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Circular economy and input–output impacts of phasing out the coal sector in Muğla, Türkiye: a regional just transition perspective

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This study evaluates the economic and environmental implications of phasing out the coal sector and discontinuing subsidies for both coal mines and coal-fired power plants in Muğla, Türkiye, with a focus on key metrics such as output, value-added, employment, and greenhouse gas (GHG) emissions. The analysis proceeds in two distinct phases. Initially, it explores the direct effects of removing investment incentives for coal mining and capacity payments to thermal power plants within the electricity market capacity mechanism on regional economic indicators and environmental outcomes. Subsequently, it examines three alternative scenarios wherein these subsidies are used as a just transition fund and redirected towards greener energy technologies, investments in the circular economy within selected industries, and lower-carbon sectors in the regional context. This two-pronged approach facilitates a comparative evaluation of the costs and benefits of subsidy reform from the perspective of a just transition. The findings aim to guide regional development strategies that balance economic growth with climate mitigation objectives. By elucidating the distributional and environmental trade-offs associated with coal subsidy removal and the reallocation of funds towards sustainable investments, the study provides valuable insights for designing policies that support equitable decarbonization and promote circular economies at the local level.

KEYWORDS
circular economy, coal subsidies, GHG emissions, green energy technologies, just transition, regional input–output analysis

1 Introduction

Türkiye's coal economy remains structurally embedded in the national energy system, sustained through a range of public subsidies that reinforce carbon-intensive production and hinder low-carbon transformation. As documented in Kızılkaya and Acar (2026), national greenhouse gas emissions increase from about 460 million tonnes CO_2-eq in 2014 to over 558 million tonnes in 2022, while coal-based activities account for a disproportionate share of this growth. Coal-fired electricity generation alone emits nearly 50 million tonnes of CO_2-eq annually, and coal mining contributes an additional 5 million tonnes. Despite this substantial environmental burden, the coal economy creates only limited economic value: coal and lignite mining generate just 0.11% of GDP, and their contribution to national employment steadily

declines—from more than 50,000 workers in 2009 to below 40,000 in 2022 (Kızılkaya and Acar, 2025). Employment in coal-fired power generation shows similar patterns; using EUROSTAT (2025) employment data and electricity production shares from the Turkish Electricity Transmission Corporation (TETC, 2023), approximately 44,916 workers are estimated to be employed in coal-based generation in 2022, representing only a modest share of total energy-sector jobs.

This imbalance between high emissions and low socio-economic returns is further reinforced by Türkiye's coal-supporting fiscal architecture. Coal benefits from tax exemptions, investment incentives, social security contribution reductions, and public guarantees that collectively sustain the sector's competitiveness despite its declining economic relevance. Among these instruments, two mechanisms stand out due to their traceability and suitability for economy-wide modelling: investment incentives for coal and lignite mining and capacity mechanism payments for coal-fired power plants. Although these subsidies constitute only a marginal share of GDP—around 0.01% for investment incentives and 0.005% for capacity mechanism payments (Kızılkaya and Acar, 2025)—their allocation is highly concentrated in emissions-intensive sectors. Recent evidence from Durmaz et al. (2024) shows that capacity mechanism transfers increasingly flow to fossil-based plants, with limited systemic economic impact and weak value-added multipliers.

These patterns create two mutually reinforcing lock-in effects. First, public transfers reduce the relative cost of coal production and electricity generation, delaying the adoption of cleaner technologies and slowing alignment with national climate targets (Bridle and Kitson, 2014; Matallah et al., 2023; de Bruin and Yakut, 2023; Li et al., 2024; Droste et al., 2024; Chavda and Mehta, 2025). Second, subsidies embed local labour markets and income structures in sectors that exhibit declining employment and low value-added creation, increasing the transition vulnerability of coal-dependent regions (Unruh, 2000; Coady et al., 2015; Carley et al., 2018a; International Energy Agency, 2022). Muğla exemplifies this challenge: its three coal-fired power plants and associated mining operations remain major emitters but provide diminishing regional employment and limited economic diversification opportunities.

More importantly, coal-related subsidies distort the regional economic structure by artificially sustaining demand for shrinking, low-productivity, and carbon-intensive activities, thereby diverting resources away from more dynamic and sustainable sectors. This subsidy-induced misallocation suppresses the emergence of alternative industries and inhibits the region's capacity to diversify, modernize, and transition toward lower-carbon development pathways. Recent research on regional vulnerabilities underscores how coal-intensive provinces like Muğla are disproportionately exposed to just-transition risks. The study by Kızılkaya and Aksoy (2025) assesses social vulnerability across coal-dependent provinces and finds that those relying heavily on mining and coal-fired electricity generation face substantial economic and labour market risks in the event of a coal exit. Drawing on the evidence presented in Kızılkaya and Acar (2025), this study treats coal-related subsidies not simply as fiscal transfers but as institutional mechanisms that perpetuate carbon lock-in. By modelling the elimination of final demand for coal mining and coal-fired electricity and reallocating the resulting demand gap through alternative investment pathways, the analysis evaluates how these subsidies shape regional economic structure—and how their removal may create space for a just and sustainable transition in Muğla.

These structural distortions create a direct and mutually reinforcing link between the coal economy, environmental outcomes, and socioeconomic vulnerability. By maintaining a regional production system centred on coal mining and coal-fired electricity generation, Muğla remains tied to some of the most carbon-intensive activities in Türkiye (CAN Europe, 2019). This dependence sustains high levels of GHG emissions and delays the emergence of cleaner and more productive sectors. At the same time, the coal economy anchors local labor markets to activities with declining employment capacity and limited value-added creation, thereby increasing the vulnerability of workers and households once a transition becomes unavoidable. In this configuration, the coal economy simultaneously intensifies environmental risk—through continued reliance on high-emission production—and exacerbates socioeconomic risk—by tying regional livelihoods to sectors that offer diminishing long-term resilience. Empirical evidence aligns with this dual mechanism. Kızılkaya and Aksoy (2025) show that coal-intensive provinces in Türkiye exhibit systematically higher vulnerability to transition shocks precisely because their economic structures are concentrated in coal-related sectors with shrinking labor demand and weak economic multipliers. This concentration of activity in coal-based value chains amplifies both climate-related and socioeconomic exposure, particularly in regions such as Muğla where coal-fired electricity and lignite mining define local production networks. As a result, the coal economy does not merely shape sectoral outcomes; it defines the entire risk profile of the region, reinforcing carbon lock-in while magnifying the social and economic costs associated with a future coal phase-out.

Despite a growing body of research on fossil fuel subsidy (FFS) reform and energy transition in Türkiye (see, for instance, Dilli and Nyman, 2015; Acar and Yeldan, 2016; Acar et al., 2018; Aşıcı, 2026), several important gaps remain. First, regional and subnational input–output evaluations of coal phase-out are notably scarce. National-level assessments provide useful insights, but they overlook the spatially uneven nature of economic linkages, labour markets, and emission patterns—factors that are especially pronounced in coal-dependent provinces such as Muğla. Second, there is limited empirical evidence on the role of circular economy investments as instruments of a just transition. While circular economy strategies are increasingly promoted in policy discourse, their capacity to absorb labour, stimulate local value creation, and offset the contraction of high-carbon sectors is not well understood in regional contexts. Third, literature lacks comparative scenario analyses that examine alternative transition pathways for coal-intensive regions. Existing studies tend to model single interventions or national aggregates, leaving unanswered how different reinvestment strategies—such as circular economy investments, green industrial upgrading, or sectoral diversification—perform relative to one another when the coal economy contracts (Dilli and Nyman, 2015; Acar et al., 2023; Kat et al., 2024). The present study advances this literature along several key dimensions. It aims to move beyond national aggregates and enabling a granular, subnational analysis of coal phase-out impacts. Besides, it envisions a comparative reallocation of coal subsidies across multiple reinvestment pathways, including circular economy activities, green energy supply chains, and sectoral diversification into agriculture-tourism and food processing. In doing so, it addresses a key gap in the literature, which has largely overlooked the relative performance of alternative transition strategies.

The main purpose of the current study is to address these gaps by providing the first regional input–output model for Muğla updated to the year 2022, enabling a detailed examination of coal phase-out

impacts within a subnational economic structure. The analysis proceeds in two stages. First, it models the complete elimination of final demand for coal mining and coal-fired electricity, reflecting a full regional coal exit. Second, it reallocates the resulting demand loss to alternative sectors through three reinvestment pathways—circular economy activities, food processing, and ties, green energy supply chains, and agriculture-tourism sectors—allowing for a comparative assessment of transition strategies. By integrating output, value-added, employment, and GHG emissions into a unified framework, the study offers a comprehensive evaluation of the economic and environmental consequences of coal phase-out. Moreover, by interpreting the findings through a just-transition lens that highlights distributional implications and regional vulnerability, the study contributes new evidence to ongoing debates on how coal-dependent provinces can navigate structural change in a socially equitable and environmentally consistent manner.

The remainder of the paper is structured as follows. Section 2 presents the regional economic context of Muğla and describes the necessary data to construct the 2022 regional input–output table and associated satellite accounts. Section 3 outlines the methodological approach, including the coal phase-out scenario and the three alternative reinvestment pathways. Section 4 reports the empirical results for output, value-added, employment, and emissions across all scenarios. Section 5 discusses the findings in light of regional vulnerability and just-transition considerations, summarizes the policy implications, and concludes.

2 Regional context and data

2.1 Regional context

Muğla displays a regionally distinctive economic structure shaped by the coexistence of carbon-intensive energy activities and environmentally sensitive service sectors. This dual configuration is analytically important for just transition research because it implies that a coal phase-out may generate multi-dimensional impacts—spanning employment, sectoral demand linkages, and local development trajectories—rather than a narrowly defined "energy-sector" adjustment. In the Turkish context, where transition risks are unevenly distributed across space, coal-intensive provinces tend to face heightened vulnerability profiles that reflect not only exposure to coal-related activities but also sensitivity and adaptive capacity constraints. This pattern is documented in Kızılkaya and Aksoy (2025), who identify Muğla as one of the coal-intensive provinces exhibiting relatively high vulnerability during the coal phase-out process. Their findings indicate that Muğla's vulnerability is closely linked to the province's strong reliance on coal-fired electricity generation, which translates into elevated exposure within the just transition framework. This evidence underscores that Muğla's transition challenge is not merely sector-specific but structurally embedded, reinforcing the need for place-based transition strategies rather than uniform national prescriptions.

From the standpoint of production structure, Muğla exhibits a diversified regional economy in terms of gross domestic product (GDP), with a pronounced dominance of service-related activities alongside agriculture and selected industrial branches. Sectoral GDP figures for 2022 indicate that trade, transportation, accommodation, and food services constitute the single largest component of provincial GDP, accounting for approximately 13% of total output. This reflects the central role of tourism and tourism-related services in shaping Muğla's economic base. Agriculture, forestry, and fishing represent another significant pillar of the provincial economy, contributing roughly 7 percent of total GDP. This share is notably higher than in many industrialized provinces, underscoring the continued importance of primary activities and land-based livelihoods in the region. Manufacturing and construction activities contribute more modest shares—each in the range of 3–4 percent—while real estate, professional services, and public administration together account for a substantial portion of overall economic activity (TURKSTAT, 2023). Taken together, these sectoral patterns point to a formally diversified GDP structure, spanning both service-oriented and goods-producing sectors. Yet diversification at the aggregate level does not necessarily imply resilience at the local level: coal-related activities are geographically concentrated and have historically shaped local labor markets and supplier networks, generating transition-relevant dependencies that are likely to be felt most strongly in coal-adjacent districts. Consistent with the broader vulnerability evidence for coal-intensive provinces in Türkiye, Muğla's transition risk should therefore be interpreted as a function of both coal exposure and the province's capacity to absorb structural change through alternative sectoral engines and institutional support mechanisms (Kızılkaya and Aksoy, 2025).

The sectoral composition of employment in Muğla broadly mirrors its GDP structure, but with important distributional implications. Recent labor market indicators show that services employ more than half of the provincial workforce, while agriculture and industry each account for roughly one-fifth of total employment (Social Security Institution, 2023). This pattern highlights the labor-intensive nature of service activities—particularly tourism, accommodation, and related services—relative to their contribution to provincial GDP. The coexistence of service-dominated employment with a sizeable agricultural workforce suggests that household livelihoods in Muğla are often tied to sectors characterized by seasonal demand, income volatility, and limited employment security.

Within the province's industrial structure, lignite mining and coal-fired thermal power generation occupy a structurally embedded position. Muğla hosts major lignite-based generation assets—commonly discussed in the academic and technical literature together as the Yatağan, Kemerköy, and Yeniköy power plants—which have long been central to the regional coal supply chain and are associated with substantial environmental and social externalities (CAN Europe, 2019). According to administrative records, 1,548 workers are employed directly in lignite mining activities in Muğla, while employment in the province's three coal-fired thermal power plants is estimated at approximately 4,141 workers, based on a compilation of plant-level information from multiple sources (Social Security Institution, 2023).

From a regional production-system perspective, the economic significance of these activities extends beyond their direct contribution to output and employment. Coal mining and coal-based electricity generation generate sustained intermediate input demand—including transportation, maintenance services, engineering activities, and auxiliary business services—and support localized purchasing streams that link energy production to a wider set of regional sectors. As a result, potential adjustments in coal-related activities are likely to propagate through Muğla's economy via indirect and induced channels, rather than remaining confined to the energy sector alone. This type of intersectoral propagation channel is

well-established in the regional impact literature and constitutes a primary motivation for adopting an input–output accounting framework in this study (Carley et al., 2018b; McDowall et al., 2023).

Coal remains a central element of Turkey's energy policy due to its perceived contribution to energy security, regional employment, and development objectives in lignite-rich provinces. This role has been sustained through a broad set of public support instruments embedded in industrial and regional development policies, including tax exemptions, investment incentives, and capacity-related transfers (Acar and Yeldan, 2016). Within this framework, the present study focuses on two coal-related mechanisms—investment incentives for coal mining and capacity mechanism payments for coal-fired electricity generation—not because they represent the largest fiscal transfers, but because they are identifiable, quantifiable, and traceable in official records, making them suitable for integration into an input–output framework. In quantitative terms, coal-related investment incentives amount to approximately TRY 1.55 billion (USD 93.4 million) annually at the national level, while capacity mechanism payments directed to coal-fired power plants reach TRY 709 million (USD 42.7 million). Together, these instruments correspond to roughly 0.015% of Türkiye's GDP, yet they are spatially and sectorally concentrated. Muğla accounts for approximately 54% of coal-related investment incentives and 29% of capacity mechanism payments for three coal-fired power plants, reflecting the province's prominence in lignite-based electricity generation. Crucially, these instruments provide a concrete fiscal basis for constructing a stylized just transition fund in which existing coal-related public resources—amounting approximately to TRY 1.55 billion (USD 93.4 million) in the case of Muğla—are reallocated rather than treated as marginal expenditures.

At the same time, Muğla is not a single-track coal economy. The province is situated within a national renewable expansion context in which wind, solar, and geothermal resources have become increasingly relevant for decarbonization pathways. Türkiye-wide spatial assessments emphasize that renewable potential is distributed heterogeneously across regions and can support differentiated regional transition strategies (Güngör-Demirci, 2015). For Muğla, this implies that transition planning can be framed not only as a contraction of coal-related activity but also as an opportunity for reallocation toward cleaner and potentially more labor-intensive activities—particularly when combined with circular-economy policies that strengthen local supply chains and resource efficiency. This dual positioning—coal-intensive legacy assets alongside renewable potential—makes Muğla a compelling case for evaluating whether coal phase-out scenarios can be paired with circular reallocation channels to mitigate regional losses while remaining consistent with just transition principles.

2.2 Data

This study is based on an updated input–output (IO) framework for Türkiye, developed to evaluate the economic and environmental implications of coal exit. As the most recent official national IO table published by the Turkish Statistical Institute (TURKSTAT, 2023) corresponds to 2012, the analysis first requires updating the national IO structure to reflect the economy's IO in 202.

The original 2012 TURKSTAT IO and its updated 2022 version were adapted to construct the 2022 Muğla regional IO table through a combination of sectoral disaggregation and aggregation (see Table A1). The construction of the 2022 IO table draws on multiple official data sources and results in a system comprising 68 aggregated sectors. While TURKSTAT's original IO table is organized into 64 sectors, two key sectors—Mining and Quarrying (B) and Electricity, Gas, Steam and Air Conditioning Supply (D35)—are further disaggregated to better represent fossil fuel–related production processes. Specifically, the mining sector is divided into coal mining (including lignite and hard coal) and other mining activities. This split is based on TURKSTAT's 2022 Production Value of Industrial Products statistics, with the share of coal and lignite in total mining production value used as a proxy for coal mining's share within the aggregated IO sector. Applying this approach yields a coal mining share of 0.3480 within total mining and quarrying.

Similarly, the electricity sector is decomposed into five sub-sectors: (i) coal-based electricity generation (hard coal and lignite), (ii) other thermal generation, (iii) hydropower, (iv) renewables (geothermal, wind, and solar), and (v) other renewable sources (waste and heat). This disaggregation relies on 2022 gross electricity generation shares by primary energy source, as reported in the annual statistics of the TETC. Through this procedure, the updated IO table explicitly captures the heterogeneity of electricity generation technologies, which is critical for analyzing coal phase-out scenarios. In parallel, selected service and manufacturing sectors were aggregated to reduce excessive sparsity and to avoid structurally zero or near-zero technical coefficients in the regional transaction matrix (see Table A1). This aggregation strategy ensures numerical stability of the IO system while preserving the analytical relevance of key transition-related sectors.

The updating process covers both final demand accounts (Quadrant I)—including household consumption, government consumption, gross fixed capital formation, and exports—and primary input accounts (Quadrant III)—covering total output, gross value added, compensation of employees, gross operating surplus, and imports. These components are updated using the 2012 TURKSTAT IO table in combination with sectoral and macroeconomic indicators, following established procedures in the literature (Aydoğuş et al., 2021). As detailed information on intermediate input flows for 2022 is not publicly available, Quadrant II is estimated using the RAS algorithm, a widely applied matrix-balancing technique in input–output analysis. This approach ensures internal consistency between row and column totals while preserving the underlying technological structure of the economy. The resulting 2022 IO table thus achieves both macroeconomic coherence and the sectoral resolution required to model the structural consequences of coal subsidy reform in Türkiye.[1]

Beyond economic accounts, the analysis incorporates environmental and labor market dimensions to capture the broader impacts of FFS removal. Sector-specific greenhouse gas (GHG) emissions are derived from EUROSTAT's 2022 emissions dataset, reported in CO_2 equivalents and covering a comprehensive set of gases, including CO_2, CH_4, N_2O, HFCs, PFCs, SF_6, and NF_3. Emissions are classified according to NACE Rev. 2 activity codes, enabling direct alignment with the sectoral structure of the IO table. These data are used to compute direct emission intensities for each sector, which subsequently allow for the estimation of economy-wide emission effects under alternative subsidy removal scenarios.

To assess labor market implications, the study employs sectoral employment data from EUROSTAT's Employment by NACE Rev. 2 activity database for 2022. This dataset reports the number of people

1 The Muğla regional input–output table constructed for 2022 is provided in Supplementary Table S1.

employed by industry, facilitating the calculation of employment coefficients (employment per unit of output) for each sector. These coefficients are combined with the results of the Leontief model—described in detail in the methodology section—to estimate employment changes associated with production restructuring following subsidy reform. Together, the emission and employment coefficients provide the necessary parameters to evaluate not only output and value-chain effects, but also the implications of coal subsidy removal for job creation and greenhouse across the economy.

The regional input–output (IO) table for Muğla is constructed using the updated 2022 national IO table for Türkiye as the benchmark framework. All regional accounts are fully aligned with the sectoral classification and accounting identities of the national system to ensure internal consistency between national and regional estimates. The construction of the 2022 Muğla IO table draws on a combination of official statistical sources, administrative records, and firm-level microdata. Provincial production values are informed by province-level net sales data obtained from the Entrepreneur Information System (EIS), while data on taxes, subsidies, and government expenditures are compiled from budget statistics published by the Ministry of Treasury and Finance. Sectoral gross value added figures are taken from TURKSTAT regional accounts, with labor compensation and operating surplus components derived using firm-level information.

Provincial exports and imports are estimated by combining province-level foreign trade statistics with sectoral trade distributions, while final demand components—including household consumption, government consumption, and investment—are constructed using population statistics, national IO aggregates, and investment incentive data.[2] Building on this regional context and data foundation, the next section details the methodological framework used to construct the updated national and regional input–output tables and to assess the economic and environmental implications of phasing down coal-related activities.

3 Methodology

3.1 Updating the national input–output table

To represent Türkiye's economic structure in 2022, the analysis updates the official 2012 input–output table published by TURKSTAT using a modified RAS balancing procedure. The RAS algorithm is a standard matrix-adjustment technique that updates intersectoral transaction matrices while preserving the underlying production structure embodied in fixed input–output relationships (Wang et al., 2015). In practice, the method iteratively scales the technical coefficient matrix so that intermediate input rows and columns are consistent with target-year totals for sectoral supply and demand.

Following Acar et al. (2022), the updating process begins with a reorganization of the value-added block of the 2012 table. Sectoral value added is decomposed into compensation of employees, net taxes on production, and capital income, allowing total output to be defined as the sum of intermediate inputs and value added. Total supply is correspondingly obtained by adding imports to domestic output.

Base-year technical coefficients are calculated by dividing intermediate input flows by sectoral output levels. This approach assumes constant returns to scale and stable production technologies within each sector, implying fixed input proportions per unit of output (Miller and Blair, 2009). Under these assumptions, the technical coefficient matrix is updated to 2022 through repeated application of the RAS procedure until row and column totals converge to the target values derived from official macroeconomic and sectoral statistics.

To enhance the relevance of the IO framework for energy transition analysis, the original 64-sector classification is expanded to 68 sectors. The Mining and Quarrying sector is disaggregated into coal mining (lignite and hard coal) and other mining activities using TURKSTAT's 2022 *Industrial Product Statistics*. Likewise, the Electricity, Gas, Steam and Air Conditioning Supply sector is decomposed into five generation technologies based on fuel-specific gross electricity generation data reported by TEİAŞ for 2022. In addition, sectors S96 (other personal services) and T (household services) are consolidated into a single category (S96 + T), consistent with common aggregation practices in applied IO modeling.

The updating of primary inputs (Quadrant III) and final demand components (Quadrant I) follows the methodology proposed by Aydoğuş et al. (2021). Sectoral gross output totals are obtained from TURKSTAT's institutional sector accounts and allocated across sectors using a hybrid approach that combines 2012 IO shares with sector-specific growth dynamics observed between 2012 and 2022. For sectors with limited or suppressed data coverage—such as agriculture, public administration, and selected service activities—proportional allocation based on the 2012 structure is applied.

Gross value added is computed by allocating compensation of employees, gross operating surplus, and net taxes on production to sectors using income-based GDP statistics were available, supplemented by proportional scaling when direct matching is not feasible. Intermediate input use is then obtained residually as the difference between gross output and value added, ensuring consistency with aggregate accounting identities. On the final demand side, household consumption, government expenditure, gross fixed capital formation, and exports are sourced from national accounts and distributed across sectors using the 2012 IO structure, with adjustments based on updated investment and trade statistics. Sectoral intermediate demand totals serve as the balancing targets for the RAS procedure applied to the intermediate transaction matrix.

3.2 Construction of the final demand shock vector

Within the input–output framework, an economy consisting of n sectors can be represented as:

$$X = AX + Y$$

where X denotes the vector of gross output, A is the matrix of technical coefficients, and Y represents final demand. Rearranging yields the standard Leontief solution:

$$X = \left(I - A\right)^{-1} Y$$

2 All monetary values are expressed in current 2022 prices and reconciled within the national IO accounting framework.

Final demand Y is defined as the sum of household consumption, fixed capital formation, government expenditure, and exports. Changes in any component of final demand can therefore be translated into sectoral output differences. For instance, the output effects of a contraction in government expenditure (G) are calculated as:

$$\Delta X = \left(I - A\right)^{-1} \Delta G$$

The column sums of the resulting output-change matrix quantify the economy-wide production effects associated with a demand shock originating in a given sector.

3.3 Multiplier calculations

In the final stage, output multipliers are derived from the Leontief inverse and subsequently transformed into value-added, employment, and emission multipliers using sector-specific requirement coefficients. The total (direct and indirect) requirements associated with a change in final demand are expressed as:

$$Z = K\left(I - A\right)^{-1} Y$$

where K is a diagonal matrix of coefficients linking output changes to specific outcome variables. For value added, the diagonal elements of K are defined as the ratio of sectoral value added to gross output. Analogously, employment multipliers are obtained using employment-to-output ratios, while environmental multipliers are constructed using greenhouse gas emissions per unit of output. This formulation allows changes in final demand to be consistently mapped into output, income, employment, and emission effects within a unified analytical framework.

3.4 Regionalization of the national IO table: location quotient approach

To derive the regional input–output structure for Muğla from the national 2022 Türkiye IO table, the study adopts a location quotient (LQ)–based regionalization approach, which is widely used in non-survey regional IO construction when detailed interregional transaction data are unavailable. LQ techniques are particularly suitable for regional IO analysis as they rely on readily accessible regional indicators, such as GDP, employment or establishment data, while preserving the national technological structure (Lahr, 1993; Flegg et al., 1995).

In this study, regional specialization is measured using two complementary indicators: The number of establishments and the number of registered employees, both obtained from the Social Security Institution (SSI) Statistical Yearbooks for 2022. For each sector, LQs are calculated separately for establishments and employment by comparing Muğla's sectoral shares with their national counterparts. To mitigate potential bias arising from reliance on a single indicator, the regional intensity of each sector is represented by the average of establishment-based and employment-based LQ values.

The LQ methodology and its variants are commonly applied in regional IO studies across different national contexts, including Germany (Kowalewksi, 2015), Argentina (Flegg et al., 2016), and Greece (Kolokontes et al., 2008). Despite differences in formulation, most LQ-based estimators rest on the assumption that regional production technologies are, on average, similar to national technologies, with deviations arising from differences in regional specialization and import dependence. Under the standard LQ framework, regional technical coefficients are derived as scaled versions of national coefficients, such that the regional input coefficient a_{ij}^{R} differs from its national counterpart a_{ij}^{N} by a sector-specific location quotient factor:

$$a_{ij}^{R} = lq_{ij}\, a_{ij}^{N}$$

Where subscripts $i$and $j$denote supplying and purchasing sectors, respectively. Here, a_{ij}^{R} represents the amount of input from sector i required to produce one unit of output in sector j at the regional level, while a_{ij}^{N} denotes the corresponding national coefficient.

Based on the computed location quotients, the regional technical coefficient matrix for Muğla is derived by combining establishment-based and employment-based measures of regional specialization. For each sector, the average of the establishment LQ and the registered employment LQ is taken as the representative location quotient. This composite indicator is then used to adjust the national technical coefficients when constructing the regional matrix. Specifically, for sectors in which the averaged LQ value is greater than or equal to one, the corresponding national input coefficients are retained unchanged, reflecting the assumption that regional production can meet intermediate input requirements domestically. For sectors with an average LQ value below one, national technical coefficients are proportionally scaled by the LQ factor to account for weaker regional specialization and a higher reliance on interregional imports. The resulting adjusted coefficients constitute the Muğla-specific technical coefficient matrix, which preserves the national production technology while incorporating region-specific differences in sectoral intensity.

3.5 Scenario architecture overview

The scenario architecture is built around a common coal phase-out and three alternative policy scenarios that accompany the phase-out, all implemented as exogenous final-demand shocks within the regional input–output framework. The coal phase-out represents a situation where final demand for coal mining and coal-fired electricity generation is fully eliminated. To maintain electricity system continuity, the total final demand withdrawn from coal-based activities is reallocated to renewable electricity generation which includes wind, solar, and geothermal energy. This substitution reflects the role of renewables as the primary replacement for coal in meeting regional electricity demand and provides a neutral reference case against which alternative transition strategies can be evaluated.

Beyond this coal phase-out scenario, three policy scenarios are considered, each reflecting a different interpretation of how public resources released through the coal phase-out could be redeployed under a just transition framework. In all three cases, reallocation takes the form of public investment.

The idea of repurposing the money from FFS reform in order to enhance social and economic well-being of the vulnerable groups as well as affected sectors is quite new. Recent assessments by the International Institute for Sustainable Development (IISD) and the World Bank highlight that FFS—particularly those supporting coal—constitute a major structural barrier to coal phase-out while generating significant social, environmental, and fiscal costs (Gass and Echeverria, 2017; Damania et al., 2023). By artificially lowering production and consumption costs, coal subsidies contribute to air pollution, environmental degradation, and regressive distributional outcomes, as benefits tend to accrue disproportionately to

higher-income groups. Recent literature increasingly frames the gradual removal of coal subsidies not only as a climate mitigation measure but also as a fiscal reform capable of creating substantial budgetary space (see, for instance, Coady et al., 2015; Black et al., 2025). For instance, Coady et al. (2015) argue that energy subsidy reforms can yield substantial fiscal savings and efficiency gains, while Damania et al. (2023) assert that reallocating resources freed through subsidy reform into a dedicated just transition fund can play a critical role in managing the socioeconomic impacts of coal exit. Such a fund can support income protection, reskilling and redeployment of workers, regional economic diversification, and environmental remediation, thereby enhancing the political feasibility and social equity of coal phase-out strategies.

Morocco provides a relevant example of how FFS reform can be leveraged as a policy instrument to support a just transition. Initially introduced in the 1930s to protect vulnerable groups and promote domestic industries, FFS gradually became fiscally burdensome. By 2012, FFS expenditures had reached nearly 5% of GDP, highlighting the unsustainability of the existing system and triggering reform efforts (Bousselmame, 2017). In response, Morocco implemented a phased pricing reform beginning in 2012, supported by a comprehensive communication strategy to enhance public acceptance. By 2014, subsidies for gasoline, industrial fuel oil, and fuels used in power generation were largely removed, creating fiscal space that was partially redirected toward renewable energy investments (Acar, 2024). These investments contributed to employment creation and energy diversification, with renewable electricity capacity reaching 34% of total installed power by 2019 (World Resources Institute, 2021). At the same time, the reform process incorporated social protection measures, including increased spending on education, the introduction of a health insurance scheme, and the retention of targeted subsidies for liquefied petroleum gas, basic food items, and electricity to shield low-income and rural households from adverse impacts (IISD, 2020). Similarly, in Indonesia, a portion of the fiscal savings generated by FFS reform was redirected toward infrastructure investment, contributing to economic growth; and toward education, health and poverty reduction, contributing to the just transition of the vulnerable groups in the country (Gass and Echeverria, 2017).

The World Bank Group (2022) Country Climate and Development Report (CCDR) for Türkiye outlines a resilient and net-zero development pathway in which power-sector emissions decline sharply by 2040, even as electricity demand increases. Within this pathway, coal-fired power generation is neither required nor the least-cost option, underscoring the necessity of an early and managed coal phase-out anchored in the gradual removal of coal subsidies. Phasing out coal subsidies is central to enabling a just and sustainable transition. The CCDR highlights that a significant share of coal-fired power plants would need to retire within this decade, requiring advance planning to address impacts on workers, communities, and coal-dependent regions. Costs associated with early plant retirement, mine closures, environmental remediation, and social transfers are substantial; however, these costs can be partly offset by savings from foregone coal subsidies. From a public finance perspective, redirecting resources currently allocated to coal support into a dedicated just transition fund could help finance worker compensation, retraining programs, regional economic diversification, and land reclamation, while simultaneously supporting investments in renewable energy and alternative generation capacity.

Viewed through this lens, coal subsidy reform in Türkiye can function not only as a decarbonization measure but also as a financing mechanism for a just transition. By reallocating coal subsidies toward social and economic transition needs, the coal phase-out can be aligned with equity objectives and long-term development goals, even as coal assets would likely become economically unviable over time regardless of climate policy.

In our models, the first scenario represents a renewable-energy-focused transition strategy. Here, the fiscal resources previously directed to coal through capacity mechanism payments and coal-related investment incentives in Muğla are consolidated into a dedicated "just transition fund". The full amount of TRY 1.55 billion (USD 93.4 million) fund is allocated to renewable energy subsector investment in sector D35. This scenario captures a policy approach in which the coal exit is addressed primarily through accelerated decarbonization of the energy system, without explicit diversification toward non-energy activities.

The second scenario adopts a broader circular economic perspective. In this case, the just transition fund is redirected toward activities that support repair, reuse, waste management, and resource recovery, reflecting the growing policy emphasis on circular economy strategies as complements to decarbonization. Within this scenario, the just transition fund is allocated across circular economy–related activities, with 50% directed to waste management and materials recovery activities (E37–39), and the remaining 50% distributed equally across machinery and equipment installation and repair (C33), repair of computers and personal and household goods (S95), and wholesale, retail, and repair services related to motor vehicles and motorcycles (G45) considering their calculated value added and employment coefficients from Muğla IO table. The sectoral focus is guided by empirical studies demonstrating that circular economy activities exhibit higher labor intensity and stronger local value-chain linkages, making them particularly relevant for employment-centred just transition strategies (Cambridge Econometrics Trinomics and ICF, 2018; Willeghems and Bachus, 2018).

The third scenario adopts a place-based diversification logic tailored to Muğla's regional economic structure. In this scenario, the just transition fund is allocated across agriculture- and tourism-related activities, with 15% assigned to agriculture and hunting (A01), forestry (A02), and fishing and aquaculture (A03), respectively, 40 percent directed to accommodation and food service activities (I), and the remaining 15% allocated to food, beverage, and tobacco manufacturing (C10–C12); sectoral shares are determined based on relative value-added and employment coefficients to reflect both income generation and labor absorption capacity. Beyond their quantitative contribution to value added and employment, these activities constitute core components of Muğla's long-established production systems and livelihood regimes. Regional evidence indicates that agriculture—particularly olive and citrus cultivation, horticulture, greenhouse farming, livestock production, apiculture, fisheries, and related food-processing activities—continues to account for a non-negligible share of provincial value creation and remains closely intertwined with rural settlement patterns and local income generation. Tourism and accommodation services, in turn, function as a central economic engine of the province, supporting a wide range of service activities and reinforcing demand linkages across trade, transport, and food-related manufacturing (CAN Europe, 2019; Muğla Planning Agency, 2025).

Table 1 summarizes the key characteristics of each scenario (e.g., sectoral reallocations, underlying assumptions, policy rationale) described above.

4 Results

This section presents the economic, employment, and environmental impacts of the coal phase-out and alternative demand reallocation scenarios for Muğla, as quantified using the regional input–output framework. The results focus on how changes in final demand associated with coal withdrawal and public investment reallocation propagate through the regional production system via intersectoral linkages. Effects are reported in terms of output, value added, employment, and greenhouse gas emissions, with a distinction between impacts occurring within directly affected sectors and those transmitted indirectly to the rest of the regional economy. This structure allows for a comparative assessment of transition pathways in terms of their economic costs, labor market implications, and potential contributions to emissions mitigation.

Table 2 reports the baseline results of the coal phase-out scenario, in which final demand for coal mining and coal-fired electricity generation is fully withdrawn and reallocated to renewable electricity production within the province. The results reveal pronounced asymmetries across sectors in terms of output, employment, and emission responses, reflecting differences in production technologies and intersectoral linkages. Reallocating the withdrawn coal-related demand—amounting to TRY 893,702 thousand (USD 53.8 million)—to renewable electricity production generates positive economic and employment effects that partially offset these losses. The redirected demand results in a total output gain of TRY 1,995,688 thousand (USD 120.2 million) and a value-added increase of TRY 897,121 thousand (USD 54.0 million), alongside 1,364 additional jobs. The output multiplier of renewable electricity (2.23) is identical to that of coal-fired electricity, implying that demand reallocation toward renewables propagates through the regional economy with comparable intensity. However, the composition of impacts differs. While own-sector effects account for a large share of output and value-added gains (TRY 1,026,032 thousand, USD 61.8 million, in output), employment gains are predominantly generated beyond the renewable electricity sector itself, with 1,278 jobs arising through intersectoral spillovers.

Decomposing the results into own-sector and beyond-own-sector effects highlights the importance of intersectoral transmission channels. In coal-fired electricity generation, a substantial share of total losses materializes outside the sector, with spillover output losses reaching TRY 608,238 thousand (USD 36.6 million) and employment losses amounting to 630 jobs. This indicates that coal phase-out affects not only direct production and employment but also a wide range of connected activities. In contrast, renewable electricity expansion generates limited direct employment within the sector (86 jobs), while the majority of employment gains are transmitted indirectly across the regional economy. From an environmental perspective, coal phase-out delivers significant greenhouse gas emission reductions, primarily associated with coal-fired electricity generation. Emission reductions amount to 4,748 tCO_2-equivalent in coal-fired electricity and 891

TABLE 1 Overview of coal phase-out and policy scenarios in Muğla.

Scenario	Core intervention	Sectoral reallocation (NACE)	Allocation structure	Underlying assumptions	Policy rationale
Baseline Coal Phase-Out (Reference Case)	Full elimination of final demand for coal mining and coal-fired electricity	Renewable electricity generation (D35: wind, solar, geothermal)	100% of removed coal demand reallocated to renewables	Renewable energy fully substitutes coal in electricity supply; ensures system continuity	Establishes a neutral benchmark for comparing alternative transition strategies focused on decarbonization
Scenario 1: Renewable Energy Investment	Reallocation of coal-related public resources into a just transition fund and using this fund to increase renewables	Renewable energy sector (D35)	100% of TRY 1.55 billion allocated to renewable energy investments	Public funds previously supporting coal are fully redirected to energy transition; no sectoral diversification	Energy-centric transition pathway prioritizing rapid decarbonization of the power system
Scenario 2: Circular Economy Transition	Investment of just transition fund into circular economy activities	Waste management & recovery (E37–39); Repair & installation (C33); Repair services (S95); Motor vehicle trade & repair (G45)	50% to E37–39; remaining 50% equally split across C33, S95, G45	Circular economy sectors exhibit higher labor intensity and local value-chain linkages	Employment-oriented transition strategy emphasizing resource efficiency, job creation, and local economic multipliers
Scenario 3: Regional Diversification (Agriculture–Tourism)	Allocation of just transition fund to place-based sectors aligned with Muğla's economy	Agriculture (A01), Forestry (A02), Fisheries (A03); Accommodation & food (I); Food processing (C10–C12)	15% each to A01–A03; 40% to I; 15% to C10–C12	Sectoral shares reflect value-added and employment coefficients; aligned with existing regional strengths	Place-based diversification strategy supporting livelihoods, rural economies, and tourism-driven growth

Source: authors' own elaboration based on scenario design.

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TABLE 2 Coal phase-out and total final demand reallocation to renewable electricity: sectoral losses and incremental gains in Muğla.

Indicator	Coal mining	Coal-fired electricity generation	Renewable electricity (incremental demand reallocated from coal)
Final-demand shock	263,780	629,922	893,702
Output multiplier (ΔX/ΔFD)	1.02	2.23	2.23
Total output effect	268,446	1,406,651	1,995,688
Total value-added effect	261,397	632,331	897,121
Total employment effect	401	1,952	1,364
GHG emissions benefit	891	4,748	—
Own-sector effects			
Output	264,083	798,413	1,026,032
Value added	258,589	266,736	342,779
Employment	392	1,322	86
GHG emissions benefit	846	1,914	—
Impacts beyond own sector			
Output	4,363	608,238	969,656
Value added	2,808	365,596	554,342
Employment	9	630	1,278
GHG emissions benefit	45	2,834	—

Units are thousand Turkish Liras (TRY) for monetary variables and persons for employment; emissions are in tCO_2-equivalent. "Final demand shock" reports the exogenous change in final demand applied to each sector. "Total demand removed (coal)" is the sum of the coal-mining and coal-fired electricity demand shocks. For renewable electricity generation, reported impacts correspond to the incremental final-demand impulse reallocated from coal activities, not to the total level of renewable electricity final demand in the province. Accordingly, the renewable electricity generation's final-demand impulse equals the coal-related demand contraction. The total level of renewable electricity final demand makes 1,242,409 thousand Turkish Lira at the end. The output multiplier is defined as the ratio of the total output effect to the corresponding final-demand shock (ΔX/ΔFD). Total effects include both own-sector (direct) and intersectoral spillover (indirect) impacts transmitted through regional input–output linkages.

tCO_2-equivalent in coal mining, with substantial contributions arising from supply-chain effects. These results reinforce the role of coal-based power generation as the dominant source of emission savings in the transition.

Overall, the baseline results demonstrate that coal withdrawal in Muğla entails non-negligible economic and employment costs due to strong sectoral interdependencies. However, reallocating coal-related demand toward renewable electricity substantially mitigates these losses while preserving the bulk of emission reductions. The findings underscore the central role of demand reallocation strategies in shaping the economic, labor-market, and environmental outcomes of a coal phase-out at the regional level.

Scenario 1 evaluates a stylized, composed of forgone coal subsidies, benchmark in which the entire just transition fund is allocated to renewable electricity generation (wind, geothermal, and solar) in Muğla. This scenario is intentionally restrictive and is designed to isolate the economic and employment implications of an energy-centered transition strategy, abstracting from sectoral diversification or place-based reallocation mechanisms. As reported in Table 3, a government expenditure shock of TRY 1,548,672 thousand (USD 93.3 million) directed solely to renewable electricity generation produces a total output expansion of TRY 3,458,271 thousand (USD 208.3 million) and a value-added increase of TRY 1,554,596 thousand (USD 93.7 million). The associated employment effect amounts to 2,364 jobs, indicating that a purely energy-oriented use of transition funds can generate non-negligible labor-market responses at the regional level. These effects arise from the transmission of the public expenditure impulse through intersectoral production linkages embedded in the Muğla input–output structure, with renewable electricity acting as the sole channel through which transition-related investment propagates across the regional economy.

The expansion of renewable electricity generation generates output, value added, and employment without inducing direct greenhouse gas emissions. In addition, by increasing the share of non-fossil electricity in the energy mix, the scenario entails an indirect emission reduction effect through the avoided use of fossil fuel–based generation. Overall, Scenario 1 provides a parsimonious reference point for evaluating the economic and employment-generating capacity of a narrowly defined, renewable electricity–focused transition strategy. While it demonstrates that concentrating public resources in renewable power can yield sizable output, value-added, and employment gains, it also serves as a benchmark against which more diversified and place-based allocation strategies are assessed in subsequent scenarios.

Table 4 reports the results of Scenario 2, in which the just transition fund is reallocated toward a portfolio of circular economy–related activities, namely waste management and remediation (E37–39), machinery installation and repair (C33), repair services (S95), and wholesale, retail, and vehicle repair (G45). Unlike Scenario 1, public expenditure is distributed across multiple sectors with heterogeneous production structures and labor intensities. In the reference case, the 2022 Muğla input–output table records positive government expenditure only for waste management activities (E37–39), amounting to TRY 176,584 thousand (approximately USD 11 million), while the remaining sectors receive no public spending. Consequently, the reported differences capture the incremental economic, employment, and environmental effects generated by reallocating public expenditure under the alternative just transition configuration.

The results indicate that the expansion of the circular economy–related activities generates sizable output and value-added gains across all targeted sectors. Waste management services absorb the largest share of the expenditure shock, with an incremental output increase of TRY 1,306,594 thousand (approximately USD 79 million) and a value-added gain of TRY 798,831 thousand (approximately USD 48 million). Employment effects in this sector are also substantial, with 4,054 additional jobs generated relative to the reference case. These

TABLE 3 Scenario 1—public investment–led expansion of renewable electricity (wind, geothermal and solar) in Muğla.

Indicator	Alternative scenario (Renewables)
Government expenditure shock	1,548,672
Total output effect	3,458,271
Total value-added effect	1,554,596
Total employment effect	2,364

Units are thousand TRY for monetary variables and persons for employment; emissions are in tCO_2-equivalent. The reference case reflects the 2022 Muğla IO table, in which government expenditure for the renewable electricity sector is recorded as zero; accordingly, no baseline effects are reported for this sector.

magnitudes reflect both the scale of the expenditure reallocation and the sector's strong intersectoral linkages within the regional economy.

At the same time, sectors starting from a zero public expenditure baseline—machinery installation and repair (C33), repair services (S95), and wholesale, retail, and vehicle repair (G45)—exhibit non-negligible responses. Incremental output gains amount to TRY 424,177 thousand (approximately USD 25.6 million) in C33, TRY 401,606 thousand (approximately USD 24.2 million) in S95, and TRY 299,031 thousand (approximately USD 18.0 million) in G45, accompanied by employment increases of 1,911, 748, and 309 jobs, respectively. This pattern indicates that reallocating public resources toward circular economy activities activates labor-demand channels across a diverse set of production and service linkages, rather than concentrating impacts in a single sector.

From an environmental perspective, the expansion of the circular economy–related activities is associated with positive emission outcomes, particularly in waste management services. The incremental greenhouse gas emission effect in E37–39 reaches 67,895 tCO_2-equivalent, while smaller but positive effects are observed in the remaining sectors. These outcomes are driven by changes in sectoral activity levels and operational characteristics rather than by direct substitution away from fossil fuel–based generation, and therefore complement the emission reductions identified under the coal phase-out scenario. Overall, Scenario 2 demonstrates that reallocating just transition resources toward a circular economy–related activities yields substantial economic and employment gains while distributing impacts more evenly across sectors compared with an energy-centered investment strategy. By leveraging sectors with relatively high labor absorption capacity and diversified intersectoral linkages, this configuration offers an alternative pathway for mitigating regional adjustment costs associated with the coal phase-out in Muğla.

Table 5 reports the results of Scenario 3, which allocates public investment toward sectors that are structurally embedded in Muğla's regional economy, namely agriculture, forestry, fishing and aquaculture, accommodation and food services, and food-related manufacturing (C10–C12). This scenario adopts a place-based investment logic by directing transition resources toward activities with established production bases, employment capacity, and local value-chain integration. The results indicate that public investment in these sectors generates substantial output and value-added effects, with accommodation and food services accounting for the largest share of aggregate gains. This pattern reflects the central role of tourism-related activities in Muğla's production structure and their strong interconnections with agriculture, food processing, and local services. Manufacturing activities in food and beverages also contribute meaningfully to regional output and value added, reinforcing linkages between primary production and downstream processing (Muğla Planning Agency, 2025). Employment effects are particularly pronounced in agriculture-related activities and accommodation and food services. Compared with the energy-centered and circular economy–oriented scenarios, job creation in Scenario 3 is more evenly distributed across multiple labor-intensive sectors, indicating a broader absorption capacity within the regional labor market. This dispersion of employment effects suggests that place-based investment can mitigate transition-related labor adjustment pressures by leveraging sectors with existing workforce participation and local embeddedness.

Environmental impacts under this scenario display sectoral heterogeneity shaped by Muğla's agro-food–tourism nexus. While agriculture- and food-related activities are associated with positive emission responses due to higher production levels, these effects differ markedly in scale, intensity, and composition from those observed in coal-related activities. In the Muğla context, agricultural expansion is increasingly linked to organic and low-input production practices that are closely integrated with tourism demand and local food processing. Evidence from the Rodale Institute indicates that organic farming systems tend to exhibit lower lifecycle greenhouse gas emissions per unit of output, reduced dependence on synthetic fertilizers and pesticides, and enhanced soil carbon sequestration potential relative to conventional systems (Rodale Institute, 2014; Rodale Institute, 2022). Within the input–output framework employed here, reported emission outcomes therefore primarily capture activity-level effects rather than technological or practice-based differences. As a result, the quantified emissions should be interpreted as conservative upper-bound estimates, given that broader mitigation co-benefits associated with organic agriculture, local food systems, and tourism-linked short supply chains are not explicitly modeled. Overall, Scenario 3 highlights the potential of place-based public investment to support regional economic resilience during the coal phase-out process. By strengthening sectors that already constitute key pillars of Muğla's economy, this configuration offers an alternative transition pathway that prioritizes employment absorption and local value-chain continuity alongside structural adjustment.

Table 6 synthesizes the results and compares the three transition scenarios against the current coal-dominated energy system in Muğla.

Taken together, the results point to clear trade-offs across alternative transition pathways in Muğla. The baseline coal phase-out combined with demand reallocation to renewable electricity is most effective in delivering greenhouse gas emission reductions, primarily through the elimination of coal-fired electricity generation, while partially cushioning output and employment losses through renewable expansion. Scenario 1, which channels the entire just transition fund into renewable electricity, yields the largest gains in aggregate output, underscoring the strong production linkages associated with energy-sector investment, but generates more moderate employment effects. The fact that those employed in the coal economy in the region have higher levels of education than the average in other sectors, predominantly graduates from engineering departments, and work in relatively highly qualified positions, indicates that they can be easily re-employed in similar fields (Akgül et al., 2024). By contrast, Scenario 2 delivers the strongest value added and also strong employment outcomes relative to the scale of public expenditure, reflecting the labor-intensive nature and diversified linkages of circular economy–related activities, while also producing complementary emission benefits driven by changes in activity

TABLE 4 Scenario 2—public investment–led expansion of circular economy–related activities in Muğla.

Indicator	E37–39 waste management and remediation	C33 machinery installation and repair	S95 repair of computers and personal goods	G45 wholesale, retail and vehicle repair
Government expenditure – Reference	176,584	0	0	0
Government expenditure – Alternative scenario	774,336	258,112	258,112	258,112
Reference				
Output	297,963	0	0	0
Value added	182,170	0	0	0
Employment	925	0	0	0
GHG emissions	15,483	0	0	0
Alternative scenario				
Output	1,604,557	424,177	401,606	299,031
Value added	981,001	254,232	265,294	258,417
Employment	4,979	1,911	748	309
GHG emissions	83,379	2,818	1,798	1,864
Difference (Alternative – Reference)				
Output	1,306,594	424,177	401,606	299,031
Value added	798,831	254,232	265,294	258,417
Employment	4,054	1,911	748	309
GHG emissions	67,895	2,818	1,798	1,864

Units are thousand TRY for monetary variables and persons for employment; emissions are in tCO_2-equivalent. The reference case reflects the 2022 Muğla IO table, in which government expenditure is positive only for waste management activities (E37–39) and zero for the remaining circular economy–related sectors. Reported differences therefore capture the incremental effects of reallocating public expenditure under the alternative just transition scenario.

TABLE 5 Scenario 3—place-based public investment supporting agriculture, tourism, and food-related activities in Muğla.

Indicator	A01 agriculture and hunting	A02 forestry products	A03 fishing and aquaculture	I accommodation and food services	C10–12 food, beverages and tobacco
Government expenditure (alternative scenario)	232,301	232,301	232,301	619,469	232,301
Output	337,781	313,413	329,495	955,564	374,130
Value added	229,427	235,373	232,119	622,332	229,626
Employment	129	2,223	2,288	4,222	252
GHG emissions	12,765	1,384	3,154	5,316	3,823

Units are thousand TRY for monetary variables and persons for employment; emissions are in tCO_2-equivalent. The reference case reflects the 2022 Muğla IO table, in which government expenditure is zero for all related sectors. Reported differences therefore capture the incremental effects of reallocating public expenditure under the alternative just transition scenario.

TABLE 6 Comparison of transition scenarios.

Indicator	Current situation (as of 2022)	S1 (renewables)	S2 (circular)	S3 (place-based)
Output	100	206	145	138
Value added	100	174	176	173
Employment	100	100	299	387
GHG	100	0	23	8

Source: authors' own elaboration.

composition. Scenario 3 stands out in terms of employment absorption and sectoral dispersion, as place-based investment in agriculture, tourism, and food-related activities spreads gains across multiple labor-intensive sectors and reinforces locally embedded value chains, albeit with more limited short-term emission reductions compared with coal phase-out–driven effects. Although these sectors are among those with the highest employment share in the region, them also being among rapidly contracting sectors over the past 10 years suggests they may need additional support to absorb jobs lost due to coal phase-out (Akgül et al., 2024). Overall, the comparison highlights that no single allocation strategy dominates across all dimensions: renewable-energy-centered investment maximizes output and minimizes emissions, circular economy–oriented reallocation performs best in value-added generation, and place-based diversification offers the broadest labor-market absorption and regional resilience. These differences underscore the importance of combining emission-oriented phase-out policies with diversified and locally grounded investment strategies when designing just transition pathways for coal-dependent regions such as Muğla.

5 Conclusion

By analyzing the economic, employment, and environmental impacts of the phase-out of coal mining and coal-fired electricity generation in Muğla province within a regional input–output framework, the current study presents a comparative evaluation of different transition strategies by reallocating the resulting loss of final demand to alternative sectors. The findings reveal that the phase-out of coal creates significant costs for the regional economy, but these costs can be partially or fully offset depending on the reinvestment and demand redirection strategies pursued.

The first scenario, focusing on renewable electricity generation, shows that concentrating just transition funds in the renewable energy sector can create high output and value added increases. Furthermore, this scenario sustains the environmental gains that complement emission reductions resulting from the phase-out of coal. However, this approach has a relatively limited job creation capacity. This result indicates that while an energy-centric transition strategy is strong in terms of macroeconomic variables such as total output, it may not be sufficient on its own in terms of employment and distributional effects. Nevertheless, the relatively high level of education and technical expertise of workers in the coal sector in Muğla suggests that this group may adapt relatively more easily to fields requiring similar qualifications, such as renewable energy.

The circular economy-focused investment mix considered in the second scenario exhibits the strongest performance in terms of job creation. Public spending directed towards labor-intensive and diversified sectors such as waste management, repair, recycling, and maintenance creates indirect and direct job increases across a wide range of sectors; offering the potential to reduce the social costs of the transition process. These findings demonstrate that just transition policies should not only focus on energy technologies but also on labor-intensive activities with strong local connections.

The third scenario suggests that a place-based investment approach based on agriculture, tourism, food processing, and related manufacturing activities can strengthen regional resilience. Spreading employment impacts across numerous sectors can mitigate labor adjustment pressures during the transition. However, the tendency for these sectors to contract in terms of employment over the last decade suggests that they may require additional policy support to absorb the labor losses resulting from the coal phase-out. From an environmental perspective, the emission profiles of agriculture and tourism-based activities are lower in intensity compared to the coal sector, and considering practices such as organic farming and local supply chains, the emissions calculated in this study can be considered upper bounds.

Overall, the findings clearly show that there is no single "best" just transition strategy for Muğla. While energy-centric investments maximize output, circular economy-focused strategies stand out in terms of value added; and place-based diversification provides advantages in terms of job creation and indirect employment effects. Therefore, to manage the phase-out of coal in a socially just and economically sustainable manner, policies that consider emission reduction targets must be designed together with diversified investment strategies that take into account local production structures and workforce characteristics. This study contributes to the discussions on just transition in coal-dependent regions by providing holistic and comparative quantitative evidence at the regional level.

These conclusions should be interpreted in light of several limitations of the study. First, as the analysis presents a static framework based on regional input–output tables for the year 2022, it cannot internally reflect structural or technological change, price adjustments, substitution behaviors, and productivity gains that may occur over time. Therefore, the results should be interpreted primarily as an upper bound estimate of short-term and demand-side effects. Second, GHG emissions were calculated based on average emission coefficients at the sector level. Learning curves and competitiveness increases in renewable energy technologies, organic farming and ecotourism practices, energy efficiency investments, and behavioral transformations could not be directly represented within the scope of the analysis. Third, employment effects were limited to the quantitative level, whereas qualitative dimensions of the labor market such as skills mismatch, wage dynamics, informality, and gender were excluded. Future studies could develop scenarios including the time dimension with dynamic input–output or computable general equilibrium models; and examine the distributional and socio-demographic effects of the transition in more detail through analyses supported by micro-level labor market data. Furthermore, mixed methods approaches, including qualitative policy analyses and local stakeholder engagement, will offer important complements that will strengthen the applicability of quantitative findings in the context of a just transition.

Data availability statement

The dataset underlying this study consists of an author-constructed regional input–output table for Muğla, Türkiye, developed using multiple official data sources. Due to data confidentiality, licensing restrictions, and intellectual property considerations, the full dataset is not publicly available. A condensed version of the input–output table is provided as Supplementary Material to facilitate replication of the core results reported in this study. Access to the full dataset may be granted by the corresponding author upon reasonable request

solely for the purpose of academic verification; however, the full dataset may not be published, redistributed, or used for further analytical or empirical research without explicit written permission.

Author contributions

SK: Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Resources, Software, Validation, Visualization, Writing – original draft, Writing – review & editing. SA: Conceptualization, Data curation, Formal analysis, Funding acquisition, Investigation, Methodology, Project administration, Resources, Software, Supervision, Validation, Visualization, Writing – original draft, Writing – review & editing. BÖ: Conceptualization, Formal analysis, Investigation, Methodology, Resources, Supervision, Validation, Writing – original draft, Writing – review & editing.

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Conflict of interest

The author(s) declared that this work was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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Supplementary material

The Supplementary material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/frsus.2026.1811466/full#supplementary-material

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