9th International Scientific Conference ERAZ 2023 – Selected Papers
DOI: https://doi.org/10.31410/ERAZ.S.P.2023.23

Interregional Analysis of Energy Consumption and Sustainable Development in Morocco

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Received: August 30, 2023
Revised: January 19, 2024
Accepted: January 22, 2024
Published: March 16, 2024

Keywords:
Energy consumption;
Renewable energy;
Energy efficiency;
Input-output model

Abstract: *This article presents a multi-regional assessment of energy consumption optimization in Morocco using an inter-regional input-output model in 2019. It aims to present a theoretical analysis of energy optimization and sustainable development models. The study results reveal that different regions of Morocco face distinct challenges in energy consumption and that certain sectors such as oil refining and energy products, electricity and water, as well as transportation, have the highest energy consumption multipliers, suggesting that investment in renewable energy sources and energy efficiency initiatives are essential to reducing energy consumption in the long term and helping Morocco to achieve its energy efficiency objectives.*

1. INTRODUCTION

Morocco has committed to a long-term goal of reducing greenhouse gas emissions in the energy sector by 45.5% by 2030 as part of its effort to create an environmentally friendly economy (Fragkos, 2023). To achieve this, the country is focusing on increasing efficiency measures and adopting clean technologies, particularly in the electricity and water sectors. As Morocco aims to ultimately achieve a zero-emission economy, it is crucial to consider the potential implications of new energy scenarios. In addition to environmental benefits, such scenarios could also stimulate economic growth and job creation (Boulakhbar et al., 2020).

To gain a comprehensive understanding of future energy consumption trends in Morocco and assess the social, economic, and environmental impacts of the electricity sector, a multi-sectoral and multi-regional assessment using quantitative tools is necessary (Dettner & Blohm, 2021). This assessment should utilize input-output analysis and connect bottom-up and top-down models to link energy system models with macroeconomic models. By doing so, a feedback effect between energy cost and energy service needs can be included in the analysis (Rocco et al., 2018).

This article aims to present the theoretical framework and findings of a multisectoral and multiregional evaluation of energy consumption optimization in Morocco. The first step is to define the interregional input-output model and explain why this methodology was chosen. Then, the structural indicators to be used in the assessment will be introduced. The ultimate goal is to provide a comprehensive theoretical analysis of energy optimization models and the sustainable development of Moroccan energy resources. The decision to adopt a multisectoral and multiregional approach to evaluate energy consumption optimization in Morocco using this model is

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largely motivated by previous studies that have integrated energy system models with macroeconomics to achieve optimal energy consumption and balance energy cost and demand.

The Ministry of Economy and Finance and Policy Center for the New South's 2020 report titled "Structural analysis of short-term economic scenarios for Morocco: a multi-sectoral and multi-regional approach" serves as the primary justification for using the interregional input-output model methodology to analyze energy consumption and its impact on the Moroccan economy. This report provides reliable information and methodological approaches on the potential short-term effects of different financing plans aimed at mitigating the consequences of the COVID-19 crisis in terms of economic growth, job creation, inclusion, and long-term sustainability at the regional level (Mohammed et al., 2022).

In addition to this report, several studies published in indexed journals support the rationale for this methodology and highlight its advantages and disadvantages, as well as the results of the ensuing discussion. Moreover, the justification for this methodology is strengthened by referring to various studies published in indexed journals from different countries. These studies highlight the significance of adopting this methodology and bring to light its advantages, disadvantages, and the outcomes of the ensuing discussions.

Furthermore, Bekhet et al. (2016) conducted a study on the energy consumption and performance of Malaysia's manufacturing sectors during the 2008-2009 global financial crisis using the output multiplier approach based on the input-output model. They used two Malaysian input-output tables from 2005 and 2010 and found significant changes in the output multipliers of the manufacturing sectors between these two years. The energy and manufacturing sectors' output multipliers experienced a decline during the global financial crisis due to the export-oriented industries' downturn during that period. They concluded that good planning in the manufacturing sector is crucial to reducing the high dependence on imports, skilled labor shortages, lack of competitiveness, and limited indigenous technological capacities, which have contributed to the decline in energy consumption. This study highlights the importance of using the input-output model to analyze energy consumption and sectoral performance during economic crises (Bekhet et al., 2016).

Otherwise, Wen et al. (2020) conducted a study on the energy efficiency of China's construction industry at the provincial level. They used a combination of a multi-regional input-output model and data envelopment analysis. The results of the study indicate that the majority of provincial building sectors are energy inefficient, and the level of regional economic development is strongly associated with energy efficiency performance. While the scale efficiency in the regional construction sectors is relatively high, the technical aspects are insufficient. The study also reveals that interregional energy allocation is more efficient than the energy structure. The authors attribute the inefficient use of dirty and clean energy to the lack of instruments that facilitate clean production processes in the construction industry. To tackle these issues, the authors propose several government measures and market-oriented strategies from institutional, technical, and managerial perspectives.

To conclude, the article is organized as follows: Section 2 introduces the interregional input-output model. Section 3 gives an overview of the data used. Section 4 presents the findings of the evaluation, and Section 5 discusses the conclusions and potential directions for future research.

2. THE INTERREGIONAL INPUT-OUTPUT MODEL

The origin of input-output analysis can be traced back to the early 20th century when Wassily Leontief made significant contributions to the field (Leontief, 1936). Today, the input-output model is widely recognized as one of the most important methodological tools for economic analysis, and its applications have expanded to various fields (Towa et al., 2020).

TES serves as the foundation for more complex models like the Social Accounting Matrix (SAM), which incorporates information on economic agents, creating multipliers and developing macroeconomic models (Feto et al., 2023). SAM is also essential for Computable General Equilibrium (CGE) models, which evaluate interdependencies between sectors and the behavior of different economic agents to assess alternative scenarios arising from shocks affecting an economy (Kimuli et al., 2022).

The input-output methodology draws from several sources such as economic censuses, household income, and expenditure surveys (Wang et al., 2023). However, the national accounts of each country remain the primary source of information from which three tables are generated: the supply table, the use table, and the symmetrical tables, which include the TES. The TES is a two-way matrix providing the composition of the gross value of production in terms of expenses and revenues. It comprises the intermediate input matrix (Z), the final demand matrix (y), and the value-added matrix (VA) (Haddad & Hewings, 2004).

Moreover, the interregional input-output model relies on an interregional input-output table for 2019 divided into 12 regions and 20 branches of activity. This model is calibrated to calculate several regional and sectorial structural indicators, enabling a better understanding of the impact of optimizing energy consumption on economic competitiveness and sustainable development in Morocco under the National Energy Strategy prioritizing efficiency. The indicators will aid decision-makers in assessing the multiple effects of energy strategies and identifying various scenarios to guide energy policy orientation.

The conventional form of the input-output model, as described by Miller and Blair (2009) is presented below:

$$\mathbf{x} = \mathbf{Ax} + \mathbf{f} \tag{1}$$

And

$$\mathbf{X} = (1-\mathbf{A})^{-1}\mathbf{f} = \mathbf{BF} \tag{2}$$

where $\mathbf{x}$ and $\mathbf{f}$ are vectors representing gross output and final demand, respectively. $\mathbf{A}$ is the matrix of technical input-output coefficients, denoted as $\boldsymbol{a}_{ij}$, which is defined as the quantity of product $\boldsymbol{i}$ required per unit of product $\boldsymbol{j}$ (in monetary terms), where $\boldsymbol{i}, \boldsymbol{j} = \boldsymbol{j}, \ldots, \boldsymbol{n}$. The matrix $\mathbf{B}$ is the inverse of the Leontief matrix.

By using equation (2), we are able to compute the gross production levels required to fulfill specific levels of final demand. Additionally, we can utilize this equation to approximate the impacts of augmenting sectoral gross output on energy consumption. To achieve this, we need to multiply the economy's gross production vector, $\mathbf{x}$, with a diagonal matrix, $\mathbf{V}$, which consists of the specific coefficients related to the particular activity examined, along with the anticipated outcomes.

$$\Delta \mathbf{x} = \mathbf{B}\Delta \mathbf{f} \tag{3}$$

Similarly,

$$\Delta \mathbf{v} = \widehat{\mathbf{V}}\Delta \mathbf{x} = \widehat{\mathbf{V}}\mathbf{B}\Delta \mathbf{f} \tag{4}$$

Or; $\Delta\mathbf{v}$ is a vector of results containing the impacts on alternative dimensions. By taking equations (1) and (2) into account in an inter-regional context with **r** regions, we can express the equation as follows:

$$\mathbf{x} = \begin{bmatrix} \mathbf{x}^1 \\ \vdots \\ \mathbf{x}^R \end{bmatrix}; \mathbf{A} = \begin{bmatrix} \mathbf{A}^{11} & \cdots & \mathbf{A}^{1R} \\ \vdots & \ddots & \vdots \\ \mathbf{A}^{R1} & \cdots & \mathbf{A}^{RR} \end{bmatrix}; \mathbf{f} = \begin{bmatrix} \mathbf{f}^1 \\ \vdots \\ \mathbf{f}^R \end{bmatrix}; \text{ and } \mathbf{B} = \begin{bmatrix} \mathbf{B}^{11} & \cdots & \mathbf{B}^{1R} \\ \vdots & \ddots & \vdots \\ \mathbf{B}^{R1} & \cdots & \mathbf{B}^{RR} \end{bmatrix} \tag{5}$$

and

$$\begin{aligned} \mathbf{x}^1 &= \mathbf{B}^{11}\mathbf{f}^1 + \cdots + \mathbf{B}^{1R^R}R \\ &\vdots \\ \mathbf{x}^R &= \mathbf{B}^{R1}\mathbf{f}^1 + \cdots + \mathbf{B}^{RR}\mathbf{f}^R \end{aligned} \tag{6}$$

By using equation (6), we can estimate how changes in final demand components can affect regional and national production. It is evident from equation (6) that a region's production depends on various factors, including direct injections of funds into the region and injections into other regions, based on the level of interregional integration between different regions of the country.

3. DATA AND METHODOLOGY USED

The figure displayed below illustrates the configuration of the interregional input and output flows database, along with additional sectoral data pertaining to energy consumption at the regional level.

		transformation sectors							final demand					total demand
		11	⋯	rn	⋯	r1	⋯	rn						
transformation sectors	11	$\mathbf{Z}^{11}_{11}$	⋯	$\mathbf{Z}^{11}_{1n}$	⋯	$\mathbf{Z}^{1r}_{11}$	⋯	$\mathbf{Z}^{1r}_{1n}$	$\mathbf{c}^{1\bullet}_1$	$\mathbf{i}^{1\bullet}_1$	$\mathbf{g}^{1\bullet}_1$	$\mathbf{h}^{1\bullet}_1$	$\mathbf{e}^{1\bullet}_1$	x^1_1
	⋮	⋮	⋱	⋮	⋯	⋮	⋱	⋮	⋮	⋮	⋮	⋮	⋮	⋮
	1n	$\mathbf{Z}^{11}_{n1}$	⋯	$\mathbf{Z}^{11}_{nn}$		$\mathbf{Z}^{1r}_{n1}$	⋯	$\mathbf{Z}^{1r}_{nn}$	$\mathbf{c}^{1\bullet}_n$	$\mathbf{i}^{1\bullet}_n$	$\mathbf{g}^{1\bullet}_n$	$\mathbf{h}^{1\bullet}_n$	$\mathbf{e}^{1\bullet}_n$	x^1_n
	⋮		⋮		⋱		⋮		⋮	⋮	⋮	⋮	⋮	⋮
	r1	$\mathbf{Z}^{r1}_{11}$	⋯	$\mathbf{Z}^{r1}_{1n}$		$\mathbf{Z}^{rr}_{11}$	⋯	$\mathbf{Z}^{rr}_{1n}$	$\mathbf{c}^{r\bullet}_1$	$\mathbf{i}^{r\bullet}_1$	$\mathbf{g}^{r\bullet}_1$	$\mathbf{h}^{r\bullet}_1$	$\mathbf{e}^{r\bullet}_1$	x^r_1
	⋮	⋮	⋱	⋮	⋯	⋮	⋱	⋮	⋮	⋮	⋮	⋮	⋮	⋮
	rn	$\mathbf{Z}^{r1}_{n1}$	⋯	$\mathbf{Z}^{r1}_{nn}$		$\mathbf{Z}^{rr}_{n1}$	⋯	$\mathbf{Z}^{rr}_{nn}$	$\mathbf{c}^{r\bullet}_n$	$\mathbf{i}^{r\bullet}_n$	$\mathbf{g}^{r\bullet}_n$	$\mathbf{h}^{r\bullet}_n$	$\mathbf{e}^{r\bullet}_n$	x^r_n
Import		m^1_1	⋯	m^1_n	⋯	m^r_1	⋯	m^r_n	$m^\bullet_c$	$m^\bullet_i$	$m^\bullet_g$		$m^\bullet_e$	m
indirect tax		t^1_1	⋯	t^1_n	⋯	t^r_1	⋯	t^r_n	$t^\bullet_c$	$t^\bullet_i$	$t^\bullet_g$		$t^\bullet_e$	t
add values		n^1_1	⋯	n^1_n	⋯	n^r_1	⋯	n^r_n						n
total expenses		x^1_1	⋯	x^1_n	⋯	x^r_1	⋯	x^r_n	c	i	g	h	e	
employment	1	L^1_{11}	⋯	L^1_{1n}	⋯	L^r_{11}	⋯	L^r_{1n}						L_1
	⋮		⋮		⋯		⋮							⋮
	q	L^1_{q1}	⋯	L^1_{qn}	⋯	L^r_{q1}	⋯	L^r_{qn}						L_q
energy consumption		$ENRG^1_{q1}$	⋯	$ENRG^1_{qn}$	⋯	$ENRG^r_{q1}$	⋯	$ENRG^r_{qn}$						$ENRG$

Figure 1. The configuration of the interregional input and output flows database

Source: Own research

- z^{rs}_{ij}, with $i, j = 1, \dots, n$ and $r, s = 1, \dots, r$ denotes inter-industry sales from industry i of region r to industry j in region s;
- m^{s}_{i} and t^{s}_{i} with $i = 1, \dots, n, c, i. g, h, e$ represent, respectively, imports and indirect taxes paid in region s;
- n^{s}_{j}, with $j = 1, \dots, n$ and $s = 1, \dots, r$ denotes payments made by sectors for all value-added items in region s;
- $c^{r}_{i}, i^{r}_{i}, g^{r}_{i}, h^{r}_{i}\, e^{r}_{i}$ and $i = 1, \dots, n$ and $r = 1, \dots, r$ denote regional components of final demand, f^{r}_{i} household purchases, investment purchases, government purchases, non-profit institution purchases serving households and exports from region s;
- x^{r}_{i}, with $i = 1, \dots, n$ and and $r = 1, \dots, r$ is the total sectoral output of region r; L^{s}_{ij} with $i = 1, \dots, q$ and $j = 1, \dots, n$ and $s = 1, \dots, r$ represents the total number of workers per sector in region s;
- $ENRG^{s}_{i}$ with $i = 1, \dots, n$ and $s = 1, \dots, r$ represents the total energy consumption by sector i in region s.

To estimate the environmental impacts of the Moroccan economy, we utilize sector coefficients sourced from the Eora database (Lenzen et al., 2013). These coefficients are instrumental in calculating the energy consumption multiplier. With the aid of this database, we can obtain a comprehensive breakdown of energy consumption across various industrial sectors at the national level, specifically for the year 2019.

4. RESULTS

Energy intensity refers to the proportion between the energy consumed by various sectors (Energy consumption) and the production of input-output tables (Value added) (Zhang et al., 2022).

The figure depicted below exhibits the energy consumption intensity coefficient (TJ/GB in GHS million) across different sectors. The majority of the sectors exhibit either zero or insignificant energy consumption intensity coefficients. However, there is one noteworthy exception - the petroleum refining and energy products sector, which possesses an intensity coefficient of 5.27. This finding implies that this sector consumes significantly more energy in comparison to other sectors. Consequently, this sector must adopt a more efficient and sustainable approach towards energy consumption.

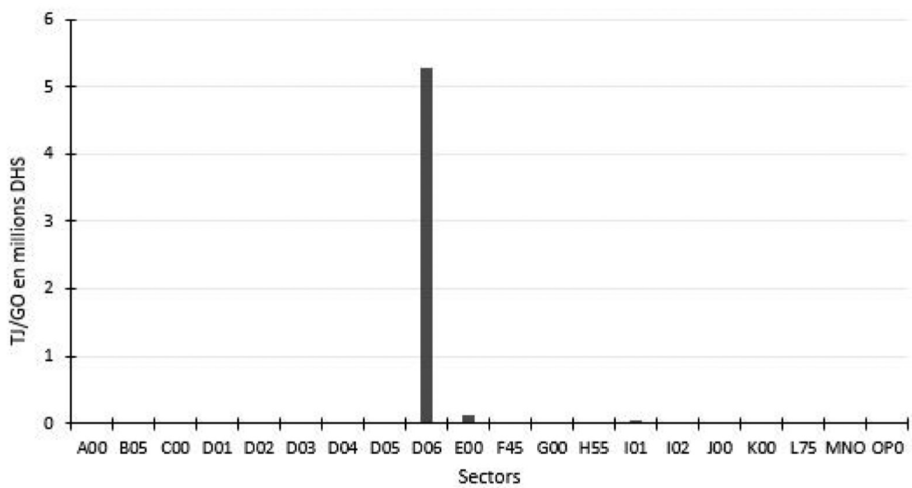

Figure 2. The intensity coefficient of energy consumption by sector in Morocco

Source: Own calculations

For every sector (*j*) in a specific region (*r*), an energy consumption multiplier is established. This multiplier is determined by the combined value of energy consumption across all sectors and regions that are necessary to fulfill a final demand of one dirham in the production of sector j (Yu et al., 2010). Furthermore, the multiplier effect can be separated into two distinct components: intra-regional (internal multiplier) and inter-regional (external multiplier) effects. The internal multiplier represents the product impacts of the sectors in the region where the change in final demand has been initiated, while the external multiplier demonstrates the effects on other regions within the system (inter-regional ripple effects) (White et al., 2018).

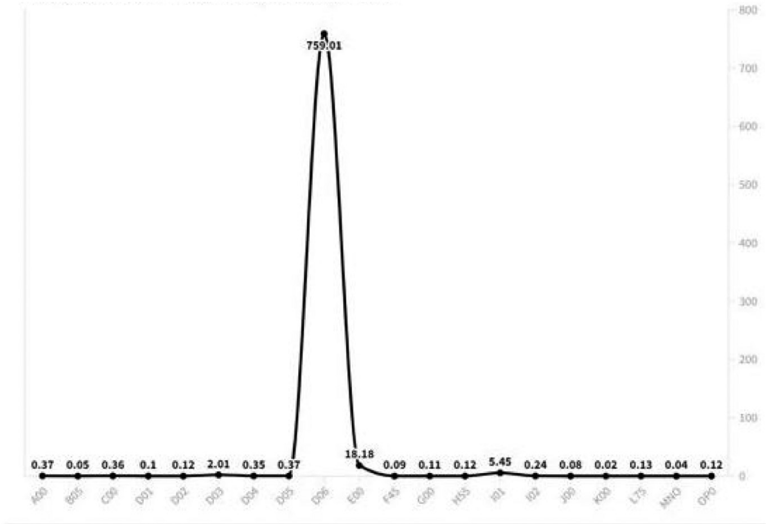

Figure 3. Energy consumption multiplier in 2019 by sector
Source: Own calculations

Regarding the energy consumption levels of each sector in 2019, the aforementioned figure indicates that sectors D06 (oil refining and other energy products), E00 (Electricity and water), and I01 (transport) possess the highest energy consumption multipliers, which are 759.01, 18.18, and 5.44 TJ/GB in millions DHS, respectively. This finding highlights that these sectors are significantly energy-intensive. Conversely, sectors MNO, K00, F45, and B05 exhibit the lowest energy consumption multipliers, which are 0.04, 0.09, and 0.05 TJ/GB in millions DHS, respectively. This signifies that these sectors are comparatively more energy-efficient in Morocco.

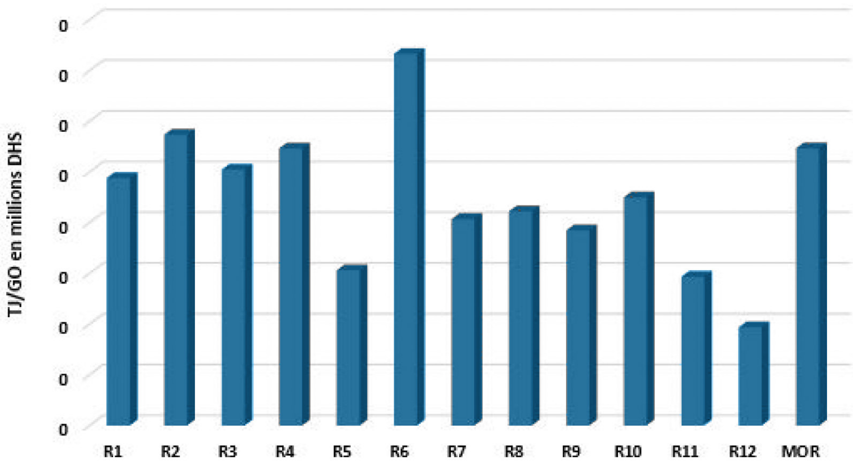

Figure 4. Average energy consumption multiplier by region in 2019
Source: Own calculations

Regarding the regional distribution of the average energy consumption multipliers in 2019 in Morocco, it is evident that these multipliers differ significantly from one region to another. The Grand Casablanca-Settat region holds the highest average multiplier of 0.15 TJ/GB in million DHS, followed by the Oriental region with 0.11 TJ/GB in million DHS. Conversely, the Dakhla-Oued Eddahab region records the lowest average multiplier at 0.04 TJ/GB in millions DHS. This discrepancy in the average energy consumption multipliers across regions highlights the economic inequality that exists between various regions of Morocco. Regions with the highest average multipliers are typically the most industrialized and appealing, while regions with the lowest average multipliers are usually the least industrialized.

The analysis of intra-regional and inter-regional shares is crucial in formulating a rational policy to optimize energy consumption, and examine regional differences, spatial patterns, and dynamic evolution of energy consumption intensity (Hong et al., 2019). This analysis is significant in identifying areas where policy interventions can enhance energy efficiency and reduce energy consumption. It also provides insight into the structural changes, energy and emissions flow within and between regions, enabling intra-regional and inter-regional collaboration to improve energy efficiency (Nejati & Shah, 2023).

To illustrate, the following figure displays the intra-regional and inter-regional shares of the average energy consumption multipliers across 20 sectors in the 12 regions of Morocco. The shares are expressed as percentages, providing an overview of the level of dependence between regions.

Figure 5. The intra-regional and inter-regional shares of average energy consumption multipliers in 2019

Source: Own calculations

The two energy-consuming sectors are "oil refining and other energy products" and "electricity and water." Furthermore, some regions have a higher interregional distribution, meaning that these regions need more energy consumption than others, perhaps energy audits, energy efficiency labels, and energy standardization will solve this problem due to differences in economic, technological, demographic, and climatic systems. Alongside these energy efficiency measures, investments in renewable energy such as solar, wind, geothermal, and hydropower are essential to reduce energy consumption in the long term and help Morocco achieve its energy efficiency target.

In summary, the research conducted in this study reveals energy consumption patterns in various Moroccan regions and sectors, providing valuable information for the development of energy efficiency strategies. The study shows that various Moroccan regions face specific challenges in energy consumption and that local authorities can benefit from a well-designed energy advisory program to improve the level of security. Ultimately, this increases per capita access to energy and can contribute to sustainable economic and social development by ensuring energy security and sustainability.

The above data demonstrates the significance of conducting a comprehensive multi-sectorial assessment to optimize energy consumption in Morocco. The analysis of the energy consumption multipliers across different sectors reveals substantial variations. This information can be leveraged to identify potential opportunities to enhance energy efficiency, reduce pollution, and promote sustainable economic growth and development at both national and regional levels. To achieve this, an action plan tailored to each sector can be formulated and implemented, which would help in reducing energy consumption and achieving a more favorable environmental balance. To further examine the multipliers, we will now delve into the structural decomposition analysis (SDA), which helps identify the influence of external factors such as technology, demand, and demographic changes on variations in total energy consumption. This analysis involves both SDA and index decomposition analysis (IDA). The SDA method is particularly useful for estimating the impact of factors based on input-output tables, especially consumption coefficient matrices, and it has been found to offer more advantages than IDA (Zhu et al., 2022).

The figures below show the distribution of energy sources by sector and region in Morocco in 2019. The graph reveals that the main sources of energy are households, exports, investments and the government at 67%. Exports are the second largest, accounting for 28% and 33% of total energy consumption respectively. The latter contribution comes marginally from investment and government, contributing 2% and 5% and 1% and 4% respectively.

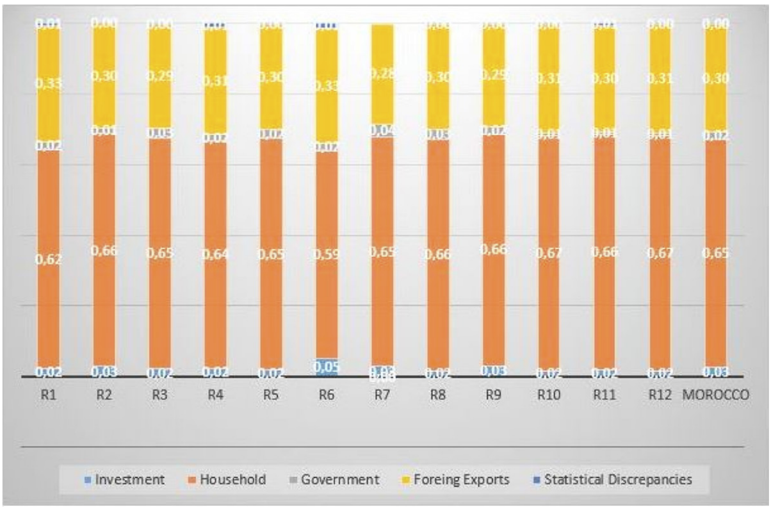

Figure 6. The main sources by sector and by region of energy consumption in Morocco in 2019
Source: Own calculations

On average, households account for 65% of total energy demand in most regions of Morocco, while exports are secondary, contributing on average 30% of total needs, while investments represent only 3% of total energy demand. These findings highlight the need for active measures, particularly in households, to reduce energy consumption through the adoption of energy-saving technologies and environmentally friendly practices. Energy consumption implementing efficiency measures and encouraging users to invest in environmentally friendly technologies can be costly. Additionally, investments in renewable energy and energy-efficient technologies can help reduce energy consumption and greenhouse gas emissions.

5. CONCLUSION

The article analyzes the importance of thinking about the capacity implications of the latest eventualities of new energy scenarios while Morocco ultimately aims to achieve a zero-emission economy. To benefit from comprehensive expertise on future energy supply trends in Morocco and assess the social, economic and environmental impacts of energy consumption, a multi-sector and multi-regional assessment using quantitative tools is necessary. In addition, the article presented the theoretical framework and results of a multi-sector and multi-regional evaluation of the optimization of energy consumption in Morocco.

The initial step involved defining the interregional input-output model and explaining the rationale behind choosing this methodology. Following that, the structural indicators used in the assessment were introduced. The ultimate objective was to offer a comprehensive theoretical analysis of energy optimization and sustainable development models for Moroccan energy resources. Furthermore, the article highlights investment in renewable energy sources such as solar, wind, geothermal, and hydroelectric power, as well as energy efficiency initiatives such as energy audits and energy labels. Energy efficiency and energy standards are essential to reduce energy consumption in the long term and help Morocco achieve its goals. Finally, the analysis carried out in this study highlights the level of energy consumption in various regions and sectors of Morocco, providing information for developing energy consumption optimization strategies.

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