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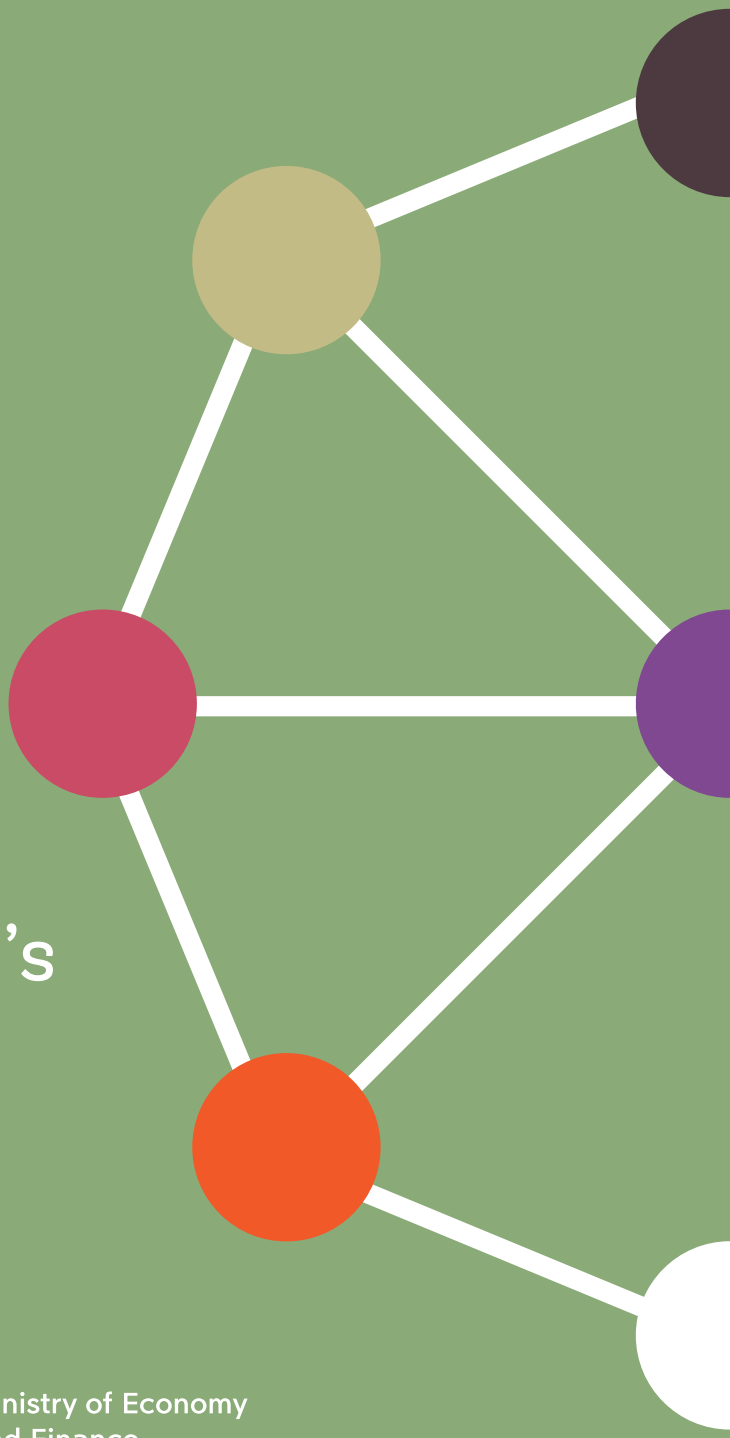

Lessons from Korea's Energy Efficiency Policies in the Industrial Sector

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Acronyms and Abbreviations

CHP	Combined Heat and Power
CO_2	Carbon Dioxide
COP 22	22nd session of the Conference of the Parties to the UNFCCC
DSM	Demand-side Management
EEIS	Energy Efficiency Information Strategy
EIP	Eco Industrial Park
EnMS	Energy Management System
ESCO	Energy Service Company
ESP	Energy Saving through Partnership
ETS	Emission Trading Scheme
FEMS	Factory Energy Management System
GDP	Gross Domestic Product
GGGI	Global Green Growth Institute
GGP	Green Growth Partnership
GHG	Greenhouse Gas
GIR	Greenhouse Gas Inventory & Research Center of Korea
HVAC	Heating, Ventilation, and Air Conditioning
IEA	International Energy Agency
IPR	Intellectual Property Right
ISO	International Organization for Standardization
KATS	Korean Agency for Technology and Standards
KDHC	Korea District Heating Corporation
KEA	Korea Energy Agency
KECO	Korea Environment Corporation
KEEI	Korea Energy Economics Institute
KEPCO	Korea Electric Power Corporation
KESIS	Korea Energy Statistical Information System
KETEP	Korea Institute of Energy Technology Evaluation and Planning
KICOX	Korea Industrial Complex Corporation
KIER	Korea Institute of Energy Research
KOGAS	Korea Gas Corporation
KRX	Korea Exchange
KSIC	Korean Standard Industry Code
KVER	Korea Voluntary Emission Reduction

LEEN	Learning Energy Efficiency Network
MAC	Marginal Abatement Cost
MEPS	Minimum Energy Performance Standards
MKE	Ministry of Knowledge Economy
MOE	Ministry of Environment
MOEF	Ministry of Economy and Finance
MOLIT	Ministry of Land, Infrastructure, and Transport
MOTIE	Ministry of Trade, Industry and Energy
MRV	Monitoring, reporting and verification
Mt CO_2e	Million Tonnes Carbon Dioxide Equivalent
Mtoe	Million Ton of Oil Equivalent
OECD	Organization for Cooperation and Economic Development
RD&D	Research, Development and Demonstration
ROI	Return on Investment
SMEs	Small and Medium Enterprises
TDR	Turn-down ratio
TMS	Target Management Scheme
toe	Ton of Oil Equivalent
UNFCCC	United Nations Framework Convention on Climate Change

* The exchange rate used in this report is the 2022 annual average at US$ 1 = KRW 1,291.7, based on https://www.irs.gov/individuals/international-taxpayers/yearly-average-currency-exchange-rates.

Executive Summary

The industrial sector is a major consumer of energy and emitter of greenhouse gases (GHG) worldwide. Energy efficiency is typically known as the least expensive and the fastest route to green growth and sustainable development. Despite its promise, adoption of energy efficiency solutions by firms and industries is often riddled with a complex set of economic, technical, and informational barriers. Public policy has a key role in alleviating these burdens, and Korea's energy efficiency policies offer an opportunity for learning given their diversity and coverage.

Rising energy consumption and GHG emissions from the industrial sector have been a key motivation for pursuing energy efficiency policy in the Republic of Korea. As of 2021, Korea accounts for approximately 1.5 percent (616 million tons of CO_2) of the world's total CO_2 emissions (37.12 billion tons of CO_2) and its industrial sector is responsible for over half of the GHG and other pollutant emissions. Energy-intensive manufacturing sectors, namely petrochemicals, iron and steel which are often hard-to-abate industry sectors, play a key role as the backbone of Korea's industry structure, making energy efficiency improvement even more challenging. Moreover, a significant amount of energy consumption originates from energy-intensive firms that consume more than 2,000 tons of oil equivalent (toe) per year. Despite the increased electrification in the industrial sector, energy intensive firms still heavily rely on fossil fuels. Notwithstanding these challenges, Korea's energy intensity for the industrial sector was maintained at a relatively stable level over the past decade.

Reducing the energy intensity of industrial production poses several public policy challenges. Subsidies to energy consumption and tax policies that do not reflect the true environmental and social cost of energy production impede efforts to improve energy efficiency. Imperfect market competition (for example due to dominant state-owned enterprises in energy intensive sectors) and informational barriers increase the transaction costs facing industrial firms attempting to reduce energy use. Lack of protection of intellectual property rights, as well as import tariff policies, pose significant barriers. The lack of appropriate institutions and information can impede the effectiveness of energy efficiency programs. Inadequate access to finance, the short payback periods often required by industrial firms, volatile energy prices, and lack of energy infrastructure with advanced technology limit investment in energy efficiency. Firms often fail to understand the value of energy efficiency improvements and lack the ability to evaluate them properly. Finally, success in increasing energy efficiency and the consequential cost savings can increase energy use if the cost savings are used to expand production (the rebound effect).

This report offers a comprehensive overview of Korea's energy efficiency policy experience for the benefit of policy makers and industry practitioners aiming to promote and scale up energy efficiency in the industry sector, particularly in manufacturing. It introduces the country's overarching energy policy framework and reviews its energy efficiency policy mix. Among the 22 energy efficiency programs reviewed, six exemplary programs were selected as good practices based on experts' opinion and perceived effectiveness, and are described in detail. Korea's energy efficiency policy mix, developed over the last three decades, leverages a combination of modalities of public policy support including regulatory and voluntary incentives targeting both energy supply and demand actors. Korea's experience highlights that individual industrial energy efficiency programs are more effective when closely linked with complementary policies throughout their design and implementation. On the energy demand side, mandatory energy audits target energy-intensive firms that consume more than 2,000 toe annually while voluntary programs are tailored for small and medium enterprises (SMEs). On the supply side, energy suppliers (utilities) are mandated to set energy savings targets every year and invest in energy efficiency improvement projects. At the same time, Korea has been placing greater emphasis on market-based approaches such as the GHG Emission Trading Scheme (ETS) which puts prices on carbon with the objective of indirectly improving access to finance and inducing behavioral change in firms. The Energy Standards and Labeling Program sets the standards for acceptable energy efficiency in appliances and creates opportunities for energy efficiency improvements by providing information for consumers and incentives for firms to improve their products. The national eco-industrial park (EIP) and the smart green industrial complex programs aim to increase energy efficiency of the manufacturing sector in Korea through improved energy management systems and resource circularity at the industrial park level. While there is much room for further reducing the energy intensity of its industry sector and fully internalizing environmental costs, policy efforts to date indicate the country's commitment to the energy efficiency agenda and are correlated with an overall decrease in Korea's energy intensity.

The report concludes with six key policy lessons that could be relevant for other economies, particularly those with economic structures that are heavily reliant on manufacturing:

1. **Align energy efficiency policies and programs with national long-term goals and establish a well-designed coordination mechanism between various stakeholders.**

   Energy efficiency is linked to different policy goals, such as energy security, industrial competitiveness, green growth, mitigation of climate change, and others. Korea systematically tackled these coordination problems by establishing a regulatory, legal, and institutional framework which served as a foundation for coordinated action and alignment with national long-term goals. Also, Korea's institutional framework clearly delineated the lines of authority and responsibility for energy efficiency among line ministries and implementing agencies. This provided a more coherent approach across different ministries, allowing policies to work towards a unifying goal.

2. **Incorporate energy intensity implications into industrial policy and economic plans to avoid the development of captive economic structures that constrain energy efficiency gains in the long run.**

   The economic structure and the sectoral composition of the industrial sector dictate the degree of energy efficiency improvements a country could achieve. In Korea, hard-to-abate sec-

tors such as petrochemicals, iron and steel production account for around 90 percent of total energy consumption within the manufacturing sector. Moreover, firms that consume more than 2,000 toe annually are responsible for approximately half of total energy consumption. The wide range of energy efficiency policies introduced by Korea has led to improvements in industrial energy intensity but is yet slowed by structural constraints in energy efficiency gains. Transformation of the economic structure post industrialization is likewise challenging, considering the share of energy intensive sectors in Korea's GDP. As such, industrializing economies today are at an advantage and do have a choice to avoid development pathways that can predetermine the limits of energy efficiency gains. Industrial policies and economic plans targeting industrial sectors that are greener could allow economies a more feasible route towards energy efficiency gains.

3. **Gradually and incrementally develop the energy efficiency policy mix to leverage complementarities among programs and induce behavioral change among firms and industries.**

   Korea's industrial energy efficiency policies have been gradually developed and regularly revised and updated. Although there is a need for further research to rigorously assess the effectiveness of programs, the experimental policy approach resulted in a diverse and comprehensive policy mix that serves as a learning resource for other countries. Korea's policy mix today is characterized by a combination of mandatory and voluntary programs that collectively incentivize firms of all types and sizes to participate in energy saving practices. Korea's experience also demonstrates that individual policy programs and modalities of public policy support are more effective when they are closely linked and complementary by design.

4. **Establish effective monitoring, reporting and verification (MRV) systems and leverage digital technologies to collect, analyze, and monitor energy data.**

   Continuous development and improvements to the MRV system is one of the notable features of the Korea energy efficiency policy experience. Collecting data on energy consumption and turning this data into useful information available for policymakers, utilities, firms and individual consumers could help address information asymmetry between the energy suppliers and consumers, as well as contribute to program evaluation. Evidence on which programs are effective, and why, will be critical to improving Korea's energy efficiency programs' outcomes and provide valuable knowledge to policymakers globally.

5. **Leverage voluntary agreements and local knowledge sharing activities to facilitate technology transfer and collective actions.**

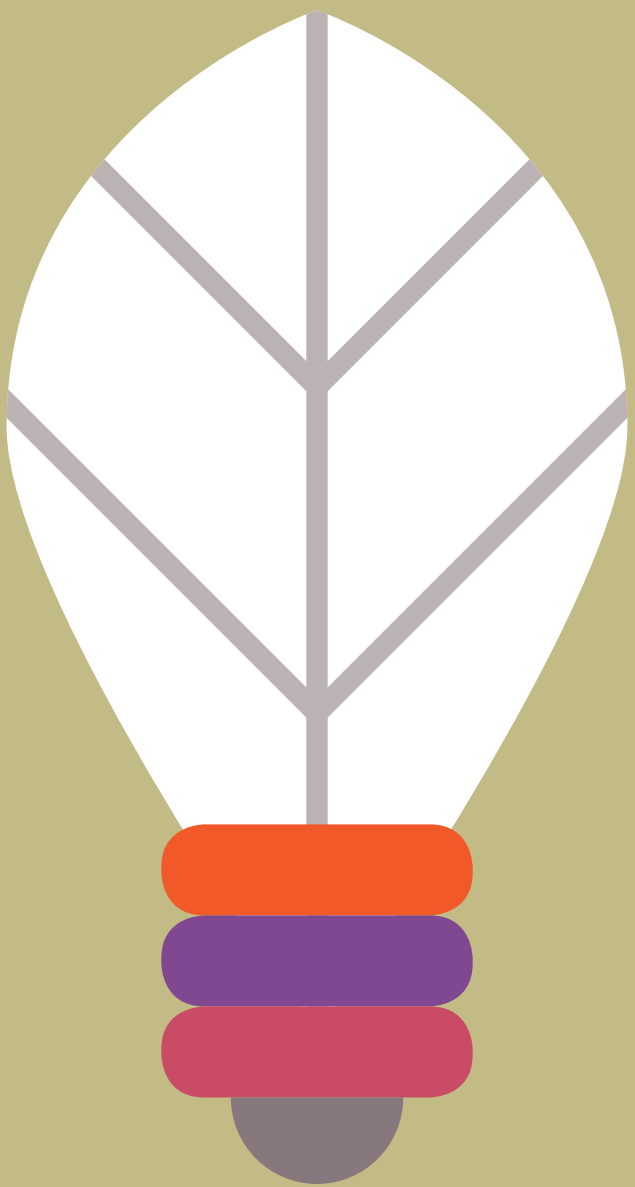
   Energy efficiency policy can play an important role in facilitating knowledge sharing and transfer by promoting networking among firms. The Korean government has introduced local initiatives and voluntary agreements to improve information flow and awareness raising among firms regarding the best practices to enhance industrial energy efficiency. However, there are significant impediments to knowledge spillovers from these activities. An important issue is reluctance to share information or know-how with competitors. To overcome this challenge, public policy can consider diverse options to promote cooperation, such as through incentives to participate in knowledge-sharing activities and leveraging local governments, local industrial associations, research networks, and existing consortiums.

6. **Develop policy design and implementation capabilities to effectively execute a comprehensive energy efficiency policy mix.**

Effective design and implementation of energy efficiency policy is to a large extent a function of capable implementing agencies with a clear mandate, abundant financial and technical resources and strong organizational capabilities. The Korea Energy Agency (KEA) has been key to the development and implementation of the energy efficiency policy mix. Three lessons can be extracted from KEA's policy implementation experience. First, providing a clear mandate for KEA and conducting regular monitoring and evaluation helped KEA establish itself as the key energy efficiency policy implementation agency. Second, setting realistic targets along with technical guidelines, methodologies, and metrics to meet such targets was crucial. Third, given the complexity of legal and economic arrangements, communication with the industries and disseminating relevant, timely information is essential.

01

Introduction



01 Introduction

In the face of the recent energy crisis, improving energy efficiency has regained attention as one of the key strategies to achieve sustainable growth of the industry sector and carbon neutrality targets set by governments. Energy efficiency means increasing productivity and output for the same amount of energy input and is measured in terms of the amount of output that can be produced with a given input of energy. It is often referred to as the "first fuel" of a sustainable global energy system by the IEA (IEA 2019). The term "industrial energy efficiency" means the energy efficiency derived from commercial technologies and measures to improve energy efficiency or to generate or transmit electric power and heat, including electric motor efficiency improvements, demand response, direct or indirect combined heat and power, and waste heat recovery (US Department of Energy 2015). As of 2021, industrial activity accounted for 25 percent of global emissions, or 9.4 Gt of CO_2 (IEA 2022c).[1] Energy consumption in the industry sector has continuously risen over the past decade due to the global trend of rising production in energy-intensive industry subsectors (chemicals, iron and steel, and cement).

Energy efficiency measures are considered the first and most cost-effective responses to address energy-related challenges while meeting the climate goals. For the industrial sector, especially for energy-intensive sectors such as cement, steel and iron, chemicals, food processing, paper and pulp industries, energy efficiency measures can help reduce production costs by lowering energy bills and overcome market pressures following the international climate change agreements and active green growth policies implemented around the world.[2] The Sharm el-Sheikh Implementation Plan adopted during the COP 27 in Egypt called upon all the participating member countries to accelerate development and adoption of policies and technologies that will help rapidly scale up the deployment of energy efficiency measures and clean power generation across all sectors including the industrial sector (UNFCCC 2022).

However, progress in improving energy efficiency in the industrial sector is slow, and challenges remain unresolved across the world, especially in emerging markets. IEA reports that energy efficiency progress in the industrial sector is occurring far too slowly. While industrial ener-

1 These emissions do not include indirect emissions from the electricity use in the sector.

2 As energy is not the most significant expense even in the most energy intensive sectors, there are limitations to the savings gains through energy efficiency. However, improving energy efficiency still has merit in that the sectors are nevertheless the largest consumers of all sources of energy, except oil where transportation dwarfs other demands.

gy efficiency needs to increase by approximately 3 percent annually until 2030 to achieve the Net Zero target (IEA 2022c), improvements in energy efficiency have been modest due to low energy and carbon prices, lack of access to finance, lack of public and private stakeholders' awareness of good practices, brown economic structure, and limited market competition (details are discussed in Section 2). Knowledge gaps still exist in terms of what has worked and what did not, and how different policy instruments can help tackle barriers to improve industrial energy efficiency.

Increasing industrial energy efficiency has been the government's priority in Korea, with its broad policy commitment to the green growth model. Despite mixed results in generating impacts, the green growth model has underpinned a range of economic policies implemented in Korea, including both industrial and energy policies. Industrial energy efficiency programs have been implemented as a key element of Korean government's efforts to green industries while strengthening their competitiveness. Like its peers, Korea has set a target of reaching carbon neutrality by 2050 and seeks to significantly improve energy efficiency while ramping up the share of renewable energy sources and fostering innovative green technologies. To achieve neutrality by 2050, industrial emissions must be cut by 80 percent from the 2018 level, or a reduction of 210 million out of 686.3 million CO_2 eq in nationwide emissions (Presidential Commission on Carbon Neutrality and Green Growth 2021). In 2022, President Yoon Suk-yeol's administration in Korea reaffirmed the country's commitment to energy efficiency, strengthening existing policies and introducing new initiatives, some of which have a particular focus on industry such as strengthening market-based approaches to promote innovation in energy-intensive industry sectors (MOTIE 2022).[3] With a track record of energy efficiency policies, Korea's experience could provide lessons and illuminate challenges and barriers that may need to be addressed when designing and implementing energy efficiency measures targeting industrial sectors.

This report aims to give an overview of Korea's energy efficiency policy experience for the benefit of policy makers and industry practitioners aiming to promote and scale up energy efficiency improvements in the industry sector, particularly in manufacturing. The report also aims to provide industry practitioners with lessons drawn from practices implemented by industry subsectors and groups of energy-intensive firms in Korea (see Section 5). The report draws upon publicly available data, literature, and policy documents, and has been enriched with qualitative interviews with energy policy experts, researchers, and practitioners. The report is laid out as follows:

— **Section 1** discusses the objectives of the report and introduces the definitions of energy efficiency and the scope of the industrial sector examined in this report.

— **Section 2** discusses why industrial energy efficiency has become ever more important in the face of global struggles to ensure energy security, lower energy costs, and tackle climate change and other sustainable development issues. It reviews current worldwide trends in in-

3 Through the five new energy policy directions and Carbon Neutrality & Green Growth Strategy announced in July and October, 2022, respectively, the Korean government emphasized optimizing energy demand and streamlining the market structure based on market principles. Regarding the power market and rates, the priority is establishing a market that runs on the basic principles of competition and fairness. The policy direction also emphasized the importance of improving the carbon emission trading system, prompting autonomous carbon reduction markets.

dustrial energy use and efficiency, identifies the benefits of improving industrial energy efficiency, and lays out the typologies of policy instruments used in improving industrial energy efficiency.

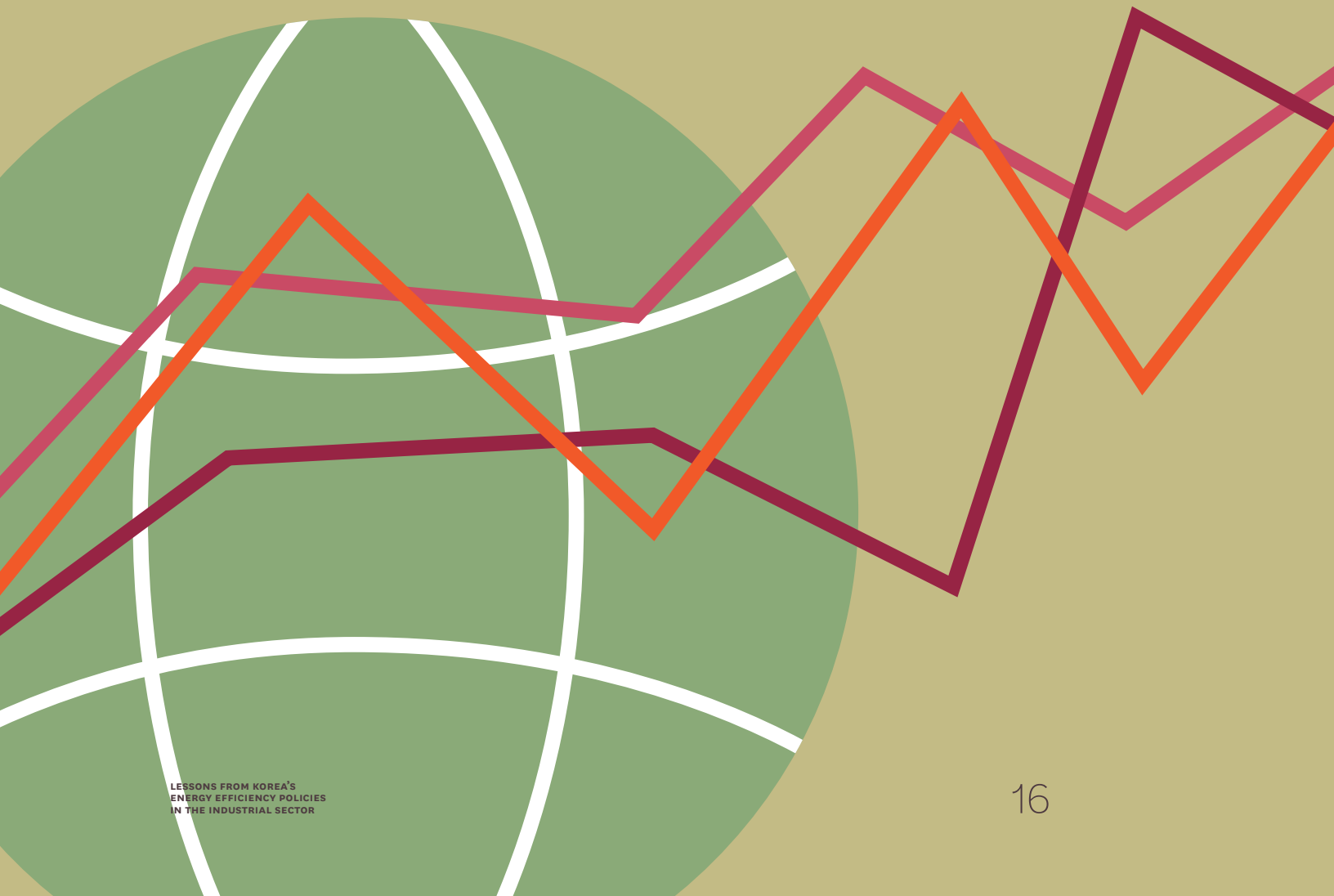
— **Section 3** examines Korea's overall trends in industrial energy use and efficiency over time. GHG emissions, energy consumption, and energy intensity in the industrial sector are reviewed.

— **Section 4** provides a typology of Korea's policies and programs that specifically target improving energy efficiency in the industry sector, with an example of each type of program.

— **Section 5** provides lessons learned from Korea's case that may be applicable to developing and to advanced economies.

02

Global trends in industrial energy efficiency: Benefits, challenges, and policies

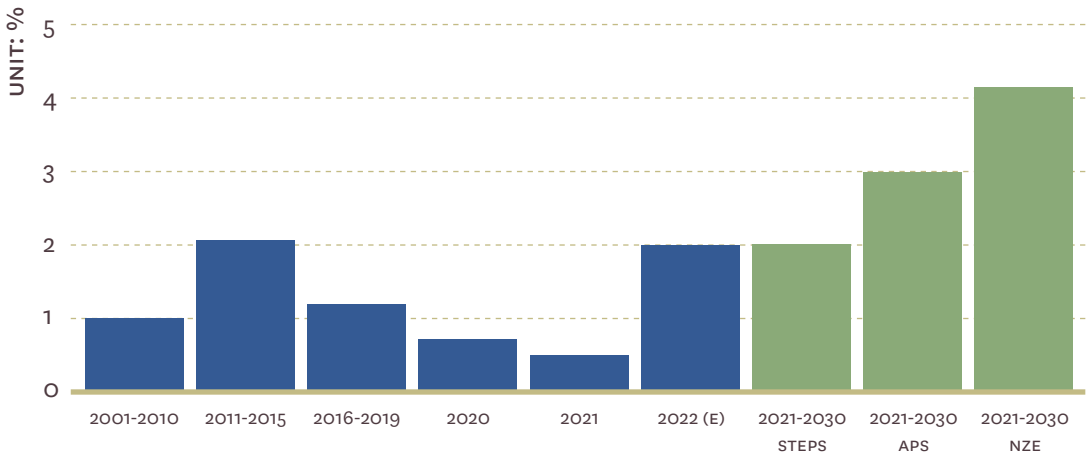


02 Global trends in industrial energy efficiency: Benefits, challenges, and policies

2.1 Global trends

The pace of global energy intensity[4] improvements has slowed. COVID-19 has posed a unique set of challenges to implementing industrial energy efficiency improvements. It includes lower expenditures on energy efficiency, and low energy prices during the pandemic, lower demand for goods, and supply chain bottlenecks that impeded planned energy efficiency improvements (IEA 2020b). The annual rate of global energy intensity improvement decelerated from 2.2 percent over 2010-15 to 1.4 percent over 2015-2020 (IEA 2022a). Since the outbreak of the COVID-19 pandemic, the energy intensity improvement in 2020 and 2021 dropped to 0.6 percent and 0.5 percent, respectively (Figure 1). However, the sluggish progress in energy efficiency improvement is expected to rebound going forward, as the increase in energy cost, supply disruptions and looming shortages have sharpened the focus on improving energy efficiency.

FIGURE 1. ANNUAL GLOBAL PRIMARY ENERGY INTENSITY IMPROVEMENT BY SCENARIO (2001-2030)



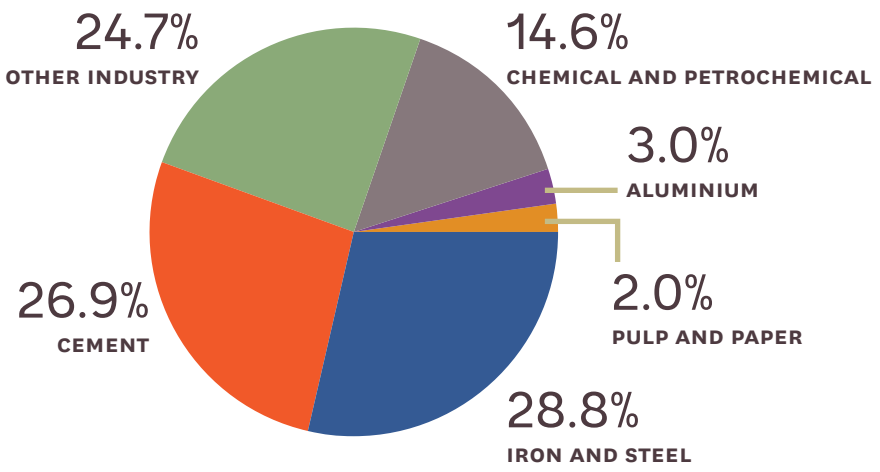
SOURCE: IEA 2022a
NOTE: STEPS = Stated policies scenario; APS = Announced pledges scenario; NZE = Net zero emissions scenario

4 Energy intensities, which are inversely related to energy efficiency, reflect the amount of energy used per unit of output, thus the lower the energy intensity, the more efficient the process, plant, or sector/subsector is in producing output.

Industrial energy consumption has grown over the past two decades. The industrial sector's share of total final energy demand increased from 33 percent in 2000 to 38 percent in 2022. Global industrial energy consumption in 2021 was 165 EJ, and three heavy industries (chemicals, steel and cement) accounted for nearly 60 percent of industrial energy demand (IEA 2022a). According to the IEA estimate, to achieve the Net Zero target, the growth in the industrial sector's energy use needs to be kept below 0.5 percent annually through 2030 (IEA 2022c).

The industrial sector is a major emitter of GHGs worldwide. Industrial activity in 2021 was directly responsible for emitting 9.4 Gt of CO_2, accounting for a quarter of global emissions.[5] Industrial CO_2 emissions fell in 2020 due to the COVID pandemic, but by considerably less than in other sectors and not as much as in transport. In 2021, global CO_2 emissions from the industrial sector rebounded to 2019 levels (IEA 2022b). Within the industrial sector, three sub-sectors, namely iron and steel (28.8 percent), cement (26.9 percent), chemicals and petrochemical (14.6 percent) dominated CO_2 emissions (IEA 2022e) (Figure 2).

FIGURE 2. SHARE OF DIRECT CO_2 EMISSION FROM INDUSTRIAL SECTOR (2021)



SOURCE: IEA 2022e

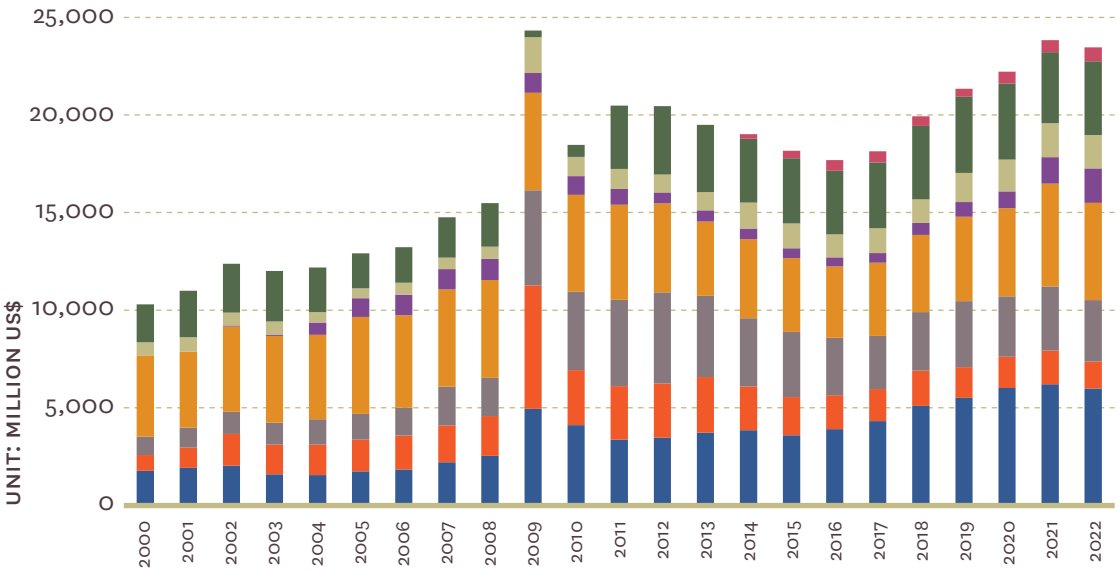
Digitalization and technological adoption can improve energy efficiency in the industrial sector, and governments have increased research, development and demonstration (RD&D) support. Digital technologies have the potential to optimize the use of energy across different activities, from manufacturing an industrial product to cooling a home (IEA 2019b). Researchers are exploring ways to make industrial and manufacturing processes more energy efficient, and a vast variety of energy efficiency technical solutions are already deployed in the market. Technologies required for improving energy efficiency vary by sector, as the production process and input, output materials differ. Annex 1 provides more details on energy efficiency technological adoption in the industrial sector. Governments have been intensifying investment in research, development and demonstration (RD&D)[6] of energy-efficient technologies; the aggregated public energy RD&D

5 This does not include indirect emissions from electricity used for industrial processes.

6 According to IEA, energy research, development, and demonstration (RD&D) covers (i) basic research on energy-related technologies, (ii) applied research, (iii) experimental development, and (iv) demonstration. Since 1974, IEA has been collecting data on energy technology RD&D budget from IEA countries. For information on the definition of energy RD&D as well as the definition of each of the technology categories, please refer to the IEA guide to Reporting Energy RD&D Budgets/ Expenditures Statistics. https://iea.blob.core.windows.net/assets/751c1fce-72ca-4e01-9528-ab48e561c7c4/RDDManual.pdf

budget in IEA member countries increased from US$ 10.3 billion in 2000 to US$ 23.4 billion in 2022, while the RD&D budget in energy efficiency more than tripled from US$ 1.8 billion to US$ 6.0 billion in 2022 (IEA 2022d) (Figure 3). The portion of the total energy RD&D budget devoted to energy efficiency increased from 17.2 percent in 2000 to 25.5 percent in 2022. Nevertheless, only 4.7 percent of the total public R&D budget was spent on energy as of 2019 (IEA 2020a). Energy has accounted for a diminishing share of government's R&D spending, as other public research objectives such as health and defense have received more public R&D funding than energy in OECD countries (IEA 2020a).

FIGURE 3. PUBLIC ENERGY RD&D BUDGET IN IEA MEMBER COUNTRIES (2000-2022)



AREAS	2000	2022	CAGR	FOLDS
ENERGY EFFICIENCY	1,770.6	5,989.4	5.44%	3.4x
FOSSIL FUELS	811.5	1,384.6	2.35%	1.7x
RENEWABLES	940.6	3,141.6	5.38%	3.3x
NUCLEAR	4,168.2	4,986.8	0.78%	1.2x
OTHER POWER AND STORAGE TECHNOLOGIES	667.6	1,707.6	4.17%	2.6x
OTHER CROSS-CUTTING TECHNOLOGIES/RESEARCH	1,936.9	3,774.3	2.94%	1.9x
HYDROGEN AND FUEL CELLS		1,763.5		
UNALLOCATED		713.6		
TOTAL BUDGET	**10295.5**	**23454.3**	**3.64%**	**2.3x**

SOURCE: IEA 2022d
NOTE: Peak in 2009 was due to post 2007-08 financial crisis stimulus funding, especially in the United States.

2.2
Benefits of energy efficiency improvements

Energy efficiency is one of the most cost-effective ways to reduce both the carbon and environmental footprints of the industry sector. Energy efficiency is considered as the "first fuel" that can help achieve countries' net zero goals, as it provides some of the quickest and most cost-effective GHG emissions mitigation options by avoiding increases in energy demand while lowering energy bills and strengthening energy security (IEA 2022a). Industrial energy efficiency options often feature prominently as low-net-cost, high potential options on "marginal abatement cost" curves (MAC).[7] Improving industrial energy efficiency has long been hailed as the "low-hanging fruit" of GHG abatement, reducing energy use and GHG emissions while offering cost savings in the bargain.

Energy efficiency can also safeguard energy security. Energy security encompasses a range of different attributes, from issues of fuel supply to the environmental, social and political implications of energy choices. The term refers to security from disruptions in energy supplies, including disruption related to supply cut-offs and disruption related to rapid increases in energy prices. Industrial energy efficiency measures can reduce reliance on imports of energy resources such as coal, oil, gas, and in the likely future, of electricity and renewable energy forms (such as "green hydrogen" or ammonia produced using renewable energy). Improving energy efficiency can help make countries less vulnerable to unexpected supply interruptions due to events in the supplying country, international political disagreements, or, in the extreme, war. As such, industrial energy efficiency measures play a crucial role in improving energy security.

Energy efficiency measures can lead to gains in firm productivity and competitiveness by reducing spending on energy costs. Energy consumption reduction per unit of output, done cost-effectively, reduces overall costs of production, helping to make firms and industries more competitive with their domestic and international counterparts. Adoption of energy efficiency measures can also enhance industrial competitiveness by reducing regulatory compliance costs.

Increased energy efficiency can generate positive macroeconomic impacts, including improvements in social welfare and contribution to job creation. These benefits can accrue in terms of GDP gains, improvements in employment, benefits to trade balances (as demand for imported energy is reduced), and improvements in energy price stability to the extent that energy efficiency allows a more stable relationship between energy supply and demand. The improvements in net economic output and employment can be partly attributed to the energy efficiency measures implemented in the industrial sector. In 2017, the European Commission examined the impact of energy efficiency measures on several aspects (economy, labor market, health, environment, etc.) and found that improvements in energy efficiency could increase GDP ranging from 0.1 percent (least ambitious EUCO30 scenario) to 2.0 percent (most ambitious EUCO40 scenario) annually by 2030 compared to a 2007 baseline in EU countries (European Commission 2017). The

7 MAC curves show the net cost for various measures that reduce energy consumption or GHG emissions, including industrial energy efficiency improvements and replacing fossil fueled power plants with renewables.

American Council for an Energy-Efficiency Economy finds that cost-effective energy efficiency can yield a net positive benefit for the nation's overall employment (ACEEE 2011).

2.3 Challenges and barriers

A range of significant challenges and barriers have impeded improvements in industrial energy efficiency. Typical market failures to energy efficiency investments occur due to low energy and electricity prices, high transaction costs for small and medium-sized energy efficiency project investments, a distorted market for energy efficiency investments, high risk for local banks to extend low-interest loans to SMEs, and lack of firms' capacity and knowledge to design and implement energy efficiency projects (Yang and Yu 2015). These challenges are common across economies with different development levels, economic structures, prioritized sectors and types of businesses, but some are more acute in emerging markets. These challenges relate to both the demand (end-use) side (industrial firms) and supply side (utilities), requiring improvements and actions on both sides. The challenges and barriers can be grouped into three categories: (i) regulatory and institutional, (ii) economic and financial, and (iii) infrastructure, informational, and technological challenges.

REGULATORY AND INSTITUTIONAL CHALLENGES

Inadequate energy and carbon pricing policies can make it difficult to improve energy efficiency in the industry sector. In theory, energy prices are equal to marginal social costs, but energy prices may be below their true marginal costs because they do not adequately reflect environmental costs, or because final energy or fuel uses are subsidized. Energy subsidies have specific policy goals, such as lowering expenditure associated with energy use by industries and households, and are provided in the form of price controls, government-led energy services, or low-interest credits for investments in energy supply (UNIDO 2011). The same applies to electricity prices. Industrial production has become increasingly dependent on electricity consumption as a result of the electrification of the industry sector.[8] In a competitive market, such as in some EU countries and the United States, wholesale electricity prices are formed as a result of the competition between generators who bid in the day-ahead and forward markets, and the wholesale price is defined when supply meets demand. In a regulated market with a few dominant players, however, the price of electricity is often subsidized and can be kept low by the government or the regulators. In this case, the "regulated sale price" of electricity may be significantly below the marginal cost to produce electricity (Golove and Eto 1996). In China, Indonesia, and India, for instance, the governments have provided subsidies to energy suppliers to address the mismatches between regulated electricity and oil product prices and the cost of the raw inputs for producing

8 As of 2019, the industry sector accounted for 42 percent of total electricity consumption worldwide. In Korea, the industry sector accounted for 55 percent of total electricity consumption (IEA 2021; KEPCO 2023). Source: https://www.iea.org/data-and-statistics/charts/world-electricity-final-consumption-by-sector-1974-2019; https://home.kepco.co.kr/kepco/EB/A/htmlView/EBAAHP002.do?menuCd=FN430102.

the energy (Zhou, Levine, and Price 2010). In some countries, energy prices have increased significantly, but the electricity tariffs remain below the cost of generating electricity.[9] In the case of Korea, one study found that the electricity price needed to be increased by 15 percent to resolve inefficient electricity use and to resolve the market distortion effect that stemmed from the below-the-margin electricity price (KEEI 2021). On the end-of-use side, with subsidized electricity rates, industrial firms may not have sufficient motivation to make energy efficiency investments to stay cost competitive. In other words, firms may not see the financial returns on their energy efficiency investments due to the low and differentiated electricity rates for the industry sector. On the energy supply side, the subsidized electricity rates reduce utilities' revenues, especially in the face of rising energy prices, reducing their interest in supporting and promoting industrial energy efficiency projects.[10] In addition, the traditional regulatory model can discourage utilities' effective demand response if their financial returns are mainly derived from building new energy generation infrastructures.

Energy tax policies and tax structures that do not reflect the true cost of environmental and social externalities may also contribute to distorted energy prices, which in turn can disincentivize energy efficiency investments. In many countries, electricity is directly taxed.[11] Energy tax policies need to be designed and implemented to balance energy demand and supply, and to encourage the use of cleaner energy sources with lower emission intensity. However, taxation of energy use sometimes can fail to reflect the costs incurred by environmental and carbon footprints of energy sources (OECD 2019). An increasing number of countries have introduced measures to achieve better alignment, such as carbon tax policies in Sweden and Denmark, or a market-based system such as ETS in countries including China, EU and Korea, with varying levels of success (OECD 2019). Even in cases of limited direct impact, the introduction of policies such as ETS by themselves provide price signals to the industry and strengthens international regimes on energy efficiency.

Lack of energy efficiency standards and their enforcement can also limit industrial consumers' awareness of equipment efficiency performance and hence discourage energy efficiency investments. Energy efficiency standards provide definitions and measurements of performance, help disseminate and promote energy efficiency technologies, and set minimum energy performance requirements. In some countries, standardization and labeling of high efficiency electrical equipment may be limited due to the lack of related testing infrastructure. For example, while there has been increased efforts to establish standards and labelling programs for equipment and appliances in Southeast Asia, the region still suffers from the lack of adequate testing laboratories (Copenhagen Centre on Energy Efficiency 2015).

9 The electricity price for the industry sector increased from US$68.8 per MWh in 2010 to US$94 per MWh in 2020 while the electricity tariff increased by only 4.7 percent in the OECD countries over the same period.

10 There was an incentive to encourage supply-side demand response programs in the 1970s and 1980s, as a result of the oil crises (e.g. U.S.) and as the investment cost for power generation facilities rapidly increased due to economic growth. The program emerged as an alternative to supply optimal electricity at lower costs. Demand management program is possible to promote energy resource saving and cost reduction by stabilizing power supply and demand and suppressing energy use.

11 The share of taxes in electricity prices for industry varies greatly by country, ranging from as low as 1.4 percent (Czech Republic in 2018) and 3.3 percent in Korea to as high as 49.8 percent (Germany in 2017) (IEA 2019a).

Limited market competition can pose transaction costs for industrial firms trying to adopt cost-effective energy efficient industrial equipment or products. In this case, certain powerful firms can constrain new competitors from entering the market and introducing energy efficient, cost-effective products (Golove and Eto 1996). This problem is especially apparent in countries where state-owned enterprises (SOEs) play a dominant role in energy intensive sectors. The legal and regulatory framework such as energy efficiency codes and standards could be used to promote fair competition and lower the market entry barrier for firms with new energy efficiency technologies.

Lack of protection of intellectual property rights (IPR), and closed trade policies, could prevent the diffusion of advanced energy-efficient technologies in a country. The lack of protection of IPR has been identified as a barrier particularly relevant in developing countries (Worrell and Price 2001). Uncertain IPR regimes can increase the discount rates applied in investment appraisal, and as a result inhibit investment in energy efficiency solutions (UNIDO 2011).

Other institutional challenges include the lack of a designated government agency with authority and/or expertise to implement and evaluate energy efficiency programs. In some cases, to the extent that this authority exists at all, it is dispersed among multiple line agencies, none of which has the full expertise needed to effectively implement energy efficiency policies.

ECONOMIC AND FINANCIAL BARRIERS

Financial constraints and lack of access to capital are one of the main barriers for industries to make energy efficiency investments. Lending by financial institutions for energy efficiency projects is limited, particularly in emerging economies. Furthermore, loans for energy efficiency are often focused on a small number of large industrial companies with high creditworthiness. SMEs and small energy service companies (ESCOs) do not have similar levels of creditworthiness or equity resources as large companies, and therefore have limited access to capital. Financial entities also lack incentives to provide long-term loans to energy efficiency investments. They may perceive energy efficiency as highly risky due to their limited experience and technical capacity to appraise such investments.

Limited capital availability (Worrell and Price 2001) **and split incentives could hinder firms' ability to invest in energy efficiency.** Firms often have limited capital available for energy efficiency projects and frequently require short payback periods of between one and three years (US Department of Energy 2015). These challenges may be caused by their ownership structure, internal capital budgeting criteria and procedures that work against energy efficiency projects (Schleich and Gruber 2008).[12] The challenges related to split incentives are also caused by failure to recognize the benefits of efficiency, including non-energy and non-financial benefits (e.g. marketing benefits or improved working conditions).

12 For example, in their survey of firms in brewing sector, Sorrell et al. (2004) found that, while firms had few issues in accessing commercial capital markets, the limited access to capital issue had risen largely from the reluctance to take on additional borrowing. These self-imposed restrictions mainly took the form of applying tight payback criteria when assessing proposed investment projects including energy efficiency investments.

Volatile energy prices and inconsistency in energy policy direction can increase uncertainty, thus hampering firms' ability to make timely investment decisions. Volatile energy prices, disruptions in supply chains and sharp changes in the government budget devoted to supporting energy efficiency projects can reduce firms' investment in improving energy efficiency over the long term. Such challenges can be particularly important during complex crises, such as the COVID-19 pandemic.

A rebound effect, that is, increased use of energy due to increased energy efficiency, may offset the impact of energy efficiency improvement. The linkage between energy efficiency improvements and proportional reductions in energy demand are complex and rebound effects are often large (Sorrell 2007). When cost savings from energy efficiency investments are achieved, firms may decide to expand production, which may cause an increase in overall energy use. In other cases, the costs reductions achieved in one sector may allow other sectors to spend more on energy and energy services.

INFRASTRUCTURE, INFORMATION, AND TECHNOLOGICAL BARRIERS

Lack of data could prevent firms and policymakers from understanding energy consumption patterns and the types of industrial energy efficiency measures that are viable for a given plant or production process. Detailed and accurate energy use data and output data are needed to inform the design and improvement of industrial energy efficiency programs. Some countries, including Korea, have comprehensive, systematic, and regular approaches to gathering and publishing economic and other output data. In countries with less stringent reporting requirements for industrial output and energy use data, the degree to which trends in industrial energy intensity and efficiency can be identified is constrained. For example, lack of information related to the remaining lifecycle of existing facilities and equipment could discourage firms from making energy efficiency investments.

Lack of access to digital technologies and infrastructure may further constrain data collection (mostly concerning granular energy consumption data), monitoring and reporting, and energy efficiency investments at the firm level (Reddy 1991; Carroll et al. 2014). Energy demand is soaring in emerging markets while the generation capacity has not increased in the same proportion as the demand, creating a significant energy deficit. Increased operational inefficiency within the grid, for example greater power losses, can further increase the gap. Demand side management (DSM) solutions are often proposed to address these problems, which requires improved communication between energy consumers and generators. Digital technologies and infrastructure such as smart metering and smart grid systems can help boost communication flows and data collection, and increase energy efficiency in power generation, transmission and end-use (Gellings 2009). In the residential sector, households that have participated in smart metering programs with time-of-use tariffs have reduced energy demand significantly, leveraging the information generated by smart meters. Despite these benefits, the commercial use of smart meters is limited in the industry sector because of operational uncertainties and data privacy issues, as well as a lack of business applications and awareness of the benefits associated with the use of digital technologies for improving energy efficiency (Knayer and Kryvinska 2022; Aslam et al. 2015).

Lack of awareness of energy saving potential, limited understanding of the business value of energy efficiency by managers and the limited technical capacity to evaluate energy efficiency options may hinder energy efficiency investments. Lack of investment in energy efficiency can occur when managers are not familiar with the benefits of energy efficiency. If energy costs are a relatively small portion of the overall budget of an industrial firm, such costs may not be seen as priorities by top managers. Also, there is a tendency to wait to invest in energy efficiency technologies if economic, policy, or technological conditions are uncertain (van Soest and Bulte 2001). Long payback time and low return on investment (ROI) are other issues that may hinder energy efficiency investment. For instance, industrial heat pumps are one of prominent technologies that can facilitate energy saving by using waste heat that would otherwise be released to the environment; however, the payback period of such investment exceeds 15 years (Biskupski et al. 2023). Firms' technical capacity could also be a barrier. This could include lack of staff and management awareness, lack of management accountability for energy expenditures and lack of skilled employees in positions such as energy facilities maintenance (van Soest and Bulte 2001).

2.4
Modalities of public policy support to energy efficiency

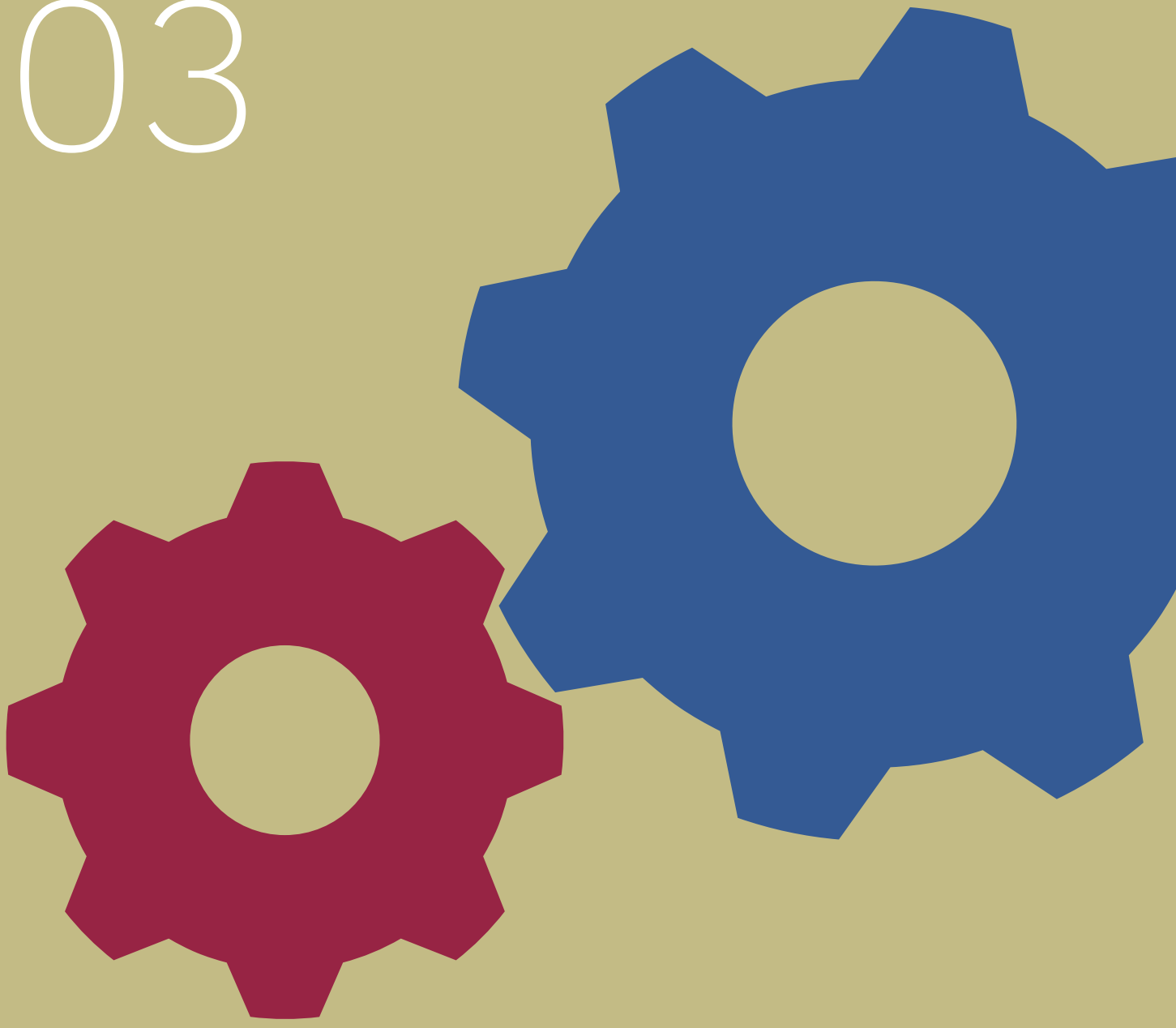
Public policy interventions can be used to overcome some of the barriers and challenges associated with the energy efficiency gap mentioned in the previous section. Table 1 summarizes six modalities of public policy support that address the market failures or challenges of improving energy efficiency in the industrial sector. These modalities include (i) target and performance setting, (ii) regulatory and legal instruments, (iii) standards setting, (iv) information generation and sharing, (v) financial support, and (vi) operational support.

TABLE 1. MODALITIES OF PUBLIC POLICY SUPPORT

MODALITIES OF SUPPORT	CORRESPONDING BARRIERS	POLICY MEASURES	DESCRIPTION
TARGET AND PERFORMANCE SETTING	— Coordination problem — Institutional challenge	Setting national plans, roadmap, and enacting laws	This includes setting national level master plan, roadmap, enacting laws and strategies that provide guidance on the common policy goals and directions across ministries.
		Voluntary target setting and monitoring	The promulgation of targets for energy efficiency improvement or GHG emissions reduction are set by firms or industrial associations whose members are energy and carbon intensive. These targets can be established based on voluntary or negotiated agreements with the government.
REGULATORY AND LEGAL INSTRUMENTS	— Informational barriers — Limited market competition	Setting energy audits and reporting requirements	Government requirements for energy audit, reporting, and/or disclosure of data on energy consumption of industrial firms, especially targeting energy-intensive firms and sectors. Mandated reporting or monitoring could benchmark internationally accepted standards and rules.
		Setting minimum energy performance requirements	Manufacturers and importers are obliged to report the efficiency ratings of their products, and appliances failing to meet the minimum energy performance standards (MEPS) are terminated from production and sales.
		Intellectual property (IP) framework	Intellectual property rules advance the development and deployment of industrial energy efficiency technologies.
STANDARDS SETTING	— Information asymmetry — Imperfect market competition — Split incentives	The use of scaled energy efficiency labels and certificates	Voluntary certification and labeling schemes can help raise energy efficiency performance standards and compliance in the industrial sector.
		Adoption of global standards	This refers to the use of ISO standards to ensure global compliance. For instance, ISO 50001 specifies the requirements for an organization to establish, implement, maintain and improve an energy management system (EnMS).
INFORMATION GENERATION AND SHARING	— Information asymmetry — Infrastructure and technological barriers — Limited access to technology — Limited market competition	Provision of technical information	Information is provided to industry practitioners and decision makers to assist in choosing and adopting energy-efficient equipment and systems.
		Dissemination of best practices	Government encourages sharing of energy efficiency know-how and best practices through partnership-building among firms in the same sector or region.
		Dissemination of tools for better data collection	Government supports or mandates firms to collect energy consumption data using tools such as smart meters and other equipment.
FINANCIAL SUPPORT	— Limited access to internal capital and split incentives — Limited access to finance — Regulatory barriers (e.g. tax policies) — Volatile energy prices	Direct and indirect financial support to firms	Government provides direct government funding, favorable tax treatment, or soft loans for firms' energy saving activities.
		Performance based economic incentives	Government designs an economic incentives mechanism to induce firms to reduce energy consumption (e.g. financial support for firms participating in the Emission Trading Scheme)
OPERATIONAL SUPPORT	— Capability failure — Limited access to technology	Technical assistance to firms through third-party engagement	SMEs can engage with third-parties from the private sector (e.g. energy service companies) and receive consulting services, and/or technical assistance.
		Workforce training for capacity building	Government provides support for training and certifying the industrial workforce.
		Public R&D expenditures	Government funds energy research, development and demonstration (RD&D) activities.

SOURCE: Author's

03

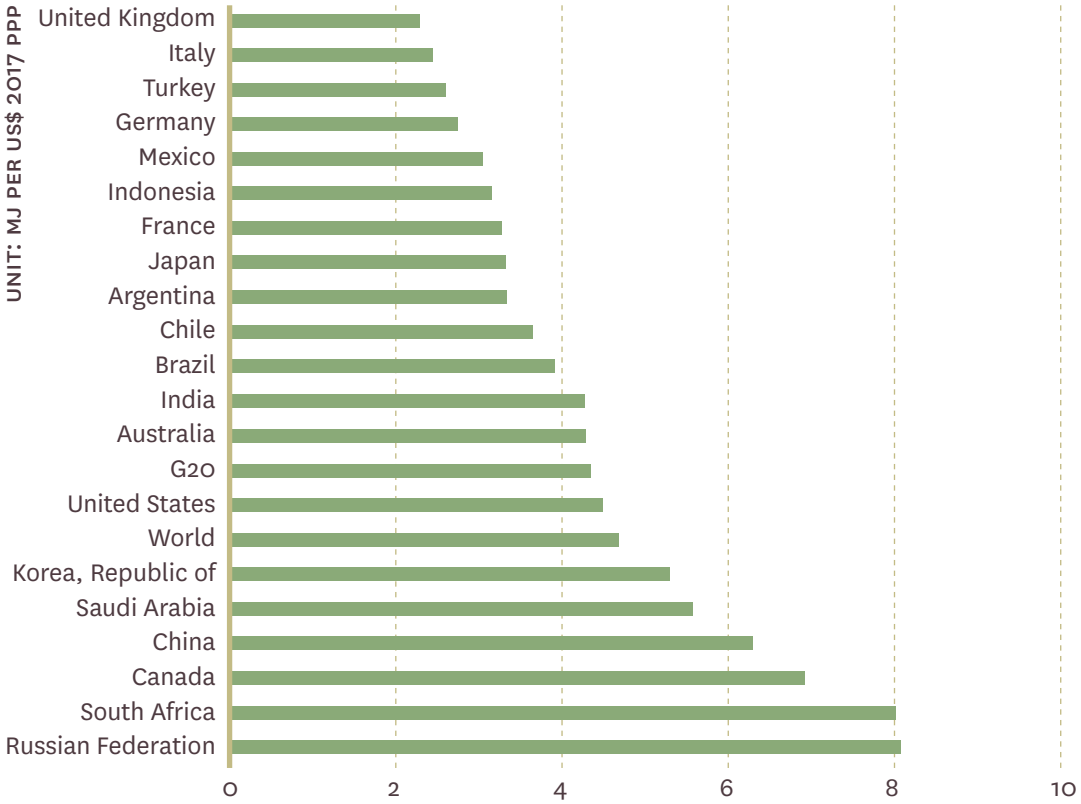


Korea's trends in industrial energy efficiency

03 Korea's trends in industrial energy efficiency

Korea's energy intensity is comparable to world and G20 averages, and it is improving. In 2019, Korea ranked sixth highest in energy intensity among the G20 countries, following Russia, Canada, South Africa, Saudi Arabia, and China (World Bank 2023) (Figure 4). Korea's energy intensity fell from 0.26 toe/thousand US$ in 1980 to 0.20 toe/thousand US$ in 2000 and reached 0.18 toe/thousand US$ in 2018 (KEEI 2021b) (Figure 5). The 5-year average annual energy intensity improvement for 2010-15 and 2015-20 shows that Korea managed to accelerate the energy intensity progress. While the global rate of energy intensity improvement decelerated from 2.2 percent over 2010-15 to 1.4 percent over 2015-20, Korea moved up from 1.3 percent per year in 2010-15 to 1.8 percent in 2015-20 (IEA 2022). Despite this record, Korea's energy intensity is higher than major economies (Germany, Italy, Japan, US, UK), which implies that Korea still has room for improvement in lowering its energy intensity.[13]

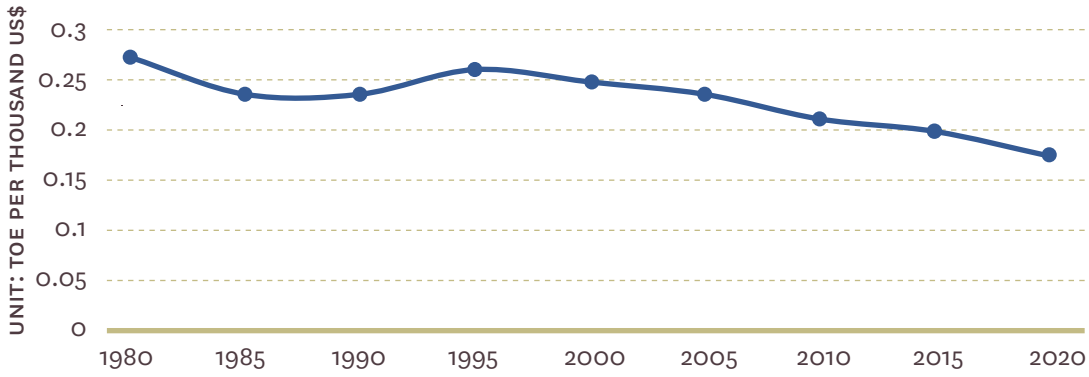
FIGURE 4. ENERGY INTENSITY IN G20 COUNTRIES (2020)



SOURCE: World Bank 2023

13 When comparing Korea's energy intensity with other countries, it is important to note that Korea's economic structure differs from other countries with high energy consumption in the commercial and building sectors. Korea's manufacturing sector accounted for 27.2 percent of total GDP in 2021. Approximately half of Korea's energy consumption is from the industrial sector, more specifically from energy-intensive sectors such as steel and petrochemical industries.

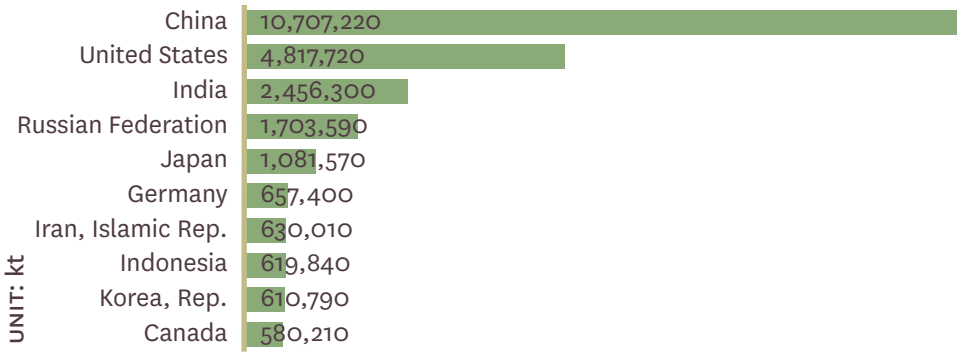
FIGURE 5. KOREA'S ENERGY INTENSITY (1980-2019)



SOURCE: IEA, KEEI 2021c

Korea is a significant source of global GHG emissions, and the industrial sector is responsible for over half of the GHG and other pollutant emissions. Korea's CO_2 emissions were the 9th highest in the world in 2019 and accounted for 1.5 percent of global emissions (Figure 6) (Climate Watch 2023). Korea's GHG emissions increased with its GDP growth in all years between 1990 and 2021, except during the Asian Financial Crisis of the late 1990s, in 2014 and 2021 (Figure 7) (KOSIS 2023). It is also evident that while emissions growth has slowed compared to GDP growth, full decoupling is yet to be achieved in Korea.[14] The industrial sector's share of total GHG emissions rose as high as nearly 56 percent of the national total in 2014 after hovering around 50 percent for most of the 2000s, and equaled 53 percent in 2019. This growth in emissions has been behind Korea's concerns and policy efforts to promote a green economy and related policy initiatives such its "Green New Deal" announced in 2020.[15]

FIGURE 6. TOP 10 CO_2 EMITTING COUNTRIES (2019)

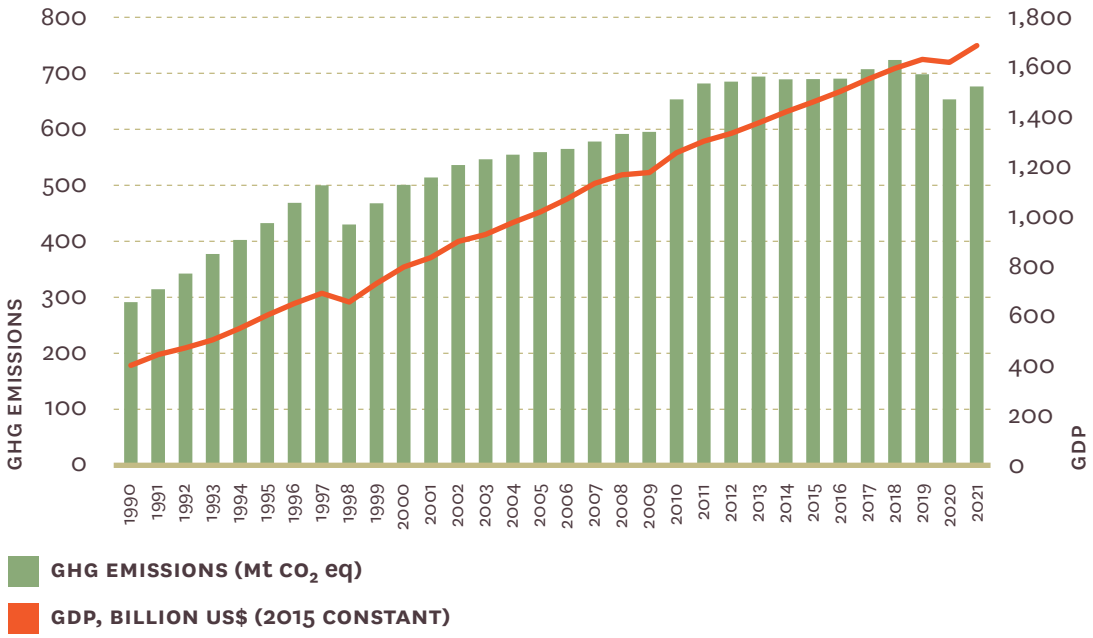


SOURCE: Climate Watch, World Bank

14 Accordingly, Korea's plans for carbon neutrality by 2050 highlight decoupling as one of its objectives.

15 In announcing the "Korean New Deal 2.0", including a "Green New Deal", MOEF described the original Korean New Deal as accelerating remote work and education, promoting low carbon and eco-friendly manufacturing, and leading the transformation into a green and digital economy through investment and regulatory improvement. Recent additions to this policy focusing on green aspects include adding a new category of carbon neutrality with funding for projects to achieve Korea's Nationally Determined Contributions under the UNFCCC, as well as building emissions measurement systems and creating a carbon reduction program for industries.

FIGURE 7. GDP AND GHG EMISSION TRENDS IN KOREA (1990-2021)

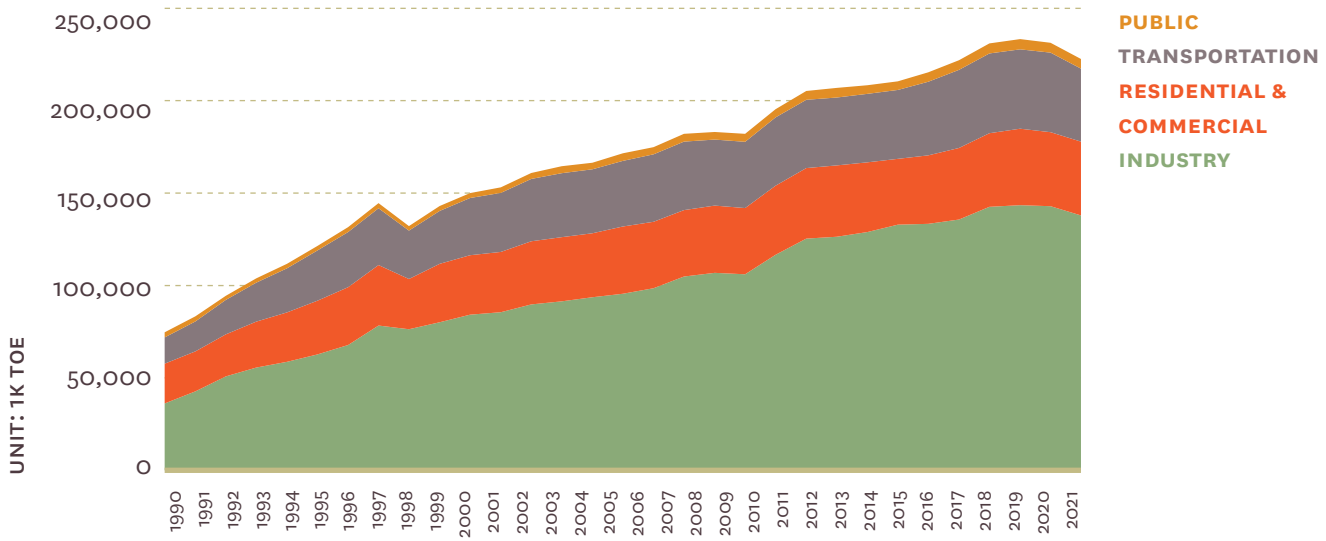


SOURCE: KOSIS
NOTE: Emissions for 2021 are preliminary figures

The industrial sector accounts for more than half of final energy consumption, and energy consumption in industry is increasing more rapidly than in other sectors. As of 2021, the industrial sector accounted for 63.3 percent of the country's total energy consumption, equivalent to 150,293 thousand toe, followed by residential & commercial (17.4 percent), transportation (16.9 percent), and public (2.4 percent) (Figure 8) (KEEI 2021c). Between 1990 and 2021, energy consumption in the industrial sector increased 4.2-fold, whereas for residential & commercial, transportation, and public sector, energy consumption increased by a factor of 1.9, 2.8, and 2.0, respectively. Within the industrial sector, the manufacturing sector[16] accounts for more than 90 percent of total industrial energy consumption.

16 In Korea, the definition and classification of the industrial and manufacturing sectors have been revised multiple times since 1991. The 10th Korean Standard Industrial Classification, or Korea Standard Industry Code "KSIC" announced in 2017, was prepared by reflecting the 4th amendment to the International Standard Industrial Classification (ISIC Rev.4) (Statistics Korea 2023). KSIC defines manufacturing as "an industrial activity that converts input raw materials into new products with different properties by applying physical and chemical actions to raw materials (materials or components)." In the KSIC, manufacturing (categories 10-34) includes food, beverage, textile, wood, leather, apparel, electronic parts and equipment manufacturing, metals, pulp and paper manufacturing, and other subsectors. The manufacturing category thus represents a subset of the activities included as "industry" in various statistical compendia, including compilations of economic, energy, and environmental statistics.

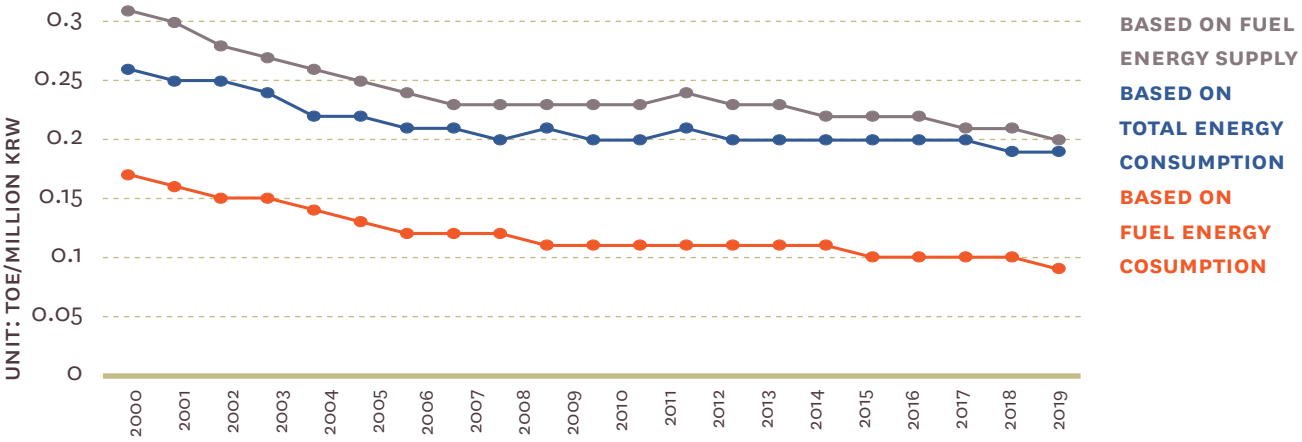
FIGURE 8. FINAL ENERGY CONSUMPTION BY SECTOR IN KOREA (1990-2021)



SOURCE: KEEI 2022

Despite the increasing energy consumption in the industrial sector, energy intensity in the industrial and manufacturing sectors declined after 2000 and has remained stable since the 2010s. Korea's energy intensity in the industrial sector steadily declined from 0.26 toe/million KRW in 2000 to 0.19 toe/million KRW in 2019 (IEA) (KEEI 2021b). Since the mid-2000s, energy intensity has remained stable at around 0.20 toe/million KRW. Energy intensity for the manufacturing sector alone followed a similar trend (Figure 10) (KESIS).[17]

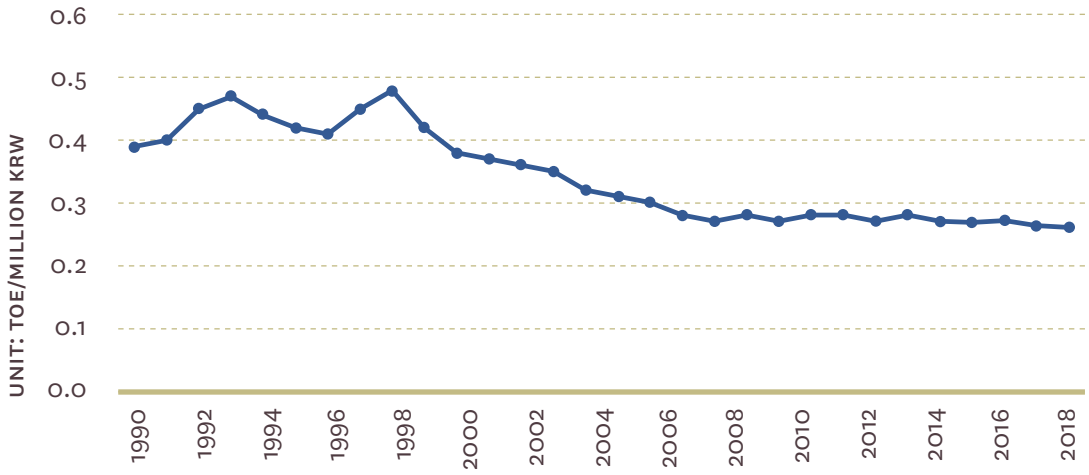
FIGURE 9. ENERGY INTENSITY FOR THE INDUSTRIAL SECTOR



SOURCE: KEEI 2021

17 Korea Energy Statistical Information System (KESIS) is a portal website which provides energy-related data, statistics, and information. Korea Energy Economics Institute (KEEI) is operating and managing KESIS, and the portal aggregates data from various sources.

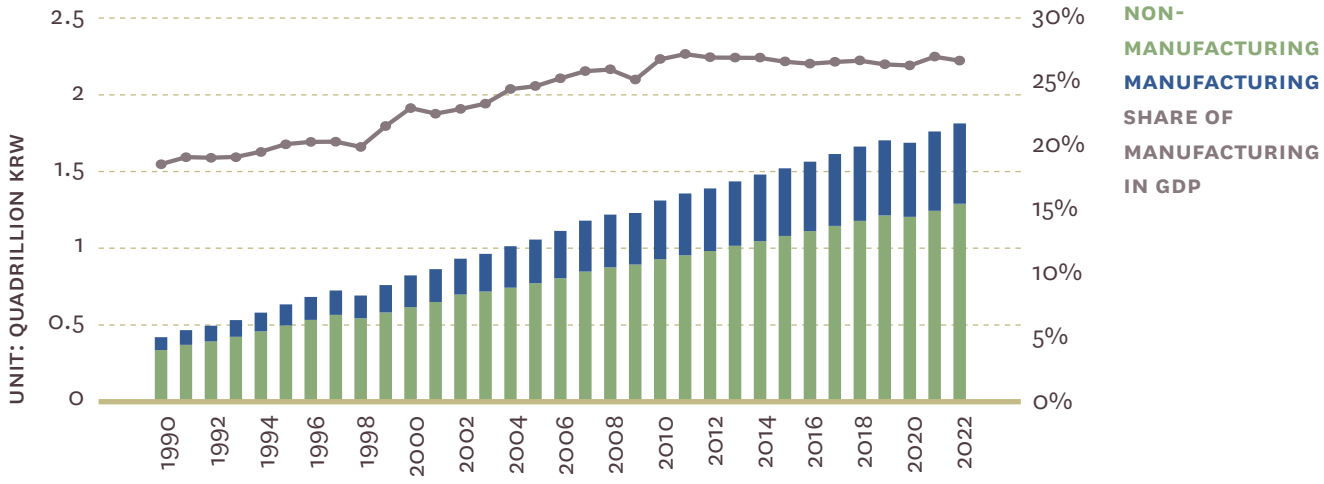
FIGURE 10. ENERGY INTENSITY FOR THE MANUFACTURING SECTOR IN KOREA



SOURCE: Korea Energy Statistical Information System (KESIS)

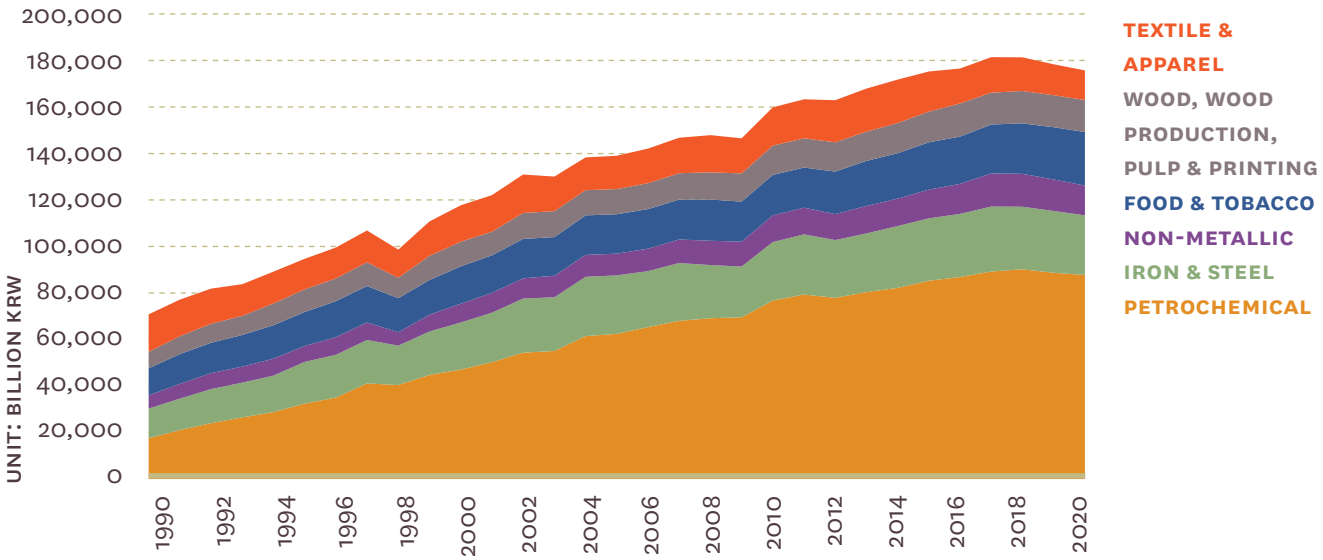
Energy-intensive manufacturing sectors, namely petrochemicals, iron and steel, play a key role as the backbone of Korea's economy, which makes energy efficiency improvement challenging. The manufacturing sector has been a mainstay of Korea's economy, an engine of its economic growth over the past 30 years. The share of Korea's manufacturing sector in GDP rose from 18.6 percent in 1990 to 27.2 percent in 2021 (KOSIS 2023) (Figure 11). Within the manufacturing sector, petrochemical, iron and steel sectors account for the most significant share, about 65 percent of the manufacturing GDP (Figure 12). The fact that most of Korea's industrial energy consumption is from a limited number of sub-sectors explains the policy focus on promoting energy efficiency within these sectors.

FIGURE 11. KOREA'S GDP GROWTH AND SHARE OF MANUFACTURING IN GDP (1990-2022)



SOURCE: Korea Statistical Information Service (KOSIS), Bank of Korea 2023
NOTE: GDP by economic activities (not seasonally adjusted, chained 2015-year prices)

FIGURE 12. REAL GDP OF MANUFACTURING SUB SECTOR IN KOREA

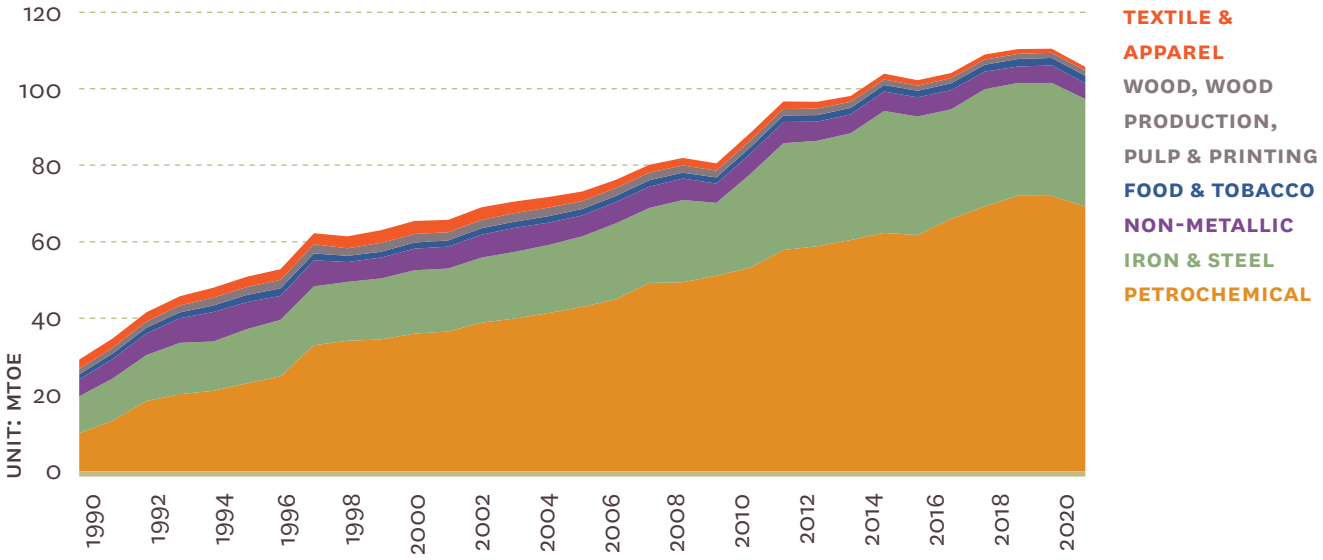


SOURCE: KEEI 2021c; Bank of Korea 2023

Although the overall energy intensity in the industrial and manufacturing sector decreased, energy intensity trends within the manufacturing sub-sectors varied. The hard-to-abate sectors, namely petrochemical, iron and steel, combined account for around 90 percent of total energy consumption within the manufacturing sector (Figure 13). The energy intensities of the two sectors are more than twice the average of the manufacturing industry, and their energy intensities decoupled from the manufacturing's average trend. Especially the energy intensity of the iron and steel sector has increased since the mid-2000s, and it has the highest energy intensity among the manufacturing sub sectors (Figure 14).[18] Choi and Oh (2014) decompose the aggregate change in energy intensity between 1981 to 2010 into the change in real energy intensity in each sector and the change in each sector's share of total production. They find that the decrease in energy intensity was due to the sector level energy intensity decrease. However, the growing share of the highly energy-intensive petrochemical and iron & steel sectors put upward pressure on energy intensity in Korea. Therefore, these energy-intensive sectors take center stage when it comes to managing energy efficiency.

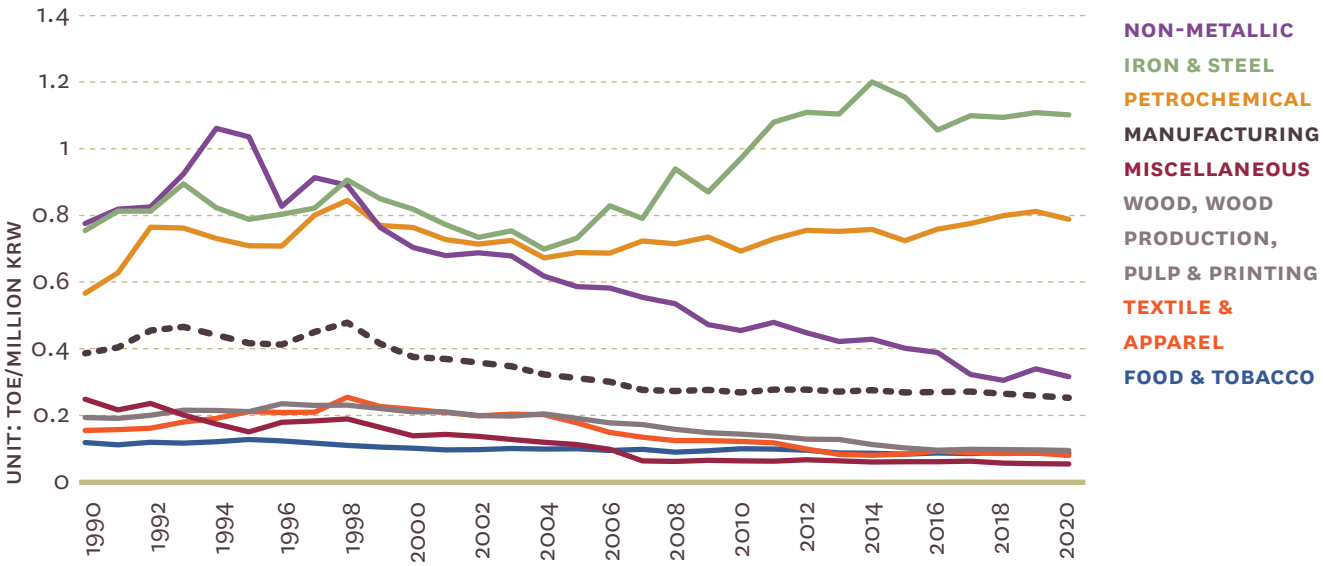
18 This might be partially caused by the start of operation of Hyundai Steel's electric arc furnace, a mega consumer of electricity in 2010.

FIGURE 13. FINAL ENERGY CONSUMPTION IN MANUFACTURING SECTOR IN KOREA



SOURCE: KEEI 2021c; Bank of Korea 2023

FIGURE 14. MANUFACTURING ENERGY INTENSITY BY SECTOR



SOURCE: KEEI 2021c; Bank of Korea 2023

A significant amount of energy consumption originates from energy-intensive firms, and therefore several energy policies and programs target these firms. Out of total energy consumption in 2019 (231,235 thousand toe), energy-intensive firms (firms that consumed more than 2,000 toe annually) accounted for 110,249 thousand toe, or 47.7 percent (Table 2) (KEA 2020). In 2019, 4,695 firms were categorized as energy-intensive firms, and among them 2,920 were from the industrial sector. As the 4,695 energy-intensive firms consume almost half of total energy in Korea, several policies are targeted to these firms specifically.

According to the Energy Use Rationalization Act, energy-intensive firms are required to report their annual energy consumption to KEA and undergo a mandatory energy audit every 5 years. Several voluntary programs, such as the energy saving through partnership (ESP) and voluntary energy efficiency target management scheme (TMS), also state that their primary target is energy-intensive sectors and firms. For example, the ESP, which is a program developed to share energy efficiency best practices and know-how among firms within the same sector, knowledge-sharing committees have been established for 8 energy-intensive sectors including petrochemical, steel, energy, automotive, and cement sectors (section 4.3.4). Nevertheless, there is little evidence on the effectiveness of these programs in improving energy efficiency of energy-intensive firms.

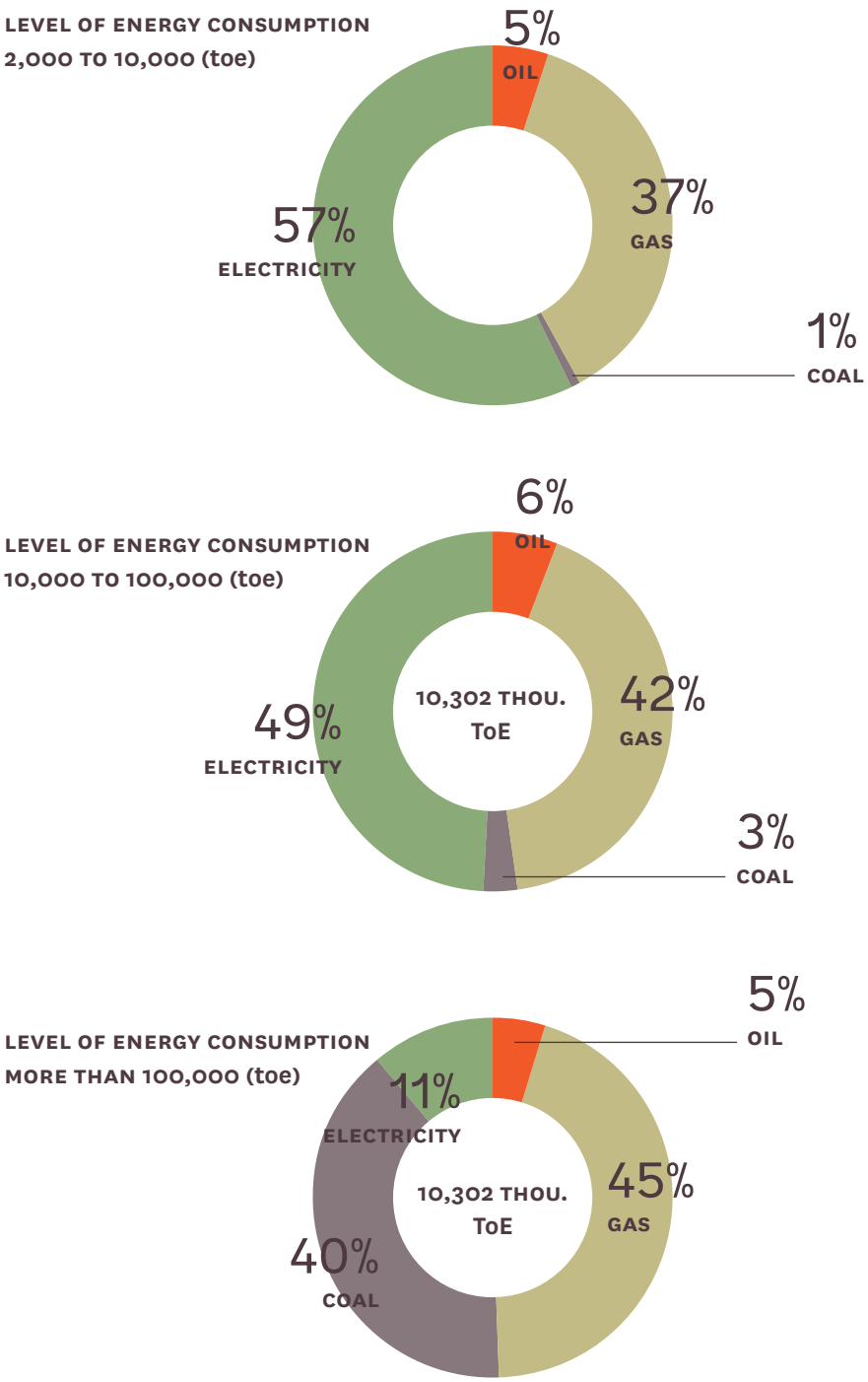
TABLE 2. ENERGY CONSUMPTION BY THE ENERGY INTENSIVE FIRMS BY SECTOR (2019)

	NUMBER OF ENERGY INTENSIVE FIRMS		ENERGY CONSUMPTION BY ENERGY INTENSIVE FIRMS (THOUSAND toe)	
SECTOR	2018	2019	2018	2019
Industry	2,919	2,920	102,718	104,014
Manufacturing	2,806	2,801	74,122	76,076
Energy	113	119	28,596	27,938
Building	1,297	1,302	2,920	2,897
Transportation	441	436	3,354	3,338
Power	37	37	60,569	57,906
Total	4,694	4,695	108,991	110,249

SOURCE: KEA 2020
NOTE: Energy intensive firms are firms that use energy above 2,000 toe per year

Although the electrification of the industrial sector helped improve energy efficiency, energy intensive firms are still heavily dependent on fossil fuels. Korea shifted away from using coal and gas and shifted towards using electricity in nearly all sectors; the share of electricity of final energy consumption increased from 13.7 percent in 2000 to 19.7 percent in 2020 (KEEI 2021b). As depicted in Figure 15, for industrial firms that consume more than 2,000 toe and less than 10,000 toe per year, 57 percent of their consumption was from electricity. For firms that consume energy between 10,000 to 100,000 toe per year, 49 percent was from the electricity. In contrast, highly energy-intensive companies that consume more than 100,000 toe annually largely depended on coal and gas, with electricity accounting for only 11 percent of their energy consumption.

FIGURE 15. AVERAGE SHARE OF ENERGY SOURCES IN INDUSTRIAL ENERGY CONSUMPTION, BY ENERGY CONSUMPTION LEVELS OF FIRMS (AS OF 2020)



SOURCE: MOTIE and KEA. 2020
NOTE: Values within the circles shown are total aggregate annual energy consumption for the firms using more than 2,000 toe annually in each group.

04

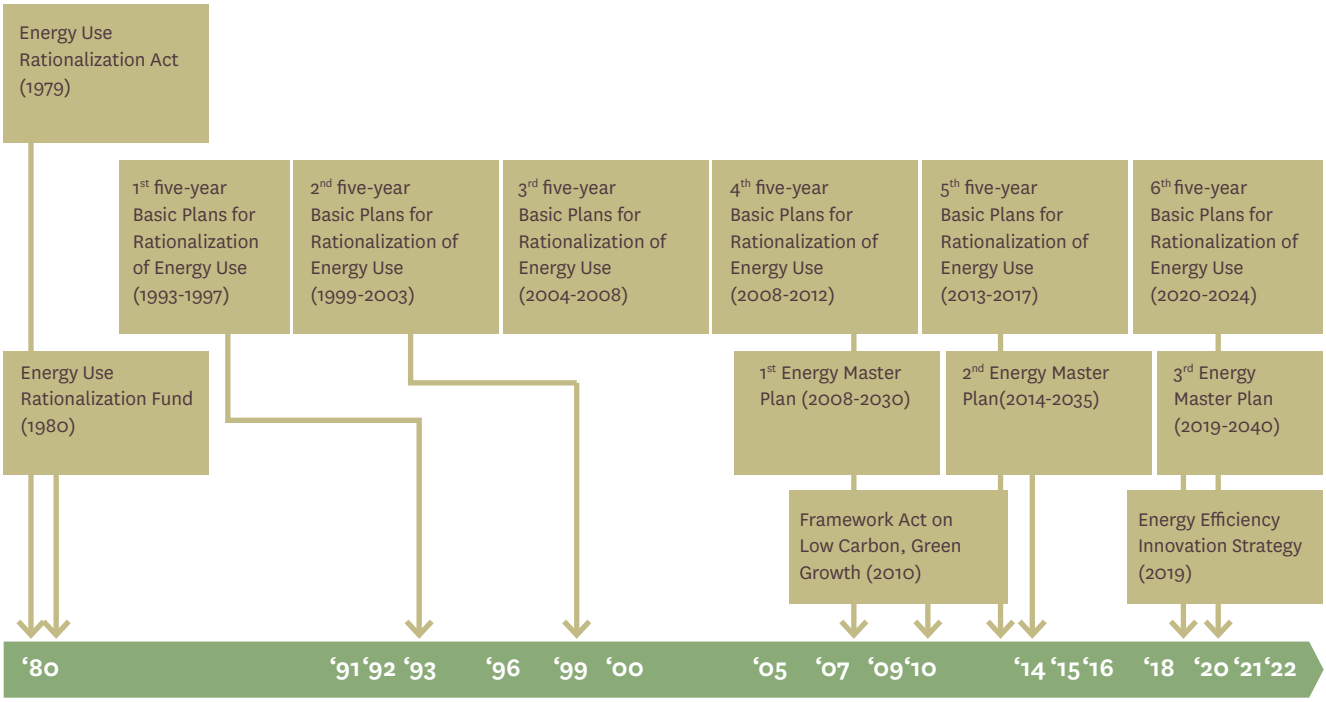
Industrial energy efficiency policies in Korea

04 Industrial energy efficiency policies in Korea

4.1
Overview of Korea's energy policy framework

The Korean government has introduced several laws, regulations, national plans, and strategies, which constitute an overarching regulatory framework for Korea's energy efficiency policies. As depicted in Figure 16, the Energy Use Rationalization Act was first promulgated in 1979 following the oil price shocks of the 1970s. Key elements of the Act involve developing a long-term strategy for energy use, providing for reporting on energy use and performance targets for energy intensive industries, regulating and monitoring the registration of energy efficient equipment, providing financial incentives and preferential tax treatment for energy efficient equipment, supporting ESCOs and promoting energy management systems.

FIGURE 16. KOREA'S NATIONAL ENERGY PLANS AND STRATEGY TIMELINE



SOURCE: Author's
NOTE: 'Framework Act on Low Carbon, Green Growth (2010)' was revised to the 'Framework Act on Carbon Neutrality and Green Growth to Cope with Climate Crisis' in 2022

The Korean government has attempted to balance multiple policy goals throughout the design and implementation of the national energy regulations and strategies. It has aimed to reduce the country's dependence on imported energy while improving the competitiveness of industry and the overall economy, providing reliable and affordable energy supply, ensuring low carbon development, and greening industries. In the 1980s, for example, the Energy Use Rationalization Fund was created to provide low-interest loans for ESCO projects and for the installation of energy saving facilities. Since the 1990s, the government pursued a systematic promotion of energy efficiency through five-year Basic Plans for Rationalization of Energy Use, which have included updates of the demand-side management strategies and performance targets to improve energy efficiency in the three key sectors (industry, building, and transportation).

Energy efficiency plans, strategies, and programs have been continuously and incrementally updated to improve complementarity among existing and new programs. In 2008, Korea announced its first 20-year Energy Master Plan, an overarching plan that covers all energy sectors, provides a mid-to-long-term vision of energy policy, and sets targets to be addressed. The first Energy Master Plan, announced in 2008, emphasized the importance of improving energy efficiency across the sectors and set a goal of reducing energy intensity by 47 percent. The plan called for a reduction in final energy consumption of the industry sector of 12.5 percent by 2030, compared to a business as usual scenario. The third Energy Master Plan, announced in 2019, set the goal of reducing the energy intensity of the industrial sector from 0.150 toe/million KRW in 2017 to 0.129 in 2030 and 0.119 in 2040. As a supplement to the third Energy Master Plan, the Energy Efficiency Innovation Strategy (EEIS) focuses on the use of advanced technologies to help improve energy efficiency and identifies three strategic areas of industry-focused energy efficiency measures to be promoted: the Factory Energy Management System, Micro-grid industrial complex and Learning Energy Efficiency Network (LEEN), and voluntary energy efficiency target system.

Korea's policies and regulations to improve industrial energy efficiency are aligned with the national targets and regulations set forth to achieve a low carbon economy. Together with the Energy Use Rationalization Act, the Framework Act on Low Carbon, Green Growth enacted in 2010 requires the government to gradually transform the energy and resource-intensive industrial structure into a low-carbon green industrial structure through the creation of new green industries, conversion of existing industries to green industries, and linkage with related industries. The Act lays the foundation for low-carbon green growth to foster harmonious development of the economy and the environment.[19]

19 In 2022, this Act was revised to the Framework Act on Carbon Neutrality and Green Growth to Cope with Climate Crisis.

4.2
Institutional framework

The institutional framework for energy efficiency in Korea is defined by the roles of the three main stakeholder ministries and their subordinate agencies, while theme-based inter-ministerial committees coordinate crosscutting issues. Figure 17 below provides an illustration of the framework. The Ministry of Industry, Trade and Energy (MOTIE)[20] is responsible for formulating the overall energy policy and programs related to energy efficiency. The Ministry of Environment (MOE) includes the Climate Change and Carbon Neutrality Bureau, which is responsible for managing the GHG Target Management Scheme for the industry sector.[21] The Emission Trading Scheme is jointly managed by the Ministry of Environment and the Ministry of Economy and Finance (MOEF). These line ministries are responsible for the development and implementation of a number of individual programs and policies.

A number of committees and agencies play important roles in coordinating and managing energy-related policies and strategies. The National Energy Committee, chaired by the Minister of MOTIE, deliberates on higher-level policy issues of energy and relevant long-term plans.[22] The agenda for emissions control is incorporated in the Carbon Neutrality and Green Growth Committee belonging to the presidential office. The individual energy efficiency programs are managed through affiliated implementing agencies. The Korea Energy Agency (KEA), a public institution established by the Energy Use Rationalization Act and reporting to MOTIE, manages the bulk of the programs as illustrated in the figure. The Korea Environment Cooperation manages the Emission Trading Scheme and programs related to GHG emission management on behalf of the Ministry of Environment. These implementing agencies operate, evaluate, and deliver the results of programs developed by the ministries.

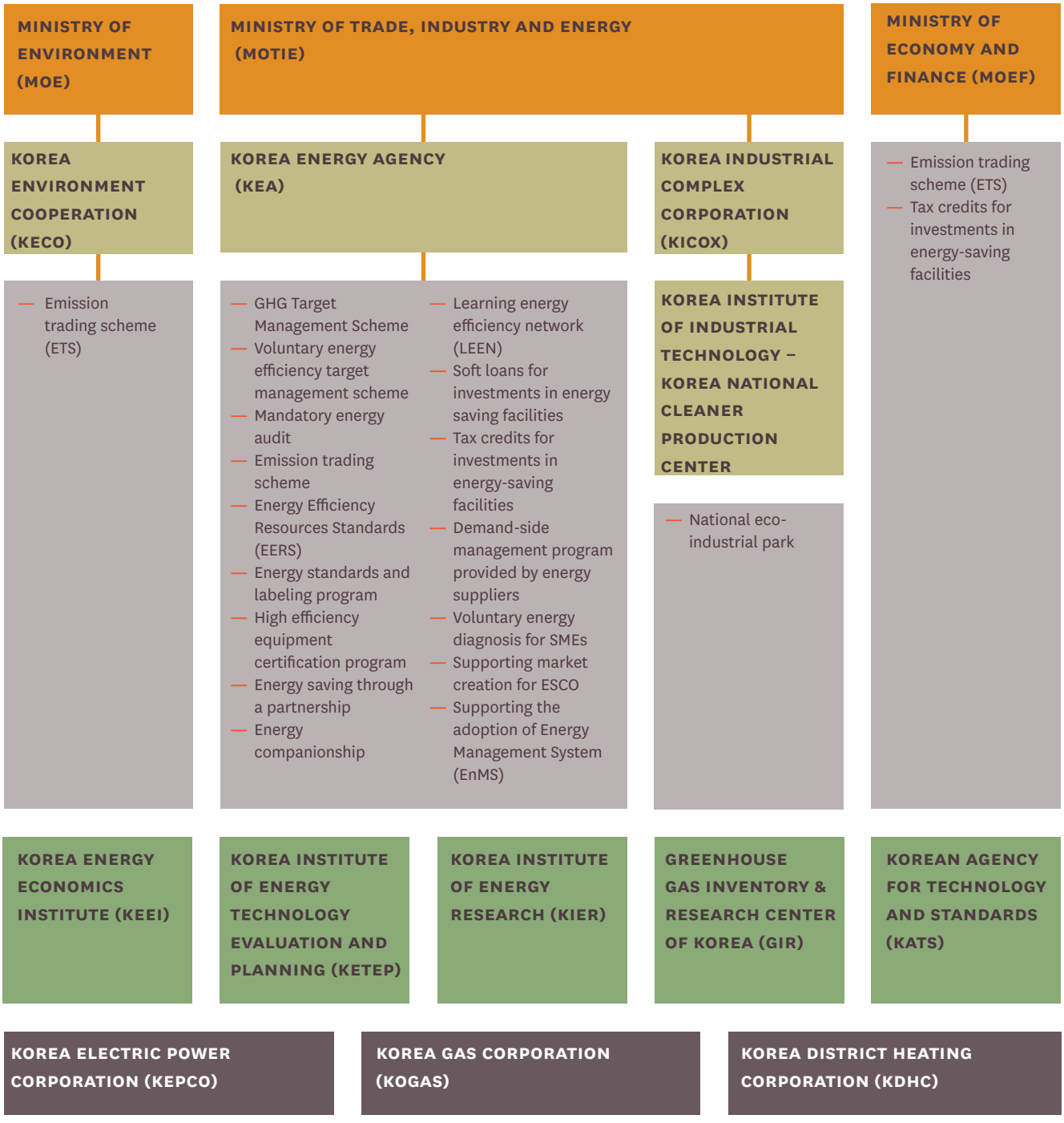
Several research institutions and associations support the implementation of policies through diverse roles. For example, the Korea Energy Economics Institute (KEEI) formulates relevant policies and also collects, analyzes, and disseminates data and statistics with the KEA. The Korea Institute of Energy Technology Evaluation and Planning (KETEP) is responsible for researching innovation in energy-related technology. The utilities in charge of generation, transmission and distribution of electricity are mainly state-owned enterprises in Korea. The government routinely regulates energy prices with the view of protecting industries from rising energy prices and production costs. As a result, however, it has largely restricted private sector participation in the electricity market. Since the 6th Energy Use Rationalization Plan, the government has placed more emphasis on regional level participation rather than a single state-level enforcement. For example, the government devolved some of the roles of MOTIE and KEA in the mandatory energy audit to the city and province levels to enhance autonomy and to strengthen local authority on firms within the region.

20 In 2009, Energy Efficiency Bureau was established under MKE (Ministry of Knowledge Economy), and in 2013, when MKE was reorganized into MOTIE, the Energy Efficiency Bureau was renamed the Bureau of Energy Demand Management Policy. Followed by another major institutional change in 2019, as of Nov 2022, energy policy has a separate division within the energy policy division, which is managed by the director general.

21 Since energy efficiency spans a wide range from the industrial sector itself to economy and environment, there are cases when the ministry in charge changed. For instance, in 2016, the overall responsibility for ETS moved from the MOE to the MOEF. In January 2018, the responsibility was transferred back to the MOE, although the MOEF still chairs the Allocation Committee.

22 The committee consists of vice ministers from five other ministries (Economy and Finance, Science and ICT, Foreign Affairs, Environment, and Land, Infrastructure and Transport), and civilian experts in energy designated by the Minister of MOTIE.

FIGURE 17. STAKEHOLDERS RESPONSIBLE FOR INDUSTRIAL ENERGY EFFICIENCY POLICIES AND PROGRAMS

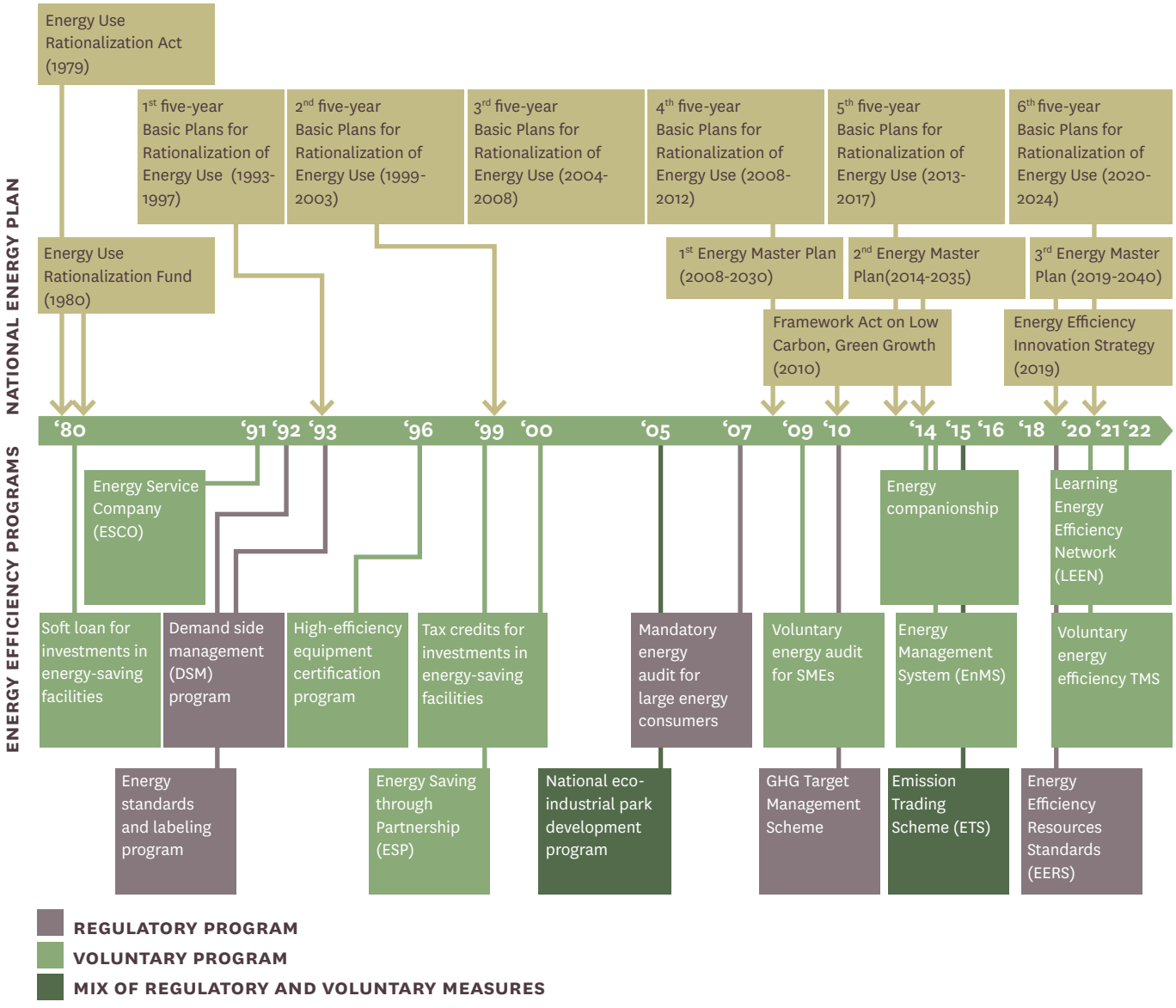


SOURCE: Author's
NOTE: As of March 2023

4.3
Key energy efficiency policies and programs

Korea's energy efficiency policies and programs have been designed and implemented since the establishment of the Energy Use Rationalization Act in 1979. These range from setting the framework for the operations of energy service companies (ESCO) and provision of mandatory energy audits, to a more market-based approach such as ETS. Figure 18 depicts active energy efficiency programs in chronological order by the year they were first introduced. This timeline shows how Korea's energy policy has evolved and changed throughout the past 40 years.

FIGURE 18. ENERGY EFFICIENCY POLICY AND PROGRAM TIMELINE (AS OF JUNE 2023)



SOURCE: Author's
NOTE: EERS was initiated in 2018 through a pilot test with KEPCO.

To tackle the energy efficiency challenge, Korea has leveraged a broad policy mix that targets different types of firms, industries and modalities of policy support. Korea's energy efficiency programs today are comprehensive and cover both regulatory and voluntary measures that provide incentives to firms to improve their energy efficiency. Although some of the policy programs are mandatory where firms could incur fines if they don't comply, many of the programs are voluntary, and extend operational and financial support to SMEs which usually lack technical and organizational capabilities or resources to identify and invest in energy efficiency measures. On the other hand, more stringent enforcement, including mandatory audits, are applied to larger industrial enterprises that consume high volumes of energy. Also, energy-intensive sectors, such as petrochemicals, steel and metal sub-sectors, are more closely monitored given their large share of GHG emissions.

Korea's industrial energy efficiency policies have been regularly revised and tracked, but a deeper evaluation of their outcomes would be necessary to assess their impact. Beneficiaries are required to report the results of individual steps taken, such as energy savings realized due to replacement of equipment funded by the policies. Reporting methods follow international standards on measurement and verification[23], and implementing agencies disseminate further specific guidelines for reporting. Output for more indirect programs, such as awareness raising, certifications, and networking schemes, is measured through simple metrics such as participation rate and the number of certifications. The results of individual projects are aggregated and reported by the implementing agencies. Meanwhile, sister agencies such as the Korea Energy Economics Institute (KEEI) conduct research on improving the implementation of policies, such as a better methodology to measure performance, incentive structures to induce participation, and firm behavior regarding energy efficiency investments. Other agencies such as the National Assembly Budget Office (NABO) tracks performance of implementing agencies with regards to budget execution levels (vis-à-vis the original proposed budget) and utilization levels by agency clients. Yet, assessments of policy outcomes beyond direct impacts, such as cost-benefit analysis and comparative analysis, are done only sporadically and there are no regular comprehensive assessments of the outcomes from each industrial energy efficiency policy or of the outcomes from a combination of these policies. Future research to develop an evaluation matrix for industrial energy efficiency policies would help to gain deeper understanding of the relative impacts of the diverse programs in place.

Policy measures to improve energy efficiency in Korea are implemented at different levels and scales. Some programs incentivize firms to replace existing equipment and machinery on one small part of the production process, while others are applied to an entire facility or even across a multi-building industrial campus or multi-company industrial park. On an industrial park scale, energy efficiency options can be implemented through aggregation of demands and leveraging common infrastructure and services to reduce the costs and risks facing individual firms. These options can be implemented along with other industrial symbiosis measures, such as re-use or recycling of waste heat, wastewater and materials, or sharing of renewables and other energy facilities.[24]

23 Korea utilizes IPMVP (International Performance Measurement and Verification Protocol), an internationally adopted protocol for measurement and verification of energy efficiency investments initially developed by the US Department of Energy.

24 Industrial symbiosis refers to a process in which waste or byproducts of an industrial process is provided for use by another. The relationship creates a circular economy, where resources are recycled to eliminate disposal and production costs, improving the collective sustainability of industrial processes.

The majority of the government budget on energy efficiency in 2022 was allocated to programs that required direct financial support (e.g. soft loan, tax credits, investment, subsidies). The DSM program implemented by energy suppliers was the largest program measured in terms of the amount of spending, followed by the soft loan program, energy efficiency resources standards (EERS) and tax credits programs (Table 3). Naturally, financing for programs related to information generation and sharing or target setting required minimal administrative budgets. In terms of coverage of the beneficiaries, the high efficiency equipment certification program reached the largest number of benefiting firms, followed by the soft loan program and the mandatory audit program.

TABLE 3. YEARLY BUDGET AND COVERAGE/BENEFICIARIES BY PROGRAM

PROGRAM	2022 (MIL KRW)	2022 (THOUSAND US$)	COVERAGE/BENEFICIARIES (2021)
Demand-side management (DSM) programs provided by energy suppliers	439,700	340,404	3 energy suppliers (KEPCO, KOGAS, KDHC)
Soft loan for investment in energy saving facilities	308,800	239,065	984 applications approved
Energy Efficiency Resources Standards (EERS)	109,500	84,772	3 energy suppliers (KEPCO, KOGAS, KDHC)
Tax credits for investments in energy saving facilities	33,997 (2021)	26,320	797 firms (incl. 629 SMEs)
National Eco-industrial Park (Eco-Industrial Development) and Smart Green Industrial Complex Programs[25]	15,785	12,142	
Support the adoption of EnMS	5,400	4,181	43 companies (24 for EnMS and 19 for FEMS)
Emission Trading Scheme (ETS)	2,488	1,926	637 firms (2020)
GHG Target Management Scheme (TMS)	1,460	1,130	

25 The national EIP program that was implemented between 2005 and 2016 has evolved into two different but related programs called Eco-Industrial Development (EID) and Smart Green Industrial Complex support programs. The former focuses on reducing industrial GHG and environmental emissions by supporting industrial symbiosis and circular economy solutions between firms (including firms operating inside the industrial parks) while the latter focuses on supporting the green and digital transformation of the national industrial complexes in Korea.

PROGRAM	2022 (MIL KRW)	2022 (THOUSAND US$)	COVERAGE/BENEFICIARIES (2021)
Energy standards and labeling program	923	714	459 firms, 11,297 newly certified models
Mandatory energy audit for large energy consumers	865	670	756 target facilities, 595k toe/year savings
Voluntary energy efficiency TMS	833	645	63 facilities
Energy consulting for SMEs through energy supporter	300 (2021)	232	120 facilities consulted by 4 energy supporters, 4k toe/year savings
Learning Energy Efficiency Network (LEEN)	200	155	2 region-based consortiums
Energy companionship	175	135	14 large firms supporting 58 SMEs
High efficiency equipment certification program[26]	110	85	4,632 newly certified models; 23 firms expired
Supporting market creation for Energy Service Companies (ESCO)	91	70	293 registered ESCOs
Energy Saving through Partnership (ESP)	n/a	n/a	8 subcommittees are established by industrial subsector, 204 total firms

SOURCE: MOTIE, MOE, KEA, KITECH, KOSIS
NOTE 1: n/a refers to budgets that were not available to the public. For some programs, data on the budget and coverage/beneficiaries for the most recent year was not available, so the table reports the latest year available.
NOTE 2: Budget for DSM includes budget for EERS.

The majority of energy efficiency programs leverage two or more policy support modalities, and some type of financial support. In Table 4, seventeen ongoing energy efficiency programs are matched to the six modalities of public policy support categories. Each program is characterized by its primary and secondary modalities of support based on the review of the program description. The ongoing energy efficiency programs show that there are more voluntary programs with incentives than regulatory ones. The mix of regulations and incentives characterizes the Korean energy efficiency policy mix. Descriptions of other ongoing programs are presented in Annex 2 while terminated programs are presented in Annex 3.

26 The budget is used to support SMEs to do testing when applying for the high efficiency equipment certification program. Max 3 million KRW (US$ 2,300) is allocated per company.

TABLE 4. ENERGY EFFICIENCY PROGRAMS BY THE MODALITIES OF PUBLIC POLICY SUPPORT

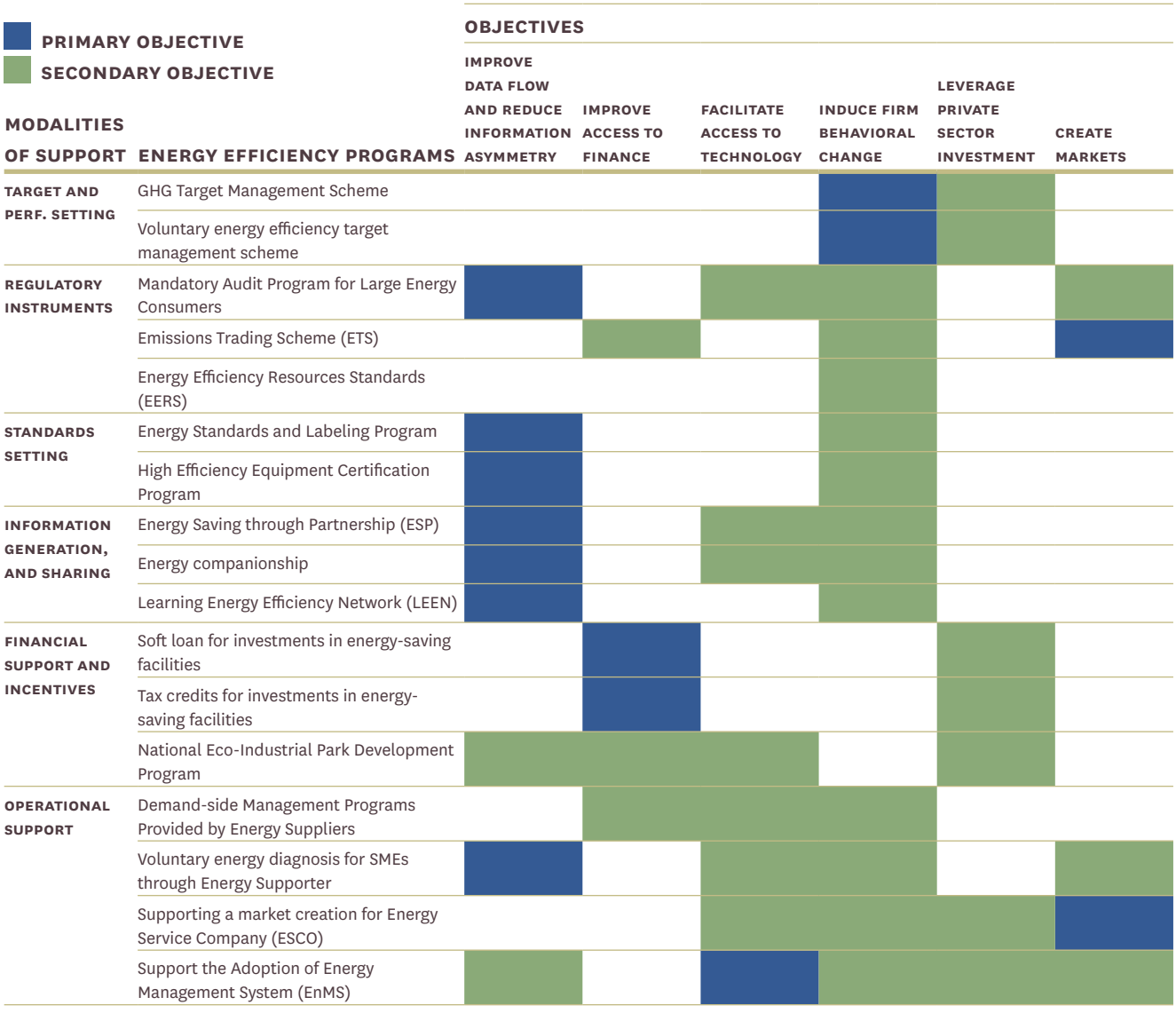
#	ENERGY EFFICIENCY POLICY PROGRAMS	TARGET AND PERFORMANCE SETTING	REGULATORY AND LEGAL INSTRUMENTS	STANDARDS SETTING	INFORMATION GENERATION, AND SHARING	FINANCIAL SUPPORT	OPERATIONAL SUPPORT
1	GHG Target Management Scheme	○				●	
2	Voluntary energy efficiency target management scheme*	○				●	
3	Mandatory energy audit*		○				●
4	Emission Trading Scheme (ETS)		○			●	
5	Energy Efficiency Resources Standards (EERS)	●	○				
6	Energy standards and labeling program*	●	●	○	●		
7	High efficiency equipment certification program	●		○	●		
8	Energy Saving through Partnership (ESP)*				○		
9	Energy companionship				○		
10	Learning Energy Efficiency Network (LEEN)				○		
11	Soft loan for investments in energy-saving facilities					○	
12	Tax credits for investments in energy-saving facilities					○	
13	National eco-industrial park/ development program*				●	○	●
14	Demand-side management programs provided by energy suppliers*	●	●			●	○
15	Voluntary energy diagnosis for SMEs through energy supporter				●	●	○
16	Supporting a market creation for Energy Service Company (ESCO)					●	○
17	Support the adoption of Energy Management System (EnMS)*			●		●	○

SOURCE: Author's
NOTE1: ○ refers to the primary modality of support, and ● for secondary modality of support.
NOTE2: *indicates exemplary programs examined in detail in section 4.3. Other programs are examined in Annex 2.

Each of the energy efficiency programs targets multiple objectives. The objectives of the energy efficiency programs can be grouped into six different categories: (i) improve data flow and reduce information asymmetry, (ii) improve access to finance, (iii) facilitate access to technology, (iv) induce firm behavioral change, (v) leverage private sector investment, and (vi) create markets.

The 17 energy efficiency programs were mapped with the objectives, and 'improving data flow and reducing information asymmetry' and 'inducing firm behavioral change' emerged as the two most common objectives of the energy efficiency policy mix. Most programs had dual objectives, and programs related to operational support had multiple objectives (Figure 19). For example, the primary objective of the ESCO program is to create markets for energy services companies. The Korean government provided support to nurture ESCO service providers and assisted their operations by linking ESCO's remuneration with the energy savings achieved. The ESCO program also tries to leverage private sector investment by lowering the financial burden on firms that attempt to implement new equipment or technology as a secondary objective.

FIGURE 19. STATED OBJECTIVES OF ENERGY EFFICIENCY PROGRAMS



SOURCE: Author's

In the next section, one exemplary program for each modality of support is described in detail. The six example programs were selected based on the feedback provided by the expert interviewees and the perceived effectiveness and reach of these programs. The descriptions of the rest of the programs can be found in Annex 2.

4.3.1 TARGETS AND PERFORMANCE SETTING

Policy measures that established energy efficiency and GHG emission reduction targets and performance requirements have evolved over the past two decades, seeking a balance between voluntary and mandatory approaches. 'Voluntary Agreement for energy conservation and reduction of GHG emissions' introduced in 1999 encouraged firms to set their own energy and emission saving targets. The objective was to induce firms to voluntarily set their target goals and identify ways to improve energy efficiency, and to plan and implement necessary actions. Since the GHG Target Management Scheme was introduced in 2012, the Korean government became more involved in the target setting stage and introduced mandatory requirements for firms with certain energy consumption and emission levels. The types and number of firms subject to monitoring under the mandatory target management schemes have gradually increased since 2012. As a result of various performance targets introduced over the past decades, Korea currently has a mix of voluntary and mandatory target management schemes. The Voluntary Energy Efficiency Management Scheme, introduced in 2020, provides an example of a voluntary program.

VOLUNTARY ENERGY EFFICIENCY TARGET MANAGEMENT SCHEME[27]

— Program description and objectives

The aim of this scheme is to meet long-term national targets to reduce energy consumption and GHG emissions[28] by encouraging industrial actors to participate in energy efficiency activities, not through regulation but through voluntary agreement. By voluntarily participating in the program, firms can increase their capacities to measure, monitor, and manage energy use using the guided methodology, and this may also lay the foundation for participating in other programs such as the ETS.

— Eligibility and support provided

The program is completely voluntary. Once the agreement has been made between applicant and the KEA, the first step of the voluntary agreement is to assess the current state, and to set the energy intensity targets for the following year. Firms can set their targets in two ways. One is by setting the target goal to improve 1 percent in energy intensity[29], which is the recommended guideline set for all industries. Alternatively, firms can use benchmark targets set by industries. For example, steel, petrochemicals, and cement firms can set their targets either using the 1%

27 See https://www.energy.or.kr/web/kem_home_new/ener_efficiency/industry_21.asp

28 Under the 2019 Energy Efficiency Innovation Strategy, MOTIE set a long-term national target to reduce energy consumption by 14.4 percent and GHG emissions by 37 percent compared to the business-as-usual scenario by 2030 (MOTIE 2019).

29 Energy intensity is calculated based on the production - energy consumption divided by the production quantity.

target or using the benchmark outlined in Table 5 below. Companies that do not meet the target can get consultation and technical assistance from energy experts and come up with improvement plans. Firms that emit more than 2,000 toe per year are eligible for the program, and the agreement has a long-term outlook, covering a period of five years.

Whereas most of the incentives related to energy efficiency are given to SMEs, this program attempts to provide incentives to large firms as well. Although the benefits upon accomplishing the targets are still under discussion, certificates recognizing superior performance in meeting energy efficiency targets can be awarded to firms. Also, firms may be given extra points when they apply for the energy saving facility tax credit program. The government plans to expand the incentives to have more participants for this program.

As the pilot program started in 2020, the evaluation of the outcomes of the program is limited. In 2020, 44 firms participated in the program and achieved on average 1.78 percent of energy intensity improvement. Among the 44 participants, 19 were selected as best practices. In 2021, 63 firms and facilities made an agreement to participate in the program and achieved 3.54 percent improvement in energy intensity. In Korea, there are more than 2,900 industrial sector entities that use over 2,000 toe annually, so the participation rate is still low.

TABLE 5. ACHIEVEMENT OF THE VOLUNTARY ENERGY EFFICIENCY TMS

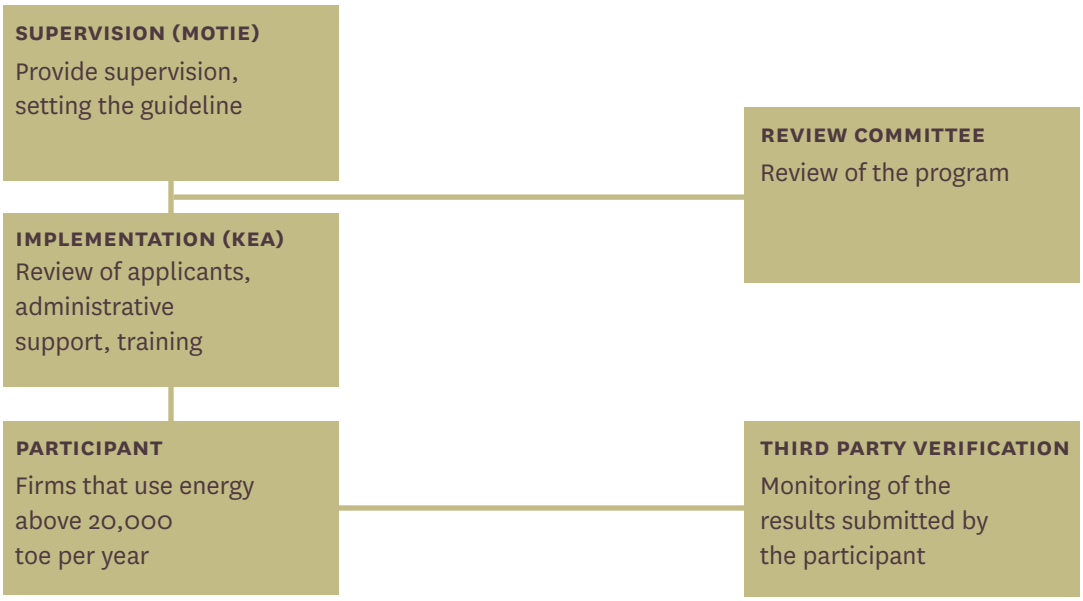
YEAR	PARTICIPANT	ENERGY INTENSITY IMPROVEMENT GOAL (AVERAGE)	ENERGY INTENSITY IMPROVEMENT ACHIEVEMENT (AVERAGE)
2020	44	1.13%	1.78%
2021	63	1.26%	3.54%

SOURCE: KEA

— Program stakeholders and governance

KEA oversees the voluntary energy efficiency target management scheme. Since this program started its first pilot test in 2020 and the second-year pilot initiated in 2021, the guidelines have been continuously modified by the KEA. The program also involves 3rd party verification agencies that monitor the results submitted by the participants (Figure 20).

FIGURE 20. GOVERNANCE AND KEY STAKEHOLDERS



SOURCE: Recreated from KEA

4.3.2 REGULATORY AND LEGAL INSTRUMENTS

The Korean government has used various instruments to establish a legal basis for line ministries to provide energy efficiency programs. Programs that leverage regulatory instruments include mandatory energy audits for large energy consumers, ETS, and the Energy Efficiency Resources Standards (EERS). These mandatory programs are accompanied by strict penalties in case of non-compliance. Many regulatory measures and legal instruments are stipulated in or based on the Energy Use Rationalization Act and Framework Act on Low Carbon, Green Growth. A useful example of this approach is the mandatory energy audit program.

MANDATORY ENERGY AUDIT[30]

— Program description and objectives

The Korean government introduced a mandatory energy audit program in 1985 to help improve the energy efficiency of large energy consumers and reduce the country's industrial energy consumption and GHG emissions in the face of rising energy prices. The objective of this program is to improve data flow and induce behavioral changes of the large energy consumers by helping them to understand the baseline of energy use at industrial sites, identify inefficient processes or factors that cause energy losses, and implement solutions that can optimize energy use. Energy audits are performed by companies that have relevant expertise, equipment, and capacity to perform the audits.

30 See https://www.energy.or.kr/web/kem_home_new/ener_efficiency/industry_13.asp

— **Eligibility and support provided**

Firms (including SMEs) that consume more than 2,000 toe annually are required to undergo an energy audit every 5 years unless they are exempted for specific reasons. The mandatory energy audit program is undertaken at the firms' expense by audit firms registered with the Korea Energy Agency. Firms that are subject to the energy audit sign contracts with registered energy auditors and negotiate the focus and scope of the audit. The level of energy audits is assigned to the firms based on their latest energy consumption levels reported to the local government.

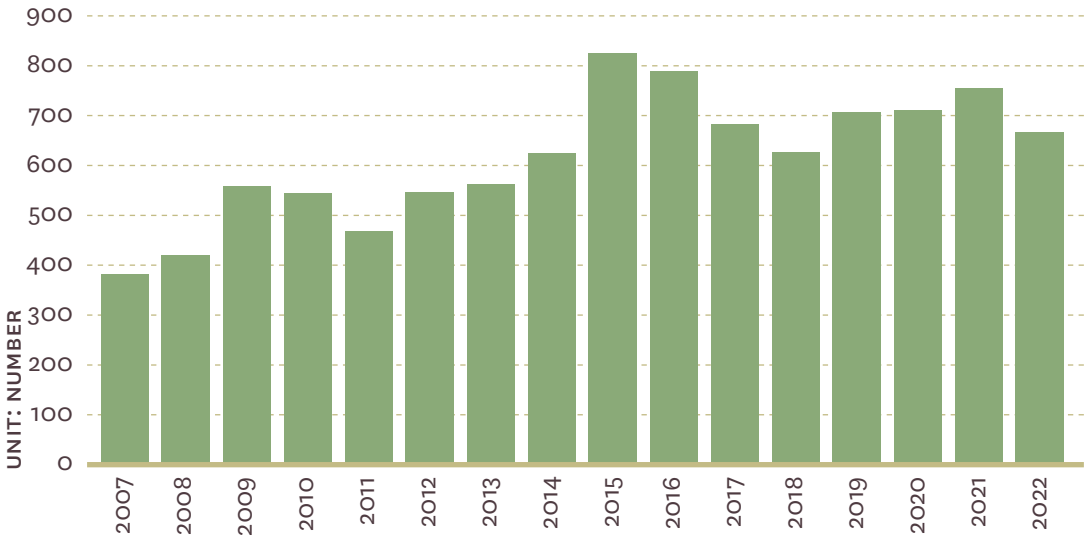
In addition, firms (both industrial and commercial) with annual energy use over 2,000 toe must report their energy use to their Provincial Governor. SMEs that consume more than 2,000 toe but less than 10,000 toe per year can get up to a 30 percent discount of the total audit fee. Firms can voluntarily choose their course of action and the types of energy efficiency investments following the audit. However, firms that consume more than 2,000 toe per year but do not comply with the mandatory energy audit are subject to a penalty fee of up to 20 million KRW (US$ 15,500). The result of the audit will:

— Suggest specific measures to improve operational efficiency
— Identify waste heat and energy loss factors that could be addressed
— Propose plans to reuse waste heat and examine its economic feasibility
— Identify areas or processes in which renewable energy use can be integrated
— Suggest an effective energy use model for the production site / facility

From 2007 to 2021, a total of 9,206 entities were audited. On average, these audits typically identify opportunities to reduce energy use by an estimated 4.6 percent (KEA) (Figure 21). This is equivalent to a total of 19,303,546 tonnes of CO_2 of GHG reductions over the 15 years or 1,286,903 tonnes of CO_2 per year (KEA) (Figure 22). As many of the facilities covered by the program are now entering their third round of energy audits, both the average estimated energy savings from potential measures identified and the actual energy savings from measures implemented have been decreasing over the years.

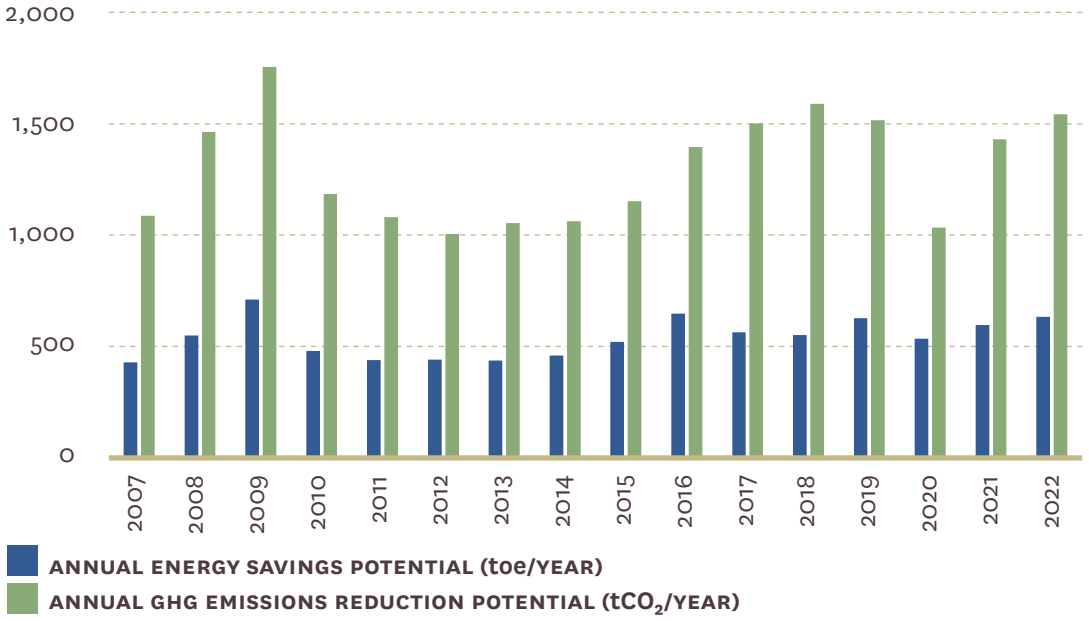
The mandatory energy use reporting requirements for firms consuming over 2,000 toe of energy annually were completed by 62.5 percent of firms in recent years. Firms in the metals and chemicals industries constituted over 60 percent of the reporting firms. Reporting firms accounted for 68 to 73 percent of industrial energy use annually from 2016 and 2020 (KEA 2022a).

FIGURE 21. NUMBER OF FACILITIES SUBJECT TO MANDATORY ENERGY AUDIT EVERY YEAR



SOURCE: KEA 2023b

FIGURE 22. ENERGY SAVINGS AND GHG EMISSIONS REDUCTIONS POTENTIAL IDENTIFIED FROM THE ENERGY AUDIT



SOURCE: KEA 2023b

— Program stakeholders and governance

KEA has been responsible for certifying energy audit firms and providing some audit services with its own staff. KEA also compiles energy use data from the documents provided by the firms.

4.3.3 STANDARDS SETTING

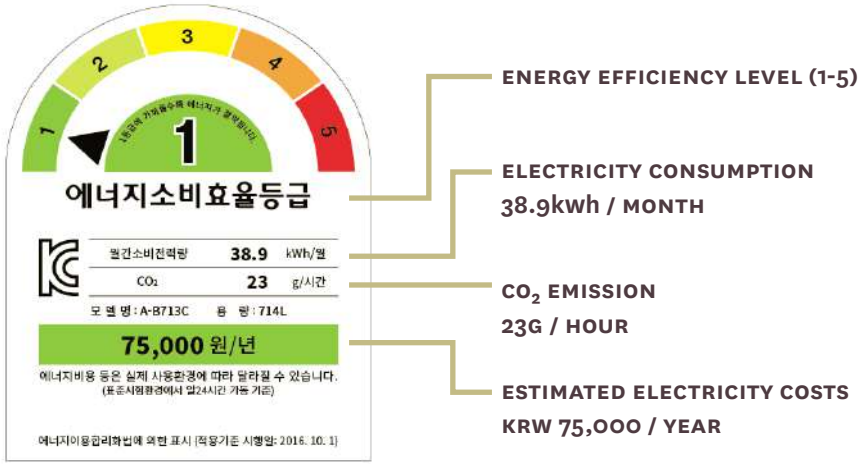
Since the 1990s, the Korean government has introduced different standards to resolve information asymmetries and encourage R&D investments to produce energy-efficient products and equipment. The two main programs related to standards setting are 'energy standards and labeling program', and 'high efficiency appliance certification program'. The requirement levels are regularly adjusted to reflect the latest technological progress.

ENERGY STANDARDS AND LABELING PROGRAM[31]

— Program description and objectives

The energy standards and labeling program, initiated in 1992, mandates manufacturers to attach an energy efficiency label (ranging from level 1 to 5) to 33 energy-intensive appliances. The appliances include refrigerators, washing machines, televisions, electric fans, etc. The objective of the program is to reduce information asymmetry between the consumer and the product supplier. Consumers are provided an estimate of how much they would have to pay in energy use for the appliance per year, which can encourage energy conservation (Cleary and Palmer 2020). The label also includes, depending on the product type, the monthly energy usage of the device, its hourly carbon emission equivalent, and efficiency rating (Figure 23). The disclosure of information induces firms to produce energy saving products in order to be more competitive in the market.

FIGURE 23. ENERGY STANDARDS AND LABELING



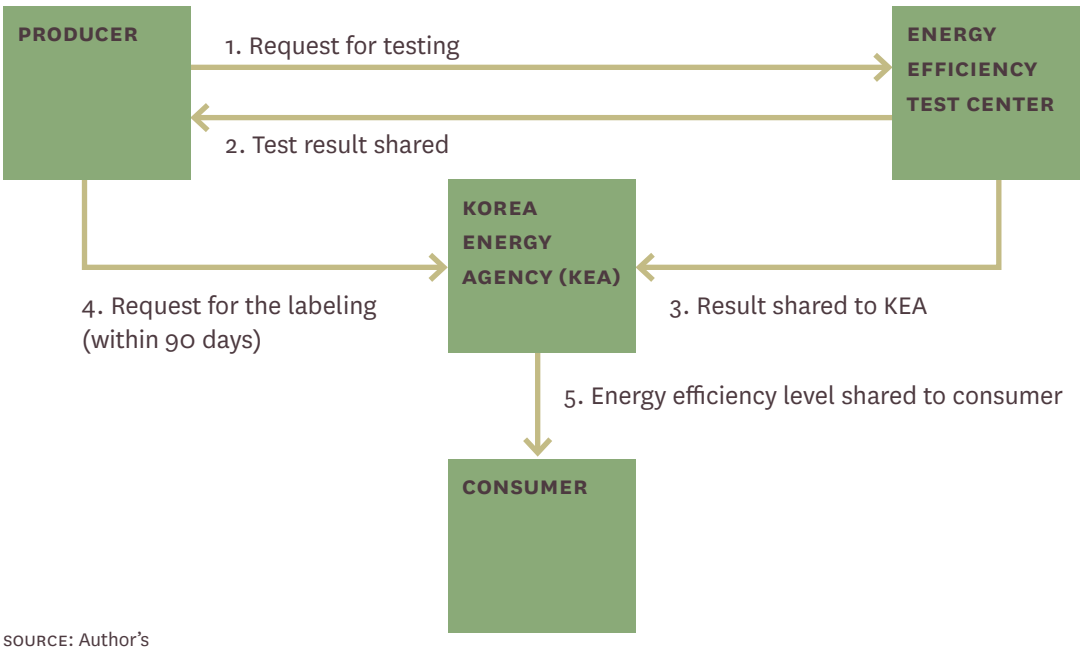
SOURCE: KEA

31 See https://dco.energy.or.kr/renew_eng/energy/appliances/labeling.aspx

— Eligibility and support provided

This is a mandatory program, and all manufacturers and importers of the selected appliances are obliged to report the efficiency ratings of their products. All appliances that are on the market should have a visible label indicating their energy efficiency standards (Figure 24). Appliances failing to meet the minimum energy performance standards (MEPS) are banned in the market for production and sales. Firms that do not comply with this are fined up to 20 million KRW (US$ 15,500) for violation. By the end of March every year, firms producing the 33 appliances need to report the sales performance to KEA.

FIGURE 24. ENERGY STANDARDS AND LABELING PROCEDURE



SOURCE: Author's

— Program stakeholders and governance

MOTIE and KEA continue to update the energy efficiency requirement and the list of appliances. Firms that plan to release their products need to get a test from selected test centers and submit the result to KEA within 90 days. The test applies to both domestic production and imports. Products that have minor changes, such as change in color, design, size, or sales channel, from the prior model are exempted from the test.

4.3.4 INFORMATION GENERATION AND SHARING

Most of the programs implemented in Korea related to 'information generation and sharing' are voluntary programs. Although some programs have been successful, for example the Energy Saving through Partnership (ESP) has been ongoing for more than 20 years and proved to be effective in propagating the importance of energy efficiency, there still remain challenges to such programs.

The biggest challenge is the lack of incentives for firms to disclose their best practices or information about energy efficiency technologies to other firms. A second challenge is related to the awareness of such programs. The Korea Energy Economics Institute conducted a survey in 2021 to identify which of Korea's energy efficiency programs were well-known, and found that non-regulatory programs had limited awareness, and low participation rates (KEEI 2021).[32]

ENERGY SAVING THROUGH PARTNERSHIP (ESP)[33]

— Program description and objectives

The aim of the program is to reduce energy and GHG emissions through sharing knowledge and experience among firms that are in similar sectors.

— Eligibility and support provided

This is a voluntary program, and companies using more than 2,000 toe per year are eligible for participation. ESP is composed of 8 divisions (electric and electronics, petrochemicals, paper, food, energy, steel, automotive, and cement, the last added in 2021); as of 2021, 204 companies were participating in the program (KEA 2022a). In 2021, 40 best practices were shared from this program (Table 6). Eligible firms can apply to participate all year round to KEA. The program is free of charge, and firms who play an active role receive a reward every year. Companies participating in the program can benefit from the network of participants in similar sectors.

— Program stakeholders and governance

KEA collects best practices and opens seminars and workshops to introduce new energy efficiency policies and to advise firms to adopt new technologies. KEA regularly holds meetings with practitioners and collects survey information to find ways to better facilitate knowledge sharing between participants.

TABLE 6. ENERGY SAVING THROUGH PARTNERSHIP (ESP) RESULT FOR 2021

DIVISION	PARTICIPATING FIRMS	BEST PRACTICES SHARED
Electric and electronics	36	4
Petrochemicals	38	1
Paper	24	1
Food	31	10

32 The KEEI conducted a survey in 2021 to identify which of Korea's energy efficiency programs were well-known and had high participation rates. Most of the respondents to the KEEI survey reported more awareness of regulatory/financial programs than of non-regulatory programs. The program that had the most recognition and participation among industrial firms was the mandatory energy audit program.

33 See https://www.energy.or.kr/web/kem_home_new/ener_efficiency/industry_16.asp

DIVISION	PARTICIPATING FIRMS	BEST PRACTICES SHARED
Energy	32	7
Steel	13	7
Automotive	12	9
Cement	18	1
Total	**204**	**40**

SOURCE: KEA 2022a

4.3.5 FINANCIAL SUPPORT

The majority of energy efficiency programs use some type of financial support or incentive to induce voluntary participation from firms and industries. Financial support, which may include low-interest loans, tax credits, or direct grants and subsidies to firms or to the energy service providers, is the most used modality of support in the energy efficiency policy mix. An example is the National Eco-Industrial Park Development Program.

NATIONAL ECO-INDUSTRIAL PARK (EIP) DEVELOPMENT PROGRAM

— Program description and objectives

Korea's industrial parks[34] consume more than 100 million toe of energy annually and account for about 45 percent of the country's total GHG emissions. The Eco-Industrial Park (EIP) program aims to reduce resource and energy use as well as the environmental and carbon footprints of agglomerated industrial areas where multiple firms operate.

Responding to calls for sustainable industrial development, the MOTIE implemented a long-term program[35] designed to transform industrial parks into Eco-Industrial Parks over the period between 2005 and 2019. The goal was to save nearly half a billion dollars in resource and energy costs, including additional income due to the measures implemented, and to reduce emissions of GHGs by 2 million tonnes annually.[36]

Under the EIP program, the government has supported R&D projects that identify opportunities for resource circulation and industrial symbiosis networks, and has promoted private investments

34 As of 2022, 1,262 industrial parks operate in Korea, with 116,288 firms – 21.2 percent of total manufacturing firms in Korea – operating within these parks and approximately 2.28 million people employed (KICOX 2023). Industrial parks accounted for 44 percent of total industrial output of the country, producing a total of 631 trillion KRW (US$ 488.5 billion) in total output value in 2021 (KOSIS 2023). Industrial parks also contributed to generating US$ 224.2 billion worth of exports in 2022 through September.

35 The program was first piloted in large industrial parks in the southern cities of Pohang, Ulsan, and Yeosu in 2005. By 2019, through 3 stages, the Parks were expanded across a hub and spoke model to promote a symbiotic network effect with 2 hubs per region and 4 to 13 spokes, encompassing 9 regions in Korea.

36 The latest estimated emissions for 2021 are expected to be 680 million tonnes.

in industrial symbiosis. The industrial symbiosis opportunities help improve energy efficiency and conservation through providing examples such as recovering waste oil or waste heat from tenant firms or facilities nearby. Emulating these examples can help firms to ensure the maximum utilization of available energy at lower cost, replace the energy and fossil fuels required for operating industrial boilers, and reduce wastage of energy and resources. MOTIE continues to provide this line of support through eco-industrial development (EID) and smart green industrial complex programs.

— Eligibility and support provided

The EIP program provides several instruments to support energy efficiency improvements, including operational support for energy audit and financial support for R&D projects to identify feasible EIP investment opportunities at the firm and park levels (e.g. waste heat recovery projects). In addition, it provides energy management systems and infrastructures as well as data management systems to inform energy and resource efficiency measures. The Korean government also set up a framework to enable the Korea Energy Agency to "institutionalize" the energy performance contracts of ESCOs servicing industrial parks.

MOTIE, through the Korea Industrial Complex Corporation (KICOX) and KITECH-KNCPC, has provided additional financial support for R&D projects that improved resource and energy efficiency at the industrial parks. Under the EIP program, selected industrial symbiosis project proposals[37] can receive R&D funding to conduct feasibility assessments. Through KICOX, MOTIE supported between 33 and 75 percent of the total R&D costs (World Bank 2018). For the projects in which SMEs participate, MOTIE provided double the amount of R&D budget to encourage their participation. The local government provided additional funding to symbiosis projects with significant local and environmental impact.

Through 2020, the EIP program was estimated to have saved an average of nearly 400,000 toe of energy annually, or nearly 6 million toe in total over the project implementation period. Estimated average annual savings over the period were thus equivalent to 6 percent of annual energy consumption of all of the industrial parks in Korea (World Bank 2021). The resulting annual GHG emissions reductions averaged 2.1 million tonnes of CO_2 equivalent, equal to approximately 4 percent of industrial emissions. Economic benefits were also substantial, totaling US$ 665 million over the project period, with additional revenue from the industrial symbiosis reaching US$ 401.3 million (World Bank 2021).

The Ulsan Eco-Industrial Park, one of the largest industrial parks in Korea and home to the operations of many energy-intensive industrial firms, has received substantial support under these programs.[38] KEA provided loans to ESCOs to replace and improve the performance of the energy

37 Industrial symbiosis projects improve resource and energy efficiency at both firm and industrial park levels through various technological options, such as recovering waste heat or reusing used fuel, etc.

38 At the time of initiating the industrial symbiosis project in 2008, the Ulsan Eco-industrial Park produced annual output valued at US$ 68 billion, and it had employment of nearly 88,000 in an area covering over 46 square kilometers.

facilities in the Ulsan Park through a guaranteed savings model (World Bank 2021). An example of the energy efficiency synergies achieved through this financing arrangement include a chemical company that was able to use ESCO and other financing to build a 6.2 km steam line to provide excess steam to other heat users in the Ulsan industrial park.

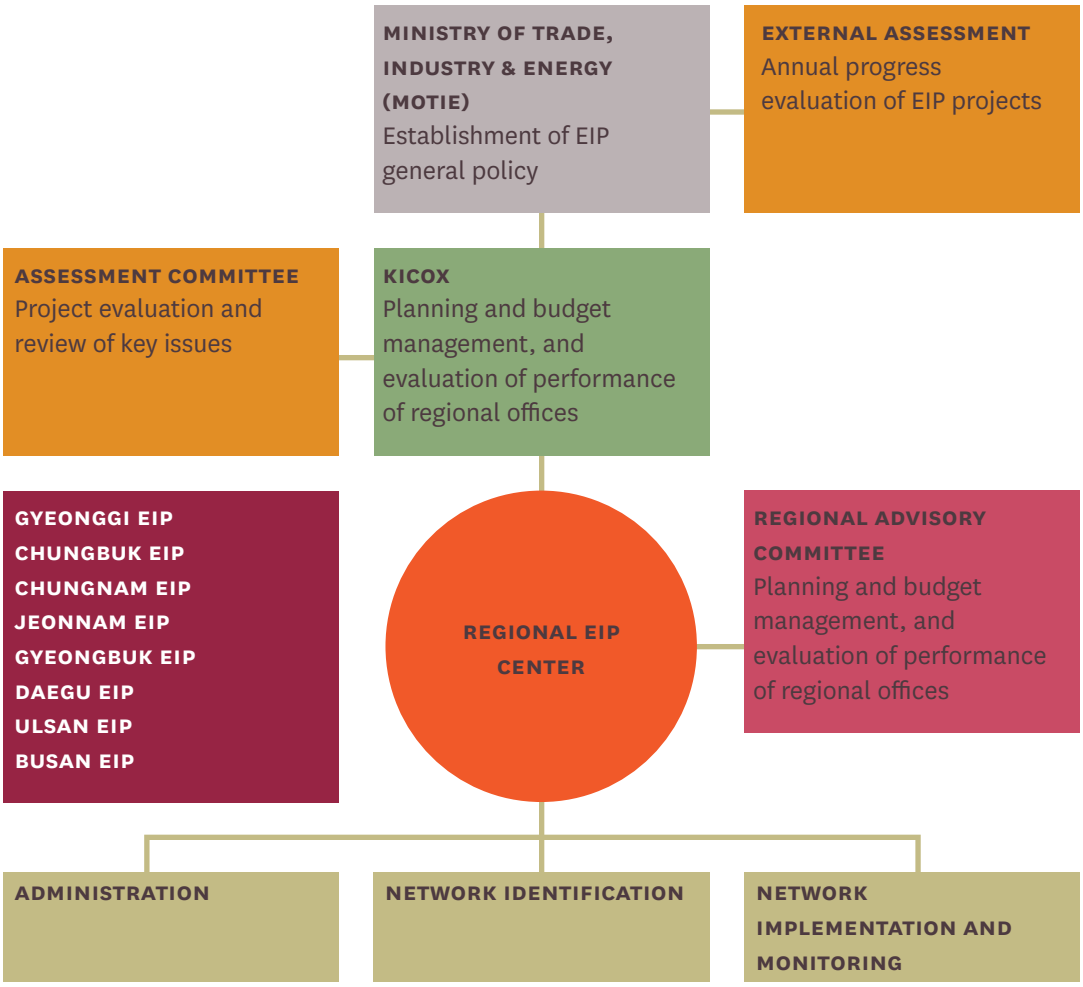
The industrial synergies developed within the Ulsan Eco-industrial park, along with other investments, were tracked through the collection of a range of economic and environmental parameters that were evaluated before and after the "networking" between industrial systems in the park was completed (UNIDO et al. 2018). The first phase of over 20 of these industrial symbiosis activities through about 2008 were estimated to have produced profits of over US$ 50 million per year, yielding an average payback period of under one year.[39] Environmental benefits ranged from an annual park-wide reduction in energy use and greenhouse gas emissions on the order of 0.5 percent, with reductions in industrial wastes and sulfur oxide emissions of two to three percent. Although these first-phase results indicate relatively modest savings, in comparison with the production and emissions of the firms in the industrial park in aggregate, they show the potential of this industrial synergy approaches to offer energy and environmental benefits cost-effectively. A later review of the effectiveness of the measures taken in the Ulsan EIP reported "eco-efficiency of industrial waste generation and energy use has improved by 35.0 and 21.4 percent", presumably meaning a reduction in energy use per unit output of over 20 percent, over the period 2000-2015 (Shah, Dong, and Park 2020).

— Program stakeholders and governance

A dedicated governance structure was established to facilitate the implementation of the overall EIP program at the national level. This structure included government departments, ministerial bodies (MOTIE), industrial park developers, operators, and resident firms, as well as business service providers, engineers, consultants, equipment suppliers, financiers, academic institutions, and other actors. The Korea Industrial Complex Corporation (KICOX) is the project management agency established under the MOTIE. The overall structure for EIP governance in Korea is shown in Figure 25 below.

39 The payback period and feasibility will be different by country depending on the price of the raw materials or by-products and the capital investment costs.

FIGURE 25. EIP GOVERNANCE STRUCTURE IN KOREA

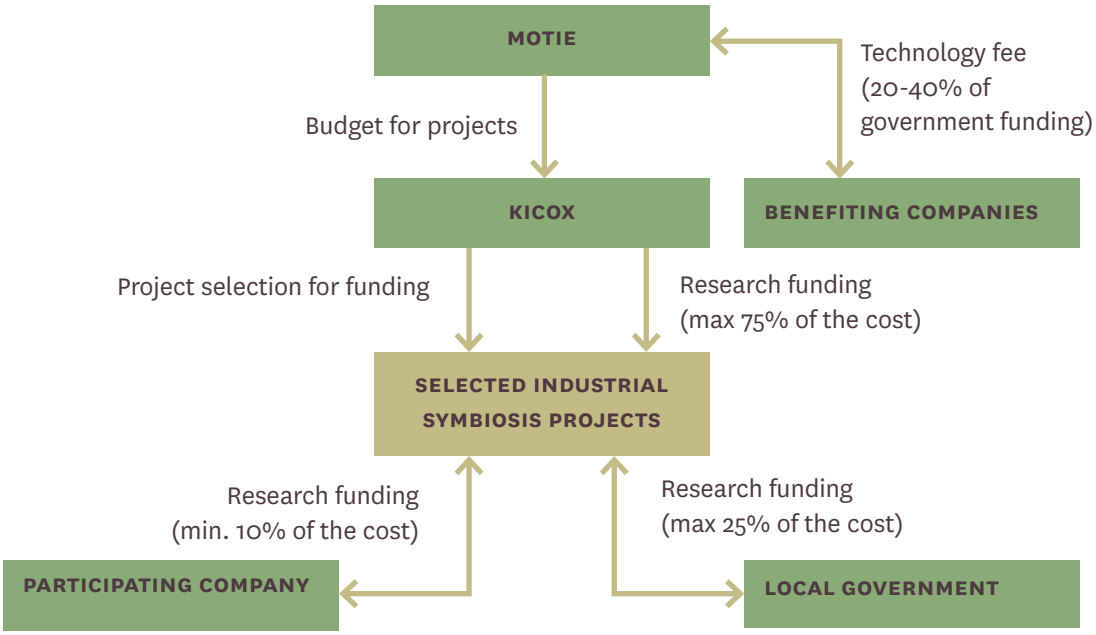


SOURCE: UNIDO et al. 2018 based on information from KICOX

In R&D-related projects, after an EIP project is completed, KICOX performs an evaluation of its outcomes and determines a fraction (20 to 40 percent) of the original R&D budget to be paid back to MOTIE by the participating companies. An evaluating committee assesses whether the original goals of the project were met and if innovative outcomes have been produced.[40] A schematic of the procedure for selecting and funding EIP R&D projects is provided in the figure 26 below.

40 The payback of R&D fees is based upon the guidelines for payment and management of technology fees under the Industrial Technology Innovation Promotion Act. Under this Act, MOTIE is authorized to charge entities willing to use, transfer, distribute usage rights, or export technology developed through R&D projects.

FIGURE 26. PROCEDURE FOR FUNDING R&D PROJECTS FOR ECO-INDUSTRIAL PARKS IN KOREA



SOURCE: UNIDO et al. 2018 based on information from KICOX

4.3.6 OPERATIONAL SUPPORT

Many of the energy efficiency policy programs that provide 'operational support' combine financial instruments to increase the impact of the programs. The 'operational support' is provided to firms through third parties such as ESCOs (Energy Service Companies), which bring technical expertise and financial resources, or through firms that deploy energy management systems (EnMS). Many of the energy efficiency policy programs that provide 'operational support' combine financial instruments to increase the impact of the programs. An example is the program to support the adoption of Energy Management Systems.

SUPPORT THE ADOPTION OF ENERGY MANAGEMENT SYSTEM (ENMS)

— Program description and objectives

The primary objective for the EnMS program is to provide access to technology to SMEs that do not have, or have substandard, EnMS installed. From installing the EnMS, firms can collect more accurate data related to energy consumption, which helps firms to monitor and find ways to improve their energy use. Also, from the consulting service by the EnMS service provider, firms can identify outdated equipment that may be causing large energy losses at the production site. As EnMS implementation fee can be partly supported by the government for the SMEs, which can induce private sector firms to invest in energy efficiency activities.

— **Eligibility and support provided**

The EnMS program provides targeted support for energy-intensive SMEs with energy consumption over 500 toe annually in the industrial and power sectors. The program supports firms in establishing EnMS infrastructure in three ways: (i) consulting and infrastructure support, (ii) training and information sharing, and (iii) certification of performance (Table 7):

TABLE 7. TYPE OF SUPPORT PROVIDED TO FIRMS IN IMPLEMENTING ENMS INFRASTRUCTURE

CATEGORY	CONTENTS
CONSULTING AND INFRASTRUCTURE SUPPORT	1. **Pre-implementation consulting service** — Raising awareness and education on the concept and application of EnMS — Consulting support to evaluate energy management status and the quality of energy management, to provide energy efficiency evaluations and to set performance targets, and in developing plans to introduce EnMS 2. **Infrastructure support** — Real-time energy consumption measurements and ICT-based instrumentation and monitoring infrastructure for monitoring collected energy data — Establishing control infrastructure to identify and control energy losses in processes and facilities based on monitoring results — Support for facility entities to improve energy efficiency based on monitoring results 3. **Post-implementation consulting services** — Provides guidelines and consulting for companies to continuously manage energy and improve efficiency based on the evaluation of performance during the support period
TRAINING AND INFORMATION SHARING	1. **Improving awareness and strengthening human capabilities** — Training CEOs and EnMS technical experts 2. **Conducting surveys of the status of EnMS** 3. **Continuously developing policies to increase adoption of EnMS in companies**
CERTIFICATION OF HIGH-PERFORMING INDUSTRIAL SITES AND ADDITIONAL SUPPORT	1. **Skills training** — Provide training on specific methods to measure improvements in energy efficiency 2. **Provide support for energy efficiency performance evaluation** 3. **Certifying high-performing firms** — Award certifications to firms that meet the standards of high-performance — Provide promotion opportunities to high-performing firms (promotion of their energy efficiency-related achievements)

SOURCE: Annex 1. Categories of Support for Energy Management Systems in Regulations on Supporting Energy Management Systems subordinate to the Energy Use Rationalization Act (Ministry of Government Legislation 2023)

The program provides differentiated financial support of up to 70 percent of investment costs for small firms and 40 percent for medium-scale firms (Table 8). The maximum amount of financial support ranges from 100 to 200 million KRW depending on the firm's yearly energy consumption amount.

TABLE 8. ENMS PROGRAM ELIGIBILITY CRITERIA AND LEVELS OF SUPPORT

SIZE OF FIRMS	LEVEL OF GOVERNMENT SUPPORT	PRIVATE CAPITAL	ENERGY CONSUMPTION (toe/YEAR)	MAXIMUM LEVEL OF SUPPORT (MIL KRW)	MAXIMUM LEVEL OF SUPPORT (US$)
SME	70%	30%	500-2,000	100	77,500
			2,000-10,000	150	116,000
			> 10,000	200	155,000
MEDIUM-SIZED ENTERPRISES	40%	60%	500-2,000	100	77,500
			2,000-10,000	150	116,000
			> 10,000	200	155,000

SOURCE: KEA 2023b
NOTE: In Korea, definitions of SMEs differ by sector (Ministry of SMEs and Startups 2023).

In 2019, the government expanded the target program recipients from individual firms to support factory energy management systems (FEMS) in industrial complexes. As an example, KICOX implemented a smart energy platform at the Banwol-Sihwa industrial complex, where 20,266 firms, mainly in the electronics and machinery manufacturing sectors, operate.[41] The team supported: i) the installation of equipment and sensors to monitor energy consumption (electricity, heat, and gas usage), ii) the implementation of a central energy management system (CEMS) that collects and analyzes energy data available from the sensors, and iii) the provision of services that visualize energy consumption patterns and identify areas for improvement (Figure 27 is an example of a smart energy platform). The purpose of having a central monitoring system is to reduce peak demand and optimize energy use in the industrial complex.

From the implementation of this program in 2014 to 2021, MOTIE provided support to 227 firms (KEA 2023b). This includes a total of 163 firms that received EnMS infrastructure support, as well as 64 firms that received support for FEMS installation under the Smart Green Industrial Complex Program. Cumulatively, a total of 28.1 billion KRW (US$ 20 million) was spent for the program. In 2021 alone, 43 firms (24 for EnMS and 19 for FEMS) received support, and the budget was 5.2 billion KRW (US$ 4 million) (Figure 28).

41 Based on information provided by KICOX to the World Bank Group.

FIGURE 27. SMART ENERGY PLATFORM AT BANWOL-SIHWA INDUSTRIAL COMPLEX

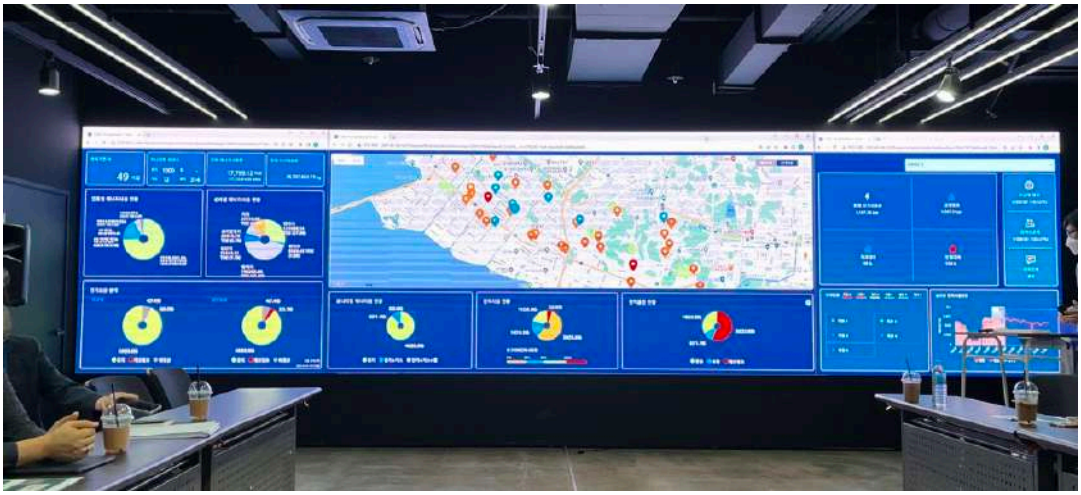
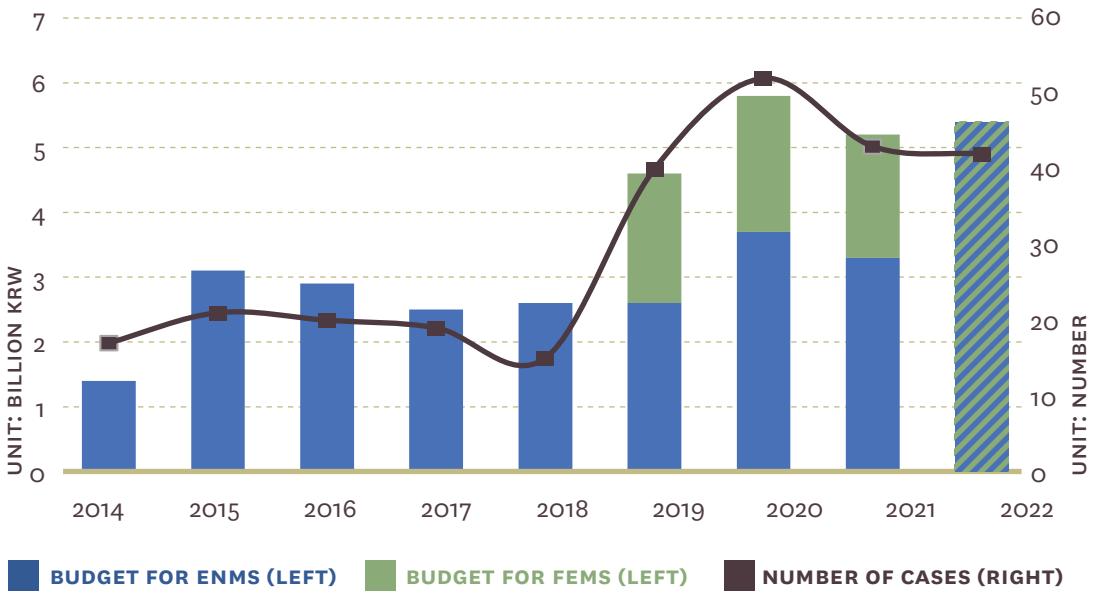


PHOTO CREDIT: Nah-yoon Shin
COURTESY: KICOX Banwol-Sihwa Smart Green Industrial Complex Project Team

FIGURE 28. ENMS PROGRAM BUDGET AND NUMBER OF PROGRAM RECIPIENTS



SOURCE: KEA 2023b

— Program stakeholders and governance

Under the supervision of MOTIE that designed the program, KEA provides the overall support for the EnMS project. KEA organizes a review committee that selects and evaluates the EnMS service providers. Consultation and the actual installation of the EnMS is conducted by private EnMS service providers. Those eligible for the program need to partner with a EnMS service provider and submit the application to the KEA.

05

Lessons learned from Korea's energy efficiency policy experience

5. Lessons learned from Korea's energy efficiency policy experience

The Korean case study offers lessons on the development and application of industrial energy efficiency policies. The lessons emerging from this review of Korea's energy policies could be of value to policymakers when designing or developing new energy efficiency policies. Several countries, both in developed and emerging economies, face similar challenges in improving energy efficiency in the industrial sector, including low energy prices, lack of incentives for firms to adopt energy efficiency solutions, and dependence on government support (such as the free distribution of emissions allowances for ETS, financial support to ESCOs). In a developing country context, it might be more difficult to replicate some of the Korean programs, especially those that require significant budgets, technical, and implementation capabilities.

Below are some of the key policy lessons that could be relevant for other economies, particularly those with economic structures that are heavily reliant on manufacturing:

1. **Align energy efficiency policies and programs with national long-term goals and establish a well-designed coordination mechanism between various stakeholders.**

   Designing and implementing energy efficiency policy is challenging in large part due to the difficulty in coordinating the agenda among different stakeholders. Energy efficiency is linked to different policy goals, such as energy security, industrial competitiveness, green growth, mitigation of climate change, and others. MOTIE has a dual mission of providing a foundation for economic growth and, at the same time, tackling energy efficiency issues which may, in turn, put financial and competitive pressure on firms.

   Korea systematically tackled these coordination problems by establishing a regulatory, legal, and institutional framework which served as a foundation for coordinated action and alignment with national long-term goals. With the establishment of the Energy Use Rationalization Act in 1979, Korea introduced various Acts, 5-year basic plans, and 20-year master plans that guided energy efficiency policy. Korea periodically updated its goals and strategies, and energy efficiency programs were introduced under the plan. Also, Korea's institutional framework clearly delineated the lines of authority and responsibility for energy efficiency among line ministries and implementing agencies. This provided a more coherent approach across different ministries, allowing policies to work towards a unifying goal.

2. **Incorporate energy intensity implications into industrial policy and economic plans to avoid the development of captive economic structures that constrain energy efficiency gains in the long run.**

   Korea's experience shows that a structural industrial transformation is necessary to significantly improve industrial energy efficiency but is difficult to achieve. While a wide range of energy efficiency policies have been introduced since 2000, the energy intensity of the Korean industrial sector decreased significantly from 2000 to 2010 but has remained relatively stable since 2010. This is mainly attributed to the growing industrial output and energy consumption of the hard-to-abate sectors such as iron, steel and petrochemical sectors. Without changing the industrial structure, it is difficult to achieve additional efficiency gains because of the specific characteristics of the sectors (e.g. Korean steel sectors' dependence on blast furnace-based processes, which are highly energy intensive). However, achieving a structural transformation of the industry sectors is difficult given the significant contribution of these sectors to the competitiveness and the growth of the Korean economy. The Korean government has recently begun supporting innovative R&D projects in key energy-intensive sectors with a long-term vision to accelerate the structural shift toward a less energy-intensive and carbon-neutral manufacturing paradigm. Policymakers in industrializing economies can avoid hard-to-abate sectors in favor of greener industries to reduce the risk of being captive to energy efficiency constraining industrial structures in the long run. Industrial policies and economic plans could take into consideration the energy-intensity implications of targeted or selected industries and favor greener industries.

3. **Gradually and incrementally develop the energy efficiency policy mix to leverage complementarities among programs and induce behavioral change among firms and industries.**

   Korea's industrial energy efficiency policies have been gradually developed and regularly revised and updated. New programs are frequently introduced first on a voluntary basis or as pilots with a small number of firms within a defined sector. This experimental policymaking approach resulted in a diverse and comprehensive policy mix which also serves as a learning resource for other countries.

   Korea's energy efficiency policy mix leveraged different types of policy modalities, targeting two main objectives: (i) improving the flow of data and reducing information asymmetry and (ii) inducing firm behavioral change to adopt energy efficient solutions. Its policy mix is characterized by a combination of mandatory, voluntary, and market-based approaches that collectively incentivize firms of all types and sizes to participate in energy saving practices.

   Korea's experience also demonstrates that individual policy programs and modalities of public policy support are more effective when they are closely linked and are complementary by design. As an example, the mandatory audit program, which requires energy-intensive firms to conduct energy diagnosis on their own facilities, is complemented with other programs which extend low-interest rate loans or financial support for ESCOs that work with firms on making the necessary investments to upgrade their facilities with energy efficient equipment. Another example relates to complementarity between standards setting and public procurement programs. To encourage active program participation among firms, appliances with a high-ef-

ficiency appliance certificate and those that acquired the highest energy efficiency grade are given priority in public procurement programs.

Korea's experience has demonstrated that close collaboration and consultation with industry is critical for policy design and implementation. The incremental approach and the use of voluntary and mandatory programs contrast with radical or sudden policy changes which could create an environment of uncertainty and expose firms to high risks of noncompliance, and eventually lead to opposition from the target firms and industries. Therefore, continuous and close communication with various stakeholders, including firms, agencies, and research institutes, and incorporating the feedback into policy design is imperative to the success of the policy design. As an example, before EERS was first piloted in Korea in 2018, the program went through various rounds of reviews by experts from policy makers, academia, and practitioners from the industries. The following year, EERS was expanded to two other energy suppliers.

4. **Establish effective monitoring, reporting and verification (MRV) systems and leverage digital technologies to collect, analyze, monitor energy data.**

Continuous development and improvements to the MRV system is one of the notable features of the Korea energy efficiency policy experience. Collecting data on energy consumption, by firms, industries, and industrial parks, and turning this data into useful information available for policymakers, utilities, and individual consumers could help address information asymmetry between suppliers and consumers of energy – one of the key challenges facing the adoption of energy efficiency solutions. Korea's MRV system is multifaceted and is continuously upgraded. As an example, under the Enforcement Rule enacted to implement the Energy Use Rationalization Act (Article 26-2), energy-intensive firms are required to submit their detailed consumption data and targets for improving their energy efficiency. KEA is also required to collect comprehensive energy data every 3 years under the Energy Use Rationalization Act, and the data is documented in the Korea Energy Statistical Information System (KESIS), which is made public. Korea's National GHG Emission Total Information System (NETIS) is another database that includes information on energy use in industrial processes as well as other sectors. Such data and information are made available for establishing emissions reduction targets for firms and energy suppliers, such as through the GHG Target Management Scheme and EERS programs, as well as form a baseline for measures to reduce energy use and emissions. One area that is underutilized is the use of the collected data (or collecting additional data) to evaluate programs. Evidence on which programs are effective and which are not, and why, will be critical to improving Korea's energy efficiency programs' outcomes and provide valuable knowledge to policymakers globally.

Granular data collected through digital monitoring tools enables firms to better understand their performance, which may lead to improved control of their energy usage. For example, the accumulation of data via smart metering and energy management systems allows firms to identify energy intensive processes or equipment at their production sites that could be either improved or replaced. This is the reasoning behind the growing number of policy programs providing support for firms' adoption of EnMS, advanced sensors, smart metering systems, and digital technologies that enabled firms to collect precise and real-time data. Nevertheless, more research is needed to assess the impact of this awareness on companies' decisions to invest in energy efficient solutions.

5. **Leverage voluntary agreements and local knowledge sharing activities to facilitate technology transfer and collective actions.**

In addition to the conventional approach focused on financial and operation support, energy efficiency policy can play an important role in facilitating knowledge sharing and transfer by promoting networking among firms, especially between large and smaller, resource constrained firms. These knowledge-sharing initiatives have been introduced as voluntary measures to resolve information barriers, to facilitate access to technology, and ultimately to induce firm behavioral change.

The Korean government has introduced local initiatives and voluntary agreements to improve information flow and awareness raising among firms regarding the best practices to enhance industrial energy efficiency. For example, programs such as energy saving through partnership (ESP) and 'learning energy efficiency network' facilitate the transfer of relevant technologies and best practices between firms and raise awareness of energy efficient practices.

However, there are significant impediments to knowledge spillovers from voluntary knowledge sharing activities. An important issue is the reluctance to share information or know-how with competitors, particularly those in the same sector. In some energy-intensive sectors, the ability to cut energy costs and thus increase profit margins is an important source of competitive advantage, and therefore sharing such information with competitors may not be a preferred option. This may likely be behind the low participation rate and public awareness of the voluntary programs in Korea compared to other programs. To overcome this challenge, public policy can consider diverse options to promote cooperation, such as through incentives to participate in knowledge-sharing activities and leveraging local governments, local industrial associations, research networks, and existing consortiums.

6. **Develop policy design and implementation capabilities to effectively execute a comprehensive energy efficiency policy mix.**

Effective design and implementation of energy efficiency policy is to a large extent a function of capable implementing agencies with a clear mandate, abundant financial and technical resources and strong organizational capabilities. In Korea, KEA has been key to the development and implementation of the energy efficiency policy mix. Additionally, KEA's role as an intermediary or liaison between MOTIE and the private sector contributed to better implementation of energy policies and programs. Three lessons can be extracted from KEA's policy implementation experience. First, providing a clear mandate for KEA and conducting regular monitoring and evaluation of the organization and the programs helped KEA establish itself as the key EE policy implementation agency. Second, for each program, setting realistic targets along with technical guidelines, methodologies, and metrics to meet such targets was also crucial. Third, given the complexity of legal and economic arrangements, communication with the industries and disseminating relevant, timely information is essential.

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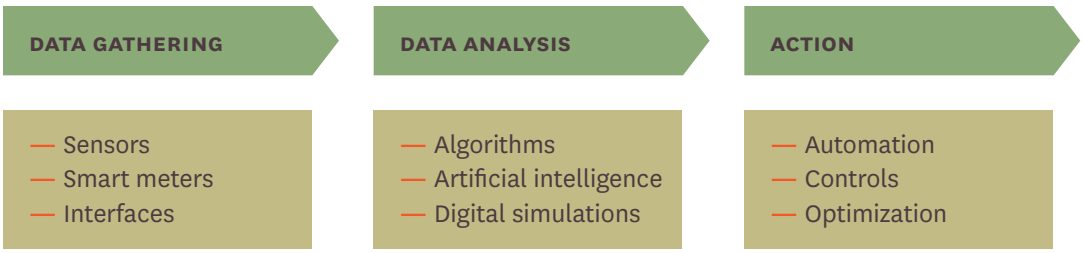
Annexes

Annex 1: Digitalization and other technical solutions in energy efficiency

Digitalization and technological adoption are becoming more critical in improving energy efficiency in the industrial sector. Digital technologies have the potential to optimize the energy uses in different activities, from manufacturing an industrial product to cooling a home. As depicted in Figure 29, sensors and smart meter technologies used in the industrial sector offer the potential to increase energy efficiency through the collection of granular data at different data points. Technologies such as AI algorithms are used to process real time data into useful information, which can be sent to devices that optimize energy use. Some devices require human intervention, but many are now being developed to optimize energy use automatically and autonomously (IEA 2019).

FIGURE 29. HOW DIGITALIZATION AND TECHNOLOGICAL ADOPTION CAN IMPROVE ENERGY EFFICIENCY



SOURCE: IEA 2019b

Researchers are exploring ways to make industrial and manufacturing processes more energy efficient, and a vast variety of energy efficiency technical solutions are already deployed in the market. Table 9 summarizes some of the energy efficiency technical solutions and measures available in the market, for example high-efficiency refrigeration equipment, pressure relief turbines, LED lighting, and motion sensors. Technologies required for improving energy efficiency vary by sector, as the production process and input and output materials differ. Tables 10 and 11 include examples of sector-specific energy efficiency technologies in the aluminum and the cement and concrete industries (Hasanbeigi, Price, and Lin 2012; Springer and Hasanbeigi 2016).

TABLE 9. EXAMPLES OF ENERGY EFFICIENCY TECHNICAL SOLUTIONS BY END USE

END USE	EXAMPLES
PROCESS HEAT AND WATER HEAT	High-efficiency water heating (solar and heat-pump water heaters)
	High-efficiency boilers and furnaces including condensing gas furnaces
MOTIVE POWER	High-efficiency motors and drives, better matching of motor output needs of a process
	Replacing diesel powered equipment (such as excavators), on-site generators, and transportation with electric or hybrid vehicles used inside and outside of the plant
REFRIGERATION	High-efficiency refrigeration equipment, well-insulated cold storage rooms and freezers
ON-SITE POWER AND HEAT	Combined heat and power systems providing self-generated electricity and process heat, with configurable fuel types and heat requirements
	Making available waste for combustion and waste heat for other processes as well as heating residences and offices
	Pressure relief turbines instead of pressure relief valves to generate power for industrial processes such as blast furnaces, fluid catalytic crackers used in the petrochemical industries, and for natural gas grids, as well as in industrial steam networks and by using organic Rankine cycle turbines with low-temperature waste streams (Worrell et al. 2009)
INDUSTRIAL PROCESS IMPROVEMENTS AND WASTE REDUCTION	Process improvements for specific industries such as high-temperature reactors, corrosion-resistant metal- and ceramic-lined reactors and process controls in petroleum refining (10-20% in energy savings) (Connolly 2022; National Academies of Science and Engineering 2022)
	Minimizing use of materials to reduce waste, energy use such as through 3D printing
MONITORING AND CONTROL EQUIPMENT	Energy management systems and smart meters (and related automated monitoring and control) to identify specific points of excessive energy use in industrial plants and measure impact of energy efficiency measures, allowing for better monitoring of energy efficiency investments
BUILDING ENERGY EFFICIENCY	High-efficiency space conditioning units, building envelope measures (insulation, sealing of air links, improved windows and door seals, daylighting) and building energy controls
	High-efficiency lighting, including LED (light-emitting diode) lighting, motion sensors and other lighting controls

SOURCE: Compilation of literature.

TABLE 10. EMERGING ENERGY EFFICIENCY TECHNOLOGIES FOR THE ALUMINUM INDUSTRY

AREAS	TECHNOLOGIES
EMERGING ELECTRODE TECHNOLOGIES	Insert Anodes
	Wetted Cathodes
	Multipolar Cells
	Novel Physical Design for Anodes
ALTERNATIVE REDUCTION TECHNOLOGIES	Carbothermic Reduction
	Kaolinite Reduction
EMERGING LOW-TEMPERATURE REDUCTION TECHNOLOGIES	Ionic Liquids
	Carbon Capture Using Absorption Technologies
EMERGING ALUMINUM RECYCLING TECHNOLOGIES	Novel Physical Recycling techniques
	Aluminum Mini Mills

SOURCE: Springer and Hasanbeigi 2016
NOTE: Technologies are in different commercialization status from pilot to research, development, commercialized stage.

TABLE 11. EMERGING ENERGY EFFICIENCY TECHNOLOGIES FOR CEMENT AND CONCRETE INDUSTRY

AREAS	TECHNOLOGIES
EMERGING GRINDING TECHNOLOGIES	High activation grinding
EMERGING KILN TECHNOLOGIES	Fluidized bed kiln
EMERGING ALTERNATIVE RAW MATERIAL TECHNOLOGIES	Use of steel slag as kiln raw material
	Non-carbonated raw material for cement production - use of carbide slag
EMERGING ALTERNATIVE CEMENT PRODUCTS	Cement with low lime saturation factor
	Calcareous oil shale as an alternative raw material
EMERGING CARBON CAPTURE TECHNOLOGIES FOR THE CEMENT INDUSTRY	Cement primarily of fly ash and recycled materials
	Cement and construction materials based on magnesium oxide
	Geopolymer cement
	Celitement: Ahydraulic binder based on calcium hydrosilicates
	Oxygen enrichment technology & oxy-fuel technology
	Post-combustion carbon capture using absorption technologies
	Calera process
	CO_2 sequestration in concrete curing technology
	Carbonate looping technology
	Industrial recycling of CO_2 from cement process into high-energy algal biomass
	Bio-technological carbon capture
	Capturing the CO_2 resulting from limestone precalcination
	Use of nanotechnology in cement and concrete production

SOURCE: Hasanbeigi, Price, and Lin 2012
NOTE: Technologies are in different commercialization status from pilot to research, development, commercialized stage.

Annex 2: Korea's ongoing energy efficiency programs

This annex describes the Korean programs to improve energy efficiency in industry that are not discussed in the main text.

TARGETS AND PERFORMANCE SETTING

— GHG Target Management Scheme (2012-present)[42]

Program description and objectives: The objective of the GHG Target Management Scheme is to induce behavioral change in firms by setting GHG reduction targets for firms and facilities to reduce emissions by 40% by 2030 relative to 2018 baseline levels. The concept was first introduced in 2009 during the inter-ministerial meeting to develop energy demand management policies that can help industries deal with high energy prices. After a pilot initiative and a range of regulatory revisions, including those stipulated in the Framework Act on Low Carbon, Green Growth, the program was finally implemented in 2012.

Eligibility and support provided: The scheme was initially introduced for electricity generation and industry sectors but later expanded across waste, transportation, building, agriculture, and ocean/ shipping sector. The target companies are those whose average energy consumption levels during the last three years exceed 50,000 tonnes of CO_2 equivalent, and individual facilities that consume more than 15,000 tonnes of CO_2 equivalent. These firms are mandated to set their emission reduction targets for the following year in consultation with the government. The criteria have been strengthened (more specifically, the emission and energy consumption threshold levels were lowered) since the initial implementation of the Scheme so that more companies are covered, as depicted in Table 12.

42 See https://www.keco.or.kr/kr/business/climate/contentsid/1516/index.do

TABLE 12. CRITERIA FOR ENTITIES SUBJECT TO GHG TMS

	COMPANY		FACILITY (PRODUCTION SITE)	
YEAR	GHG EMISSION (tCO_2 eq)	ENERGY CONSUMPTION (TJ)	GHG EMISSION (tCO_2 eq)	ENERGY CONSUMPTION (TJ)
2010 – 2011.12.31.	125,000	500	25,000	100
2012. 1.1.	87,500	350	20,000	90
2014. 1.1	50,000	200	15,000	80
2022. 3.25 – Present	50,000	-	15,000	-

NOTE: Firms whose GHG emissions exceed 125,000 tonnes of CO_2 equivalent and production sites whose emissions exceed 25,000 tonnes of CO_2 equivalent are required to participate in the ETS.
SOURCE: Global Green Growth Institute (GGGI), Korea Environment Corporation (KECO).

Program stakeholders and governance: As with other programs, a range of public and private stakeholders are involved, including the Presidential Commission on Carbon Neutrality and Green Growth[43], whose responsibilities include, among other things, establishing mid-to-longer-term GHG emissions reductions goals for each sector; each relevant line ministry responsible for setting up annual emission targets for each subsector (e.g., MOE, MOTIE, MOLIT); and companies[44] that are mandated to meet the targets. Unlike the previous program where participating entities did self-verification, this TMS also requires third-party verification such as Korea Environment Corporation (KECO), which follows the guideline laid down by the government.

REGULATORY AND LEGAL INSTRUMENTS

— GHG Emission Trading Scheme[45] (2015-present)

Program description and objectives: The objective of the GHG ETS is to create a market for trade in emission rights and indirectly improve access to finance and induce behavioral change in firms. By facilitating trade, the policy leverages market mechanisms to meet national GHG reduction goals. It is a "cap and trade" system, where the emissions from emitters are capped. But within specified limits, the entities are allowed to buy and sell allowances through the trading system.

43 Presidential Commission on Carbon Neutrality and Green Growth. https://www.2050cnc.go.kr/eng/contents/view?contentsNo=37&menuLevel=2&menuNo=58.
44 As of June 30, 2022, the number of firms subject to the GHG TMS are 360, including 177 firms closely followed by MOTIE.
45 See https://www.keco.or.kr/kr/business/climate/contentsid/1520/index.do

Korea implemented the K-ETS in 2015, the second country in Asia (after Kazakhstan) to introduce a nationwide system.

Eligibility and support provided: The controlled entities under the ETS policy are businesses with average annual emissions greater than 125,000 tonnes of CO_2 equivalent and facilities with average annual emissions greater than 25,000 tonnes of CO_2 equivalent. The number of participating business entities increased each year, from 586 in 2018 to 610 in 2019 and 636 in 2020. For the third cycle of implementation between 2021 and 2025, 684 firms are obliged to participate in the ETS (GHG Inventory and Research Center 2020). 477 industrial enterprises are covered under the Korean ETS including in cement, paper and pulp, and steel manufacturing industries. Eligible sectors are determined based on nationwide emissions impact, the success potential for respective sectors, and the verifiability of emissions data. Based on the criteria, the sectors include energy generation, refining, petroleum, paper, cement, chemicals, transportation, and construction. Participating companies are required to reduce greenhouse gas emission to the level of the allowances granted to them by the government. The companies may trade surplus allowances or buy allowances on the trading market if their reductions are insufficient.

Implemented in cycles, the policy was steadily introduced with focus on gaining experience in operating the system during the earlier phases while increasing the reduction targets in the later phases. During the 1st phase (2015-2017), 100 percent of allowances was distributed for free, and during the 2nd phase (2018-2020) 97 percent was distributed for free and 3 percent was auctioned. From the 3rd phase, less than 90 percent was free allowances, and the rest was auctioned. The allowances are the trading currency of the market and are traded on the Korea Exchange (KRX). The carbon price under the Korean ETS is lower (on average approximately US$ 18 per metric tons of CO2 equivalent in 2022) than the price under the EU ETS (US$ 87 per metric tons of CO2 equivalent).

Program stakeholders and governance: ETS is a complex program, with several ministries and implementation agencies being involved. During the initial stage, the Ministry of Environment (MOE) was responsible for managing all aspects of the scheme's operation. Several governance restructurings have occurred, and today, the Ministry of Economy and Finance (MOEF), MOE, MOTIE are involved in different modules of the ETS program.

— Energy Efficiency Resources Standards (EERS)[46] (2018-present)

Program description and objectives: The EERS sets mandatory energy saving targets for energy suppliers (electricity, gas, and heat suppliers). Introduced as an important mechanism to support energy demand management under the 8th Basic Plan for Long-term Electricity Supply and Demand, the program aims to reduce information asymmetry that exists between energy suppliers and consumers and provides incentives or penalties for energy suppliers based on their compliance with the targets. Energy suppliers that operate the energy infrastructures have better access to information about consumer's energy consumption behaviors than energy consumers themselves. While such information can be utilized in designing energy efficiency programs, en-

46 See https://www.energy.or.kr/web/kem_home_new/ener_efficiency/industry_06.asp

ergy suppliers lack incentives to voluntarily participate in such programs as doing so could reduce their revenues (increased energy demand and consumption increases energy suppliers' revenues). Similar programs have been implemented in many countries, including the United States and the EU, to address information barriers and lack of incentives for energy suppliers to improve efficiency by setting mandatory savings targets for energy suppliers. In Korea, the EERS system was first introduced by MOTIE as a pilot program in 2018 and implemented in 2019 via the Third Basic Energy Plan to encourage structural transformation in energy savings from the supply side.

Eligibility and support provided: The mandatory energy savings targets are set in proportion to the amount of energy sold by the suppliers. The target rate was first assigned for KEPCO in 2018 during the piloting stage, at 0.15 percent of the total energy sales two years before (Table 13). Therefore, the Energy Saving Mandatory Target set for KEPCO in 2018 was 746 GWh, which is 0.15 percent of the total amount of electricity sold by KEPCO in 2016. In the public notice updated in 2019, MOTIE set 0.2 percent as the mandatory target.

TABLE 13. EERS ENERGY SAVING MANDATORY TARGETS BY ENERGY SUPPLIERS (2018-2031)

ENERGY SUPPLIERS	2018	2019	2031
KEPCO	0.15 %	0.2 %	1.0 %
KOGAS	-	0.02 %	To be determined
KDHC	-	0.15 %	To be determined

SOURCE: MOTIE. Enforcement Decree 2019-55.
NOTE: EERS was piloted in 2018. KOGAS and KDHC were not part of the pilot program.

The Korean government established a supporting regulatory requirement for the EERS in the Energy Use Rationalization Act (Article 3: Responsibilities of Government and Energy Users/Suppliers, etc.), which required energy suppliers to develop and implement investment projects for demand management. Despite this legal basis, energy suppliers tend to prioritize load management-related projects over energy efficiency improvement projects. To address this challenge further, MOTIE revised the relevant law, requiring energy suppliers to meet the mandatory targets.

Program stakeholders and governance: Energy suppliers, including KEPCO, KOGAS, and KDHC, are the major targets of this program, and they are mandated by MOTIE to implement specific projects designed to meet the stated goals of the program. In addition, a range of public and private stakeholders are involved, including: the Presidential Commission on Carbon Neutrality and Green Growth, whose responsibilities include, among other things, establishing mid-to-longer-term GHG emissions reductions goals for each sector; the relevant line ministry responsible for setting up annual emission targets for each subsector (e.g. MOE, MOTIE, MOLIT); and companies that are mandated to meet the targets. Unlike the previous program where participating entities did self-verification, this TMS also requires third-party verification such as by Korea Environment Corporation (KECO), which follows guidelines laid down by the government.

— High Efficiency Appliances Certification Program[47] (1996-present)

Program description and objectives: A voluntary program initiated in 1996, it is designed to promote the dissemination of high-efficiency equipment in the market. A certification is issued to appliances that meet certain efficiency standards after a performance test. The secondary objective is to create markets for high efficiency appliances by raising the standards.

Eligibility and support provided: 23 types of appliances that have high energy saving potential, including motors, boilers, lighting, pumps, chillers, and heating, ventilation and air conditioning (HVAC) systems, are eligible for the program. The number of eligible equipment has fluctuated, and the standards have been strengthened. Appliances that prove to be highly efficient after the formal test can put a labeling sticker on the product (Figure 30). In 2021, 1,440 firms and 51,732 appliances were high efficiency appliances (Table 14). Around 896 thousand toe of energy (1,829 tonnes of CO_2 equivalent) was saved by this program in 2020 (KEA).

As part of the support, loans and tax reduction toward the purchase of high-efficiency equipment are provided. Also, appliances with the high-efficiency certificate are given priority under the public procurement process. By the end of March every year, firms producing the 23 appliances need to report their sales performance to KEA.

Program stakeholders and governance: KEA manages the program, and several public and private research centers (e.g. Korea Institute of Machinery & Materials) affiliated to the program conduct the product tests. KEA provides a list of certified test centers for appliances. The procedure is similar to the Energy Standards and Labeling Program. After conducting the test, the applicant needs to submit the online application form to KEA within a year.

FIGURE 30. HIGH EFFICIENCY APPLIANCE CERTIFICATE

SOURCE: KEA

47 See https://dco.energy.or.kr/renew_eng/energy/appliances/certification.aspx

TABLE 14. HIGH EFFICIENCY APPLIANCES CERTIFICATION PROGRAM STATUS

YEAR	2017	2018	2019	2020	2021
ELIGIBLE PRODUCTS CATEGORY	37	21	22	22	23
APPLYING FIRMS	1,616	1,324	1,376	1,463	1,440
PRODUCTS	24,318	30,710	39,373	47,100	51,732

SOURCE: KEA 2022b

INFORMATION GENERATION AND SHARING

— Energy Companionship[48] (2014-present)

Program description and objectives: The objective of the Energy Companionship Program is to improve knowledge dissemination and induce behavioral change in firms. It provides a mechanism for diagnosis and transfer of know-how and energy efficient technology from large firms to SMEs, improving energy efficiency in SMEs and seeking to reduce GHG emissions collectively across firms of all sizes.

Eligibility and support provided: A consortium of a large firm (with high energy consumption and possessing energy use technology) matched with an SME (less than 2,000 toe) and a consulting firm (ESCO or an energy diagnostics firm) develop a proposal with clear and specific objectives on improving energy efficiency. The proposal includes proposed investments in technology and equipment, training opportunities, specific practices and processes to be achieved, and the budget breakdown required to complete the project. The consortium applies for the program and receives a grant that funds 65% of the project, with the larger firm funding the rest. The funding by larger firms can also be in the form of in-kind contributions such as reviews, advisory services, and training.

Program stakeholders and governance: The consortiums are selected by KEA through an application process, which considers the number of training courses, the number of participating SMEs, the level of investment by larger firms, as well as the capability to implement the project, among other criteria. Once selected, a mid-term review during the process is conducted to check progress in consulting and in technical capacity building. After the end of the project, the results are evaluated and an end-of-year review is held to present the outcomes.

48 See https://www.energy.or.kr/web/kem_home_new/info/news/notice/kem_view.asp?sch_key=&sch_value=&c=296&h_page=12&q=23368

— Learning Energy Efficiency Network (LEEN)[49] (2021-present)

Program description and objectives: Benchmarked after a German program, Korea launched its LEEN program in 2021. The objective of the program is to support SMEs that lack financial and technical resources to gain knowledge on energy saving measures from other peer companies in the same geographic region.

Eligibility and support provided: The voluntary program targets manufacturing SMEs that lack financial and technical resources on energy saving measures. Firms that want to participate in the LEEN program need to apply to the KEA, and after the review process, the participating companies are selected. Around 5 to 10 firms within a similar geographic location are grouped as a consortium, and the duration of the agreement is two years. Those who participate in the program are provided with capacity-building workshops and seminars by technical experts. KEA also facilitates knowledge sharing activities among firms (Figure 31).

In 2021, twelve companies participated in the LEEN program, and two separate local networks were formed as a pilot test. Several networking sessions were held with the participating firms and energy experts from ESCOs and energy audit firms.

Program stakeholders and governance: The overall supervision of the LEEN program is the responsibility of MOTIE, and KEA is the main agency running the program. The LEEN consortium is composed of several stakeholders including the KEA, local governments, energy experts, SMEs, energy audit firms, and ESCOs. The local government, with responsibility for running the program, plays an important role in the consortium (Figure 32).

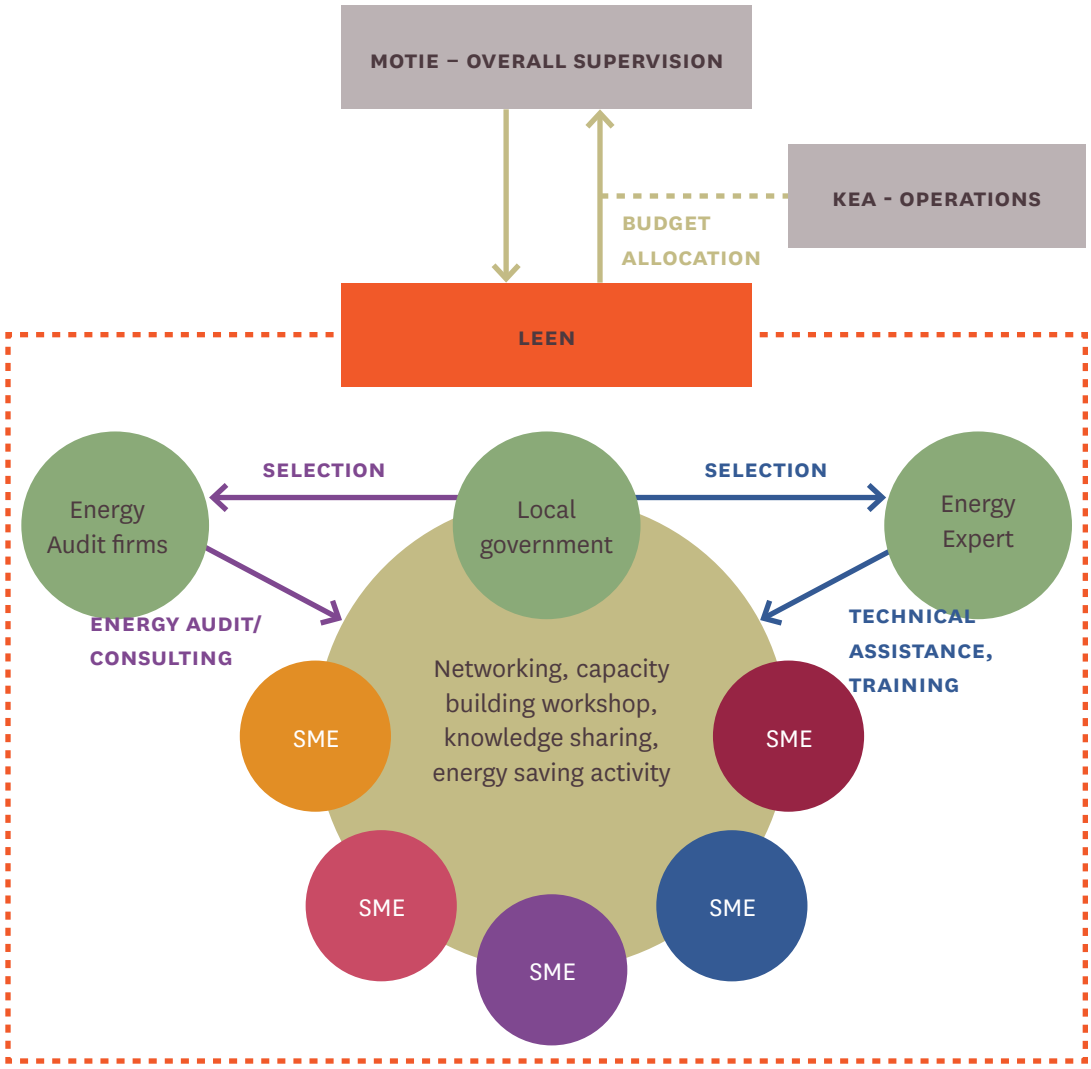
FIGURE 31. LOCAL/LEARNING ENERGY EFFICIENCY NETWORK (LEEN) PROCEDURE

	STAGE	KEY ACTIVITY
1	PROGRAM ANNOUNCEMENT	— KEA posts an announcement and calls for applications from SMEs.
2	CONSORTIUM FORMATION	— Companies are screened and selected, and an agreement is made. — 5 to 10 companies in similar geographic region are grouped into one network.
3	ACTIVITY INITIATION	— Capacity-building workshops and seminars by energy experts are held regularly. — KEA facilitates knowledge-sharing activities among firms.
4	COMPLETION OF THE PROGRAM	— Evaluation of the program — Dissemination of the results

SOURCE: KEA

49 See http://www.kemco.or.kr/web/kem_home_new/info/news/notice/kem_view.asp?sch_key=&sch_value=&c=296&h_page=10&q=23433

FIGURE 32. LOCAL/LEARNING ENERGY EFFICIENCY NETWORK (LEEN) GOVERNANCE STRUCTURE



SOURCE: KEA

FINANCIAL SUPPORT

— Tax credits for investments in energy-saving facilities (1978-present)

Program description and objectives: Tax credits for investments in energy-saving facilities aim to improve access to finance as well as induce behavioral changes in firms. The Restriction of Special Taxation Act and its Enforcement Decree specify investments in energy saving facilities as eligible for benefits in taxation, referencing the Energy Use Rationalization Act. The program was first implemented in 1978, offering tax credits to local individuals and companies that invest in energy-saving facilities with proven energy conservation benefits.

Eligibility and support provided: Firms receiving tax credits undergo a simple process of reporting and approval. The recipient submits the details of its investments to the tax offices annually. Depending on the size of the firm, energy-saving facilities can receive a 1% (large firm), 3% (mid-sized firm), or 10% (small firm) tax credit, in addition to a basic 3% that applies to all firms for their investments. Figure 33 below illustrates the amendment to the Act in 2021 where the differing rates per type of investment were unified. Before the amendment, tax credit rates differed according to the category, such as R&D (1%, 3%, 7%) and growing industrial sectors (5%, 7%, 10%). The amendment changed the rates to a uniform 1%, 3%, and 10% for large, mid-size, and small firms, respectively, in addition to the basic 3% deduction. In doing so, it also increased the effective rate for energy efficiency investments by small firms from 7% to an effective 13%. The latest data, which is from 2021 before the amendment applied, shows that 797 firms applied for the credits, and among them 629 were SMEs. The total amount was 34 billion KRW (US$ 26.3 million).

FIGURE 33. 2021 AMENDMENT TO SPECIAL TAX CREDITS

BEFORE

1. R&D (1/3/7%)
2. Productivity enhancement (1/3/7%)
3. Safety (1/5/10%)
4. Energy saving (1/3/7%)
5. Environment conservation (3/5/10%)
6. Super connectivity (5G) network (max 3%)
7. Medicine quality management facilities
8. New growth technology commercialization (5/7/10%)
9. Employee welfare improvement (3/5/10%)
10. Investment deduction for SMEs (0/2/3%)

AFTER

NEWLY CONSOLIDATED TAX CREDITS FOR INVESTMENTS

- Eligibility: All tangible commercial assets (excluding real estate, buildings, vehicles, fixtures etc.)
- Method: Basic rate (investments in the current fiscal year) + extra rate (amount exceeding last 3-year investment average)
  - Basic: 1/3/10%
  - Extra: 3/3/3%
- Support new industries: +2% for new growth technology related investments
  - Rate: 3/5/12%

SOURCE: MOEF 2022
NOTE: Credit rates are indicated inside the parentheses and expressed in the order of large, mid-size, small and medium-sized firms.

Program stakeholders and governance: Energy-saving facilities are specified within the Energy Rationalization Use Act, and MOEF oversees the policy. The recent amendment was made during the recovery from the COVID-19 pandemic, to promote firm investments in the economy (MOEF 2022).

— Soft loans for investments in energy saving facilities (1980-present)

Program description and objectives: The government provides long-term, low interest loans through financial institutions to support firms' energy efficiency investments. This soft loan program aims to increase the adoption of energy efficient facilities and equipment among firms by improving their access to finance.

Eligibility and support provided: SMEs, non-profit organizations, and ESCOs are eligible to apply for the loan. Under the Energy Use Rationalization Act, MOTIE has developed and continuously updated a long list of projects eligible for receiving low-interest loans (87 projects are on the eligibility list). For example, loans are provided to support ESCO projects that involve purchasing and installing energy saving facilities, energy monitoring or highly efficient equipment, and software. The loans also support ESCO projects that invest in GHG or energy management companies or projects that are implemented as a result of an energy audit, such as facilities evaluated as having a GHG emission effect of 5% as a result of the energy audit. Loans also are provided to SMEs that make direct investments in energy efficient facilities and equipment, such as energy efficient boilers, furnaces, kilns, waste heat recovery systems, motive equipment, and highly efficient equipment. The loan covers the cost of materials, labor, expenses, management, and construction. The loans are to be paid back after 3 years over a 5-year period. Up to 70 percent (up to 90% for SMEs) of the total investment amount can be provided through long-term loans with a low interest rate. The value of funds allocated for 2022 is approximately 308.8 billion KRW (US$ 240 million). The detailed loan terms are summarized in Table 15.

TABLE 15. LOAN TERMS BY THE TYPE OF PROJECT

TYPE OF PROJECT		BUDGET (BILLION KRW) [US$ MILLION]	MAXIMUM AMOUNT OF SUPPORT PER RECIPIENT (BILLION KRW) [US$ MILLION]	SHARE OF THE COST COVERAGE	LOAN CONDITIONS	INTEREST RATE
ESCO INVESTMENT PROJECTS		303.8 [235]	<15 [11.6]	Cover up to 100% of the project cost	Grace period: 3 years Repayment period: 7 years	Floating rate at 1.5% or fixed rate at 1.75%
ENERGY EFFICIENT FACILITY INSTALLATION PROJECT	Energy saving facilities		<15 [11.6]	Cover up to 70% of the project cost (for SMEs up to 90%)	Grace period: 3 years Repayment period: 5 years	Quarterly floating rate for SMEs: 1.5%, Quarterly floating rate for medium-sized firms: 1.75%
	Production facilities		<5 [3.8]			
	Energy demand management facilities		<5 [3.8]			
	Replacing heat transfer facilities for a long-term use	5 [3.8]	<5 [3.8]	Cover up to 100% of the project cost		
TOTAL		308.8 [240]				

SOURCE: KEA 2023b

NOTE: The heat transfer facilities include pipelines and facilities to distribute district heat, which is often done by the KDHC. The soft loan support for ESCO investment projects also includes support for the investments in energy saving, production, and energy demand management facilities. The budget information includes the combined amount of the loan support for ESCO investment projects, energy saving facilities, and production facilities. The production facilities include, for example, facilities that generate electricity and heat, or combined heat power plants.

Program stakeholders and governance: KEA accepts applications, and after the application review process, a recommendation letter is issued to the firm that is eligible for the loan. Firms then apply for the loan to the affiliated financial institutions, and the financial institutions receive the funds from the KEA. These funds are then provided to the firm that applied for the program.

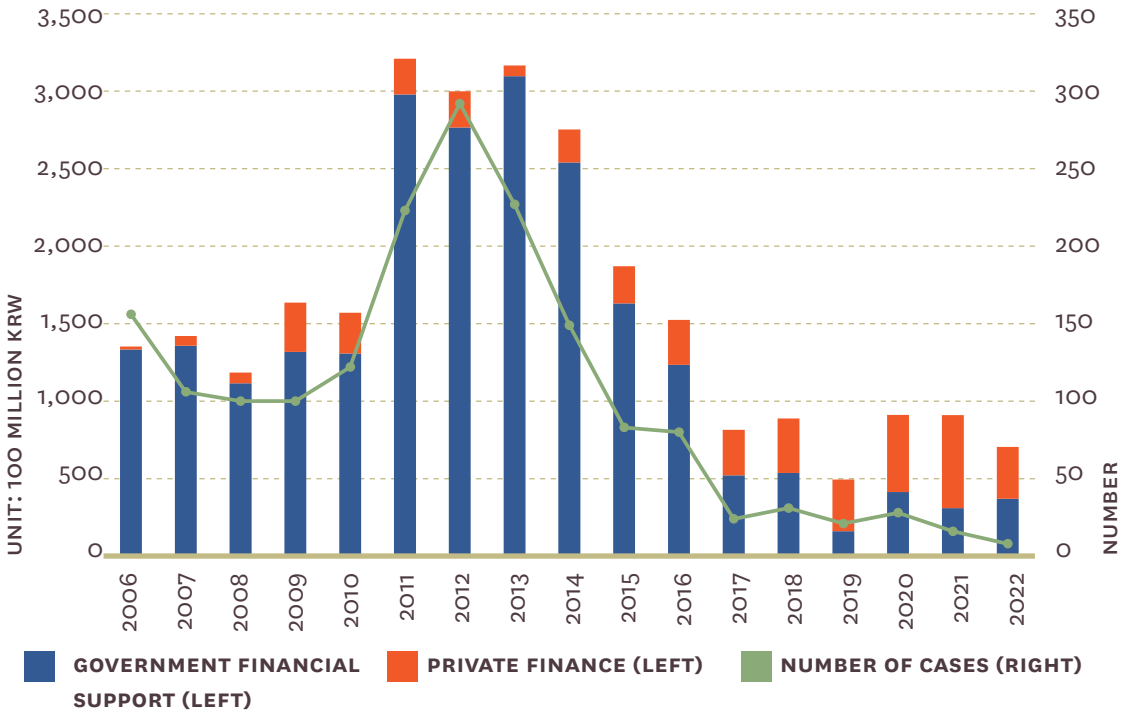
OPERATIONAL SUPPORT

— Supporting Market Creation for Energy Service Companies (ESCO) (1991-present)

Program description and objectives: The aim is to encourage voluntary participation of private entities, shifting the initiative from the government to the private sector. ESCOs are companies that provide a wide range of services to industrial firms, including site surveys for replacement or upgrading of existing facilities, design and installation of facilities, and maintenance and follow-up management services. Using a combination of shared savings and guaranteed savings models, ESCOs invest in energy saving facilities to recover their investments based on the energy savings that the industrial client achieves through the ESCOs' services.

Eligibility and support provided: As part of the energy use rationalization fund, low interest loans are provided to firms that install energy saving facilities through an ESCO. Government financial support for ESCO projects peaked in 2013 at 309.7 billion KRW (US$ 239.8 million), with 227 projects. However, as shown in Figure 34, the amount of government financial support has fluctuated, and has decreased since 2013. In 2022, only 8 projects received government financial support. The total ESCO market size for 2022 was 70.5 billion KRW (US$ 54.6 million). Although private financing has increased, the ESCO market is still highly reliant on government support.

FIGURE 34. ESCO MARKET SIZE (2006-2022)



SOURCE: Korea Association of ESCO 2023; KEA 2022c

Program stakeholders and governance: To be registered as an ESCO, the applicant needs to meet the minimum requirement described in Table 16. KEA screens the application, which includes the applicant's business and financial performance and its ESCO business plans. KEA issues a certificate if the applicant is qualified as an ESCO, and the registered ESCO has to report its sales performance every year to KEA. As of Jan 2023, there are 274 ESCOs registered in the system.[50]

The key stakeholders for the ESCO program include the client that wants to replace existing facilities and equipment to more energy efficient ones, the ESCO that provides consulting services, and KEA that will provide loans to the project. More detailed procedures of the ESCO project are depicted in Figure 35.

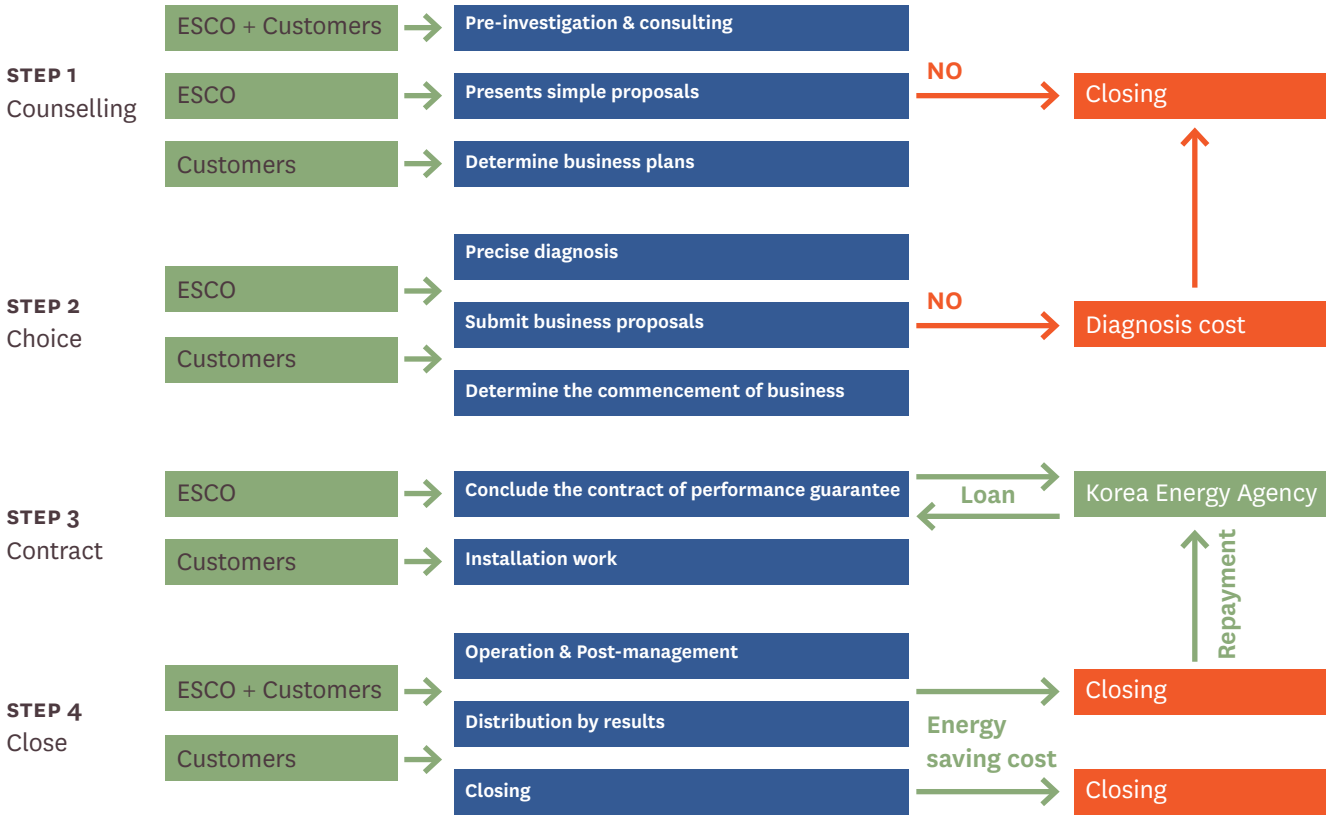
TABLE 16. ESCO REGISTRATION CRITERIA

CRITERIA	MINIMUM REQUIREMENT
Equipment - Infrared thermometer	At least one
Equipment - Datalogger	At least one
Equipment - Thermometer, hydrometer	At least one
Capital (corporation)	Above 200 million KRW (US$ 155,000)
Capital (individual)	Above 400 million KRW (US$ 310,000)
Technician	More than 3 technicians

SOURCE: Korea Association of ESCO 2023

50 ESCO registration status data from KEA (accessed January 13, 2023), https://finance.energy.or.kr/FINANCE_HP/AHP/HP_01/HP_01_02_040.do

FIGURE 35. ESCO PROJECT PROCESS FLOW



SOURCE: Korea System Business 2023

DEMAND-SIDE MANAGEMENT (DSM) PROGRAMS PROVIDED BY ENERGY SUPPLIERS

— Program description and objectives

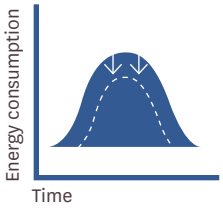
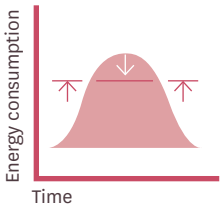
Energy efficiency can be improved from both the demand and supply sides. Policies that target the energy suppliers (utilities) can improve energy efficiency by inducing behavioral change by end users, and at the same time reduce the utilities' operating costs and improve profit margins. The DSM program aims to improve efficiency in terms of energy production, conversion, transportation, storage and use, and reduce or better manage energy demand by changing energy use patterns.

In Korea, energy consumption, including electricity and gas consumption, has increased rapidly as a result of increased industrial production and electrification since the 1990s. The Korean government sought to address this problem through an improved energy demand management program. Under the Energy Use Rationalization Act (Article 9), the three energy suppliers in Korea, namely KEPCO, KOGAS, and KDHC, are required to invest in or finance various activities that would improve the energy efficiency of the consumers.

— Eligibility and support provided

As part of the DSM programs, energy suppliers can run programs that achieve specific reductions in energy consumption, ranging from end-use applications (e.g., high efficiency lighting and appliances) to combined heat and power (CHP) systems and distribution system improvements. In Korea, DSM programs are led by three energy suppliers (KEPCO, KOGAs, KDHC), who provide two types of support: the energy efficiency program aims to reduce energy consumption through replacing existing equipment with new, highly energy efficient equipment; and the load management program aims to improve the energy efficiency of the energy consumers through flattening the energy consumption curve at different time periods. It uses energy load management technology and a differentiated pricing system to reduce energy use during the peak time. Details on each is explained in Table 17.

TABLE 17. SUPPORT PROVIDED AS PART OF THE DSM PROGRAMS

TYPE OF SUPPORT PROVIDED	CONCEPT	MEASURES
ENERGY EFFICIENCY PROGRAM 	This aims to induce energy consumption saving of the energy consumers through replacing the existing equipment to new high energy efficient equipment.	— Disseminate high efficiency equipment — Energy diagnosis — Education and training
LOAD MANAGEMENT 	This aims to improve the energy efficiency of the energy consumers through flattening the energy consumption curve at different time periods. It uses energy load management technology and a differentiated pricing system to reduce energy use during the peak time.	— Apply load management technology — Differentiated pricing system — Disseminate fuel transition technology
BUILDING THE FOUNDATION	This aims to support the two DSM programs above through conducting various supplementary activities such as funding for research projects, R&D, public relations (PR), and performance monitoring.	— PR, seminar, learning event — Funding for projects — R&D — Performance monitoring

SOURCE: KEA 2023b

DSM related investment in 2021 was 403.9 billion KRW (US$ 312.9 million). Around 70.4 percent was invested by KEPCO, 19.5 percent by KOGAS and 10.1 percent by KDHC (Table 18). As the government is placing greater emphasis on demand side management, enforced through the Energy

Efficiency Resource Standard (EERS) program[51], the investment for 2022 is expected to be 439.2 billion KRW (US$ 340 million).

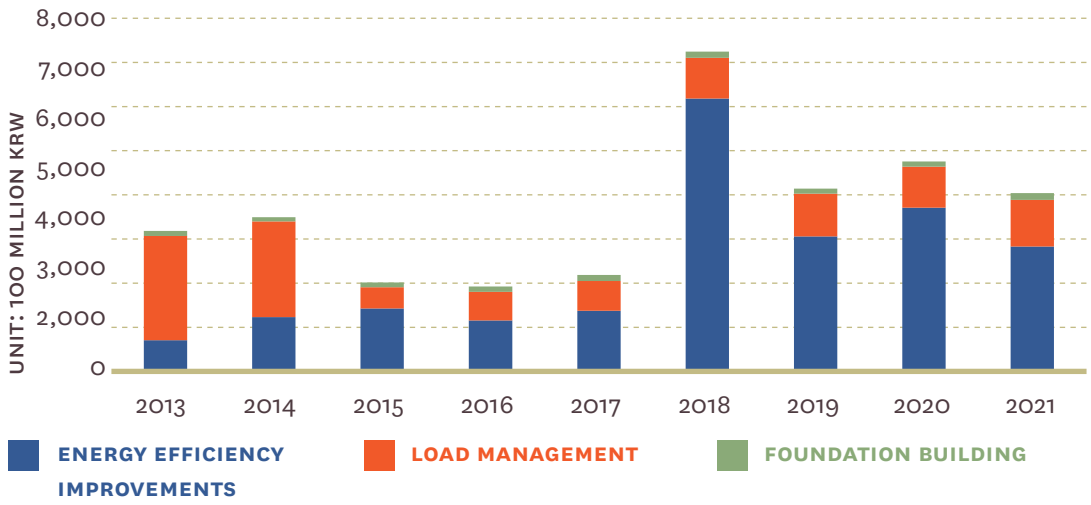
Prior to 2015, the majority of investment from the energy supplier as part of the DSM program was spent on the load management program. This was partly because investment in energy efficiency for consumers may reduce suppliers' revenues. Since 2015, government has been placing more emphasis on the energy efficiency program, and with the EERS which begun in 2018, around 70 percent of the DSM related investment is spent on the energy efficiency program (Figure 36). Table 19 summarizes the types of support offered by the energy suppliers to consumers as part of the load management program.

TABLE 18. DSM RELATED INVESTMENT BY ENERGY SUPPLIERS

ENERGY SUPPLIER	2019	2020	2021	2022 (E)
KEPCO	307.1	371.4	284.3	316.0
KOGAS	71.4	68.2	78.9	81.5
KDHC	35.6	35.9	40.7	42.2
TOTAL	414.1	475.5	403.9	439.7

SOURCE: KEA 2023b
NOTE: The amount include investment made through EERS

FIGURE 36. DSM RELATED INVESTMENT AMOUNT BY THE TYPES OF SUPPORT



SOURCE: KEA 2023b
NOTE1: From 2018, EERS budget was included as part of the DSM budget. In 2018, KEPCO's budget for energy efficiency increased from 127.9 to 609.2 billion KRW (US$ 100 to 471.6 million), but in the following year in decreased back to 300.3 billion KRW (US$ 232.5 million).

51 Energy suppliers such as KEPCO provide DSM programs in line with the Energy Efficiency Resource Standard (EERS). The EERS sets an energy saving target for energy suppliers (e.g. a target for energy reduction in proportion to energy sales volume (GWh)) and requires the suppliers to meet the target through various efficiency improvement investments. To meet this target for instance, KEPCO must either directly support the supply of high-efficiency equipment such as premium electric motors or make energy efficiency investments through ESCOs. For example, if 90 premium electric motors with an energy saving effect of 2MWh/year are supplied per unit, 180MWh (2MWh/year × 90 motors) will be reduced in the year. Various technologies and equipment have been identified as below.

TABLE 19. TYPES OF SUPPORT OFFERED BY ENERGY SUPPLIERS TO CONSUMERS AS PART OF THE LOAD MANAGEMENT PROGRAM

ENERGY SUPPLIER	EQUIPMENT COVERED BY PROGRAM	SUPPORT PROVIDED
KEPCO	Cooling equipment (ice storage)	Supports the installation of cooling equipment that operates at nighttime to make ice. The ice is stored for space cooling during the daytime, reducing daytime electricity loads.
	Building cooling and heating equipment remote management system	Installs a system that allows KEPCO to remotely control heating and cooling systems and provides subsidies to facilities based on the use of the remote control to address power supply and demand emergencies.
	Maximum power management device	Partial financial support for installation of power management devices that automatically monitor and cut off loads exceeding maximum targets.
	Emergency power saving	When an imbalance in power supply and demand is expected, the customer voluntarily adjusts its load and is compensated by KEPCO for the adjustment, based on a pre-signed agreement. In cases of non-compliance by customers, penalties are imposed.
KOGAS	Industrial incentive payments	When manufacturing process facilities are expanded, those using city gas are provided with subsidies based on the level of new gas demand
	Gas-fired air conditioner discount	During the summer season (May-September), gas costs are discounted by 75% for consumers that use them for air conditioning.
	Better fares for transportation	Creates an even pattern load year-round for transportation through launching a cheaper natural gas bus transportation rate
	High Efficiency Gas Heat Pump	Installers and architect offices are given subsidies when they install products that are registered as high-efficiency energy equipment
	High-efficiency gas direct absorption type cold/ hot water heater	
KDHC	District cooling rate discount	Discount is given to district cooling users who use medium and hot water absorption chillers in summer for year-round cooling.

SOURCE: KEA 2023b
NOTE: The types of support are based on the DSM program plan for 2022

Detailed data and information on the energy saved from the investment made by the energy suppliers are limited. Tables 20 and 21 show how the energy program and load management program contributed to energy efficiency and energy peak uses (KEA 2020).

As an expected outcome of the program, energy suppliers can generate significant cost savings for themselves through avoiding investment in energy generation and transmission and distribution

infrastructure by delaying or deferring costly system upgrades. Other benefits include improved system reliability and dampened price volatility in wholesale markets.

TABLE 20. ENERGY SAVED THROUGH THE DSM'S ENERGY EFFICIENCY PROGRAM

ENERGY SUPPLIER	2015	2016	2017	2018	2019
KEPCO (ΔGWh)	157	153	278	837	772
KOGAS (ΔTcal)	90	48	50	110	28
KDHC (ΔTcal)	55	21	20	21	69

SOURCE: KEA 2020
NOTE: These are the estimated amount of energy saved through the DSM's energy efficiency program

TABLE 21. DSM LOAD MANAGEMENT PERFORMANCE

ENERGY SUPPLIER	INDICATOR	2015	2016	2017	2018	2019
KEPCO	Load factor (%)	76.5	72.4	74.2	70.4	71.1
KOGAS	Turn-Down Ratio	3.0	3.3	3.3	3.3	3.1
KDHC	Turn-Down Ratio	8.4	8.8	7.7	8.2	7.4

SOURCE: KEA 2020
NOTE1: The higher the load rate and the lower the Turn-Down Ratio (TDR), the more effective the load management project was.

— Program stakeholders and governance

Since the program was initiated in 1993, KEA has been providing oversight of the energy supplier-provided programs under the supervision of MOTIE. The three energy suppliers (KEPCO, KOGAS, and KDHC) are obligated to submit their proposals for DSM programs to MOTIE for the subsequent year by the end of October. MOTIE delegates the proposal review to KEA, and the KEA's review committee evaluates the plan. Once the subsequent year's budget is approved by MOTIE, the energy suppliers can initiate the DSM projects. By the end of February of the following year after implementation, the energy suppliers are required to submit the program performance reports to MOTIE.

ENERGY CONSULTING FOR SMES THROUGH ENERGY SUPPORTER (2009-PRESENT)

Program description and objectives: This is a voluntary program that helps SMEs that often lack the financial and human resources required to conduct energy saving activities. Energy supporters, a group of energy experts appointed by the KEA, provide consulting services to SMEs whose energy consumption is between 500 to 2,000 toe per year. The aim of the program is to facilitate access to technologies and improve access to finance to SMEs.

Eligibility and support provided: The eligibility criteria has been revised since 2009 when the program began. Until 2011, SMEs that consume more than 2,000 toe were eligible for the program. In 2012, the target was narrowed down to SMEs that are located within the national industrial complex.[52] Since 2013, the program has been supporting SMEs that consume 500 to 2,000 toe per year.

Energy supporters provide a variety of advisory services to SMEs, including technical assistance to improve the facilities that consume a high level of energy, as well as administrative support to help firms receive policy funds that are available for the SMEs (Table 22). Since many SMEs do not know what type of support they can receive from the government, the energy supporters provide practical guidance to the SMEs and suggest energy efficiency programs firms can apply for.

Program stakeholders and governance: KEA, energy supporters and SMEs are the key stakeholders of this program. From February till April, KEA calls for applications, and SMEs can receive consulting services from the energy supporters. From May to December, around 200 SMEs receive the consulting services. KEA also provides training for the energy supporters who in turn advise SMEs on programs that they are eligible for. Energy supporters are typically those who have more than 20 years of experience doing the energy audits.

TABLE 22. TYPE OF SUPPORT PROVIDED BY ENERGY SUPPORTER TO SMES

TYPE	DESCRIPTION
TECHNICAL ASSISTANCE ON THE PROCESS EFFICIENCY	Provide technical assistance on facilities and utilities that consume high level of energy
TECHNICAL ASSISTANCE ON THE POWER EFFICIENCY	Provide technical assistance on how to respond to power crises, and power peaks.
MATCHING FIRMS WITH POLICY FUNDS	Provide guidance on the administrative procedures so that firms can receive financial support from different energy efficiency programs.
OTHER SUPPORT	Identify energy safety hazards at workplaces, share best practices, and provide consulting service on ways to improve energy safety

SOURCE: KEA 2023b

52 Since the 1960s, Korea has promoted industrial complexes for firms to take advantage of infrastructure and agglomeration effects, and to strategically nurture the country's key industries. They were first called industrial parks, but the name was later changed to industrial complexes in the 1990s.

Annex 3: Korea's terminated energy efficiency programs

— **Voluntary Agreement for Energy Conservation and Reduction of GHG emissions (1999-2010)**

This voluntary program targeted businesses in eight energy-intensive industries, such as power, metal, and petrochemistry, with annual energy consumption of over 5,000 toe per year. Although MOTIE recommended that participants adopt a goal of 5% reduction in GHG emissions to be achieved over the 5-year term of the program, each participant could set its own target. The program did not involve any regulatory command-and-control elements such as penalties or compliance requirements other than the submission of annual reports on energy efficiency management. What initially started with 15 companies, developed into an active program supported by 1,300 companies in 2009. However, this voluntary scheme eventually lost momentum with the introduction of the GHG target management scheme (TMS) which had a stringent regulatory control. While the terminated program relied only on performance goals and plans established voluntarily by participating entities, the program that followed enforced its rules and requirements with fines and public sanction in case of violation (Seok, Kim, and Park 2021).

— **Korea Voluntary Emission Reduction (KVER) (2005-2016)**

KVER, introduced in 2005, was one of the earliest programs aimed at reducing the nation's GHG emissions. Under this program, firms were required to voluntarily reduce GHG emissions by introducing energy efficient equipment and by enhancing manufacturing processes. The government certified and provided incentives for firms that successfully reduced emissions through energy efficiency improvement activities and development of renewable energy.

As part of the incentives to encourage firms to actively engage in mitigation activities, the government provided full support for administrative costs for SMEs and costs needed in self-verifying the amount of GHG reductions. This program initially targeted all firms, but after the introduction of GHG TMS in 2012, its target was narrowed down to SMEs that are not part of the GHG TMS program.

— **Green Growth Partnership (GGP) between large firms and SMEs (2007-2016)**

The Green Growth Partnership was designed as a way for large corporations to share their expertise in energy-saving technologies with small and medium enterprises (SME), and "to improve corporate governance, strengthen corporate competitiveness, and promote win-win growth". KEA

coordinated the matchmaking process between large firms and SMEs. Initially, this project involved one large company and 15 SMEs. By 2016, the project involved 16 large companies and 88 SMEs. The GGP program faded out, and was replaced by a similar program 'energy companionship' which involves SMEs and large corporations.

— Energy Champion (2015-2020)

The Energy Champion program was designed in 2015 and first piloted in 2017. The Energy Champion program employed incentives to elicit voluntary actions such as the purchase of high-efficiency equipment and improvements of operating processes. Companies applying for this program set their own annual targets and registered with KEA to be a candidate for energy champions.

KEA received applications, and then conducted an assessment of energy efficiency improvements at the firm level based on both a quantitative (70%) and qualitative (30%) evaluation. The quantitative evaluation criteria included the energy intensity improvements and the reduction of energy consumption, while the qualitative evaluation assessed companies' energy management efforts and the practical actions taken by the companies in improving energy efficiency. Companies that reached a score of at least 80 points were accepted into the program. Companies that received the energy champion certificate (valid for three years) could get an extension for the mandatory energy audits program, and they also could participate in overseas energy efficiency training. In 2019, 35 companies registered with the KEA and 25 were nominated as energy champions. These 25 companies reduced their energy consumption by 2.5% (a total of 46.7k toe) in 2018. The Energy Champion Program became part of the voluntary energy efficiency target management scheme in 2020.

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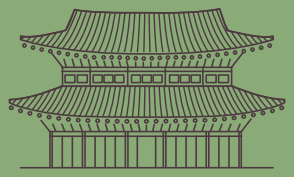

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