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° Report

Socio-economic Impacts of Energy Transition in Chungcheongnam-do

Renewable Energy vs. Gas-fired Power Generation

Study

Socio-economic Impacts of Energy Transition in Chungcheongnam-do:
Renewable Energy vs. Gas-fired Power Generation

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Socio-economic Impacts of Energy Transition in Chungcheongnam-do

Renewable Energy vs. Gas-fired Power Generation

Executive Summary

Eighteen coal-fired power plants in Chungcheongnam-do, representing 9 GW of capacity, are scheduled for decommissioning by 2038, with the majority transitioning to gas-fired power generation and only a fraction remaining in the region. This transition raises significant concerns regarding regional job security and greenhouse gas emissions. Given the region's substantial renewable energy potential, including solar photovoltaic (PV) and wind, this study quantitatively analyzes the national and regional socio-economic impacts, focusing on employment and value-added creation from expanding renewable energy and gas-fired power generation up to 2050. The analysis covers five scenarios, incorporating the intrinsic characteristics of the renewable energy system, such as local capacity and flexibility options, within the context of Chungcheongnam-do, South Korea.

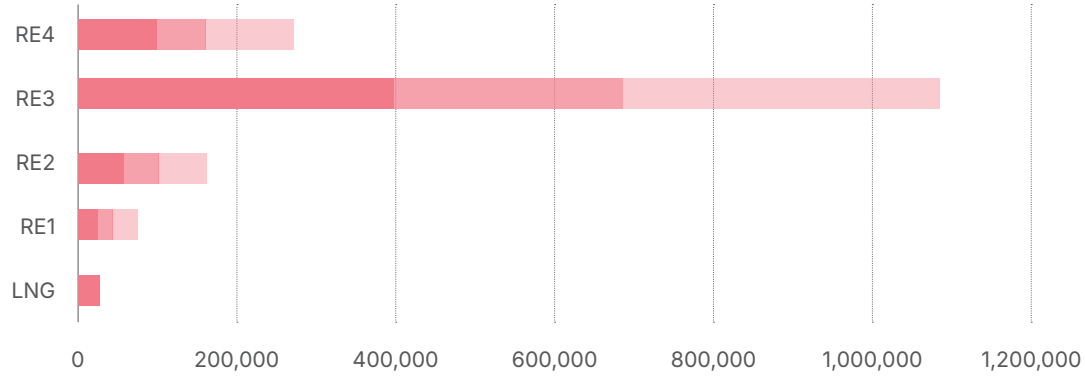
Key Messages

- **Nationally, all renewable energy (RE) scenarios create more jobs than the LNG scenario.**
  Job creation in the LNG scenario is 82,139 FTE, while in the RE scenarios, it ranges from 92,305 FTE to 3,012,447 FTE, depending on the specific scenario and additional instruments (LCR, ESS) considered.

- **Regionally, all RE scenarios create more jobs than the LNG scenario, except RE1, which surpasses LNG when either LCR or ESS is included, underscoring their importance.**
  Job creation in the LNG scenario is 29,399 FTE, while in the RE scenarios, it ranges from 27,429 FTE to 1,085,509 FTE.

- **Expanding renewable energy capacity well beyond current plans could significantly increase regional employment.**
  Under the RE3 scenario, it could create an average of 40,000 long-term jobs (FTE) across all sectors in the region—double the total employment in Chungcheongnam-do's electricity, gas, steam, and air conditioning supply industry in 2022.

Total Regional Job Creation in Chungcheongnam-do Under Various Scenarios



	LNG	RE1	RE2	RE3	RE4
Reference	29,399	27,429	59,292	397,230	100,352
+ LCR		17,381	43,373	289,967	61,613
+ ESS		31,935	61,124	398,313	112,020

(unit: FTE)

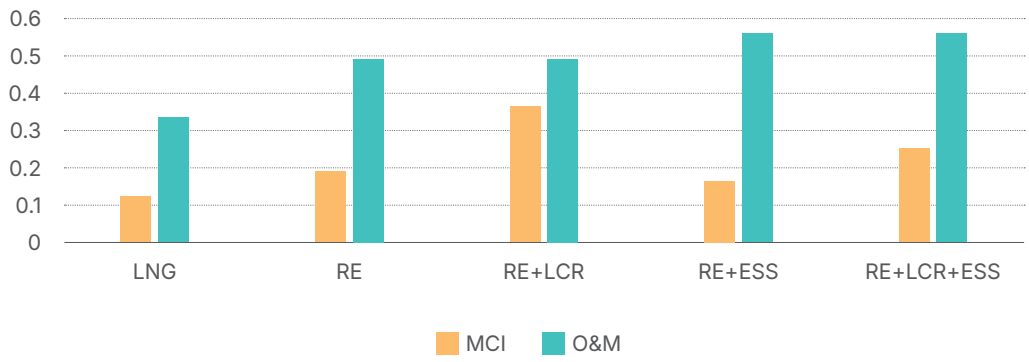
Reference + LCR + ESS

* The graph illustrates accumulated regional job creation in FTE (Full-Time Equivalent) by 2050. LNG refers to gas-fired power plants (2,550 MW) replacing coal in Chungcheongnam-do. RE1 represents the expansion of renewable energy to match the power generation of LNG. RE2 is based on Chungcheongnam-do's 6th regional energy plan. RE3 is derived from the renewable energy market potential in Chungcheongnam-do. RE4 corresponds to the expansion of renewable energy to match the power generation of the total coal phase-out (9,100 MW) in the region (see Table B.1. in Appendix B.). LCR stands for Local Content Requirement, while ESS denotes Battery Energy Storage System. The darkest section of the bar represents the minimum level of accumulated employment creation. The combined shades of the bars indicate the maximum employment levels, taking into account the impacts of LCR and ESS.

- **Nationally and regionally, all RE scenarios generate higher value-added impacts than the LNG scenario, except RE1. However, in the RE1 scenario, incorporating both ESS and LCR results in a more favorable impact compared to the LNG scenario.**
  At the national level, value-added creation in the LNG scenario is estimated at 10,602 billion KRW, while in the RE scenarios, it ranges from 6,908 to 205,307 billion KRW. At the regional level, value-added creation in the LNG scenario is 4,631 billion KRW, while in the RE scenarios, it ranges from 2,416 to 74,194 billion KRW. If the renewable energy market potential is fully realized as in the RE3 scenario, the accumulated value-added creation by 2050 in the region is projected to account for between 23.44% and 52.65% of Chungcheongnam-do's 2022 GRDP.

- **When considering total investment costs, renewable energy provides greater economic benefits than gas-fired power generation.**
  The induced value-added coefficient values indicate that renewable energy provides greater economic benefits than gas-fired power generation and can contribute more to the regional economy than key industries like steel and chemicals during the operation period.

Induced Value-Added Coefficients at the Regional Level



* The graph illustrates induced value-added coefficients, calculated by dividing total regional value-added creation by total investment. LNG refers to gas-fired power plants replacing coal in Chungcheongnam-do. RE represents renewable energy expansion. LCR stands for Local Content Requirement, while ESS denotes Battery Energy Storage System. MCI represents Manufacturing, Construction, and Installation, while O&M stands for Operations & Maintenance.

- **Leveraging the region's renewable energy potential and promoting local capacity, alongside flexibility options, offers a more socio-economically beneficial alternative to gas-fired power generation for both Chungcheongnam-do and South Korea, while ensuring a cleaner environment for future generations. Therefore, it is crucial to prepare and implement effective policies in advance to realize these benefits.**

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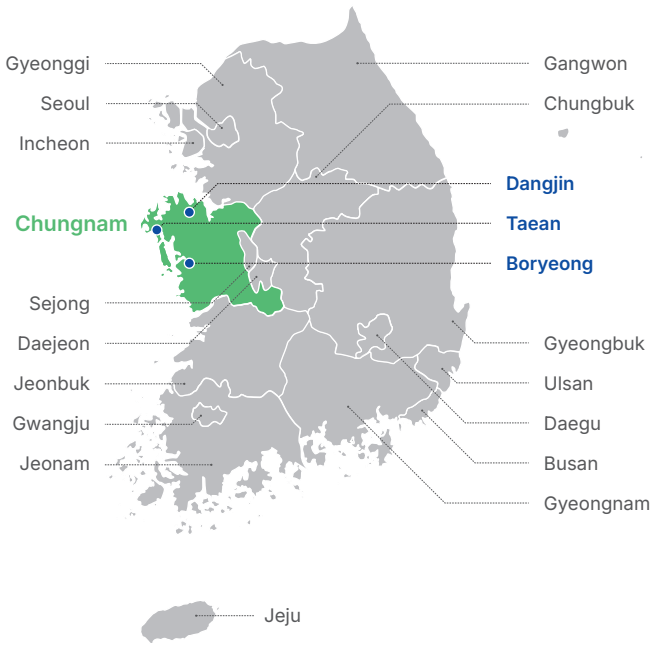
Chapter 1. Introduction

1.1. Motivation

Selecting an energy source is a significant decision, as its impact can last for generations. Chungcheongnam-do (Chungnam), a province by the West Sea, hosts nearly half of the nation's coal-fired power plants, alongside a multitude of highly industrialized and hard-to-abate manufacturing industries.

[Figure 1.1.] Map of Chungnam, South Korea



Currently 18 coal-fired power plants, accounting for approximately 9GW, have been confirmed to gradually shut down in Chungnam by 2038 to meet the nation's climate neutrality goal. Majority of these power plants are due to transform into gas-fired power generation, with the ambition of becoming entirely hydrogen-run in the future, and only a fraction is to remain in Chungnam. This shift is thought to be driven by the region's plan to accommodate 51% of the country's new liquefied natural gas (LNG) terminal capacity[1].

Natural gas supply in South Korea is entirely shipped from abroad. LNG, transported over long distances, produces substantial greenhouse gas emission throughout the lifecycle (NETL, 2014). Additionally, many studies have shown that extracting hydrogen from natural gas for power generation

1 South Korea's LNG import terminal capacity is the world's second largest, after Japan (Global Energy Monitor, 2024), with plans to expand by 47% (IEEFA, 2023).

and sustainably capturing the carbon emissions offers very little environmental benefit due to the release of fugitive methane (Howarth & Jacobson, 2021; T. Sun et al., 2024). This strategy also risks prolonging fossil fuel dependency in the power sector, resulting in stranded assets and impeding the transition to renewable energy, which is essential for achieving carbon neutrality by 2050.

It is fair to question why, given the high stakes involved in the climate crisis and the global movement toward a clean energy transition, renewable energy has not sufficiently stepped in to replace coal in the region. The closure of coal-fired plants has raised immense concerns about regional job security. Renewable energy adoption is particularly slow and complicated in South Korea, due to various reasons, grid connection and local acceptance issues being one of them. Envisioning a new economy most suited to the region, encompassing both environment and economic security concerns, requires meticulous planning over a long period of time. Hence, making the right choice becomes particularly difficult without adequate support or guidance.

Renewable energy sources, such as solar PV and wind, provide substantial socio-economic benefits, particularly by generating regional employment and creating value-added opportunities as decentralized energy systems. An understanding of the socio-economic impact of expanding renewable energy compared to gas-fired power generation is crucial for comprehensively assessing the benefits and implications for the region and the nation, based on which policy decisions can be made (Kim B., 2023). Despite numerous studies examining socio-economic prospects for different power sources, only a few have compared renewable energy with conventional options, especially at a regional level, with the absence of a study focused on Chungnam. Hence, this study aims to provide understanding of the potential benefits derived during the process of renewable energy-based energy transition by comparing the job and value-added creation derived from expanding renewable energy and gas-fired power generation focusing on Chungnam in South Korea.

The study is limited to energy sources that are most relevant in Chungnam, including gas-fired power generation, solar PV, onshore and offshore wind, and (Battery) Energy Storage Systems (ESS). Gas-fired power generation typically refers to combined cycle gas turbine (CCGT). Geographically, the analysis covers Chungnam Province as well as the entire country. The value chain considered in this study includes development, manufacturing, construction, installation, and operations & maintenance, though it excludes the decommissioning stage, and the construction of LNG terminals or harbors required for offshore wind. Impact wise, it considers not only the direct effects, but also inter-industrial linkage effects so called as indirect effects and induced effects created through income spent in the service sector. The temporal scope extends from the present up to the year 2050.

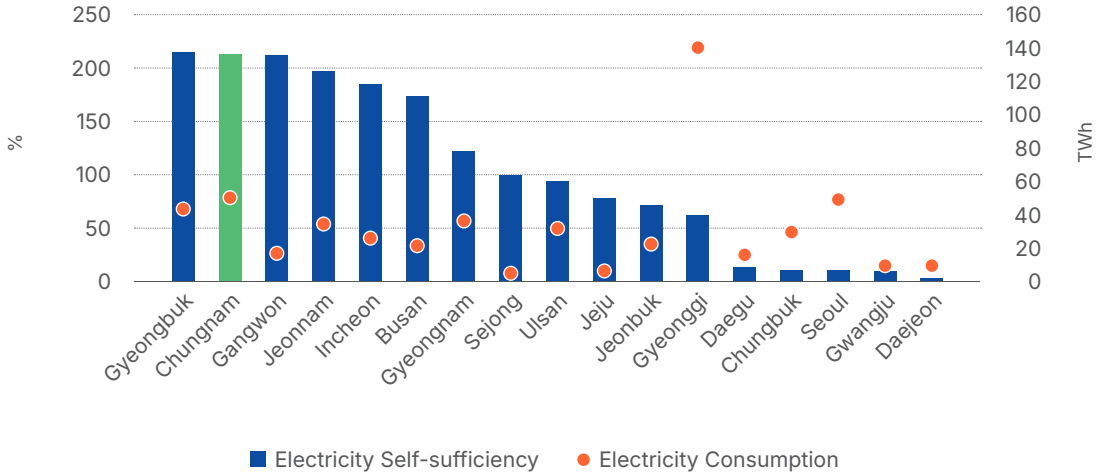
1.2. Challenges of Energy Transition in Chungnam

Energy and Industry Landscape

For decades, Chungnam has served as a powerhouse for South Korea's metropolitan cities. Currently, 28 coal-fired power plants are in operation within the province, contributing to an electricity self-sufficiency rate of 214%, as shown by the green bar in Figure 1.2. below. The electricity generated

in Chungnam is transferred to nearby urban areas, such as Seoul and Gyeonggi Province, where electricity self-sufficiency is low, and demand is high.

[Figure 1.2.] Electricity Self-sufficiency (%) and Consumption (TWh) of 17 Cities and Provinces of South Korea in 2023



Reference: based on KPX (2024)

According to the 10th Basic Plan on Electricity Supply and Demand, as well as recent announcements by KEPCO[2] subsidiary (KOMIPO, 2024), most of the 18 coal-fired power plants scheduled for shutdown are planned to be replaced by gas-fired power plants, primarily in regions outside Chungnam, closer to energy demand in metropolitan areas. This shift is partly due to the country's struggle with a saturated transmission grid and the anticipated changes in the wholesale power market through Locational Marginal Pricing (LMP), which makes power plants outside Chungnam more profitable.

Chungnam is also home to manufacturing complexes in industries such as steel, chemicals, and cement. However, the phase-out and relocation of major power plants affect certain cities more than others. Coal-fired power plants in Chungnam are concentrated in three cities: Boryeong, Dangjin, and Taean. The detailed power plant phase-out plans for these cities are outlined in Table B.1. in Appendix B.

For smaller municipalities like Boryeong and Taean, the phase-out of coal-fired power plants is expected to have a significant negative impact, as coal power is one of the main industries and a critical source of tax revenue, alongside agriculture, fishing, and tourism. These cities are also experiencing severe population decline. Boryeong, in particular, was unprepared for the abrupt shutdown of the Boryeong 1 and 2 coal-fired power plants, which led to job losses. With more closures on the horizon, finding alternative sources of stable employment has become the top priority for these regions.

2 Korea Electric Power Corporation

Just Transition

A just transition, as defined by the International Labour Organization (ILO), is 'Greening the economy in a way that is as fair and inclusive as possible to everyone concerned, creating decent work opportunities and leaving no one behind'. Accordingly, it is essential to examine the creation of decent jobs in the region, rather than merely counting numbers.

The quality of employment is a critical global issue, and scholars and institutions have developed various indicators focusing on factors such as 'job stability', 'skill improvement', 'wages', 'working hours' and 'industrial accidents and safety' (Kang, 2017). Therefore, when assessing the employment effects of gas-fired power generation and renewable energy in the region, this study considered factors such as 'stability' in terms of continuity through 2050, and 'wages' in relation to total value-added creation.

Most importantly, ensuring a just and fair transition away from coal-fired power plants towards a new economy requires looking at the wider context as the region may already have unexplored economic potential beyond green energy technologies (Śniegocki, Wasilewski, Zygmunt, & Look, 2022). Also, the process necessitates adequate time, meticulous planning, and sufficient financing to support employees involved in coal-fired power generation and to create new business opportunities in the region. Therefore, this study also highlights opportunities within the broader economic and energy system, particularly in expanding and utilizing renewable energy resources.

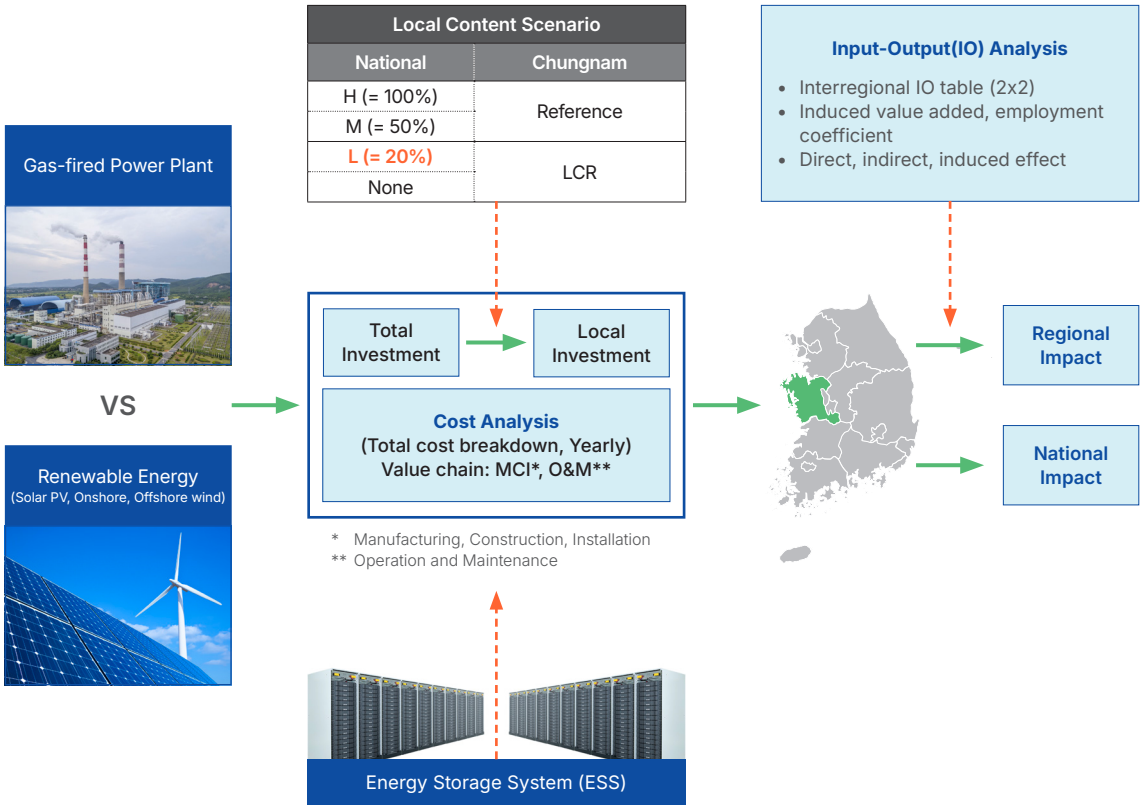
1.3. Structure of the Report

This report is structured into five main chapters. Chapter 1 introduces the topic and presents the contextual and political background of the energy transition in Chungnam. Chapter 2 provides a technical overview of the analytical methods used to derive the findings presented in Chapter 3 and 4. In addition to visualizations and numerical data, Chapters 3 and 4 emphasize key insights into employment and value-added impacts, respectively, at the national and regional levels, which inform the policy recommendations outlined in Chapter 5. The Appendix offers a more detailed breakdown of the analytical procedures, including scenario analysis, cost analysis, and local content evaluation.

Chapter 2. Research Methodology

This chapter aims to provide an academic basis for impact analysis in Chapter 3 and Chapter 4 by reviewing previous literature and outlining the analytical procedure. Figure 2.1. below illustrates the overall research flow of the study.

[Figure 2.1.] Research Flow



2.1. Literature Review

Many studies have examined the socio-economic impacts of expanding various energy sources at both the national level and within regional economies, employing a range of methodologies.

Various studies have examined the socio-economic impact analysis at the provincial level, including studies on Chungnam. Institute for Green Transformation (2023) estimated the direct job creation from the deployment of 4.5GW of solar PV and 4GW of offshore wind power plant in Chungnam, using employment coefficients and reviewing green job roles through literature and case studies. GESI (2022, 2023) analyzed the value chain cost structure of wind power and calculated various socio-economic impacts in Honam and Gangwon, respectively. The Chungnam Institute (2020, 2021) conducted

a two-year study, with the first year focusing on the supply disruption effects of coal-fired power plant closures and the second year calculating employment impact using employment coefficients based on prior research, particularly the work of Cho, Yoon, & Kim (2018) while also providing a comprehensive overview of the energy status and plans for Chungnam and its municipalities. The Korea Employment Information Service (2022) thoroughly analyzed the phase-out of coal-fired power plants in Chungnam and the transition to gas-fired power plants, estimating direct employment impacts through a bottom-up supply chain analysis. Kim B. (2023), using Interregional Input Output Analysis (IRIO), analysed the employment and value-added impact of onshore wind expansion in Jeju Island, and also made comparision with regional conventional power generation.

At the national level, Korea Labor Institute (2022a) assessed the employment impacts of renewable energy expansion, estimating job creation separately for solar PV and wind power. Another study by the Korea Labor Institute (2022b) evaluated the employment impacts of coal-fired power plant closures to estimate job creation separately for coal-fired and gas-fired power sectors. Cho, Yoon, & Kim (2018) separated gas-fired power plant construction and operation from the national Input-Output (IO) table to estimate their respective employment and value-added impacts. These studies have commonly employed IO analysis. Additionally, KEYTOWAY (2021) estimated the employment impacts of transitioning the workforce from coal-fired to gas-fired power generation in South Korea through bottom-up surveys.

Despite the abundance of studies examining various energy sources, few studies have directly compared renewable energy with conventional options, particularly gas-fired power generation, at the regional level. Notably, there is a lack of comparative studies specifically in the context of Chungnam. Therefore, this study aims to enhance understanding of the socio-economic impacts of the energy transition by comparing the employment and value-added impacts of expanding renewable energy and gas-fired power generation, focusing on Chungnam in South Korea.

2.2. Analytical Overview

This research involves four analytical steps: 1) Scenario Analysis, 2) Cost Analysis, 3) Input-Output Analysis, and 4) The Application of Additional Instruments.

Scenario Analysis

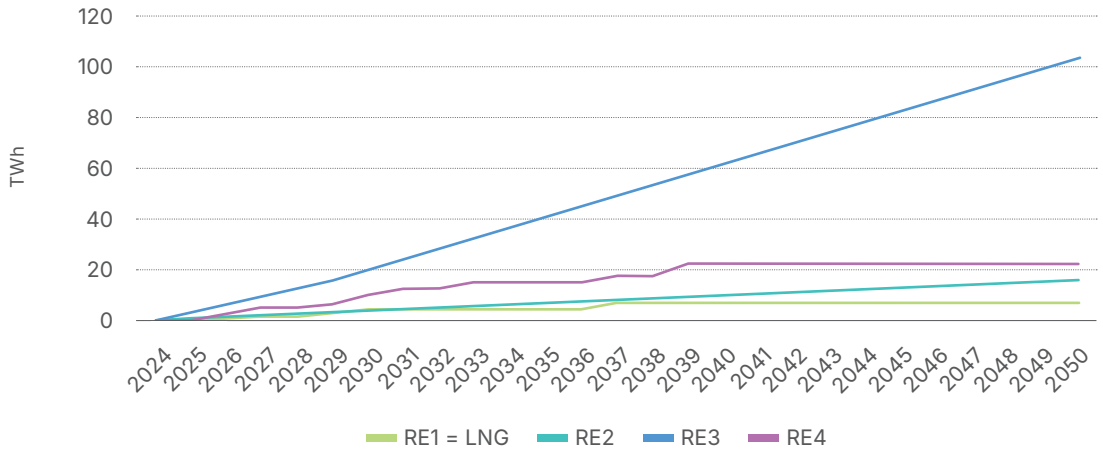
A total of five scenarios were developed for this study. The gas-fired power generation expansion scenario, referred to as the ‘LNG’ scenario, was based on gas-fired power generation construction planned in Chungnam as well as in unannounced regions, as detailed in Table B.1. in Appendix B. For renewable energy (RE) expansion, four scenarios were created based on different projections, as summarized in Table 2.1. below.

[Table 2.1.] Scenario Description

Scenarios	Description
LNG	Gas-fired power plants (2,550MW) planned to replace coal within Chungnam
RE1	Equal power generation as LNG Scenario
RE2	Based on the Chungnam 6th regional energy plan[3]
RE3	Based on the renewable energy market potential in Chungnam[4]
RE4	Equal power generation as total coal phase-out (9,100MW) planned in Table A.3.

The capacity factor for gas-fired power generation in the LNG scenario was referenced from the nationwide projection for 2030 in the 10th Basic Plan on Electricity Supply and Demand, which is set at around 28%. The capacity factor for solar PV, onshore wind and offshore wind in Chungnam were assumed to be 15%, 22% and 33%.[4] In the RE1, RE3, and RE4 scenarios, the proportion of total power generation was allocated to solar PV, onshore wind power, and offshore wind power based on the market potential ratios found in the RE3 scenario. The RE4 scenario was devised to alleviate concerns regarding the relocation of power plants in Chungnam Province. For the gas-fired power plant, the time taken during installation was assumed to be three years. The installation period for solar PV was assumed to be one year, while for onshore and offshore wind, the periods were set at three and six years, respectively. The operational period for all power sources was uniformly assumed to be twenty-five years. Due to the variability and unpredictable nature, the time required for permit and approval activities was not included in these assumptions. Power generation projections under each scenario up to the year 2050 from the present are illustrated in Figure 2.2. below.

[Figure 2.2.] Power Generation Projection by Scenario



- LNG: Refers to gas-fired power plants (2,550 MW) replacing coal in Chungnam.
- RE1: Represents the expansion of renewable energy to match the power generation of LNG.
- RE2: Based on Chungcheongnam-do's 6th regional energy plan.
- RE3: Derived from the renewable energy market potential in Chungnam.
- RE4: Corresponds to the expansion of renewable energy to match the power generation of the total coal phase-out (9,100 MW) in the region.

3 Although the regional plan contains targets up to 2040, the study extended the linear expansion for each energy source to 2050 for alignment purposes.

4 Based on KNREC (2020). New & Renewable Energy White Paper, Korean Energy Association

Table 2.2. below shows the installation capacity for solar PV, onshore wind, and offshore wind under each renewable energy scenario.

[Table 2.2.] Total Renewable Energy Installation Capacity

(unit: MW)

Scenarios	Solar PV	Onshore Wind	Offshore Wind	Total
RE1	3,489	225	386	4,099
RE2	9,241	322	847	10,410
RE3	57,458	3,898	6,700	68,056
RE4	12,450	801	1,376	14,627

Cost Analysis

In this study, the entire value chain for gas-fired generation, solar PV, onshore wind, offshore wind and ESS were identified, with a distinction made between Manufacturing, Construction, and Installation (MCI) and Operations & Maintenance (O&M). MCI encompasses activities such as site investigation, design, manufacturing, construction, and installation, while O&M includes operations, maintenance, and management activities, which were assumed to last 25 years for each installation.
The costs for each item were calculated in terms of unit cost of (KRW/kW) or (KRW/kWh) and cost distribution (%) based on literature review and expert consultations. Value chain items and associated unit cost are tabulated and listed in Table C.1. to C.5. in Appendix C.

Input Out Analysis

Input-output analysis is a useful and productive method to analyze a region's industrial structure and economic impact.[5] The Input-Output (IO) model illustrates the interconnections between industries within an economy, demonstrating how the output of one sector can serve as the input for another as shown in Figure 2.3.

5 The input-output model was originally developed by Wassily Leontief in 1951 to study the structure of the American economy. Walter Isard, a key figure in the field of regional science and location theory, assisted Leontief in modifying the model for application to local economies.

[Figure 2.3.] Input Output Table

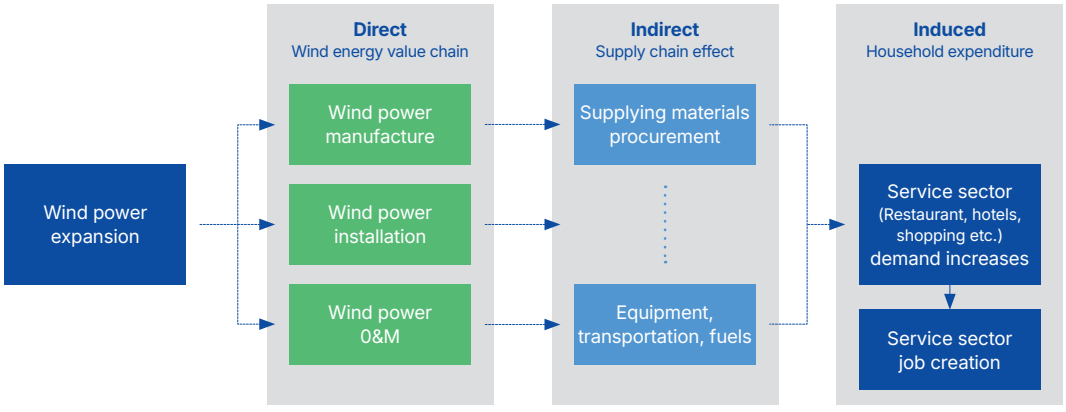
		PRODUCERS AS CONSUMERS								FINAL DEMAND			
		Agric.	Mining	Const.	Manuf.	Trade	Transp.	Services	Other	Personal Consumption Expenditures	Gross Private Domestic Investment	Govt. Purchases of Goods & Services	Net Exports of Goods & Services
PRODUCERS	Agriculture												
	Mining												
	Construction												
	Manufacturing												
	Trade												
	Transportation												
	Services												
	Other Industry												
VALUE ADDED	Employees	Employee compensation								GROSS DOMESTIC PRODUCT			
	Business Owners and Capital	Profit-type income and capital consumption allowances											
	Government	Indirect business taxes											

Reference: Miller & Blair (2009)

In the inter-industry matrix, also referred to as the input-output table, the columns usually represent inputs to a specific sector, while the rows indicate the output produced by that sector. Changes in demand for an industry also affect the activity levels of other industries connected to it. As such, the IO model captures not only direct effects but also indirect and induced economic effects by considering all interactions within the economy.

Given the extensive value chain involved, it is essential to analyze the impact of each industry within the renewable energy value chain by considering the interdependence among all related sectors (Kim B., 2023). Figure 2.4. below illustrates how the rising demand for wind power in the region generates employment opportunities locally through various channels.

[Figure 2.4.] Pathway of Economic Spill-over Effects



Reference: Kim B. (2023), adapted from Breitschopf, Nathani, & Resch (2011)

Direct effects are the immediate impacts of a renewable energy project. Indirect effects arise from supply chain effects related to these direct effects, while induced effects refer to broader economic effects stemming from increased income spent in service sectors like restaurants and retail. These indirect and induced effects are often called the 'ripple effect' or 'spillover effect', and accounting for them in the planning stage can help maximize benefits (Faturay, Vunnava, Lenzen, & Singh, 2020). The magnitude of these effects varies with the region's economic structure. Sectors with extensive linkages tend to generate greater indirect effects, while labor-intensive sectors, particularly in services, significantly influence induced effects. (Schallenberg-Rodriguez & Inchausti-Sintes, 2021). Induced effects were incorporated into the study through household endogenization by inserting row and column based on the Batey I method (The Scottish Government, 2021). However, limitations exist in IO modelling, such as not accounting for economies of scale, price changes, technological advancements, and productivity shifts.

One of the primary uses of information in an IO model is to assess the impact of changes in final demand on an economy. Some of the commonly used multipliers estimate the effects of exogenous changes, such as wind power expansion (Figure 2.4.), on sectoral outputs[6] (in monetary terms) or on employment (in physical job numbers) generated in each sector as a result of the new outputs. Additionally, various generalized multipliers are possible, such as those for value-added (monetary value) created in each sector due to the new outputs. It is often argued that value-added is a better measure of a sector's contribution to the economy, as it captures the value generated by the sector through production activities. (Miller & Blair, 2009) Value-added, which represents the difference between a sector's total output and the cost of its intermediate inputs, consists of employee compensation, operating surplus, fixed capital consumption, and production taxes. This study examines the impacts on employment and value-added in detail.

Two types of IO tables provided by the Bank of Korea were used: a medium-level national IO table and interregional IO table from 2015, which includes 83 sectors and is the most recent version available for interregional analysis. The 17-region IRIO table was aggregated into two regions: Chungnam and the rest of Korea, allowing for an assessment of the impacts on employment and value-added at both national and regional levels.

The use of IO models for studying clean energy impacts has a disadvantage in that renewable energy and energy efficiency industries are not accounted for in national accounts (Garrett-Peltier, 2017) in many cases. There are two main approaches in IO analysis for such cases: the 'final demand approach' and 'complete inclusion in the technical coefficient matrix approach' (Miller & Blair, 2009). The 'final demand approach' treats the intermediate inputs used by the new industry as an external change reflected in the final demand. This method has been extensively employed to estimate the economic impact of renewable energy, assuming that its development does not affect the inputs used by other sectors. This approach allows flexibility in analyzing various value chain activities and is also relatively feasible for regional studies. The 'complete inclusion in the technical coefficient matrix approach' integrates the new industry into the technical coefficient matrix mostly used in single-

6 The total value of production in all sectors of the economy required to satisfy a unit currency's worth of final demand for the output of a specific sector.

region models, mainly at the national level, where industry information is readily available. However, this approach requires detailed data and reaggregation of IO tables, which can be time-consuming and challenging, especially for emerging industries like clean energy. Both approaches were applied in this study.

For the MCI of combined cycle power plants of gas-fired power generation in the LNG scenario, and for the entire life cycle (MCI and O&M) of solar PV, onshore wind, offshore wind in the renewable energy scenarios, and ESS, the 'final demand approach' was applied as done in Pollin et al., (2022), GESI (2023) and Kim B. (2023) using the 2015 IRIO table.

For the O&M of gas-fired power generation, the 'complete inclusion in the technical coefficient matrix approach' was selected to reflect the characteristics of the power source such as fuel consumption. The 'gas-fired power generation' segment was extracted from the broader 'thermal power generation' category, increasing the total number of rows and columns from 83 to 84 medium classifications using the 2015 national IO table. Due to methodological limitations with the IRIO model, equal coefficients were used in both the national and regional level impact analyses. The detailed steps for this process were referenced from Cho, Yoon, & Kim (2018), Korea Labor Institute (2022b), and Kim K. (2020). Appropriate multipliers were calculated to account for direct, indirect, and induced effects for employment and value-added impact analysis. Detailed mathematical procedures can be found in Miller & Blair (2009, pp. 35, 238).

Additional Instruments

The economic impact from investment, particularly in the case of variable renewable energy, depends on various factors. This study considers two key intrinsic characteristics when analyzing a renewable energy system in the RE scenarios: 1) local capacity and 2) related infrastructure that enables the storage and consumption of the generated power.

Local Content

Local content refers to the level of actual investment made in Chungnam from the projects derived. These values were carefully developed based on an extensive literature review and expert consultations[7].

There are two hierarchies of local capacity-building measures: national and regional. National capacity building focuses on promoting national competitiveness, typically centered on manufacturing industries and imports, while regional capacity building emphasizes job and value-added creation through which local acceptance of renewable energy can be promoted. These regulations, in the form of local content requirements (LCR), will directly impact both the national and regional economies (Kim B., 2023).[8]

7 Expert consultations were held with stakeholders from gas-fired power plants, the Boryeong City Energy Department, the Chungnam Province Employment and Enterprise Support Division, and the Chungnam Economic Promotion Agency Job Creation Team, among others.

8 Although the adoption of LCR may lead to changes in cost that affect price competitiveness and consequently expansion of renewable energy, this study assumes constant prices due to methodological limitations.

At the national level, the manufacturing of core equipment in CCGT, solar panels and wind turbines were assumed to be approximately 20% (in terms of CAPEX) on average, sourced nationally, with the remainder being imported. At the regional level, two scenarios of local capacity were considered: 1) Reference and 2) LCR. These scenarios are associated with the construction and installation phases for solar PV and wind sources to reflect real-world conditions, as such policies are widely adopted to stimulate the regional economy.

Flexibility Options- ESS

Unlike conventional power sources, solar PV and wind are inherently variable and intermittent. As the power supply from these sources cannot be controlled, the point of power consumption must therefore be transferred either spatially or temporally.

Saturated transmission and distribution lines are significant barriers to expanding solar PV and wind power in the country, despite the relatively low contribution of renewable electricity. This issue arises from several factors, including a lack of an international grid, insufficient flexibility resources (such as energy storage), an inefficient power market, and social resistance to building new transmission lines.

The excess power generated from solar PV and wind in the southern regions, particularly Honam and Jeju, is sent upward, leaving no capacity for new renewable connections in Chungnam, even after the recent shutdown of Boryeong power plants #1 and #2. The government (MOTIE[9]) has recently mandated that, until 2031, new renewable power source connections will be limited in Honam Province. This critical issue could impede renewable energy expansion and consequently hinder the national carbon neutrality goal.

Among various solutions to alleviate this challenge, this study will focus on adopting flexibility resources, particularly the ESS, which is currently one of the most commercially and technically viable options. Unlike the main equipment of the power sources described in the previous section, the regional local content for ESS was assumed to be 20%, with 45% sourced from imports[10], as batteries can be procured locally in Chungnam[11]. The operational lifespan of an ESS typically ranges from 12 to 13 years, with used battery energy storage systems (UBESS) considered for the second phase after this lifespan.

The required capacity of the ESS in relation to solar PV and wind power generation depends on numerous factors, including not just the nameplate capacity in the supply side but also the region's power demand patterns. For the sake of simplicity, this study evaluated the ESS capacity solely based on the power plant's nameplate capacity, while more comprehensive analyses deferred to future research. According to Kong, Kim, Kang, & Jung (2019), approximately 1 MW:3 MWh ratio is recommended for Solar/Wind to ESS capacity. Additionally, Kim B. (2023) suggests that ESS capacity should be limited to account for the lifecycle carbon emissions produced for battery manufacturing. Therefore, this study assumed an ESS capacity of 1 MW:1.845 MWh for both solar PV and wind, to

9 Ministry of Trade, Industry and Energy

10 Only total of 65% of battery manufacturing is manufactured within the country as current localization of battery component is on average 65% according to MOTIE (2021).

11 https://skinnonews.com/archives/110015

also consider the environmental impact.

Table 2.3. below summarizes the levels of local content and ESS capacity considered in the RE scenarios.

[Table 2.3.] Summary of Additional Instruments

Scenarios	National	Chungnam	ESS
RE1, RE2, RE3, RE4	20% Manufacturing	Reference	None
		LCR	1MW: 1.845MWh

The percentiles of LCR for gas-fired power generation, solar PV, onshore wind, offshore wind, and ESS across the value chain are provided in Table C.1. to C.5. in Appendix C.

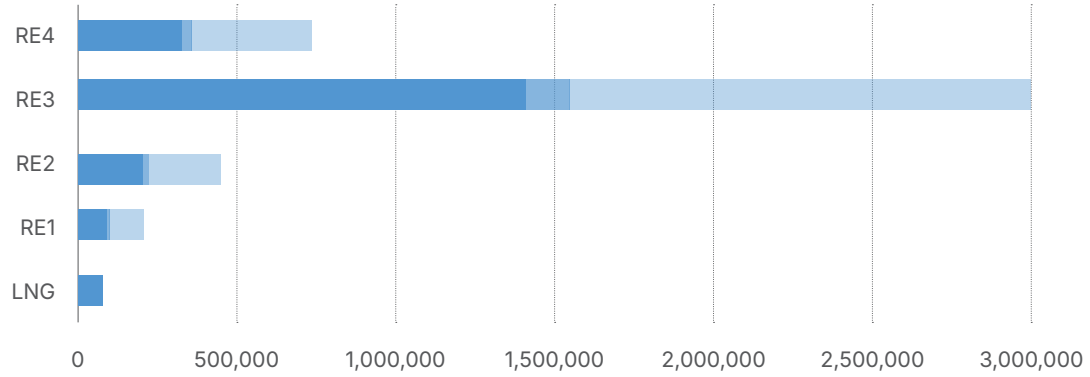
Chapter 3. Employment Impacts of Energy Transition

3.1. Results Summary

The impact on employment was analyzed across five scenarios, considering LCR and ESS installation at both the national and regional levels. Employment levels were calculated in terms of Full-Time Equivalents (FTE)[12] and tabulated in Table A.1. in Appendix A.

Figures 3.1. and 3.2. below illustrate employment levels under each scenario. The darkest section of the bar represents the minimum level of accumulated employment creation in FTE between 2024 and 2050, without any LCR intervention policy or ESS installation. The combined shades of the bars indicate the maximum employment levels, taking into account the impacts of LCR and ESS.

[Figure 3.1.] Scenario Comparison at the National Level



	LNG	RE1	RE2	RE3	RE4
Reference	82,139	92,305	205,864	1,411,777	328,754
+ LCR		8,194	20,049	138,042	29,189
+ ESS		107,747	224,049	1,462,628	379,961

(unit: FTE)

Reference + LCR + ESS

- LNG: Refers to gas-fired power plants (2,550 MW) replacing coal in Chungnam.
- RE1: Represents the expansion of renewable energy to match the power generation of LNG.
- RE2: Based on Chungcheongnam-do's 6th regional energy plan.
- RE3: Derived from the renewable energy market potential in Chungnam.
- RE4: Corresponds to the expansion of renewable energy to match the power generation of the total coal phase-out (9,100 MW) in the region.

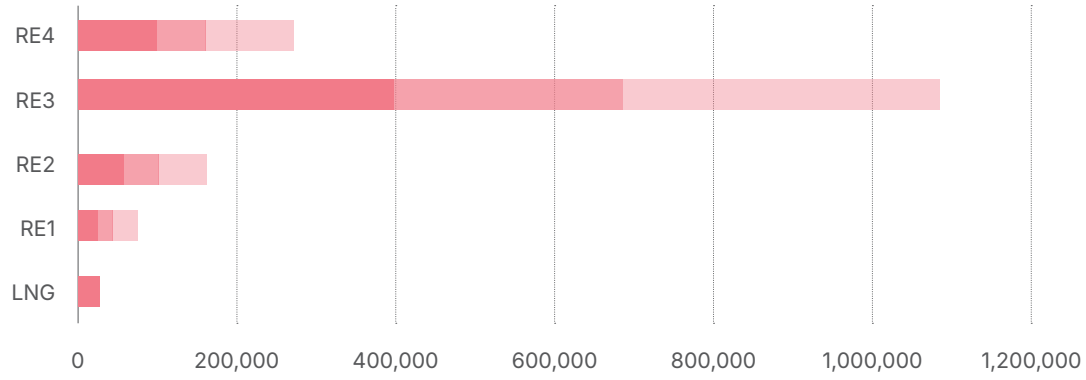
As shown in Figure 3.1. above, renewable energy sources, solar PV and wind combined, consistently generated more employment opportunities than gas-fired power plant expansion at the national level across all scenarios. Job creation in the LNG scenario was estimated at 82,139 FTE, while in the RE

12 The number of full-time employees working for one year.

scenarios, it ranged from 92,305 FTE to 208,246 FTE in RE1 and from 1,411,777 FTE to 3,012,447 FTE in RE3, depending on the specific scenario and additional instruments (LCR, ESS) considered. This highlights the potential of renewable energy as a significant job creator in the country.

At the regional level, renewable energy scenarios created more employment opportunities than the LNG scenario, except for the RE1 scenario at the reference level, where LCR and ESS were not considered.

[Figure 3.2.] Scenario Comparison at the Regional Level



	LNG	RE1	RE2	RE3	RE4
Reference	29,399	27,429	59,292	397,230	100,352
+ LCR		17,381	43,373	289,967	61,613
+ ESS		31,935	61,124	398,313	112,020

(unit: FTE)

Reference + LCR + ESS

- LNG: Refers to gas-fired power plants (2,550 MW) replacing coal in Chungnam.
- RE1: Represents the expansion of renewable energy to match the power generation of LNG.
- RE2: Based on Chungcheongnam-do's 6th regional energy plan.
- RE3: Derived from the renewable energy market potential in Chungnam.
- RE4: Corresponds to the expansion of renewable energy to match the power generation of the total coal phase-out (9,100 MW) in the region.

According to Figure 3.2., job creation in the LNG scenario was estimated at 29,399 FTE. In contrast, the RE scenarios showed a range from 27,429 FTE to 76,745 FTE in RE1 and from 397,230 FTE to 1,085,509 FTE in RE3, depending on the specific scenario and additional instruments considered. The regional aspects will be discussed further in the following section.

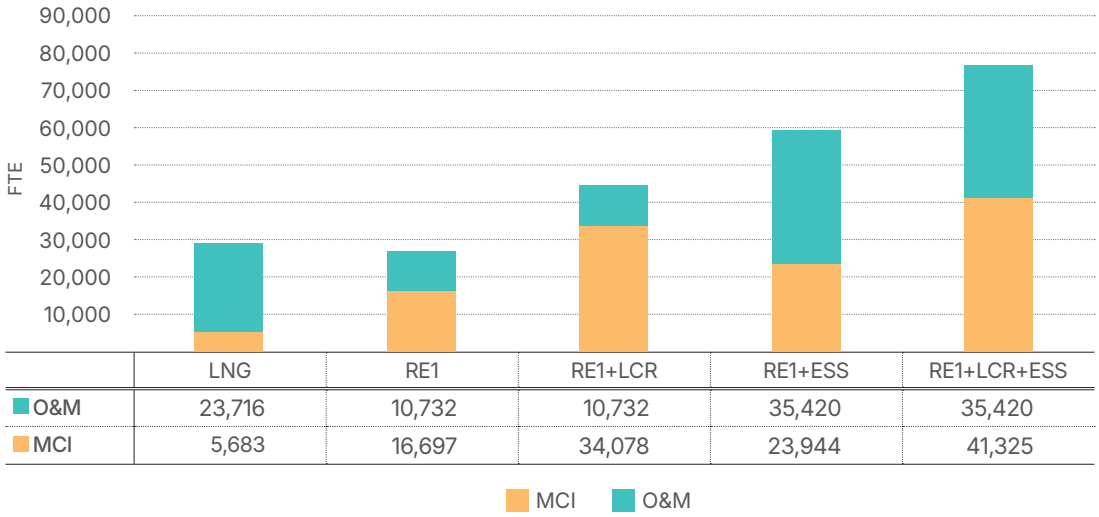
3.2. Employment Impacts of Energy Transition in Chungnam

Regional job creation is a priority and a major concern for local authorities, particularly in areas lacking industrial activities. This section aims to provide a detailed analysis of the impact on regional employment levels.

As shown in Figure 3.2., while the LNG scenario created more jobs than the RE1 scenario with equal power generation at the reference level, every other RE scenarios generated higher employment. Consequently, this chapter will focus on the LNG and RE1 scenarios at the regional level.

The expansion of renewable energy with equal power generation, when supplemented with either LCR or ESS, resulted in a higher total regional employment level, as illustrated in Figure 3.3. below. Each scenario has different implications for job creation in the MCI and O&M phases.

[Figure 3.3.] Job Creation at the Regional Level (LNG vs. RE1)



	LNG	RE1	RE1+LCR	RE1+ESS	RE1+LCR+ESS
O&M	23,716	10,732	10,732	35,420	35,420
MCI	5,683	16,697	34,078	23,944	41,325

- LNG: Refers to gas-fired power plants (2,550 MW) replacing coal in Chungnam.
- RE1: Represents the expansion of renewable energy to match the power generation of LNG.

Generally, expanding renewable energy created more MCI jobs than the LNG scenario. The implementation of LCR further increased MCI jobs, as more resources must be sourced locally, as shown by the local share (%) values in Table C.1. to C.5. in Appendix C. However, it is important to note that O&M jobs in renewables are typically fewer in number compared to fossil fuel-based energy due to less frequent maintenance needs. The operation of natural gas power plants requires fuel imports, leading to additional supply chain activities upstream, which is not the case for renewable energy resources.

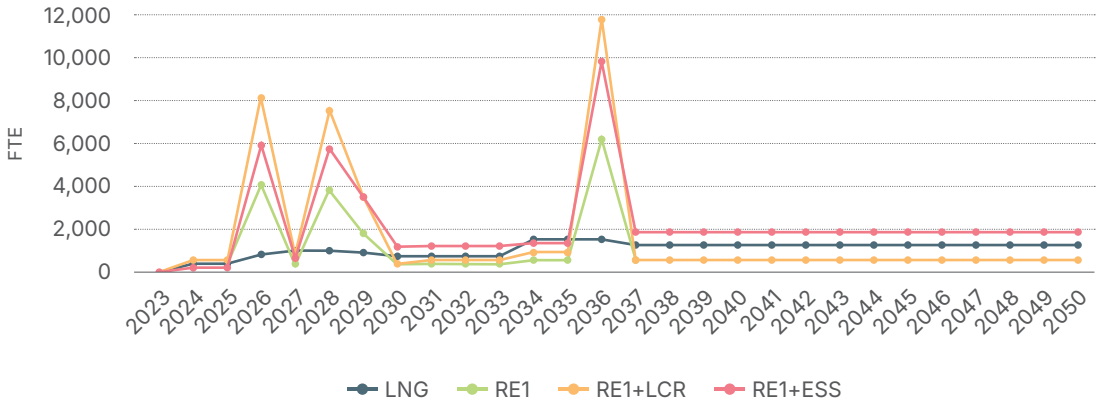
Additionally, the integration of ESS enhanced both MCI and O&M job opportunities, with the latter gaining greater significance. Hence, ensuring that local businesses are more involved in the value chain would significantly expand regional job creation in Chungnam.

Given the region's constraints on transmission lines, exacerbated by growing power production in the south despite the shutdown of two coal-fired power plants in Chungnam, local flexibility measures such as ESS are crucial. This approach would not only enable the efficient consumption of locally generated renewable energy and reduce the carbon intensity of power generation but also hold significant potential for regional job creation, as demonstrated by the results. A combined approach of

renewable energy, LCR, and ESS would reduce curtailment and maximize employment opportunities in Chungnam.

Figure 3.4. and Figure 3.5. below illustrates regional job creation from yearly perspective. Sporadic peaks represent job creation during construction and installation for new power plants planned in 2026, 2028, 2029 and 2036. Although high in numbers, the duration of the employment is relatively short term and may not satisfy the quality job criteria. On the other hand, jobs created during operation and maintenance phase can create long-term jobs, representing from 600 to 1,800 FTE each year.

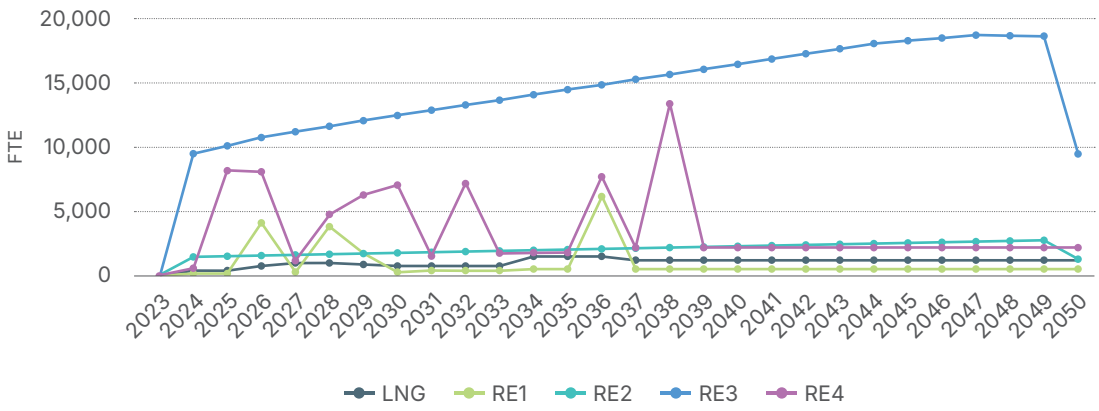
[Figure 3.4.] Yearly Job Creation at the Regional Level (LNG vs. RE1)



- LNG: Refers to gas-fired power plants (2,550 MW) replacing coal in Chungnam.
- RE1: Represents the expansion of renewable energy to match the power generation of LNG.

To ensure a steady flow of jobs over the years, it is essential to expand renewable energy installations continuously, as illustrated in Figure 3.5. below for the RE2 and RE3 scenarios.

[Figure 3.5.] Yearly Job Creation at the Regional Level (LCR and ESS Not Considered)

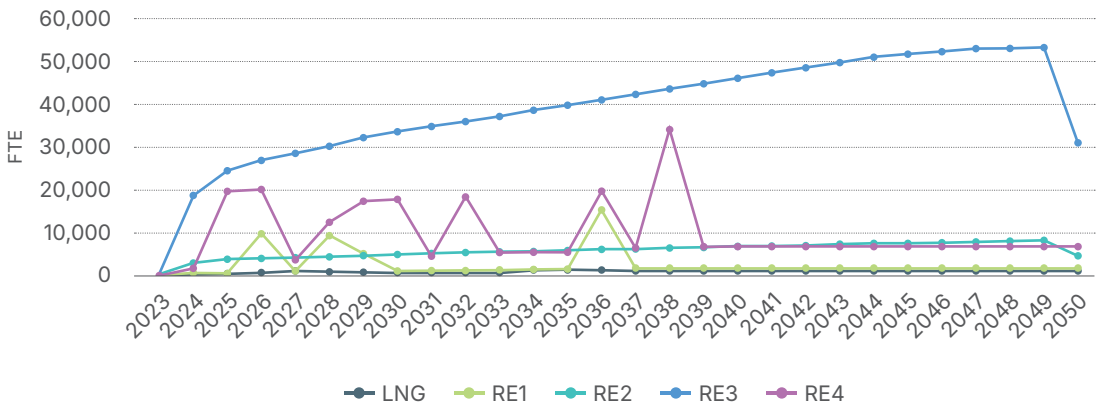


- LNG: Refers to gas-fired power plants (2,550 MW) replacing coal in Chungnam.
- RE1: Represents the expansion of renewable energy to match the power generation of LNG.
- RE2: Based on Chungcheongnam-do's 6th regional energy plan.
- RE3: Derived from the renewable energy market potential in Chungnam.
- RE4: Corresponds to the expansion of renewable energy to match the power generation of the total coal phase-out (9,100 MW) in the region.

In RE2 and RE3 scenarios, solar PV and wind power plant installations were assumed to gradually increase in accordance with regional energy plans and targets for renewable energy market potential. This approach contrasts with the LNG, RE1, and RE4 scenarios, which focused on expanding renewable energy solely to match the power generation required to phase out coal in Chungnam.

Another key takeaway from the analysis is that, given Chungnam's significant renewable energy potential, increasing renewable energy capacity beyond current plans could lead to substantial job creation. When the renewable energy market potential is fully realized, the RE3 scenario generated an average of 15,000 long-term jobs, even without LCR measures or ESS. Figure 3.6. below illustrates the annual employment impact when LCR policies and appropriately sized ESS are incorporated into renewable energy scenarios.

[Figure 3.6.] Yearly Job Creation at the Regional Level (LCR and ESS Considered)

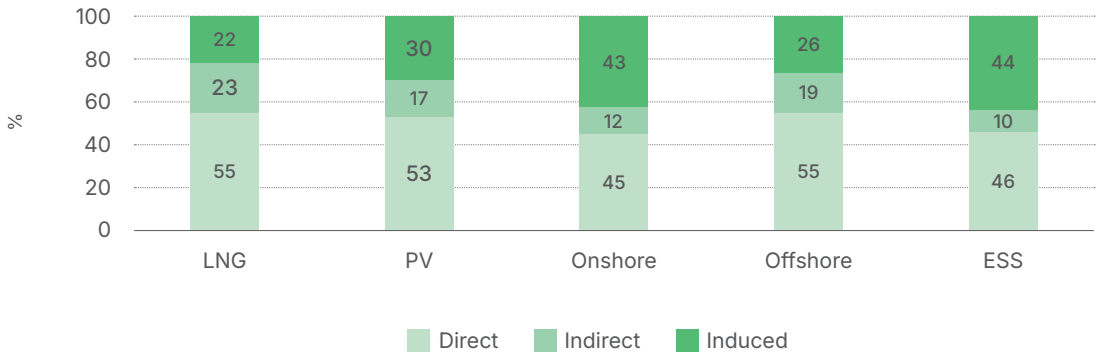


- LNG: Refers to gas-fired power plants (2,550 MW) replacing coal in Chungnam.
- RE1: Represents the expansion of renewable energy to match the power generation of LNG.
- RE2: Based on Chungcheongnam-do's 6th regional energy plan.
- RE3: Derived from the renewable energy market potential in Chungnam.
- RE4: Corresponds to the expansion of renewable energy to match the power generation of the total coal phase-out (9,100 MW) in the region.

In this case, the expansion of renewable energy created an average of 40,000 long-term jobs, twice the total employment of Chungnam's 'electricity, gas, steam, and air conditioning supply industry' in 2022[13].

As mentioned in Chapter 2, the study included not only jobs directly related to the power plant infrastructure but also indirect and induced jobs. Figure 3.7. illustrates the proportion of jobs created in each category, showing that approximately half of the total employment generated was indirectly linked to the value chain.

[Figure 3.7.] Installation and Operation of 1 MW from Different Power Sources and ESS Resulting in Different Economic Effects



13 https://alldam.chungnam.go.kr

The result indicates that renewable energy and ESS produce a higher proportion of indirect and induced jobs compared to gas-fired power generation in the LNG scenario. The significant contribution from induced effects indicates that households benefiting from income growth due to direct and indirect employment are spending more on local services, such as dining and shopping. This increases spending boosts employment in service sectors.

Therefore, even though manufacturing facilities for renewable energy-related equipment are scarce in Chungnam, the growth of renewable energy and energy storage systems can enhance job creation in the region while simultaneously diversifying the regional economy. A diversified economy can have many advantages, fostering innovation that leads to economic growth through the interactions among different types of industries (Jacobs, 1969). The relationship between the stability of local economies and the diversity of industrial structures is relatively clear and became more evident during events such as the foreign exchange crisis and global economic crises (Kim & Kim, 2017).

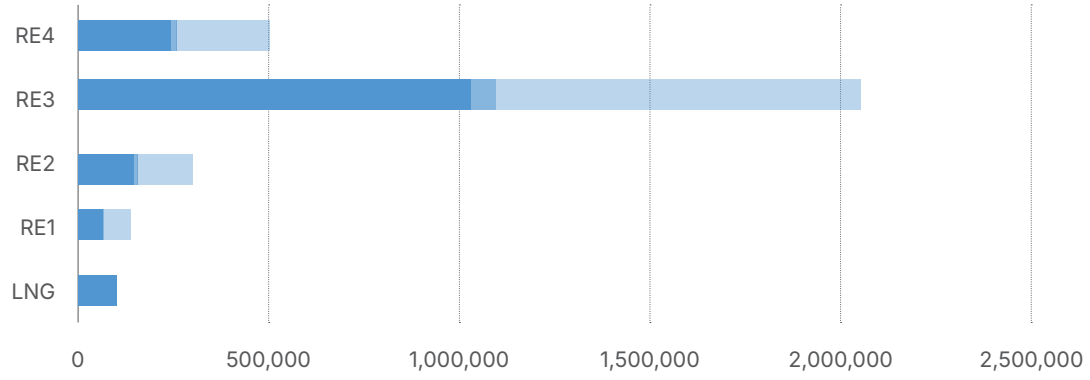
Chapter 4. Value-added Impacts of Energy Transition

4.1. Results Summary

While the employment impact quantifies job creation, the value-added impact focuses on the quality and economic contribution of those jobs. Value-added encompasses employee compensation, operating surplus, fixed capital consumption, and production taxes within the production process, offering a deeper understanding of economic benefits beyond mere job numbers. Similar to the employment impact, the value-added impact was analyzed across five scenarios, considering LCR and ESS installation at both the national and regional levels. The results are presented in Table A.2. in Appendix A.

Figures 4.1. and 4.2. illustrate total value-added creation across all sectors under each scenario. The darkest section of the bars represents the minimum level of accumulated value-added creation between 2024 and 2050, without any LCR intervention policy or ESS installation. The combined shades of the bars indicate the maximum value-added levels, incorporating the effects of LCR and ESS. At both the national and regional levels, all RE scenarios produced higher value-added impacts than the LNG scenario, except for the RE1 scenario, which exceeded LNG when LCR and ESS are included.

[Figure 4.1.] Scenario Comparison at the National Level



	LNG	RE1	RE2	RE3	RE4
Reference	10,602	6,908	15,029	103,163	24,742
+ LCR		403	982	6,783	1,433
+ ESS		6,897	14,602	95,361	24,352

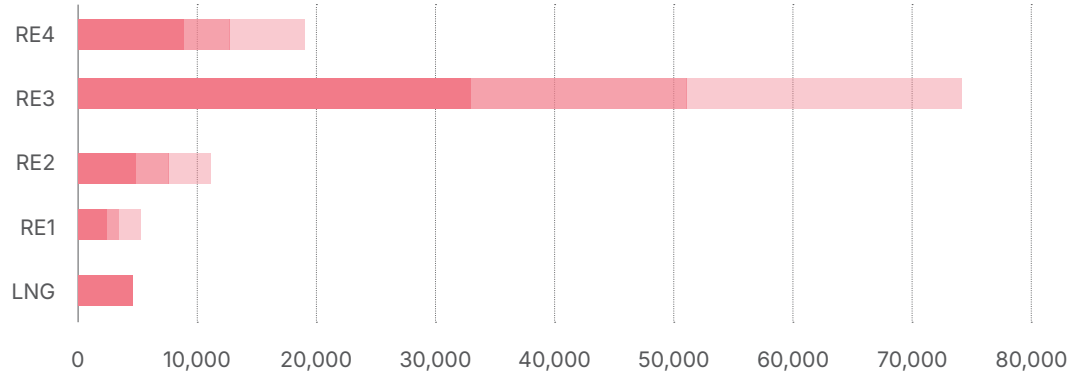
(unit: Billion KRW)

Reference + LCR + ESS

- LNG: Refers to gas-fired power plants (2,550 MW) replacing coal in Chungnam.
- RE1: Represents the expansion of renewable energy to match the power generation of LNG.
- RE2: Based on Chungcheongnam-do's 6th regional energy plan.
- RE3: Derived from the renewable energy market potential in Chungnam.
- RE4: Corresponds to the expansion of renewable energy to match the power generation of the total coal phase-out (9,100 MW) in the region.

According to Figure 4.1., at the national level, value-added creation in the LNG scenario was estimated at 10,602 billion KRW. In contrast, the RE scenarios ranged from 6,908 to 14,207 billion KRW in RE1, and from 103,163 to 205,307 billion KRW in RE3, depending on the specific scenario and additional instruments (LCR, ESS) considered.

[Figure 4.2.] Scenario Comparison at the Regional Level



	LNG	RE1	RE2	RE3	RE4
Reference	4,631	2,416	4,892	33,027	8,931
+ LCR		1,089	2,720	18,143	3,856
+ ESS		1,785	3,531	23,024	6,274

(unit: Billion KRW)

Reference + LCR + ESS

- LNG: Refers to gas-fired power plants (2,550 MW) replacing coal in Chungnam.
- RE1: Represents the expansion of renewable energy to match the power generation of LNG.
- RE2: Based on Chungcheongnam-do's 6th regional energy plan.
- RE3: Derived from the renewable energy market potential in Chungnam.
- RE4: Corresponds to the expansion of renewable energy to match the power generation of the total coal phase-out (9,100 MW) in the region.

According to Figure 4.2., at the regional level, value-added creation in the LNG scenario was estimated at 4,631 billion KRW. In contrast, the RE scenarios ranged from 2,416 to 5,290 billion KRW in RE1, and from 33,027 to 74,194 billion KRW in RE3, depending on the specific scenario and additional instruments considered.

Table 4.1. below illustrates the contribution of total accumulated value-added creation in Chungnam under each scenario to the region's economy, comparing it to the 2022 Gross Regional Domestic Product (GRDP). All RE scenarios generated higher value-added impacts than the LNG scenario, except for the RE1 scenario. However, in the RE1 scenario, incorporating both ESS and LCR resulted in a more favorable GRDP impact compared to the LNG scenario, contributing 3.75% to the GRDP.

Another key takeaway from the analysis is that, given Chungnam's significant renewable energy potential, expanding renewable energy capacity beyond current plans could lead to substantial value-added creation. If the renewable energy market potential is fully realized, accumulated value-

added creation by 2050 is projected to account for 23.44% to a maximum of 52.65% of Chungnam's 2022 GRDP, as shown in Table 4.1. below. Therefore, both LCR and ESS are important, as well as the expansion of renewable energy.

[Table 4.1.] Contribution to Chungnam's 2022 GRDP by Total Value-added Creation for Each Scenario

Local Content		Reference		LCR	
Flexibility		-	ESS	-	ESS
2022 Chungnam GRDP (140,928 billion KRW)	LNG	3.29%			
	RE1	1.71%	2.98%	2.49%	3.75%
	RE2	3.47%	5.98%	5.40%	7.91%
	RE3	23.44%	39.77%	36.31%	52.65%
	RE4	6.34%	10.79%	9.07%	13.53%

Reference: Statistics KOREA, 「Regional Income」

- LNG: Refers to gas-fired power plants (2,550 MW) replacing coal in Chungnam.
- RE1: Represents the expansion of renewable energy to match the power generation of LNG.
- RE2: Based on Chungcheongnam-do's 6th regional energy plan.
- RE3: Derived from the renewable energy market potential in Chungnam.
- RE4: Corresponds to the expansion of renewable energy to match the power generation of the total coal phase-out (9,100 MW) in the region.

The higher value-added in the LNG scenario compared to RE1 can be attributed to the fuel costs and the input structure of thermal power generation sector in the IO table. These factors likely led to a higher total value-added impacts. Typically, coal-fired power plants consume coal, while gas-fired combined cycle plants consume natural gas (LNG) and some city gas for combustion and power generation. When examining the input structure for 'thermal power generation' in the national input-output table (sector code 4502), natural gas is routed through the domestic city gas industry before being used in the 'thermal power generation' sector, unlike imported bituminous coal, which is directly input into the sector. This reflects the purchasing structure of gas-fired combined cycle plants, which acquire natural gas both through direct imports and from the Korea Gas Corporation. Cho, Yoon, & Kim (2018) point out that this input structure, which passes through intermediary stages, tends to overestimate the production and value-added impacts of thermal power plants, particularly gas-fired combined cycle plants.

To compare value-added impacts more accurately, it is common to standardize the total value-added by dividing it by the total investment. This approach offsets the effects of fuel costs, enabling a clearer comparison of industry-specific differences based on the total scale of project investment. The following section focuses on this method to provide a more accurate analysis.

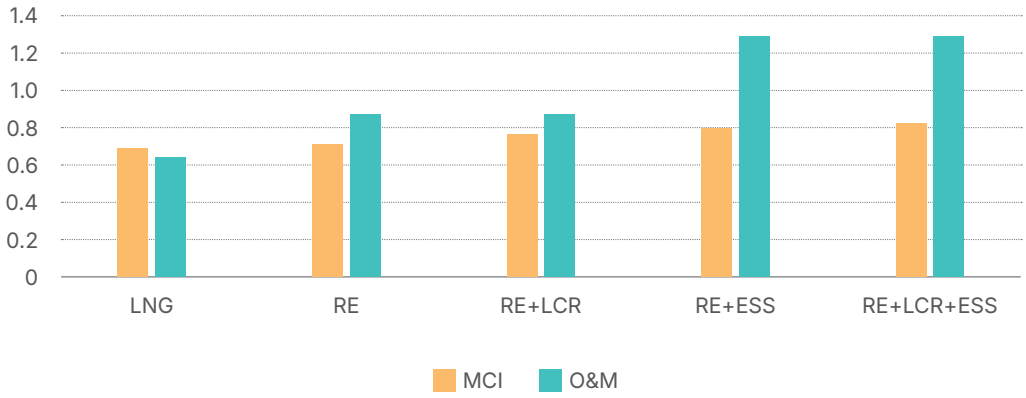
4.2. Comparative Analysis of Energy and Industrial Sectors in Chungnam

Normalizing value-added by investment costs allows for an assessment of the efficiency of investment in generating economic benefits, identifying activities that yield the highest value per

unit of investment. This analysis is essential for policymakers and stakeholders in evaluating the effectiveness of various projects and economic sectors in promoting sustainable growth. The induced value-added coefficients presented in Figures 4.3. and 4.4. illustrate these dynamics.

It can be inferred from the results that renewable energy generates more value-added per unit of investment than gas-fired power generation, both nationally and regionally. This finding aligns with the results from Kim K. (2020) and Kim & Kim (2021). The long-term operational benefits of renewable energy particularly exceed those of gas-fired power generation, especially when integrated with ESS.

[Figure 4.3.] Induced Value-Added Coefficients at the National Level



[Figure 4.4.] Induced Value-Added Coefficients at the Regional Level

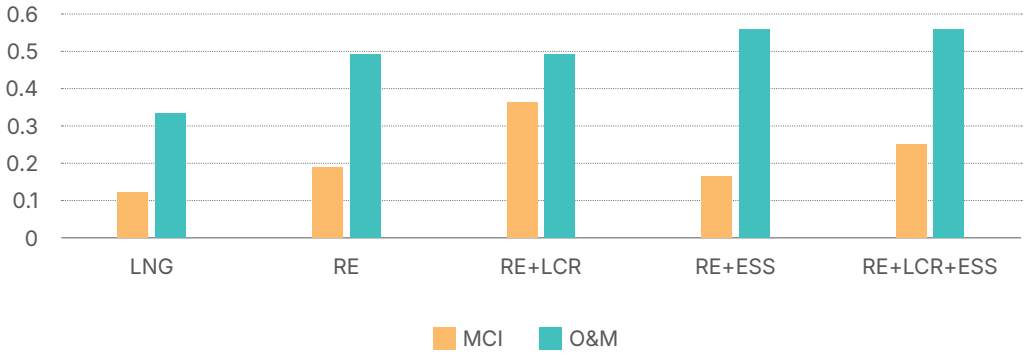
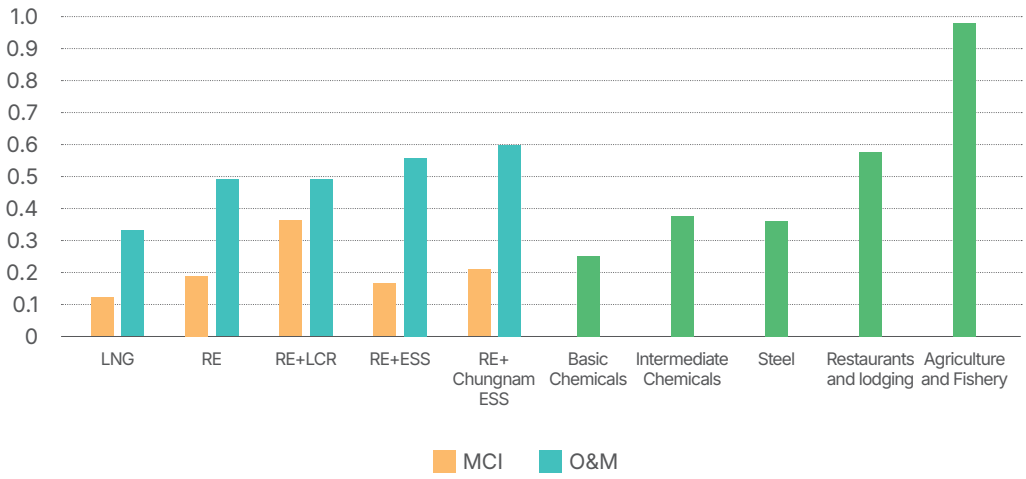


Figure 4.5. below compares the induced value-added coefficients of LNG and renewable energy scenarios with those of prominent industries in Chungnam. As mentioned in Chapter 1, Chungnam is home to manufacturing complexes in sectors such as steel and chemicals. The region is also known for its tourism, as well as various agricultural and fishery products.

[Figure 4.5.] Regional Induced Value-added Coefficient of Various Industries in Chungnam



Other than the agriculture and fishery industry, renewable energy combined with energy storage systems (RE+ESS, RE+Chungnam ESS[14]) provided the highest O&M value-added coefficients. If ESS is entirely sourced from Chungnam, it could create even greater potential in the region, as represented by RE+Chungnam ESS. Additionally, renewable energy with LCR outperformed the steel and chemical industries during the MCI phases, highlighting the economic benefits of localizing renewable energy infrastructure.

While the steel and chemical industries are key pillars of the region's economy, the transition to renewable energy, particularly with ESS, led to higher value-added across both the initial investment phase and long-term operations per KRW invested. The results align closely with Han & Min (2021), indicating that renewable energy sources and related infrastructure not only utilize local resources but also integrate innovative technologies, thereby creating jobs across various sectors due to their extensive value chain and dedicated supply chain.

In contrast, gas-fired power generation performed worse than both the steel and intermediate chemical industries in terms of induced value-added per investment during the MCI and O&M phases. This underscores that fossil fuel energy sources contribute less economically than both traditional manufacturing industries and renewable energy in the region.

14 In this case, the local share of battery manufacturing in the ESS value chain was assumed to be 65% instead of 20%, while the national share was assumed to be 0%.

Chapter 5. Conclusion

Leveraging the region's renewable energy potential and promoting local capacity, alongside flexibility options like energy storage, offers a more socio-economically beneficial alternative to gas-fired power generation, while ensuring a cleaner environment for future generations.

Jobs

- Nationally, all RE scenarios create more jobs than the LNG scenario.
- Regionally, all RE scenarios create more jobs than the LNG scenario, except RE1, which surpasses LNG when either LCR or ESS is included, underscoring their importance.
- Expanding RE capacity beyond current plans could significantly boost regional employment.

Value-added

- Nationally and regionally, all RE scenarios generate higher value-added impacts than the LNG scenario, except RE1, which exceeds LNG when both ESS and LCR are included.
- Fully realizing renewable energy potential (as in RE3) could contribute between 23.44% and 52.65% of Chungnam's 2022 GRDP.
- When considering total investment costs, renewable energy provides greater economic benefits than gas-fired power generation and can contribute more to the regional economy than key industries such as steel and chemicals during the operational period.

5.1. Summary

Eighteen coal-fired power plants in Chungnam, representing 9 GW of capacity, are scheduled for decommissioning by 2038, with the majority transitioning to gas-fired power generation and only a fraction remaining in the region. This transition raises significant concerns regarding regional job security and greenhouse gas emissions. Given the region's substantial renewable energy potential, PV and wind in particular, this study quantitatively analyzes the national and regional socio-economic impacts, focusing on employment and value-added creation from expanding renewable energy and gas-fired power generation up to 2050. The analysis covers five scenarios, incorporating LCR and ESS within the context of Chungnam, South Korea.

At the national level, renewable energy sources consistently generate more jobs than gas-fired power plant expansion. Job creation in the LNG scenario is 82,139 FTE, while in the RE scenarios, it ranges

from 92,305 FTE to 3,012,447 FTE, depending on the specific scenario and additional instruments (LCR, ESS) considered.

At the regional level, incorporating LCR and ESS plays a critical role in maximizing employment. All RE scenarios generate more jobs than LNG, except for RE1, which surpasses LNG when either LCR or ESS is included. Job creation in the LNG scenario is 29,399 FTE. In contrast, the RE scenarios range from 27,429 FTE to 1,085,509 FTE. This is because renewable energy typically requires less frequent maintenance, while the operation of natural gas power plants necessitates fuel imports, leading to additional upstream supply chain activities. Increasing renewable energy capacity well beyond current plans could significantly boost regional employment opportunities. Expanding renewable energy sources to market potential as in RE3 scenario, along with LCR and ESS, can create an average of 40,000 long-term jobs (FTE) across all sectors in the region up to 2050, twice the total employment of Chungnam's electricity, gas, steam, and air conditioning supply industry in 2022. The analysis also incorporates indirect and induced effects. Half of the total employment generated by renewable energy and ESS is indirectly linked to the value chain, thereby diversifying the regional economy. Having different types of industries in an economy leads to stability and can also foster innovation that drives economic growth.

The value-added impact, which reflects the quality and economic contribution of the jobs created, showed slightly different patterns compared to the employment impact. At both the national and regional levels, value-added creation under the RE1 scenario surpasses that of the LNG scenario only when both LCR and ESS are included. At the national level, value-added creation in the LNG scenario is estimated at 10,602 billion KRW. In contrast, the RE scenarios range from 6,908 to 205,307 billion KRW. At the regional level, value-added creation in the LNG scenario is 4,631 billion KRW and the RE scenarios range from 2,416 to 74,194 billion KRW. If the renewable energy market potential is fully realized as in RE3 scenario, the accumulated value-added creation in the region by 2050 is projected to account for between 23.44% and 52.65% of Chungnam's 2022 GRDP.

A common method for accurately comparing value-added impacts is to normalize value-added creation by total investment. The analysis on induced value-added coefficient indicates that renewable energy generates greater economic benefits per unit of investment than gas-fired power generation, both nationally and regionally. Additionally, the transition to renewable energy, especially when integrated with ESS, can lead to higher value added per unit invested during the operational period compared to the steel and chemical industries, which are key pillars of the region's economy.

This study demonstrates that utilizing the region's renewable energy potential and promoting local capacity, along with flexibility options such as energy storage, can present a more socio-economically beneficial option than gas-fired power generation for both Chungnam and South Korea in the energy transition. Therefore, it is crucial to prepare and implement effective policies in advance to realize these benefits.

5.2. Policy Recommendations

Based on the findings, this study proposes three key policy recommendations.

Enhancing Local Capacity: Municipalities, along with the Chungnam provincial government and the central government, must focus on building local capacity through an aligned strategy considering the overall national carbon neutrality goal as well as the regional context. The program should involve establishing supportive regulations, providing targeted education, and training programs, particularly for installation and maintenance work in solar PV and wind power plants.

Increasing public awareness of the energy transition's importance, as well as its regional economic impact, could motivate individuals to acquire new skills, since currently employed in conventional power plants are reluctant to pursue career changes. This effort also requires the government to convey a consistent message regarding plans to expand renewable energy and supporting infrastructure.

Adopting proactive measures that leverage the region's potential for PV installation, battery businesses, and automotive battery recycling can significantly boost employment and ensure that economic benefits are retained within the community. For example, Jeju's regulation on wind power projects mandate that a certain percentage of the workforce be local residents, while Jeollanam-do encourages the use of locally produced equipment in renewable energy projects. However, it is crucial to ensure that local companies do not exploit these provisions and take full responsibility for completing the projects.

Promoting Sector Coupling: Sector coupling describes a strategy to optimize the energy system by increasing its flexibility and reliability through the use of electricity in end-use sectors, with the goal of accelerating the transition towards 100% renewable energy (IRENA Coalition for Action, 2022). Chungnam's energy transition strategy should focus on integrating sector coupling by expanding renewable energy while simultaneously promoting demand-side electrification in the industry, buildings, agriculture, and transportation sectors, also incorporating ESS as considered in the analysis. This approach will not only enable efficient utilization of locally generated renewable energy and decarbonize power generation and the related sectors, but it will also bring substantial socio-economic benefits to the region.

Holistic Approach to Sustainable Energy Transition: The energy transition is a lengthy and ongoing process that requires sustained effort. Engaging various local stakeholders and the community is essential for fostering a sustainable and inclusive transition. This engagement can facilitate worker reskilling and ensure a smooth shift to renewable energy related jobs.

Energy transition must go hand in hand with urban planning. Establishing basic infrastructure, such as hospitals, schools, and rail services, is crucial for enabling new workers to settle in the region long-term while retaining the existing workforce.

Selecting an energy source is a significant decision, as its impact can last for generations. Transitioning to renewable energy is a proven strategy for reducing greenhouse gas emissions. When implemented with careful planning and strategic investment, the expansion of renewable energy can offer a more socio-economically beneficial option than gas-fired power generation for both the country and the region while ensuring that future generations inherit a cleaner environment.

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Appendix A. Results in Detail

[Table A.1.] Summary of Employment Impacts (unit: FTE)

Local Content		Reference		LCR	
Flexibility Resources		-	ESS	-	ESS
Korea	LNG	82,139			
	RE1	92,305	200,052	100,499	208,246
	RE2	205,864	429,914	225,914	449,963
	RE3	1,411,777	2,874,405	1,549,819	3,012,447
	RE4	328,754	708,714	357,943	737,904
Chungnam	LNG	29,399			
	RE1	27,429	59,364	44,810	76,745
	RE2	59,292	120,416	102,665	163,789
	RE3	397,230	795,542	687,196	1,085,509
	RE4	100,352	212,371	161,965	273,984

- LNG: Refers to gas-fired power plants (2,550 MW) replacing coal in Chungnam.
- RE1: Represents the expansion of renewable energy to match the power generation of LNG.
- RE2: Based on Chungcheongnam-do's 6th regional energy plan.
- RE3: Derived from the renewable energy market potential in Chungnam.
- RE4: Corresponds to the expansion of renewable energy to match the power generation of the total coal phase-out (9,100 MW) in the region.

[Table A.2.] Summary of Value-added Impacts (unit: Billion KRW)

Local Content		Reference		LCR	
Flexibility Resources		-	ESS	-	ESS
Korea	LNG	10,602			
	RE1	6,908	13,805	7,310	14,207
	RE2	15,029	29,631	16,011	30,613
	RE3	103,163	198,524	109,946	205,307
	RE4	24,742	49,094	26,175	50,527
Chungnam	LNG	4,631			
	RE1	2,416	4,201	3,505	5,290
	RE2	4,892	8,422	7,612	11,143
	RE3	33,027	56,051	51,170	74,194
	RE4	8,931	15,205	12,787	19,061

- LNG: Refers to gas-fired power plants (2,550 MW) replacing coal in Chungnam.
- RE1: Represents the expansion of renewable energy to match the power generation of LNG.
- RE2: Based on Chungcheongnam-do's 6th regional energy plan.
- RE3: Derived from the renewable energy market potential in Chungnam.
- RE4: Corresponds to the expansion of renewable energy to match the power generation of the total coal phase-out (9,100 MW) in the region.

Appendix B. Scenario Analysis

[Table B.1.] The Replacement Plan for Coal-fired Power Plants in Chungnam

Shut down | 10th Basic Plan | Announced | NA

Municipality	Company Name	Completion Date	Power Plant	Capacity (MW)	Decommissioning	Replacement	Replacement Location
Boryeong	Korea Midland Power	1983.12	#1	500	2020.12	X	-
		1984.09	#2	500	2020.12	X	-
		1993.04	#3	500	2038.04	Hydrogen combustion combined cycle/LNG CHP	NA
		1993.06	#4	500	2038.06	Pumped storage	Bonghwa, Gyeongbuk
		1993.12	#5	550	2026	Gas-fired power generation (Hydrogen co-firing combined cycle)	Boryeong, Chungnam
		1994.04	#6	550	2026	Gas-fired power generation	Haman, Gyeongnam
		2008.06	#7	500	2038	Hydrogen combustion combined cycle/LNG CHP	NA
		2008.12	#8	500	2038	Hydrogen combustion combined cycle/LNG CHP	NA
		2017.06	New #1	1,019	-	-	-
		2017.09	New #2	1,019	-	-	-
Dangjin	Korea East-West Power	1996.06	#1	500	2029	Gas-fired power generation	Yeosu, Jeonnam
		1999.12	#2	500	2029	Gas-fired power generation	Yeosu, Jeonnam
		2000.09	#3	500	2030	Gas-fired power generation	Ulsan
		2001.03	#4	500	2030	Gas-fired power generation	Ulsan
		2005.10	#5	500	2036	Gas-fired power generation	NA
		2006.04	#6	500	2036	Gas-fired power generation	NA
		2007.06	#7	500	-	-	-
		2007.12	#8	500	-	-	-
		2016.07	#9	1,020	-	-	-
		2016.09	#10	1,020	-	-	-

Taean	Korea Western Power	1995.06	#1	500	2025	Gas-fired power generation	Gumi, Gyeongbuk
		1995.12	#2	500	2025	Gas-fired power generation	Yeosu, Jeonnam
		1997.03	#3	500	2028	Gas-fired power generation	Gongju, Chungnam
		1997.08	#4	500	2029	Gas-fired power generation	NA
		2001.10	#5	500	2032	Gas-fired power generation	Yongin, Gyeonggi
		2002.05	#6	500	2032	Gas-fired power generation	Yongin, Gyeonggi
		2007.02	#7	500	-	-	-
		2007.08	#8	500	-	-	-
		2016.10	#9	1,050	-	-	-
		2017.06	#10	1,050	-	-	-

Reference: 10th Basic Plan on Electricity Supply and Demand, recent announcements by KEPCO subsidiaries

Appendix C. Cost Analysis and Local Content

[Table C.1.] CCGT Generation Value Chain and Local Content

	MCI Value Chain	Cost Distribution	Local Share	National Share
#1	Gas/Steam Turbine	39.69%	0%	8%
#2	Dyes and Coatings	0.01%	0%	90%
#3	Other Chemical Products	0.02%	0%	90%
#4	Clay Products	0.02%	0%	90%
#5	Structural Components (steel)	0.23%	0%	90%
#6	Structural Components (metal)	0.13%	0%	90%
#7	Miscellaneous Metal Parts	0.01%	0%	90%
#8	Machinery Parts	0.29%	0%	90%
#9	Industrial Conveyance Equipment	0.57%	0%	90%
#10	Heat Recovery Steam Generator (HRSG)	12.01%	0%	80%
#11	Other General-purpose Machinery	3.41%	0%	90%
#12	Other Special-purpose Machinery	1.87%	0%	90%
#13	Electrical Components	0.68%	20%	80%
#14	Construction of Transportation Facilities	0.53%	100%	0%
#15	General Civil Engineering	5.83%	100%	0%
#16	Other Special Construction	14.74%	0%	100%
#17	Logistics	4.88%	100%	0%
#18	Finance	6.50%	50%	50%
#19	Project Management	5.09%	10%	90%
#20	Engineering Services	3.50%	0%	50%
	O&M Value Chain	**Cost Distribution**	**Local Share**	**National Share**
#1	Operation and Maintenance	100.0%	52%	48%

Reference: expert consultation, Cho, Yoon, & Kim (2018), Kim K. (2020), KEEI (2018), Korea Electric Power Corporation Economic Research Institute (2012), KETEP (2023), https://www.eiass.go.kr/

[Table C.2.] Solar PV Value Chain and Local Content

MCI Value Chain		Cost Distribution	Local Share	National Share		
#1	Cell	9.5%	0%	20%		
#2	Wafer	13.9%	0%	20%		
#3	Module	12.5%	0%	20%		
#4	Inverter	7.3%	0%	20%		
			1) Reference		2) LCR	
#5	Electrical Infrastructure	17.2%	50%	50%	100%	0%
#6	Management	4.6%	50%	50%	100%	0%
#7	Construction	19.8%	50%	50%	100%	0%
#8	Supervision	0.9%	50%	50%	100%	0%
#9	Legal Services	5.3%	50%	50%	100%	0%
#10	Engineering Services	7.9%	50%	50%	100%	0%
#11	Finance	0.2%	50%	50%	100%	0%
#12	Insurance	0.1%	50%	50%	100%	0%
#13	Electrical Interconnection	0.9%	20%	80%	40%	60%
O&M Value Chain		Cost Distribution	Local Share	National Share		
#1	Compliance	18.6%	100%	0%		
#2	Field Salaries	48.4%	100%	0%		
#3	Replacement Parts (Inverter)	22.4%	45%	10%		

Reference: Kim B. (2023)

[Table C.3.] Onshore Wind Value Chain and Local Content

MCI Value Chain		Cost Distribution	Local Share	National Share		
#1	Tower, Shaft/Nacelle Housing/Main Frame, Rotor Blade	21.6%	0%	20%		
#2	Gearbox/Rotor Bearing	6.7%	0%	20%		
#3	Generator, Transformer, Power Conversion Device	7.9%	0%	20%		
#4	Yawing/Pitching	3.1%	0%	20%		
			1) Reference		2) LCR	
#5	Construction	8.6%	100%	0%	100%	0%
#6	Installation	13.5%	0%	100%	50%	50%
#7	Electrical Infrastructure	3.8%	0%	100%	50%	50%
#8	Project Management	3.5%	10%	90%	50%	50%
#9	Legal Services	0.9%	50%	50%	70%	30%
#10	Development	1.3%	10%	90%	50%	50%
#11	Electrical Interconnection	19.3%	20%	80%	40%	60%
#12	Engineering Services	6.3%	0%	100%	40%	60%
#13	Finance, Contingency, Miscellaneous	3.5%	50%	50%	70%	30%
O&M Value Chain		Cost Distribution	Local Share	National Share		
#1	Field Salaries	19.9%	100%	0%		
#2	Logistics	2.3%	100%	0%		
#3	Compliance	17.8%	100%	0%		
#4	Utilities	1.8%	100%	0%		
#5	Replacement Parts	57.3%	45%	10%		
#6	Fuel	0.9%	100%	0%		

Reference: Kim B. (2023), GESI (2023)

[Table C.4.] Offshore Wind Value Chain and Local Content

MCI Value Chain			Cost Distribution	Local Share	National Share
#1	Turbine	Bedplate	0.8%	0%	20%
#2		Main Bearing	0.8%	0%	20%
#3		Main Shaft	0.8%	0%	20%
#4		Gearbox	2.9%	0%	20%
#5		Generator	4.2%	0%	20%
#6		Power Take-off	2.9%	0%	20%
#7		Control System	1.1%	0%	20%
#8		Yaw System	0.7%	0%	20%
#9		Yaw Bearing	0.3%	0%	20%
#10		Nacelle Auxiliary Systems	0.3%	0%	20%
#11		Nacelle Cover	0.4%	0%	20%
#12		Small Engineering Components	1.1%	0%	20%
#13		Structural Fasteners	0.3%	0%	20%
#14		Blades	5.5%	0%	20%
#15		Hub Casting	0.6%	0%	20%
#16		Blade Bearings	0.8%	0%	20%
#17		Pitch System	0.4%	0%	20%
#18		Spinner	0.1%	0%	20%
#19		Rotor Auxiliary Systems	0.2%	0%	20%
#20		Fabricated Steel Components	0.3%	0%	20%
#21		Structural Fasteners	0.3%	0%	20%
#22		Other	14.3%	0%	20%
#23		Tower	2.8%	0%	20%

			1) Reference		2) LCR	
#24	Development	2.6%	10%	90%	50%	50%
#25	Engineering Services	0.2%	0%	100%	40%	60%
#26	Finance, Contingency, Miscellaneous	2.3%	50%	50%	70%	30%
#27	Electrical Infrastructure and Interconnection	7.0%	20%	80%	40%	60%
#28	Construction and Installation	36.7%	50%	50%	75%	25%
#29	Offshore Logistics	0.2%	100%	0%	100%	0%
#30	Project Management and Legal Services	8.9%	10%	90%	50%	50%

O&M Value Chain		Cost Distribution	Local Share	National Share
#1	Field Salaries	0.7%	100%	0%
#2	Onshore Logistics	0.6%	100%	0%
#3	Offshore Logistics	2.1%	100%	0%
#4	Health and Safety Inspections	0.5%	100%	0%
#5	Compliance	29.0%	100%	0%
#6	Replacement Parts	67.1%	45%	10%

Reference: BVG Associates (2019), GESI (2022), KETEP (2023)

[Table C.5.] ESS Value Chain and Local Content

MCI Value Chain		Cost Distribution	Local Share	National Share
#1	Battery Manufacturing	53.0%	20%	45%
#2	Electrical Infrastructure and Interconnection	11.3%	20%	80%
#3	Construction and Installation	12.5%	50%	50%
#4	Development	22.4%	10%	90%
#5	Project Management and Legal Services	0.8%	100%	0%
O&M Value Chain		**Cost Distribution**	**Local Share**	**National Share**
#1	Operation and Maintenance	50.0%	80%	20%
#2	Replacement Parts	50.0%	20%	45%

Reference: Kim B. (2023)

Socio-economic Impacts of Energy Transition in Chungcheongnam-do

Renewable Energy vs. Gas-fired Power Generation

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Design Nature Rhythm

Solutions for Our Climate (SFOC) is an independent policy research and advocacy group that aims to make emissions trajectories across Asia compatible with the Paris Agreement 1.5°C warming target.

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