

# KOREA'S GREEN TRANSITION AND TECHNOLOGY STRENGTHS

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# INNOVATION CENTRE

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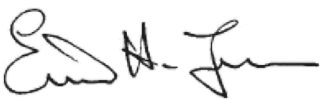


# F O R E W O R D

Korea is transforming itself to be a frontrunner of low carbon countries. In recent years, Korea has announced ambitious green targets to increase renewables in the energy mix and latest to become CO2 net-zero by 2050. Ambitions that are backed up by unprecedented green investment packages. To summarise it: Korea is on the right track to align itself with the goals of the Paris Agreement.

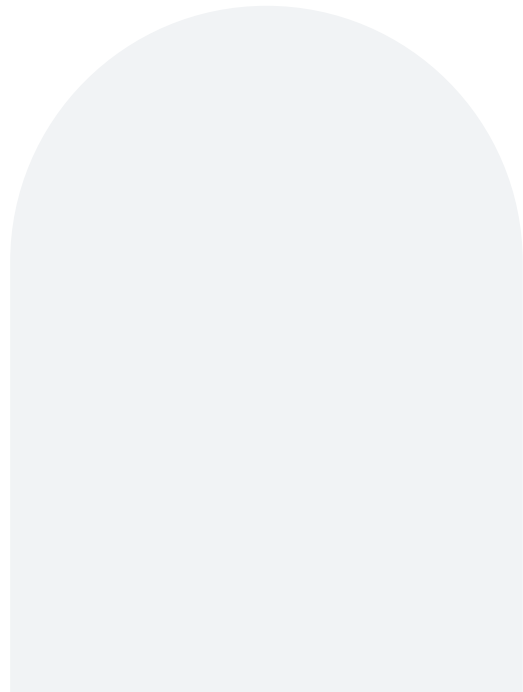
With 2021's P4G Summit in Seoul, global attention is on Korea's green growth journey. With both Denmark and Korea's positions as climate frontrunners in our respective regions, the unique Danish-Korean Green Growth Alliance has gained momentum and the room for cooperation is continuously expanding. We share the conviction that going green will not just be good for the planet, it will also lay the foundation for future growth.

In this publication, you will find an overview of Korea's green growth journey, green R&D strengths, as well as unique opportunities for Danish-Korean collaboration within our joint mission to green our economies. Regardless of the solution; Wind power generation, Power-to-X, alternative fuels for low-emission shipping, district heating, energy efficiency, smart and sustainable cities, and sustainable food production. When it comes to green transition, it is very difficult to go alone. But together, we can go far. Offshore wind is a great example of how Denmark and Korea can cover the full supply chain together. We complement each other in many ways. Together, Denmark and Korea have the opportunity to significantly contribute to the global green transition.



Danish Ambassador to the  
Republic of Korea

**H.E. Einar H. Jensen**





The Republic of Korea and Denmark are GGGI's founding member countries and key supporters of its mandate to promote green growth in emerging and developing regions of the world. Both countries have demonstrated leadership in supporting climate action by implementing policies and initiatives for deep decarbonization of their economies thus paving the way for innovation, jobs Creating, and long-term prosperity for its citizens. Korea has joined Denmark in the race to NetZero this year following the President's announcements of a Green New Deal and pledge to achieve NetZero by 2050.

As this report outlines, there is great potential for both Denmark and the Republic of Korea to collaborate further in the green technology landscape, not only on their home turf but also to support emerging and developing economies. This will not only support advance green growth in these countries but will present win-win business and commercial opportunities for all those involved.

The upcoming P4G Summit in 2021 presents an excellent platform and opportunity for the international community to join Korea and Denmark in promoting and adopting practical green growth solutions, and GGGI is working hard to support this endeavor. The summit will also provide an opportunity for GGGI's host country Korea to showcase its green growth ambitions, especially the newly unveiled Green and Digital New Deal that intends to strengthen the country's lead in the green technology arena.

With the world in the grip of the pandemic, the need for multilateralism is now greater than ever. As vaccination has started, we can begin to focus on the recovery. The recovery from COVID19 has to focus on green job creation, using green technology and accelerating climate action.

Korea's Green New Deal will also support international collaboration, including the development of Green New Deals for emerging and developing economies. At GGGI



we believe it will usher in a future where Korea could lead on green technology innovation, creation millions of green jobs, and enhancing climate resilience.

We hope this report will contribute to green growth by enhancing understanding of South Korea's green technology innovation landscape and promoting international collaboration aimed at innovation and jobs creation.

Director-General of the Global Green Growth Institute (GGGI)

**Dr. Frank Rijsberman**

## Executive summary

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This brief explores the Republic of Korea's green growth transition, and major actors and initiatives to outline concrete collaboration opportunities for Denmark in green technology research, development, and innovation with counterparts in Korea.

Many countries look to Korea's phenomenal rise from a developing country with low per capita income to an industrial and innovation powerhouse. Highly dependent on imported energy and resources, Korea pursued a green growth movement in 2009 starting with a large economic

stimulus to simultaneously address the 2008 financial crisis and climate change. Investment in research, development, and innovation in green technologies has been serving as a major pillar in Korea's growth and economic development, and delivered industry strongholds globally in key technologies such as solar power cells, energy storage systems, and Information and Communication Technologies (ICT).

Now, with a goal to become a net-zero carbon nation by 2050, the country is at the cusp of another era of innovation in green technologies. Investments and projects in research and development (R&D) have been ramped up with a focus on innovation and technology leadership in emerging technologies, such as hydrogen e-mobility, and in convergence solutions such as in smart city and energy demand management that utilizes Fourth Industrial Revolution (FIR) technologies.

There are mutually beneficial and complementing areas of collaboration between Korea and Denmark for technological innovation and decarbonization. Sectoral





R&D and business collaboration opportunities for Denmark lie in the green energy and circular economy areas that include wind power generation, power demand-side management, district heating, energy storage systems, and hydrogen e-mobility. Smart cities implementation with FIR technologies is a concrete cross-cutting collaboration area that would benefit the R&D and economic growth goals of both countries.

In Korea, government-funded research institutes, ministry-affiliated R&D funding agencies, and universities join the private sector to conduct research, development, and innovation activities. This brief provides an overview of the R&D ecosystem in Korea that includes key ministries and inter-ministerial advisory bodies such as the Presidential Committee of the Fourth Industrial Revolution. Based on stakeholder input, concrete collaboration models and examples are outlined, such as through modest-budget exploratory projects with leading Korean government R&D institutes to support exchange visits and meetings of top researchers for identifying joint research topics, preparing proposals, and securing funding.

Denmark and Korea have signed a high-level Green Growth Alliance agreement to collaborate and share new technologies and their implementation experience. Using the Denmark-led Partnership for Green Growth and Global Goals (P4G) platform, a joint Overseas Development Assistance program could focus on smart cities and green energy innovation and implementation in high economic growth regions of the world. Korea's Global Cooperation Platform on smart cities provides a concrete collaboration opportunity for Denmark.





## 01

## Objective of the report

In 2008, the Republic of Korea unveiled Low Carbon Green Growth as a long-term strategy to deal with a “triple crunch” of climate change, high energy-import dependency, and economic slowdown caused by the 2008 global financial crisis. Green technologies have been a key pillar in Korea’s green growth and economic transformation in the past decades. Significant investments have been made in green technology R&D and innovation. This has delivered the country global leadership in key technologies such as the Lithium-ion Energy Storage Systems (ESS). With recent economic growth challenges coupled with ambitious

decarbonization goals, the country is now at the cusp of further investments and innovation in green technologies including in Fourth Industrial Revolution (FIR) technologies<sup>1</sup>.

This brief outlines Korea’s transition to green growth by elucidating on major actors, strongholds and the R&D ecosystem in green technologies, with an objective to strengthen relevant take-home knowledge for Danish energy and environment solutions community, identify cooperation potential for Denmark in research and innovation, and contribute to universities, economic life, and public and private funds in areas of priority for global cooperation.

## 02

## Korea’s green growth movement

The watershed moments in Korea’s green growth movement include establishment of the inter-ministerial Presidential Committee on Green Growth (PCGG), development of the National Strategy for Green Growth (2009-2050) and enacting of the Framework Act on Low Carbon Green Growth (or Green Growth Act).

Korea’s first Five-Year Green Growth Plans (5YGGP) for 2009-2013 launched an economic stimulus equivalent of USD 38 billion, 80 per cent of which was for environmental themes such as freshwater, waste, energy efficiency, renewable energy, and

low-carbon vehicles. Even since, subsequent 5YGGPs for 2014-2018 and 2018-2022 have been guiding sectoral green growth policies and initiatives in the country.

The 2009 Green Growth Act<sup>2</sup> serves as the primary legal framework to institutionalize green growth and has provisions to support preferential treatment for green technologies and industries (Article 31), and supports SMEs’ move towards less carbon-intensive industries (Article 33). The Act has provided a legal framework for the country’s greenhouse gas (GHG) emissions reduction targets, the carbon emissions trading system K-ETS<sup>3</sup>, and various other green economy policies<sup>4</sup>.

<sup>1</sup> FIR technologies include artificial intelligence (AI), Internet of Things (IoT), big data and cloud computing, robotics, and blockchains.

<sup>2</sup> Refer to: <http://extwprlegs1.fao.org/docs/pdf/kor100522.pdf>

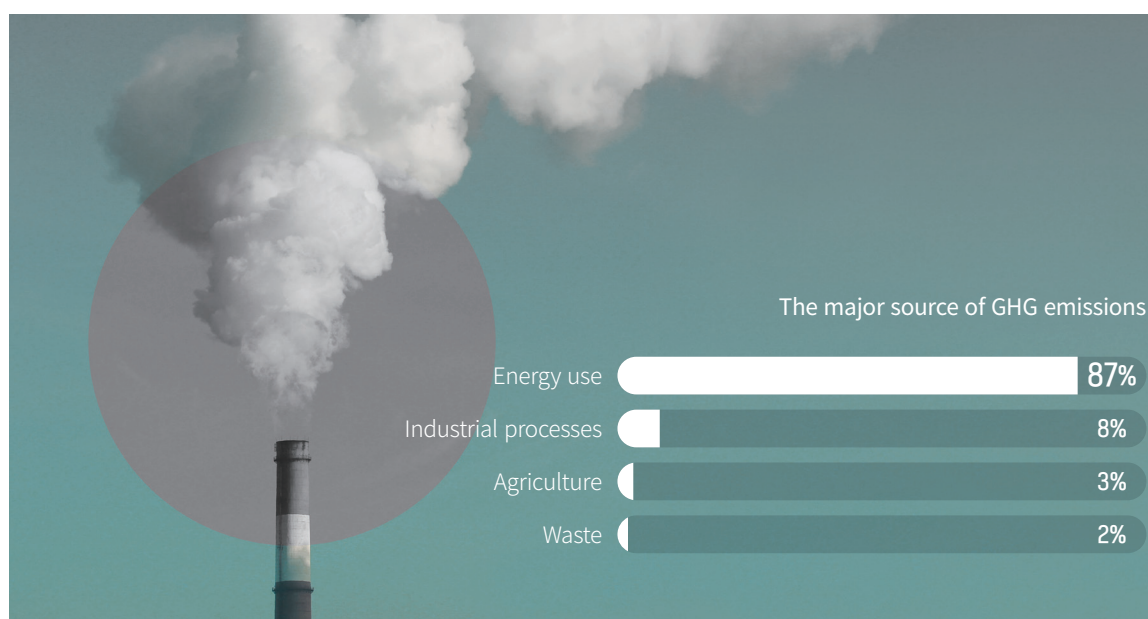
<sup>3</sup> K-ETS covers 500+ energy-intensive industries including in power generation, steel, cement, refinery, and aviation; covers 2/3 of national emissions.

<sup>4</sup> These include Smart Grid Act(2011), Frame Act on Recycling of Resources(2016), the 2nd Basic Plan for Climate Change(2019), and the 3rd Energy Master Plan(2019) with renewable energy targets.

## 03

## Transition towards a Net-Zero Carbon, Blue-Sky, Resource-circulating nation

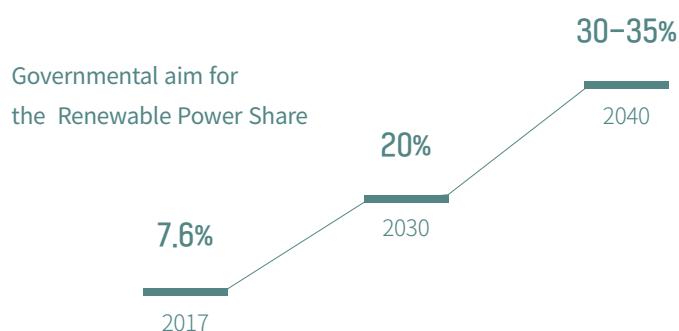
A Pew Research Center study in 2019 found that 86% of Koreans view climate change as the top global threat, ahead of terrorism or North Korea<sup>5</sup>. After winning the April 2020 parliamentary elections, the ruling party has pledged to implement a Green New Deal to make Korea the first nation in East Asia to pursue a net-zero carbon goal by 2050<sup>6</sup>. In late September 2020, the National Assembly passed a resolution to establish the net-zero carbon goal as a non-binding policy and declared 'climate emergency' making it the first East-Asian nation to do so. The resolution will see setting up a task force to guide ambitious climate action, including increasing the 2030 emissions reduction target and guiding relevant spending plans. The resolution also calls for protection against biodiversity loss and stronger conservation of nature-based carbon sinks such as forests. The resolution is available here: <https://bit.ly/3mjOPjM>



Korea's Green New Deal is part of the "Korea New Deal" (consisting of a Digital New Deal and the Green New Deal) with an initial budget of about USD 145 billion (160 trillion Won). Green New Deal investment is projected at about USD 63 billion (73.4 trillion Won) by 2025. It is a direct response to mitigate the effects of COVID19 pandemic while responding to the climate crisis and social inequality. Green technology and innovation are key themes in the Green New Deal that has three pillars: transition to green infrastructures (e.g. zero-energy buildings, nature-based urban solutions), low-carbon and distributed energy supply (e.g. renewable energy,

<sup>5</sup>According to the study available here: <https://pewrsr.ch/3avkeKj>

<sup>6</sup>According to: <https://bit.ly/2VsWQJc>.



smart-grids, electric and hydrogen mobility), and green innovation in industry (e.g. R&D in low-carbon industry, eco-industrial complexes). It aims to create 319,000 jobs by 2022 and 659,000 jobs by 2025. Approximately USD 38 billion (42.7 trillion KRW) of the investment under the Deal will be coming from the national treasury with the rest from local governments and the private sector.

Korea's first Nationally Determined Contributions (NDC) under the Paris Climate Agreement has pledged 37% below Business-As-Usual (BAU) GHG emissions reduction by 2030, which covers all sectors excluding land use and land cover change. The target is criticized as not ambitious and "highly insufficient" undermining reductions in real terms<sup>7</sup>. The target is expected to be enhanced in its next NDC due in 2020.

Annual per-capita and national GHG emissions remain high in Korea at more than 13 metric tonnes/capita (2018) and 709.1 MtCO<sub>2</sub>e (2017) respectively. The majority of emissions come from energy use (87%) including in buildings, transport, and industry, followed by industrial processes (8%), agriculture (3%) and waste (2%). In terms of energy, the power sector emits close to 45% of emissions followed by the industry and transport sectors<sup>8</sup>.

The 2030 Basic Roadmap for GHG Emissions Reduction outlines reductions from industry, buildings, transport, waste, and agriculture sectors at 20.1%, 32.7%, 29.3%, 28.9% and 7.9% below BAU emissions respectively by 2030. Electric power mix is dominated by coal (42%) followed by nuclear (23%) and LNG (26%). Carbon Action Tracker found that the country has a stranded asset risk of more than USD 100 billion<sup>9</sup> from its favoring of coal.

However, there are positive signs towards stronger climate action. The 2019 3<sup>rd</sup> Energy Master Plan<sup>10</sup>, and the 8<sup>th</sup> Basic Plan for Long-Term Electricity Supply and Demand 2017-2031 - two key policy documents - outline government's aim to increase the share of renewable power to 20% by 2030 and 30-35% by 2040, up from 7.6% in 2017.

<sup>7</sup> According to Carbon Action Tracker country analysis: <https://bit.ly/3fDL8DD>

<sup>8</sup> According to UNFCCC 2012 data, power sector at 44.6%, manufacturing and construction at 30.0% and transport at 14.4%.

<sup>9</sup> According to Carbon Action Tracker analysis: <https://bit.ly/3ctVwvE>

<sup>10</sup> Refer to the Third Energy Master Plan adopted in 2019: <https://bit.ly/3bsZYdl>





Meeting these goals would require Korea to triple renewable power capacity to 60.5 gigawatts by 2030, with solar and wind primarily contributing to this growth. Distributed power producers (DPPs) currently do not play a major role and the government has a target of 30% generation from DPPs by 2040 (up from 12% in 2017). Incentives to promote small-scale solar, solar + ESS and wind + ESS applications are being revised in the country's Renewable Portfolio Standards (RPS) that mandate power companies to increase their share of renewables. In energy efficiency, the goal is a 38% reduction in energy intensity from 2017 levels, and to reduce energy consumption by 18.6% below the BAU level by 2040<sup>11</sup>.

Smart cities play a strategic role in Korea's economic growth and decarbonization policy and are seen as a new paradigm for solving urban problems through development, innovation, and commercialization of FIR technologies. To enhance competitiveness in the sector, the government adopted a "Smart Cities Promotion Strategy" in 2018 and initiated several demonstration projects including two flagship projects in the cities of Busan and Sejong that utilize regulatory sandboxes to spur technology innovation<sup>12</sup>.

Investment in e-mobility is an important area in Korea's smart city and green technology innovation ambition. Goals include increasing the number of Battery-electric vehicles (BEV), Plug-in Hybrid Electric Vehicles (PHEV) and hydrogen fuel-cell vehicles (FCEVs) to 8.3 million by the year 2040. In 2019, Korea launched a Hydrogen Economy Roadmap that outlines a goal of ambitious goals to increase FCEVs with at least 1200 refilling stations by 2040<sup>13</sup>.

Air pollution from dust and fine particulate matter, NO<sub>x</sub>, and ground level ozone, is an increasing concern especially among the urban population mainly due to exhaust emissions from transport, power generation, industry, and transboundary air pollution. A joint Korea-China-Japan study revealed that 51% of in-country ultrafine dust comes from domestic sources, with power generation, transport, and construction as major contributors<sup>14</sup>. The government has a fine dust reduction target of 62% from power generation during 2017-2030 (8<sup>th</sup> Basic Energy Plan) and recently set up a National Council on Climate and Air Quality (NCCA), an influential solutions advisory panel chaired by the 8<sup>th</sup> Secretary-General of the United Nations Ban Ki-moon.

In waste management, plastic remains a challenge with 132.7 kg generated per capita (2015), higher than the US, and with about 60% of waste recycled within Korea. The country has set a target of reducing plastic waste by 30% by 2022 and 50% by 2030, with a recycling target of 70% by 2030.

In smart water arena, government has unveiled the Comprehensive Plan for Drinking Water Safety Management in 2019 with objectives to modernize ageing water pipes and strengthening smart water management through real-time monitoring of water supply through ICT technologies. Such technologies, such as with unmanned aerial vehicles and CCTV, are also used to monitor algae occurrences in rivers and tide monitoring in dams<sup>15</sup>.

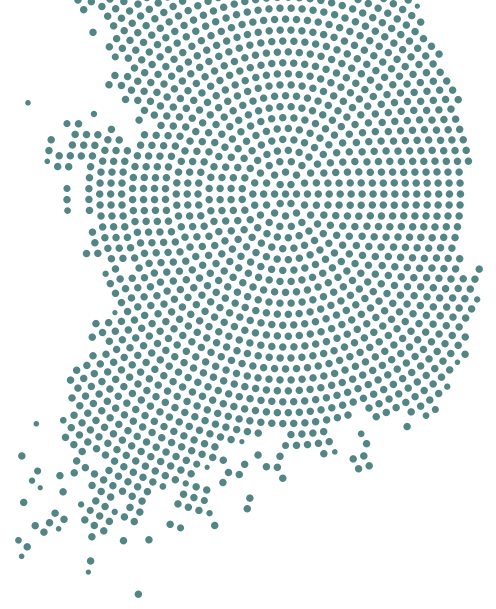
<sup>11</sup> According to written response from MOTIE.

<sup>12</sup> Refer to ICDK Outlook (2019): I-Korea 4.0: Innovation Initiatives in Smart Cities and Healthcare: <https://bit.ly/3ciMk6F>

<sup>13</sup> According to IEA website: <https://bit.ly/3foB9lk>

<sup>14</sup> According to: <https://en.yna.co.kr/view/AEN20191120004351315>

<sup>15</sup> According to responses received from Korea Water Resources Corporation.



### Green technologies in Korea's green transition

Korea's first 5YGGP outlined 27 green technologies as priority areas that would serve as pillars to the country's green transition<sup>16</sup>. The 2030 GHG reduction roadmap asks for "Fostering new industries to cope with climate change and expanding investment in new technology development" and "strengthening international cooperation" among its key seven tasks.

The terms 'green technology' or 'climate technology' are often used interchangeably in the nation's policy documents. A recent report by the Presidential Advisory Council for Science and Technology lists forty-five 'climate technologies'<sup>17</sup> – both in mitigation and adaptation – by drawing upon existing technology classifications worldwide. The government envisions Korea as an Innovation Growth Engine by 2022 by focusing on 13 areas that include Smart Cities, New and Renewable Energy, Autonomous Vehicles, and AI<sup>18</sup>.

This study used desk research and interviews with stakeholders to draw insights, and used a broad classification of green technologies as in Table 1 to guide the research and interviews.

**Table 1.**

Green technology categories used in this study to guide desk research and stakeholder interviews



#### Energy production and storage technologies

e.g. wind, solar, co-generation including with waste, district heating systems, energy storage for buildings and transportation, smart grid



#### Smart buildings and cities technologies

e.g. smart buildings, LED lighting, building/factory energy management systems, vertical farming



#### Alternative fuels and transportation

e.g. battery electric vehicles, hydrogen-powered fuel-cell transportation



#### Water & sanitation technologies

smart water and wastewater management technologies



#### Air quality management technologies

air quality monitoring and management systems and technologies



#### Cross-cutting ICT & nano technologies

*ICT technologies:* AI, IoT, Big Data, Blockchain; Nano technologies used in batteries, light-weight materials in cars, membranes in water, etc.

<sup>16</sup> As indicated in Korea's green growth experience, GGGI (2015): <https://bit.ly/2x104do>

<sup>17</sup> Refer to Climate Technology Classification and Statistics on Climate Technology Industry (2012-17): <https://bit.ly/3eKT85l>

<sup>18</sup> Refer to: <https://bit.ly/2VmzvbV>



## 04 R&D investment trends and green technology stronghold areas

### Current investments

In 2018, Korea had the highest share of R&D within OECD countries at 4.9% of GDP, double the average. Gross domestic expenditure on R&D by the business sector has grown most, more than 2.3 times during 2000-18, compared to government and higher education R&D growth of 1.9 and 1.7 times respectively<sup>19</sup>. In 2020, government's R&D budget increased 18% from the previous year to USD 22 billion and is expected to reach USD 28 billion by 2023<sup>20</sup>. Total R&D budget including the private sector is reported at over USD 73 billion for 2018. The country has over half a million researchers<sup>21</sup>.

In 2016, government targeted total investment of USD 30 billion in renewable energy, USD 4 billion into ESS, USD 2.2 billion into smart meters and USD 1.8 billion into environmentally friendly power development by 2020<sup>22</sup>. In 2019, R&D investments in renewable energy were USD 760 million, up 60% from 2016<sup>23</sup>.

For the past 5 years, 1,121 R&D projects were completed to develop green energy technologies with the support of the government. Among them, SMEs carried out 465 projects which account for 41.5%, followed by research institutes (202 projects), universities (157), state-run companies (98), conglomerates (76), mid-sized companies (71), and others (52). Companies participated in 72% of all energy R&D projects.

<sup>19</sup> Based on data from OECD Main Science and Technology Indicators: <http://www.oecd.org/sti/msti.htm>

<sup>20</sup> Based on information from Korea-EU research center website: <https://bit.ly/2VpWS4k>

<sup>21</sup> According to: <https://en.yna.co.kr/view/AEN20191218008400320>

<sup>22</sup> According to MOTIE website, <https://bit.ly/3aTL1F>

<sup>23</sup> According to: <https://bit.ly/2X68hWL>



Companies-universities-research institute consortiums carried out the biggest number of projects (approx. 29%), followed by companies-research institutes (23%) and companies-universities (20%)<sup>24</sup>.

In Smart Cities, the government budget has increased 28 times from USD 4.4 million in 2017 to USD 128 million in 2020. In 2020, USD 600 million and USD 296 million are set aside for e-mobility subsidies and charging/refilling infrastructure respectively. The goal is to build 1,400 public EV and 80 hydrogen charging stations by 2020. Government currently provides subsidies of approximately USD 6,600 for BEVs and USD 18,600 for FCEVs. Korea Environmental and Industry Technology Institute (KEITI) indicated an R&D budget of USD 138 million during 2013-20 to develop domestic waste to energy technologies.

In smart buildings, the government has committed to an investment of USD 173 million to attract more innovation to construction sites. The smart building technology development project for 2020-2025 focuses on four sectors: automation of construction equipment and management system; smart building for road structure; smart integrated safety control technology; and digital platform and test bed<sup>25</sup>.

In smart water arena, government is carrying out a “Smart Network Management Infrastructure Construction Project” with K-water based on the pilot projects in Paju and Sejong Smart Water Cities. The project is promoted across 161 local governments nationwide at a cost of USD 1.1 billion during 2020-22<sup>26</sup>.

### Current green technology stronghold

In terms of investment and commercialization, rechargeable batteries<sup>27</sup> and Light Emitting Diodes (LEDs) exhibited the best outcomes for Korea, and other technologies such as ESS, renewable energy systems, and electric vehicles were found to have made considerable progress towards being globally competitive<sup>28</sup>. In ESS, Korea's LG Chem holds the largest global market share globally by volume and Samsung SDI is serving as supplier for many system-end clients.

Past trends of patent data and R&D budgets in government research institutes (GRIs) show that the largest number of patents were in solar PV, wind, and bioenergy, although R&D investments decreased in the latter two technologies during 2014-18 (refer to Table A in the Annex). Energy storage saw the largest increase in investments with more than 166,000 patents between 2012-17. With government's push for the hydrogen economy, R&D investment in hydrogen manufacturing and storage is seeing a significant boost.

In air quality monitoring and management technologies, Korea's technology levels are considered high in stationary and mobile source emission reduction, and fugitive dust reduction technologies. Health impact assessment and policy and information services are found to be of high interest but lagging in the country<sup>29</sup>.

In waste management, Korea is a leader in food waste recycling with a 95% rate in 2019, though annual food waste remains high at about 130 kg/capita, larger than the 95 kg/capita in Europe<sup>30</sup>. The achievement was a result of banning food waste to landfills, introducing a volume-based fee system, and innovations such as RFID-equipped pay-as-you-recycle machines.

<sup>24</sup> According to written response from MOTIE

<sup>25</sup> Refer to: <https://pulsenews.co.kr/view.php?year=2020&no=65601>

<sup>26</sup> According to responses received from Korea Water Resources Corporation

<sup>27</sup> Also known as storage battery or secondary cells

<sup>28</sup> According to Korea's Green Growth Experience, GGGI (2015) <https://bit.ly/2VCIXrL>

<sup>29</sup> According to “Clean Air and Indoor Environment in South Korea” report by Innovation Center Denmark Seoul (2018)

<sup>30</sup> Refer to: <https://bit.ly/3bBb7ZU>

### ➔ Inter-ministerial advisory bodies



Green growth strategy

Green Growth Committee at Prime Minister's office



FIR technology, smart cities policy

Presidential Committee of Fourth Industrial Revolution (PCFIR)



Technology R&D policy

Presidential Advisory Council on Science and Technology (PACST)



Air quality strategy & solutions

National Council on Climate & Air Quality (NCCA)

### ➔ Ministries \*See table 4

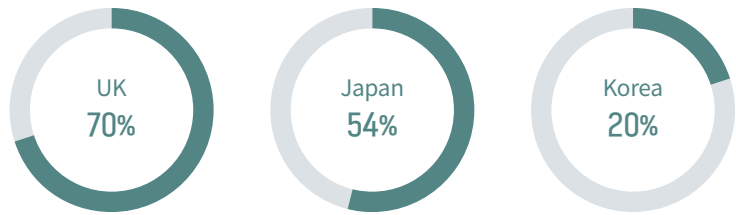
Ministry of Science & ICT (MSIT)	Ministry of Land Infrastructure and Transportation (MoLIT)	Ministry of Trade Industry and Energy (MoTIE)
S&T Policy, 5G+ policy	Smart cities, e-mobility, FIR technology policy and projects	Renewable energy and storage, smart grid, green industry policy and projects
Technology R&D in GRIs and universities	KIAT: affiliated R&D funding and coordination body*	innovation cluster platform managed by KICOX (Korea Industrial Complex corp.)
Ministry of Environment (ME)	KAIA: affiliated smart cities platform coordination body*	KETEP & KEIT: affiliated R&D funding, coordination body*
Climate change policy, K-ETS, GHG inventory	Ministry Agriculture, Food and Rural Affairs' (MAFRA)	Ministry of Education (MoE)
Smart water, waste management, and air pollution policy and projects	Agriculture, Food, Forestry policy and projects	Higher education policy and technology R&D funding in universities
KEITI: affiliated R&D funding and coordination body*	Ministry of SMEs & start-up (MSS)	Campuses in innovation clusters
	Technology start-up support including in universities	

### ➔ GRIs with green technology R&D programs

- Korea Institute of Science & Technology (KIST)
- Korea Institute of Energy Research (KIER)
- Korea Institute of Industrial Technology (KITECH)
- Korea Research Institute of Chemical Technology (KRICT)
- Korea Institute of Machinery & Materials (KIMM)
- Electronics and Telecommunications Research Institute (ETRI)
- Korea Institute of Civil Engineering and Building Technology (KICT)
- Korea Institute of Geoscience and Mineral Resources (KIGAM)
- Korea Electrotechnology Research Institute (KERI)
- Korea Research Institute of Bioscience & Biotechnology (KRIBB)
- Korea Institute of Science and Technology Information (KISTI)
- National Fusion Research Institute (NFRl)
- Korea Institute of Materials Science (KIMS)

**Figure 1:** Primary government actors in Korea's green growth and technology policy, research, innovation and implementation. Relevant jurisdiction areas are indicated. (source: author's compilation)

Comparison of the success rate of commercialization



## 05 Green technology research, development, and innovation ecosystem

### Science & Technology (S&T) policy and innovation system

Weaknesses of Korea's R&D have been cited as limited basic research and weak public-private partnership leading to low commercialization success of the country's R&D achievements, indicated at 20% compared to over 70% for the UK and 54% in Japan. While 99% of Korean companies are small and medium sized enterprises (SMEs), R&D support to them has not been considered sufficient. In response, the government in 2018 formed a Ministry of SMEs and Start-ups, and reorganized the R&D support systems to place greater emphasis on SMEs. Public R&D is focused on fundamental technologies and future growth drivers that are "difficult tasks for the private sector to manage, while businesses take charge of commercialization"<sup>31</sup>.

Public-private partnerships (PPA) is increasingly encouraged in Korea and first collaboration started in 1989. The first PPP framework was established in 1994, and currently there is a PPP Act and an Enforcement Decree. Ministry of Strategy and Finance oversees the PPP policy and quality of PPP projects conducted by line ministries, such

as MOTIE and MOLIT. The financial crisis in 1997-98 instigated a prompt shift in public-private R&D collaboration with the introduction of a *21st Century Frontier Technology R&D Program*.

As the R&D capacity of large private corporations grew in the country, the GRIs were restructured in 1982 to conduct national R&D programs with a greater focus on upstream R&D tasks. R&D by GRIs (and universities) thus ensures long-term knowledge generation that eventually leads to commercialization and strategic technology leadership for Korea. On the other hand, R&D funding by line ministries for pilot and test-bed projects, such as smart city projects by MOLIT and new and renewable energy projects by MOTIE, are provided with strong commercialization objectives and requirements. These projects involve extensive government-private sector-academic partnerships and a good portion of these projects is led by the major private players involved in these projects.

Government's new R&D financing structure also allows greater outsourcing of public R&D budget to private sector actors especially SMEs<sup>31</sup>. One example is the Small Business Innovation Research (KOSBIR) program, operated by the Ministry of SMEs and Startups, that includes several government ministries and agencies. KOSBIR requires that involved agencies reserve a percentage of their

<sup>31</sup> According to Government's R&D Innovation Plan: <https://bit.ly/3r4YKgJ>

R&D budget as subsidy for the SMEs. After coming to power in 2017, President Moon Jae-in has pledged to double the budget of KOSBIR program by 2021 from \$960 million in 2017<sup>32</sup>. New policies also enable SMEs greater avenues in utilizing GRIs' R&D facilities and to join in national R&D programs.

The Science and Technology Basic Law of 2000 requires formulation of Korea's S&T plans, which started in the 1960s. The 5YGGP is used as guiding documents for R&D investments in clean technologies. The focus on alternative energy and conservation, as well as environmental and agricultural technology R&D programs, started in the 80s and 90s. The 2000s saw the shift to industries of "global competitiveness" from the "heavy and chemical industries" in the 1970s.



<sup>32</sup> According to Kwon (2019) Analysis of the Performance of the Korean Government's R&D Subsidy for Small Businesses: [https://uknowledge.uky.edu/mpampp\\_etds/321/](https://uknowledge.uky.edu/mpampp_etds/321/)



## Major actors

Korea's research and innovation system is similar to Germany's, and different from the university-centered research seen in the United States and Northern Europe. Government-funded Research Institutes (GRIs) and large conglomerates dominate technology R&D and are joined by leading universities. Conglomerates active in green technologies include Samsung SDI (ESS, smart grid), Hyundai Motors (e-mobility), LG Electronics and LG Chemicals (ESS, smart grid), Hanwha Solar (solar PV), Doosan Heavy Industries (wind power), SK Telecom (IoT, energy), KEPCO (renewable power generation) and K-Water (public corporation on smart water management).

Figure 1 provides an overview of major government actors in the green growth and technology policy, research, innovation and implementation landscape in Korea. In terms of the green technology R&D arena, important government agencies are the Prime Minister's Secretariat (Green Growth Committee), MSIT (overall S&T R&D policy and coordination), and the Ministry of Environment (green growth and climate policy, emissions targets). The Presidential Advisory Council for Science and Technology (PACST)<sup>33</sup> serves as the advisory body on national S&T innovation. The Green Growth Committee provides overall policy advice on green growth and green technologies through a green technology and industry sub-committee.

National and regional projects – such as in smart cities and green energy – are part of national innovation strategy and are led by respective ministries in coordination with related agencies. For example, MOLIT is the governing body and coordinates smart city policy and projects with MSIT, MOTIE, ME and the Ministry of Interior and Safety. The Smart Cities Special Committee within a Presidential Commission on the Fourth Industrial Revolution (PCFIR) develops and coordinates FIR technology policies and projects in smart cities.

The National Research Council for Science and Technology (NST), under the jurisdiction of MSIT, oversees and allocates R&D budget for 25 member GRIs of NST. GRIs' R&D can span across the spectrum of Technology Readiness Levels. Electronics and Telecommunications Research Institute (ETRI), Korea Institute of Science and Technology (KIST), Korea Institute of Energy Research (KIER), Korea Institute of Industrial Technology (KITECH), Korea Institute of Civil Engineering and Building Technology (KICT), and Korea Institute of Machinery & Materials (KIMM) are among the largest public R&D funding recipient GRIs with green technology programs<sup>34</sup>. Figure 1 lists the GRIs with green technology programs, and Table B in Annex provides their indicative R&D focus areas.

Leading universities with green technology focused programs include the University of Science and Technology (UST) and "K-Star universities"<sup>35</sup> (KAIST, GIST, DGIST, UNIST, and POSTECH) under MSIT, and other leading universities such as Seoul National University and Pusan National University under the Ministry of Education.

Universities and GRIs can seek research collaboration and funding from different ministries, the private sector, and external agencies.

## Major industrial innovation clusters

Hub-and-spoke type regional innovation clusters play a major role in realizing collaborative industry-GRI-university technology research and innovation in Korea. These clusters comprise of 41 national industrial complexes across the country covering a variety of industrial sectors. KICOX (Korea Industrial Complex Corporation), appointed by MOTIE, manages the innovation cluster platform and serves as a central contact point for cluster collaboration. Table 2 lists the major industrial clusters and technologies covered.

<sup>33</sup> Refer to: <http://english.pacst.go.kr/jsp/eng/info/intro.jsp>

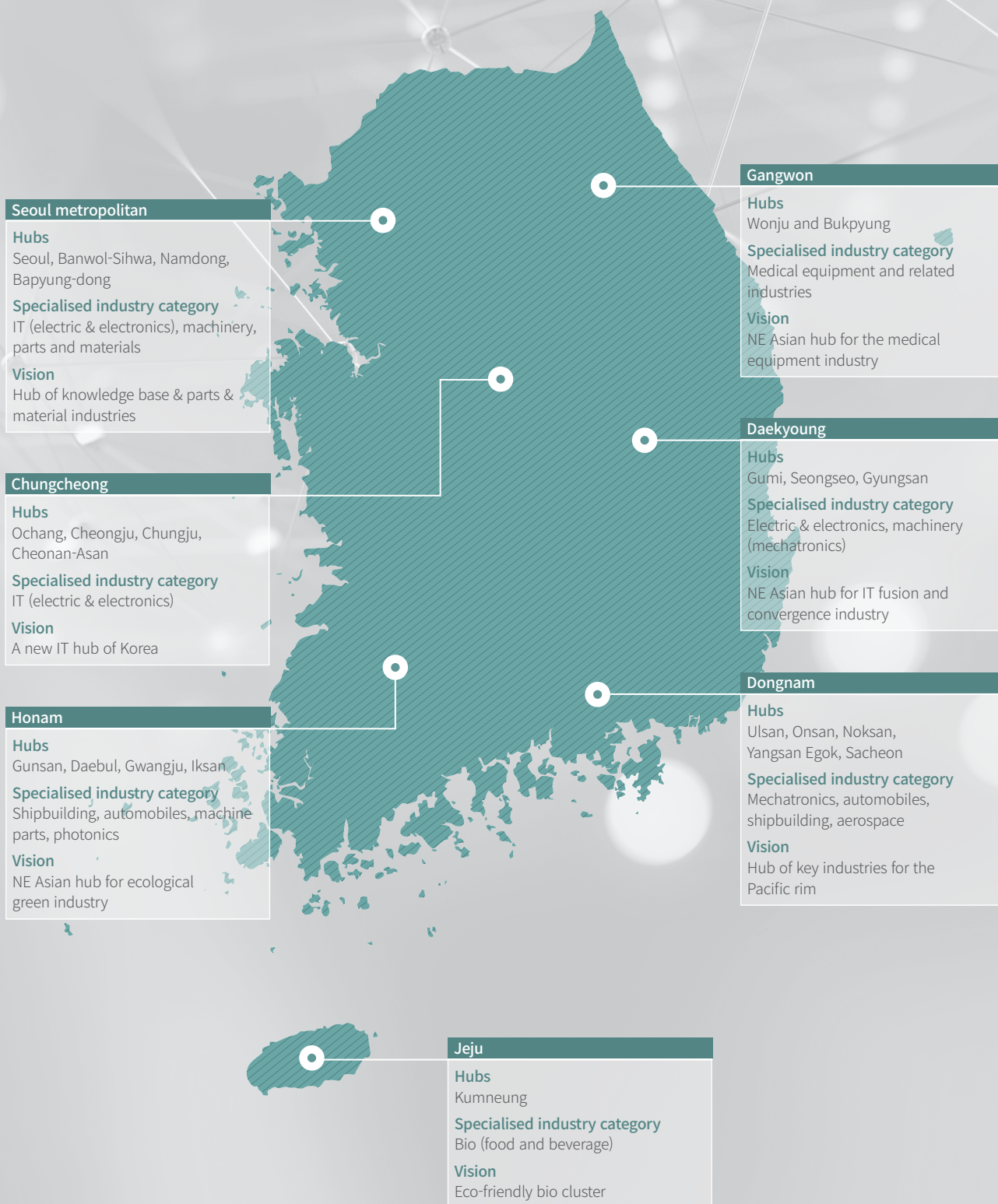
<sup>34</sup> Based on published budget by NST [https://www.nst.re.kr/nst\\_en/member/04\\_02.jsp](https://www.nst.re.kr/nst_en/member/04_02.jsp)

<sup>35</sup> K-star university program list. <http://k-star.or.kr/programs/programs21>

<sup>36</sup> Refer to Industrial Cluster Program of Korea report by KICOX: <https://bit.ly/2WwS77>

**Table 2:**

Major innovation cluster regions in Korea  
 (source: based on KICOX Industrial Program Cluster Program of Korea, KICOX<sup>36</sup>)



Regional clusters that specifically focus on green technology R&D areas include Korea Water Cluster in Daegu with testbeds on water purification, wastewater, and reuse<sup>37</sup>, national food cluster on agri-food exports, research and development in Iksan supported by MAFRA<sup>38</sup>, and Pangyo techno valley in Gyeonggi province dubbed as the Silicon Valley of Korea<sup>39</sup>. North Jeolla province has been designated by MOTIE as an energy innovation area. The province supports industry-GRI-university R&D clusters focused on solar, wind, and fuel cell technologies. It also involves companies such as Hyundai Heavy Industries (wind generator), Tech Aviation (wind blades), Solar Park Korea (solar modules) and Pro-power communications (Fuel cell), and works with R&D agencies and universities such as KIER (fuel cell), KIMM (wind blades), Korea Testing Laboratory (solar power), Gunsan and Jeonbuk National University (wind power). Saemangeum area in North Jeolla will be the venue for floating solar and offshore wind clusters, considering its geographical characteristics, while Gwangju and South Jeolla Province will be the place for an industrial ecosystem where electricity SMEs can cooperate based on the pivotal role of KEPCO.

One notable initiative is by Jeju's Special Self-Governing Provincial administration that aims to turn Korea's largest island into the world's first carbon-free island through 100% electric cars by 2030, and offshore wind-power plants along with smart grid, storage, and IoT innovations. The 4.3GW of electricity consumed by Jeju will be replaced by solar and hydropower. This initiative – known as the Green Big Bang– has a host of low-carbon and green growth projects including a smart grid demonstration site, a model electric car distribution center, land and hydropower development sites, and the Gapado island project<sup>40</sup>, in partnerships with the central government.



<sup>37</sup> Refer to Daegu Korea Water Cluster website: <http://www.gwtha.com/introducing-the-korea-water-cluster/>

<sup>38</sup> Refer to FOODPOLIS website: <http://eng.foodpolis.kr/intro/intro2.php>

<sup>39</sup> Refer to Pangyo techno valley website: <https://www.pangyotechvalley.org/eng/html/companies/consortium.asp#>

<sup>40</sup> According to news article: <http://www.koreaherald.com/view.php?ud=20180416000735>





## 06

### Existing international collaboration and relevant R&D programs

The Nature Index 2020 Annual Tables puts Korea within top-10 high-performing hubs for natural sciences R&D. The country had most collaboration with China, USA, and Japan. Germany and France are within top-10 EU collaborators<sup>41</sup>.

There are several existing initiatives supporting R&D collaboration between Denmark and Korea in the areas of green technology. These include EU's Horizon 2020 research and fellowship programs<sup>42</sup>, Eurostars R&D support to SMEs<sup>43</sup>, EUREKA/Innovation Fund Denmark's (IFD) joint research program<sup>44</sup>, and the CLEAN Cluster's initiative. Previous calls for Horizon 2020 have focused on agricultural products, 5G Next Generation communication network, and IoT Joint Research. The Danish Ministry of Higher Education and Science also annually supports a number of international network and collaboration project opportunities<sup>45</sup>. ICDK's Funding Guide lists programs and research fellowships available to Danish entities with Korean counterparts: <https://sydkorea.um.dk/en/innovation-centre/funding-guide/>. Table 3 to 6 outlines collaboration experience, initiatives, and strongholds of major government R&D entities.

<sup>41</sup> According to Nature Index 2020 Annual Table: <https://www.nature.com/articles/d41586-020-01229-4>

<sup>42</sup> Refer to Horizon 2020 website: <https://bit.ly/3bw5CLY>

<sup>43</sup> Refer to Eurostars program website focused on R&D by SMEs: <https://www.eurostars-eureka.eu/about-eurostars>

<sup>44</sup> Refer to recent EUREKA/Innovation Fund Denmark (IFD) Program calls: <https://bit.ly/2S8qJML> ; <https://bit.ly/2S6Qs8o>

<sup>45</sup> Refer to: <https://bit.ly/2ygPzDy>



**Table 3:**

Major green technology GRIs with overseas collaboration activities. (Source: author's compilation)

**Korea Institute of Science and Technology (KIST)** is Korea's first GRI and within top-ten international collaborator in the country in natural sciences<sup>46</sup>. It has regional research hubs in Germany and India to pursue R&D globalization. It houses research divisions such as the National Agenda Research Division and Clean Energy Institute focusing on clean technologies such as energy storage, energy materials, fuel cell, and biofuels research.

[https://eng.kist.re.kr/kist\\_eng/?sub\\_num=3618](https://eng.kist.re.kr/kist_eng/?sub_num=3618)

**Korea Institute of Energy Research (KIER)** is a leading new and renewable energy R&D institute with programs on PV, wind (research center in Jeju), ESS, EMS and hydrogen and fuel cell research. It has outlined a number of technologies for international R&D collaboration as listed here:

<https://www.kier.re.kr/board?menuId=MENU00641&siteId=null>

**Electronics and Telecommunication Research Institute (ETRI)** is a leader in AI R&D and one of only two public research institutes worldwide within top 30 entities for patent applications according to WIPO. (In Korea, LG is the leader in AI patent applications just ahead of ETRI). ETRI has laboratories on autonomous vehicles, smart ICT convergence, and energy and environment ICT. It also houses an innovation center to support SMEs.

<https://www.etri.re.kr/eng/main/main.etri>

<sup>46</sup> According to Nature Index: <https://www.natureindex.com/country-outputs/south-korea>



**Korea Institute of Civil Engineering and Building Technology (KICT)** has R&D programs and pilot projects on green architecture/zero energy buildings, building energy management, building materials, and others. There are programs covering smart city technologies, transport big data for autonomous driving, and air quality management. It has previously collaborated with EU partners such as Netherlands and Germany.

<https://www.kict.re.kr/menu.es?mid=a20204010000>

[https://www.kict.re.kr/menu.es?mi\\_](https://www.kict.re.kr/menu.es?mi_)

<https://www.kict.re.kr/menu.es?mid=a20210010000>

**Korean Institute for Industrial Technology (KITECH)** has programs on robotics and green manufacturing that includes R&D on green IT materials and development and commercialization of inedible biochemical materials to replace oil production technology.

<http://eng.kitech.re.kr/research/page1.php>

**Korea Institute of Machinery and Materials (KIMM)** focusses on mechanical and manufacturing systems R&D. It has programs on AI machinery, thermal systems, fuel-cell hybrid systems, and energy conservation. In Europe, it has collaborated with France and Germany, and supports researcher exchange programs.

[https://www.kimm.re.kr/e\\_resource](https://www.kimm.re.kr/e_resource)



**Table 4:**

Ministry-affiliated agencies that fund and coordinate green technology R&D, and facilitate international collaboration.  
(Source: author's compilation)

**Korea Institute for Advancement of Technology (KIAT)** affiliated to MOLIT funds and coordinates industrial technologies R&D covering “Environmental technologies and eco-innovation” and “Sustainability of energy and material resources”. It is the focal entity in EUREKA/EUROSTARS programs and has supported large international cooperation activities. KIAT recently announced a Korea-Czech Joint Technology Development Project with a green technology focus.

<https://bit.ly/2wRo8PO>

**Korea Institute of Energy Technology Evaluation and Planning (KETEP)** and Korea Evaluation Institute of Industrial Technology (KEIT) affiliated to MOTIE funds and coordinates energy technologies R&D. Notable recent projects initiated by these entities include feasibility testing projects for hydrogen storage, large-scale power generation, and hydrogen mobility. Recently KETEP initiated a Korea-Singapore joint research consortium for companies in the hydrogen and PV sectors.


<https://www.ketep.re.kr/contents/siteMain.do>;

<https://www.keit.re.kr/index.do>

**Korea Institute of S&T Evaluation and Planning (KISTEP)** affiliated to MSIT advises on science and technology (S&T) and R&D policy, planning, coordination, and performance evaluation including for the NST-funded GRIs. It has shared innovation experience through the OECD, UNESCO and International Society for Professional Innovation Management. It also provides training of overseas policy makers to guide S&T innovation master plans.

<http://www.kistep.re.kr/en/index.jsp>





**Korea Environmental Industry and Technology Institute (KEITI)** affiliated to ME provides supports for development and export of environmental technologies. Recycling, smart waterworks, technology to reduce methane, N<sub>2</sub>O, and fluorinated gas, disaster prevention and green petrol technologies are among R&D support areas. KEITI also has eco-label, environmental product declaration and green building certification research programs.

<http://www.keiti.re.kr/site/eng/main.do>

**Korea Agency for Infrastructure Technology Advancement (KAIA)** affiliated to MOLIT is Korea's smart cities R&D and innovation planning, funding and coordination platform. It supports a Smart City Synergy Alliance consisting over 100 companies and co-chaired by waste management start-up Ecube Labs and LG CNS, systems integrator within the LG group. The Alliance acts as an advisor to government agencies. Overseas companies can join the alliance by contacting the KAIA.

<https://www.kaia.re.kr/eng/main.do>

There are numerous universities in Korea with green technology related R&D and higher education programs. Table 5 lists only a few of the leading ones and is not exhaustive. It should be noted that, according to Nature Index, currently universities - topped by SNU, KAIST and UNIST - dominate international R&D collaboration in Korea in natural sciences<sup>47</sup>.

<sup>47</sup> According to Nature Index: <https://www.natureindex.com/country-outputs/south-korea>

**Table 5:**

Major green technology programs in leading universities. (Source: author's compilation)

**KAIST** is a leading technology R&D focused university. Notable schools and programs include Graduate School of Green Growth (policy and business focus), FIR intelligence center (policy and governance), Smart city research center, School of Green Transportation, and Institute for IT convergence. It also has dedicated start-up support programs (K-School and Startup KAIST).

<https://www.kaist.ac.kr/en/>


**POSTECH** started by Korea's largest steel company POSCO in 1986, has rapidly rising technology R&D centers and programs. Centers include Renewable Energy Research Institute, Fuel Cell Research Institute, LED Center, Machine Learning Research Center and Future IT Convergence Research Institute. It runs a dual degree program with Hong Kong University of Science and Technology on FIR and smart city technologies.

<http://www.postech.ac.kr/eng/>

**SNU** is Korea's top-ranked university in global ranking and houses the Institute for Sustainable Development, Graduate School of Environmental Studies, Advanced Institute of Convergence Technology (e.g. on Li-battery, super-capacitors, nano storage materials, food waste to bioenergy), Smart City Research Center, and Autonomous Driving Laboratory. SNU's Siheung campus is being set up as a large technology R&D and innovation hub.

<https://en.snu.ac.kr/>





**UST** has a unique model of running S&T graduate schools and R&D programs in association with the GRIs, such as the UST-KIST Energy and Environmental Technology Division and UST-KICT Smart City and Construction Convergence School. Faculties are drawn from GRIs' principal researchers. More information is here:

<https://bit.ly/3bbucAN>

**UNIST** is one of five K-Star STEM universities and has an R&D focus on next generation energy and advanced materials. Centers include KIST-UNIST Center for Convergent Materials, KIER-UNIST Advanced Center for Energy, Center for high performance Big-data, Center for Green Energy Materials Development, and School of NanoBioscience and Chemical Engineering.

**Table 6:**

Existing government-to-government and/or national projects with collaboration opportunities. (Source: author's compilation)

**MOTIE green energy collaborations** <https://bit.ly/3bEUKeX>

Recent collaboration agreements in green energy include with Australia (hydrogen energy), Philippines (renewable energy), Germany (hydrogen economy), Denmark (on ICT and wind power), China (on super-grids), and the Asian Development Bank (ESS and energy management systems). Korea hosted the International Renewable Energy Conference (KIREC) and 2019 Hydrogen Expo.

**MOLIT Global Cooperation Program** [www.smartcity.go.kr](http://www.smartcity.go.kr)

MOLIT's global smart cities program received submissions from 17 countries on smart city development support, including Australia, Indonesia, Thailand, and Vietnam. <https://bit.ly/2yE9ADL>. Launched in February 2020 and aimed at foreign national and local governments, it is focused on supporting smart city projects and sharing partner countries' best practices and technologies. Projects selected under the program receive financial and technical support to develop concept, master plan, and feasibility studies with up to USD 850,000 per project. Six projects were selected in April 2020 <https://bit.ly/2S6KC6J>.



**MOLIT ASEAN-ROK smart city cooperation platform**

<https://bit.ly/2yUYsmi>

In Nov 2019, under a “New Southern Policy”, the platform was launched. ASEAN countries selected through the smart city master plan or pre-feasibility study funding may develop smart city projects through a Smart City Fund. Smart-city cooperation centers are set up in 4 ASEAN countries to discover joint projects and strengthen government-to-government and business-to-business networking.

**KAIA Smart city projects** <http://www.smartcities.kr/>

Government is supporting 3 types of smart city projects: large scale national pilot projects, R&D validation projects, and regeneration projects. Two cities, Busan and Sejong, are selected in 2019 from 39 candidate cities for national pilot projects. R&D validation projects are in Daegu and Siheung serving as “living labs” with collection, storage, and sharing of data across city-wide platforms. Daejeon, Gimhae and Bucheon are urban regeneration projects with Daejeon showcasing scientific R&D and Bucheon Big data analytics for air pollution.

## 07

## Opportunities and models of collaboration for Denmark

Table 7:

SWOT of Korea's green technology R&amp;D, innovation, and implementation. (Source: author)



## S T R E N G T H S

**Technology R&D, implementation and collaboration**

- High and increasing R&D investment
- Strong focus on applied research
- R&D leader in energy and FIR technologies esp. energy storage system (ESS), Solar PV, hydrogen e-mobility, AI, IoT and Blockchain
- Top-notch ICT infra, highest smart phone uptake; nationwide 5G network

**Policy and regulation**

- Policy and regulations on GHG emissions reduction, emissions trading, air quality improvement, waste reduction and e-mobility
- Stable democracy with high level of citizen engagement

**Market and skills**

- Highly skilled STEM researcher base with English ability
- High Ease of Doing Business ranking
- Close to large markets especially China and ASEAN

## W E A K N E S S E S

**Technology R&D, implementation and collaboration**

- Weak commercialization record of R&D outputs
- Overly complex R&D assessment system
- Weak experience in non-technological aspects
- Insufficient support for R&D by SMEs
- Inadequate land or resources for expanding onshore renewables (wind, solar, biomass)

**Policy and regulation**

- Green Growth Committee advice non-binding
- No action plan for 2050 net-zero goal
- Monopoly and low electricity prices

**Market and skills**

- High entry barrier for small power producers
- Limited skilled labor in FIR industries
- Limited national market



## OPPORTUNITIES

### Technology R&D, implementation and collaboration

- Increasing focus on convergence/integrated products e.g. Big-data driven energy management systems
- Increasing R&D in hydrogen and fuel cell, and FIR technologies
- Industry decarbonization solutions
- Large test/national projects e.g. smart-cities projects

### Policy and regulation

- Ambitious GHG, renewable, air quality, e-mobility and FIR technology targets and roadmaps
- Incentives for small-scale power producers, e-mobility and energy efficiency (through K-ETS for industry)

### Market and skills

- Increasing R&D support for SMEs
- International trade links and policy towards growth markets
- High interest on green issues among millennials
- Asian Super Grid (regional power market integration)
- Replacement of older waste-to-energy plants

## THREATS / CHALLENGES

### Technology R&D, implementation and collaboration

- Extreme climate event and cybersecurity threats
- Challenges in last-mile industry decarbonization

### Policy and regulation

- Delay in power market reform
- SMEs support policy non-effective
- Weak macroeconomy from prolonged Covid-19 effects

### Market and skills

- Competition from China in R&D and market share
- Youth unemployment, and brain drain to competitor markets especially in FIR technologies
- Ageing society and declining population
- Increasing costs in major cities
- Political instability in the Korean peninsula





### Sector collaboration opportunities

The Republic of Korea and the Government of the Kingdom of Denmark signed a joint Statement on the Establishment of a Green Growth Alliance in May 2012<sup>48</sup>. The Alliance was re-signed during UNGA in September 2019. This Alliance is the cornerstone for future collaboration and along with the Partnership for Green Growth and the Global Goals (P4G) summit, planned for May 2021 in Seoul, serves as the strongest partnership platforms currently available.

Strengths, weaknesses, and opportunities in Korean green technology R&D are summarized in a SWOT analysis in Table 7. Keeping this as context, concrete sector collaboration opportunities in renewable energy and circular economy areas are put forward below. These two areas are also highlighted by the Danish Innovation Foundation's Climate Solution Panel as a core Danish knowledge stronghold and with the highest GHG reduction potential.

The Danish Circular Economy Advisory Board presented 26 recommendations to the Danish National Circular Economy Strategy<sup>49</sup> and highlighted that the transition to a more circular economy holds major potential, not only for the environment, but also for the competitiveness of Danish enterprises.

In energy, the Korea Energy Agency (KEA) and the Danish Energy Agency (DEA) have also signed implementation agreements in May 2019 for cooperation in renewable energy. MOTIE indicated that Korea's advanced IT and manufacturing could combine with Denmark's great experience in clean energy and Korea looks forward to sharing each other's experience in not only renewables, but also district heating, energy-saving (e.g. demand management), and distributed energy systems based on our reciprocal relationships.



<sup>48</sup> Joint Korea-Denmark Green Growth Alliance statement: <https://bit.ly/35CGUr8>

<sup>49</sup> Refer Dakofa Danish National Strategy for Circular Economy, <https://dakofa.com/element/danish-national-strategy-for-circular-economy/>





#### Wind power generation:

Updates in ETS and RPS incentives are encouraging KEPCO and large power producers to seek greater international R&D collaboration in power generation. In renewable power, insufficient land for on-shore renewables means off-shore options, such as floating solar plants and **off-shore wind**, will also be pursued. Currently, 13 GW of offshore wind projects are in the pipeline in the country<sup>50</sup>. Longer-term, Korea is looking at the North-East Asia Super Grid, where onshore wind and solar PV will be the primary generation sources. MOTIE sees wind power, a Danish strong hold, as an area for R&D and business collaboration with Denmark<sup>51</sup>.

#### Demand-side Management (DSM) and smart grid:

Distributed (renewable) power producers are receiving enhanced policy and incentive support and will receive greater focus during an impending power sector reform. As such, R&D and business demands for **Demand-Side Management (DSM)** and **Technology-as-a Service (TaaS)** solutions are on the rise for balancing power demand and supply. **Vehicle-to-Grid (V2G)** technologies for utilizing e-mobility storage, and **Virtual Power Plants (VPPs)** for managing bidirectional power flow, are concrete areas for collaboration. For example, the KAIST Graduate School of Green Growth indicated incorporation of non-technological aspects such as behavioral insights with smart grid and FIR technologies among the School's high interest collaboration areas.

#### District energy (DH) and Combined Heat and Power (CHP):

District energy with waste-to-energy CHP plants is identified as a high potential area. Only 15% of the population in Korea is served by DH systems compared to 50% in Denmark<sup>52</sup>. Heat-only CHP plants, primarily using municipal solid waste, supply most of DH networks serving Korean apartments. Heating efficiency of these plants is on par with European counterparts. Replacement of older CHP plants (that are Solid Refuse Fuel- and combustion-based), enhancing their electrical outputs, and introducing small distributed models are areas for business collaboration.

<sup>50</sup> <https://ijglobal.com/articles/142045/offshore-wind-takes-centre-stage-in-south-korea>

<sup>51</sup> From interview with MOTIE on 7 May, 2020.

<sup>52</sup> Refer to: <https://www.solarthermalworld.org/news/south-korea-supports-district-energy-cities-initiative>

### Energy storage:

In terms of storage, KIER identified **Redox flow batteries** as an area where R&D collaboration is sought<sup>53</sup>. Integration of solar thermal storage in CHPs support grid balancing needs with fluctuating renewable power. **Solar thermal storage**, including those that cover long-term seasonal needs (e.g. Denmark's Tank Thermal and Pit Thermal technologies), as well as CHPs that integrate solar thermal storage and use agricultural waste as feed are promising areas for collaboration.

Flexible grid and storage capabilities are prerequisites for a shift to renewables. Denmark does not necessarily have strong export opportunities in these fields, but they are vital for creating an energy system that can handle the shift to renewables and is beneficial to both countries' low carbon goals.

### Alternative fuels:

Korea has indicated its interest in joint R&D projects with other countries in 8 priority sectors such as **smart grids**, **biofuels**, and **hydrogen energy**<sup>54</sup>. Hydrogen mobility is a high priority investment area in the country. KIST has indicated collaboration interest in hydrogen production and storage R&D. In terms of future investment and attractiveness, Power2X (or green hydrogen) could be significant for Danish businesses owing to its versatility. Power2X is produced by using electricity to split water into hydrogen and oxygen by means of electrolysis. It can be used for storage and grid buffering, for decarbonizing high-heat processes in industry, where electrification is ill-suited, and as feed stock in industrial processes or the fertilizer industry.

Denmark is also a significant player in global maritime goods transport, capturing 90% of global trade. Consequently, Denmark has the potential to become home to world-leading businesses focused on low-emission alternative fuel technologies. Further electric and autonomous vehicles will form part of Danish transport solutions going forward.

### Smart cities:

This is a high potential area for large-scale collaboration and joint projects in third countries as described in the Collaboration Models section below. Copenhagen CleanTech Cluster outlined in 2017 provides an overview of Danish Smart City Competencies, which highlight concrete examples, challenges, and recommendations for Smart City Development. Smart Cities Twinning Collaboration between city practitioners are seen as one concrete step forward for collaboration.

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<sup>53</sup> Refer to list of potential technologies for R&D collaboration: <https://www.kier.re.kr/board?menuId=MENU00641&siteId=null>

<sup>54</sup> According to: <https://bit.ly/2yzSfM2>

## Collaboration models

### Government to Government (G2G) collaboration:

Korea will host the next P4G summit with a focus on renewable energy and air pollution. It is recommended that a technology R&D collaboration program is hosted under P4G to explore joint R&D projects on renewable energy (with MOTIE) and on smart cities (with MOLIT) similar to the Korean-Czech program facilitated by KIAT (see Table 4). Participation in MOLIT's smart cities Global Cooperation Program (see Table 6) is a concrete collaboration area.

Under a G2G model, a joint "North-North-South"<sup>55</sup> Overseas Development Assistance initiative holds promise for promoting joint innovation, market expansion and international development in high-growth regions, such as ASEAN and Africa. Aimed at project pipeline and investment project development, the initiative could focus on *Power with storage* (with a mix of wind and solar) and smart cities development that are of strong interest to ASEAN and African countries. The Global Green Growth Institute, an intergovernmental organization with headquarters in Seoul and a global footprint, as well as Green Technology Center Korea, a think tank under MSIT, can support execution of such initiatives.

There is significant room for graduate student and scientific researcher exchange between Korea and Denmark<sup>56</sup>, an important area for mutual cultural understanding and joint R&D project development. The Danish Ministry of Higher Education and Science and Korea MSIT could pursue a dedicated student/researcher exchange program on the green technology areas identified above.

### Innovation cluster to cluster collaboration:

Collaboration between innovation clusters in the two countries would provide direct engagement with participating universities, private sector entities, and GRIs. KICOX that manages the industrial cluster platform should be consulted to explore direct collaboration between Korean innovation clusters and Danish innovation networks<sup>57</sup>.

### Collaboration with GRIs:

Leading GRI KIST conducted a joint R&D project with the Danish Technical University (DTU) in the past. KIST's National Agenda Research Division has suggested an exploratory planning project with a modest budget – on the back of an existing NST-IFD Memorandum of Understanding (MoU) - to identify joint research topics and prepare proposals through exchange visits and meetings of top researchers<sup>58</sup>. Such a model can also be pursued with other leading GRIs with existing collaboration agreements. Bio and hydrogen energy, microplastics in water treatment, and fine dust reduction technologies are among areas of joint R&D interest indicated by KIST's National Agenda Research Division.

<sup>55</sup> An international cooperation model where economically advanced countries collaborate for international development in developing countries.

<sup>56</sup> For example, Global Korea Fellowship with limited quota per country has only 1-2 embassy quota for Denmark.

<sup>57</sup> Danish Innovation Networks funded by Ministry of Higher Education and Science: <https://bit.ly/3cdQPpw>

<sup>58</sup> Based on inputs received during interview with KIST on 27 April, 2020.



### Collaboration with universities:

A cluster-to-cluster collaboration would involve Korean universities that are participating in a cluster's R&D. Other entry points for pursuing collaboration with universities are as follows.

#### *Through open innovation labs with Korean corporations:*

Korean companies aiming for industry-academia research pursues open innovation labs to generate new ideas, products, and markets. For example, food industry leader CJ Group runs a lab in Korea for product launching and providing research grants<sup>59</sup>, and includes overseas universities. Hyundai announced an open innovation lab in Singapore<sup>60</sup> to tap into the region's R&D ecosystem and market in smart mobility and manufacturing involving FIR technologies. An innovation lab with a leading Korean company can be pursued in an area of Danish interest.

*Expanding on existing collaboration:* KAIST has an MoU with DTU<sup>61</sup> and previously ran innovation workshops involving students and researchers from both countries<sup>62</sup>. KAIST's School of Green Growth has indicated interest to collaborate with Danish counterparts in joint activities such as hackathons in TaaS and DSM topics aimed at supporting and creating green technology start-ups in Korea<sup>63</sup>.

*New collaboration* is suggested with universities that have close links with GRIs or are initiating large innovation programs. Collaboration with UST provides access to major GRIs as it runs campuses with the GRIs and faculty is drawn from GRIs' principal researchers (see Table 5). SNU's new Siheung campus, located south of Seoul, is building a large innovation hub bringing together green technology departments, corporations, and international organizations, and provides excellent collaboration opportunities on smart cities and e-mobility solutions<sup>64</sup>.



<sup>59</sup> Refer to CJ Group's open innovation website: <https://www.cj.co.kr/en/innovation/open-innovation>

<sup>60</sup> According to: <https://bit.ly/2VUvafa>

<sup>61</sup> According to: <https://herald.kaist.ac.kr/news/articleView.html?idxno=1366>

<sup>62</sup> According to: <https://startup.kaist.ac.kr/2019-innovation-workshop-univ-queensland/?lang=en>

<sup>63</sup> Based on inputs received during interview with KAIST on 17 April and 21 April, 2020.

<sup>64</sup> Based on inputs received during interview with SNU on 21 April, 2020.

## Annexes

Table A: Registered patents and R&amp;D budget growth in GRIs under the NST. (Source: PACST)

Climate Technology		Registered Patents (2012-17)	2018 R&D budget (million USD)	R&D budget growth CAGR % (2014-18)
Renewable energy	Photovoltaic	3,275	145	12.34
	Waste	437	20	10.45
	Wind power	247	5	-6.93
	Solar thermal	175	11	7.28
	Hydro power	100	9.6	3.6
	Bioenergy	99	56	-3.7
	Geothermal	75	8	-8.87
	Ocean energy	39	21	-7.8
	<b>Subtotal</b>	<b>4,447</b>	<b>318</b>	<b>2.31</b>
New energy source	Fuel cell	393	49	-2.5
	Hydrogen manufacturing	20	20	8.35
	<b>Subtotal</b>	<b>413</b>	<b>69</b>	<b>0.11</b>
Energy storage	Power storage	4,658	15	3.53
	Hydrogen storage	2	25	38.3
	<b>Subtotal</b>	<b>4,660</b>	<b>176</b>	<b>6.23</b>
Transmission and distribution, electric power IT	Transmission and distribution system	3,216	53	1.35
	Electric intelligence device	2,697	15	-12.06
	<b>Subtotal</b>	<b>5,913</b>	<b>69</b>	<b>-2.62</b>
Energy demand management	Efficient transport	7,667	209	-4.03
	Building efficiency	5,815	84	-6.22
	Industrial efficiency	1,034	209	-3.93
	<b>Subtotal</b>	<b>14,516</b>	<b>504</b>	<b>-4.37</b>
Water	Water treatment	1,070	NA	NA
	Water resources securement and supply	605	NA	NA
	Water quality and ecology	417	NA	NA
	Water disaster management	55	NA	NA
	<b>Subtotal</b>	<b>2,147</b>		
Health	Food safety prevention	127	NA	NA
	Infectious disease management	124	NA	NA
	<b>Subtotal</b>	<b>251</b>		
Forest/land	Forest production promotion	427	NA	NA
	Ecology monitoring and restoration	140	NA	NA
	Forest damage reduction	55	NA	NA
	<b>Subtotal</b>	<b>622</b>		
Multidisciplinary convergence	Renewable energy hybrid	1,213	NA	NA
	Others	476	NA	NA
	Low-power consumption equipment	145	NA	NA
	Energy harvesting	75	NA	NA
	Artificial photosynthesis	0	NA	NA
	<b>Subtotal</b>	<b>1909</b>		

## Annexes

Table B: GRIs under NST with green technology R&D strength areas (based on inputs from Green Technology Center Korea<sup>65</sup>)

Institutes	Green energy & storage	Smart buildings & cities	Alternative fuels transportation	Water & sanitation	Cross-cutting: ICT & nano-tech	Air quality management	Bio-science
Korea Institute of Science & Technology (KIST)	×			×		×	
Korea Institute of Energy Research (KIER)	×	×	×				
Korea Institute of Industrial Technology (KITECH)	×		×			×	
Korea Research Institute of Chemical Technology (KRICT)	×		×				
Korea Institute of Machinery & Materials (KIMM)	×		×	×		×	
Electronics and Telecommunications Research Institute (ETRI)	×	×			×		
Korea Institute of Civil Engineering and Building Technology (KICT)		×		×		×	
Korea Institute of Geoscience and Mineral Resources (KIGAM)							
Korea Electrotechnology Research Institute (KERI)	×				×		
Korea Research Institute of Bioscience & Biotechnology (KRIBB)	×						×
Korea Institute of Science and Technology Information (KISTI)					×		
National Fusion Research Institute (NFRI)	×			×			
Korea Institute of Materials Science (KIMS)					×	×	

<sup>65</sup> Based on inputs received during interview with Division of Technical Supervision of GTCK on 22 April, 2020.





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