 0,00% | 0,00% | 0,00% | 0,01% | 0,09% | 0,07% | 0,00% | 0,00% | 0,00% | 0,00% | 0,00% | 0,00% | 0,01% | 0,01% |
| 2 | 0,01% | 0,00% | 0,00% | 0,00% | 0,00% | 0,00% | 0,03% | 0,00% | 0,02% | 0,00% | 0,00% | 0,00% | 0,00% | 0,00% | 0,85% | 0,64% | 0,00% | 0,00% | 0,00% | 0,00% | 0,02% | 0,00% | 0,03% | 0,03% |
| 3 | 0,00% | 0,00% | 0,00% | 0,00% | 0,00% | 0,00% | 0,00% | 0,01% | 0,01% | 0,00% | 0,00% | 0,00% | 0,00% | 0,00% | 0,00% | 0,48% | 0,00% | 0,00% | 0,00% | -0,01% | 0,01% | 0,00% | 0,01% | 0,01% |
| 4 | 0,00% | 0,00% | 0,00% | 0,00% | 0,00% | 0,00% | 0,00% | 0,02% | 0,03% | 0,00% | 0,00% | 0,00% | 0,00% | 0,00% | 0,01% | 0,38% | 0,00% | 0,00% | 0,00% | 0,00% | 0,01% | 0,00% | 0,22% | 0,23% |
| 5 | 0,00% | 0,00% | 0,00% | 0,00% | 0,00% | 0,00% | 0,00% | 0,00% | 0,01% | 0,00% | 0,00% | 0,00% | 0,01% | 0,00% | 0,01% | 0,01% | 0,00% | 0,00% | 0,00% | 0,01% | 0,00% | 0,00% | 0,01% | 0,01% |
| 6 | 0,01% | 0,00% | 0,08% | 0,06% | 0,00% | 0,05% | 0,04% | 0,05% | 0,00% | 0,01% | 0,15% | 0,16% | 0,16% | 0,26% | 0,30% | 0,46% | 0,00% | 0,01% | 0,03% | 0,04% | 0,01% | 0,00% | 0,10% | 0,05% |
| 7 | 0,02% | 0,00% | 0,01% | 0,00% | 0,01% | 0,01% | 0,01% | 0,01% | 0,65% | 0,06% | 1,71% | 0,21% | 0,00% | -0,01% | 0,28% | 0,09% | 0,00% | -0,01% | 0,00% | 0,00% | 0,01% | -0,01% | 0,01% | 0,01% |
| 8 | 0,00% | 0,00% | 0,00% | 0,00% | 0,00% | 0,00% | 0,00% | 0,00% | 0,00% | 0,00% | 0,00% | 0,00% | 0,00% | 0,00% | 0,21% | 0,16% | 0,00% | 0,00% | 0,00% | 0,00% | 0,01% | 0,00% | 0,01% | 0,01% |
| 9 | 0,01% | 0,00% | 0,00% | 0,00% | 0,00% | 0,00% | 0,00% | 0,00% | 0,00% | 0,00% | 0,01% | 0,01% | 0,00% | 0,00% | 0,01% | 0,01% | 0,00% | 0,00% | 0,00% | 0,00% | 0,01% | 0,00% | 0,01% | 0,01% |
| 10 | 0,00% | 0,00% | 0,00% | 0,00% | 0,00% | 0,00% | 0,00% | 0,00% | 0,00% | 0,01% | 0,00% | 0,00% | 0,00% | 0,00% | 0,00% | 0,00% | 0,00% | 0,00% | 0,00% | 0,00% | 0,01% | 0,00% | 0,00% | 0,00% |
| 11 | 0,03% | 0,01% | 0,00% | 0,00% | 0,02% | 0,00% | 0,01% | 0,01% | 0,01% | 0,00% | 0,00% | 0,00% | 0,00% | 0,01% | 0,05% | 0,03% | 0,00% | 0,05% | 0,01% | 0,01% | 0,03% | 0,00% | 0,01% | 0,01% |
| 12 | 0,07% | 0,02% | 1,62% | 0,00% | 0,02% | 0,00% | 0,02% | 0,01% | 0,02% | 0,00% | 0,00% | 0,00% | 0,00% | 0,00% | 4,02% | 0,51% | 0,00% | 0,02% | 0,00% | 0,00% | 0,03% | 0,00% | 0,00% | 0,00% |
| 13 | 0,14% | 0,20% | 1,26% | 0,29% | 0,46% | 0,48% | 1,45% | 0,46% | 6,90% | 0,64% | 16,27% | 2,72% | 2,26% | 0,51% | 7,58% | 1,51% | 3,81% | 0,36% | 0,46% | 0,28% | 1,75% | 0,18% | 0,00% | 0,01% |
| 14 | 0,00% | 0,00% | 0,00% | 0,00% | 0,00% | 0,00% | 0,00% | 0,00% | 0,00% | 0,00% | 0,00% | 0,00% | 0,00% | 0,00% | 0,00% | 0,00% | 0,00% | 0,00% | 0,00% | 0,00% | 0,01% | 0,00% | 0,00% | 0,00% |
| 15 | 0,00% | 0,00% | 0,00% | 0,00% | 0,00% | 0,00% | 0,00% | 0,00% | 0,00% | 0,00% | 0,00% | 0,00% | 0,00% | 0,00% | 0,00% | 0,00% | 0,00% | 0,00% | 0,00% | 0,00% | 0,00% | 0,00% | 0,00% | 0,00% |
| 16 | 0,00% | 0,00% | 0,00% | 0,00% | 0,00% | 0,00% | 0,00% | 0,00% | 0,00% | 0,00% | 0,00% | 0,00% | 0,00% | 0,00% | 0,00% | 0,00% | 0,00% | 0,00% | 0,00% | 0,00% | 0,00% | 0,00% | 0,00% | 0,00% |
| 17 | 0,00% | 0,00% | 0,00% | 0,00% | 0,00% | 0,00% | 0,00% | 0,00% | 0,00% | 0,00% | 0,00% | 0,00% | 0,00% | 0,00% | 0,00% | 0,00% | 0,00% | 0,00% | 0,00% | 0,00% | 0,00% | 0,00% | 0,00% | 0,00% |
| 18 | 0,00% | 0,00% | 0,00% | 0,00% | 0,00% | 0,00% | 0,00% | 0,00% | 0,01% | 0,01% | 0,00% | 0,00% | 0,00% | 0,00% | 0,00% | 0,00% | 0,00% | 0,00% | 0,00% | 0,00% | 0,01% | 0,00% | 0,00% | 0,00% |
| 19 | 0,00% | 0,01% | 0,01% | 0,03% | 0,00% | 0,02% | 0,00% | 0,07% | 0,00% | 0,00% | 0,00% | 0,02% | 0,02% | 0,07% | 0,26% | 0,40% | 0,00% | 0,00% | 0,00% | 0,00% | 0,00% | 0,00% | 0,00% | 0,00% |
| 20 | 0,00% | 0,00% | 0,00% | 0,00% | 0,00% | 0,00% | 0,00% | 0,00% | 0,00% | 0,00% | 0,00% | 0,00% | 0,00% | 0,00% | 0,04% | 0,03% | 0,00% | 0,00% | 0,00% | 0,00% | 0,00% | 0,00% | 0,00% | 0,00% |
| 21 | 0,00% | 0,00% | 0,00% | 0,00% | 0,00% | 0,00% | 0,00% | 0,00% | 0,01% | 0,00% | 0,00% | 0,00% | 0,00% | 0,00% | 0,00% | 0,00% | 0,00% | 0,00% | 0,00% | 0,00% | 0,00% | 0,00% | 0,00% | 0,00% |
| 22 | 0,00% | 0,00% | 0,00% | 0,00% | 0,00% | 0,00% | 0,00% | 0,00% | 0,01% | 0,01% | 0,00% | 0,00% | 0,00% | 0,00% | 0,00% | 0,00% | 0,01% | 0,06% | 0,00% | 0,00% | 0,00% | 0,00% | 0,00% | 0,00% |
| 23 | 0,00% | 0,00% | 0,00% | 0,00% | 0,00% | 0,00% | 0,00% | 0,00% | 0,01% | 0,00% | 0,00% | 0,00% | 0,01% | 0,00% | 0,00% | 0,00% | 0,00% | 0,00% | 0,00% | 0,00% | 0,00% | 0,00% | 0,00% | 0,00% |
| 24 | 0,00% | 0,00% | 0,00% | 0,00% | 0,01% | 0,43% | 0,00% | 0,00% | 67,26% | 0,00% | 0,00% | 0,00% | 0,00% | 0,00% | 0,00% | 0,00% | 0,00% | 0,00% | 0,00% | 0,00% | 0,02% | 0,00% | 0,02% | 0,01% |
| 25 | 0,02% | 0,02% | 0,00% | 0,00% | 0,01% | 0,43% | 0,02% | 0,00% | 67,26% | 0,00% | 0,00% | 0,00% | 0,04% | 0,00% | 0,00% | 0,05% | 0,01% | 0,06% | 0,00% | 0,00% | 0,61% | 0,18% | 0,07% | 0,01% |
| 26 | 0,00% | 0,00% | 0,00% | 0,00% | 0,00% | 0,00% | 0,00% | 0,00% | 0,00% | 0,00% | 0,00% | 0,00% | 0,00% | 0,00% | 0,00% | 0,00% | 0,00% | 0,00% | 0,00% | 0,00% | 0,00% | 0,00% | 0,00% | 0,00% |

**Table 5.2 – Proportion of Renewable Energy Use in relation to Gross Value of Production at sectoral level for 1996 and 2016**