Strengthening innovation-driven inclusive and sustainable development

Asia-Pacific Tech Monitor

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Innovative technologies for air pollution control

UNITED NATIONS
ESCAP
Economic and Social Commission for Asia and the Pacific
Asian and Pacific Centre for Transfer of Technology (APCTT)

*The shaded areas of the map indicate ESCAP members and associate members.**

The Economic and Social Commission for Asia and the Pacific (ESCAP) serves as the United Nations' regional hub promoting cooperation among countries to achieve inclusive and sustainable development. The largest regional intergovernmental platform with 53 Member States and 9 associate members, ESCAP has emerged as a strong regional think-tank offering countries sound analytical products that shed insight into the evolving economic, social and environmental dynamics of the region. The Commission's strategic focus is to deliver on the 2030 Agenda for Sustainable Development, which is reinforced and deepened by promoting regional cooperation and integration to advance responses to shared vulnerabilities, connectivity, financial cooperation and market integration. ESCAP's research and analysis coupled with its policy advisory services, capacity building and technical assistance to governments aims to support countries' sustainable and inclusive development ambitions.

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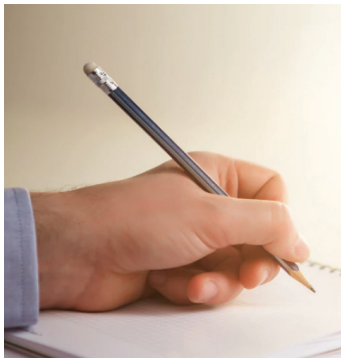
CONTENTS



Introductory note

Air pollution is one of the critical challenges affecting the health and wellbeing of people. Globally, air pollution kills nearly 7 million people every year and is considered the biggest environmental health risk. The Asia-Pacific region accounts for about 70 per cent of deaths globally due to air pollution and has recorded some of the highest air pollution levels in recent times. It is also a major transboundary environmental challenge that threatens all countries in Asia and the Pacific. Recognizing the need to improve air quality to protect human health, the United Nations General Assembly has designated 7 September as the International Day of Clean Air for blue skies, which stresses the importance of clean air and the urgent need for efforts to improve air quality to protect human health.

The countries strive to reduce air pollution through technology interventions for source-reduction of pollutants, enabling policy measures, regulations, and incentives. They are adopting action plans to control air pollution, but more needs to be done as they face multiple challenges such as capacity and resource constraints as well as limited awareness and access to effective and affordable technologies. Other limiting factors are inadequate linkages between national strategies and city level action plans, and limited opportunity for cross-border learning on good practices and collaboration at the regional level.

It is important for governments to enact and enforce enabling technologies, regulatory policies and incentives to support industry for monitoring and reducing air pollution. Efforts are required to strengthen regional cooperation and facilitate broader exchange of innovative solutions to control air pollution and good practices, including policies, strategies, data and technologies, and capacity needs. In this regard, the United Nations Nations Environment Programme (UNEP) has identified 25 clean air measures in the report titled "Air Pollution in Asia and the Pacific: Science-based Solutions", which could be widely adopted by countries. Towards strengthening the capacity of member States in the region, the Asian and Pacific Centre for Transfer of Technology (APCTT) of the Economic and Social Commission for Asia and the Pacific (ESCAP) is implementing a project titled "Enhanced capabilities to adopt innovative technologies for city air pollution control in select countries of the Asia-Pacific". The project will strengthen the capacity of stakeholders and improve the availability of knowledge regarding innovative technologies, good practices, and better understanding of technology needs and gaps in a few target countries of the region.

This issue of *Asia-Pacific Tech Monitor* discusses the enabling policies, strategies, and best practices for the adoption of innovative technologies to control air pollution in the Asia-Pacific countries.

Preeti Soni
Head, APCTT-ESCAP

INTERNATIONAL

WHO establishes global biomanufacturing training hub

The World Health Organization (WHO), the Republic of Korea, and the WHO Academy have announced the establishment of a global biomanufacturing training hub that will serve all low- and middle-income countries wishing to produce biologicals, such as vaccines, insulin, monoclonal antibodies, and cancer treatments. The move comes after the successful establishment of a global mRNA (Messenger RNA) vaccine technology transfer hub in South Africa.

The Government of the Republic of Korea has offered a large facility outside Seoul that is already carrying out biomanufacturing training for companies based in the country and will now expand its operations to accommodate trainees from other countries. The facility will provide technical and hands-on training on operational and good manufacturing practice requirements and will complement specific trainings developed by the mRNA vaccine technology transfer hub in South Africa. The WHO Academy will work with the Korean Ministry of Health and Welfare to develop a comprehensive curriculum on general biomanufacturing.

In parallel, WHO is intensifying regulatory system strengthening through its Global Benchmarking Tool (GBT), an instrument that assesses the regulatory authorities' maturity level. The GBT will serve as the main parameter for WHO to include national regulators in the WHO-listed Authorities list. Another aim is to build a network of regional centres of excellence that will act as advisers and guides for countries with weaker regulatory systems.

Five more countries will also receive support from the global mRNA hub in South Africa: Bangladesh, Indonesia, Pakistan, Serbia and Viet Nam. These countries were vetted by a group of experts and proved that they had the capacity to absorb the technology and, with targeted training, move to the production stage relatively quickly. Argentina and Brazil were the first countries from the region of the Americas to receive the mRNA technology from the global hub in South Africa, joining the initiative in September 2021. The companies from these two countries are already receiving training from the technology transfer hub.

Numerous countries responded to the call for expressions of interest from the technology transfer hub in late 2021. The WHO will provide support to all of the respondents but is currently prioritizing countries that do not have mRNA technology but already have some biomanufacturing infrastructure and capacity. The WHO will enter into discussions with other interested countries and other mRNA technology recipients will be announced in the coming months.

https://www.who.int

ASIA-PACIFIC

BANGLADESH

New patents bill passed

The parliament has enacted the Bangladesh Patents Bill 2022, aiming to make a century-old patents law more time-befitting and to safeguard the intellectual property rights. The law, among others, extends the validity period of patents from 16 years to 20 years.

Sheikh Faezul Amin, the additional secretary (policy, law, and international cooperation) to the industries ministry, said the new law included provisions enabling joint registrations if needed. The pre-existing patent and design law was enacted in 1911. In 2016, the law was divided into two parts, a patent law and a design law. According to him, the act was needed to enable updates to stay attuned with the current growth of the economy and the expansion of trade and commerce.

The bill states that any technological product would be patentable if it has something new in it. However, inventions, scientific theories and mathematical methods, business methods, rules or methods of performing purely mental work or sports and any such computer programmes would not be patent protected. In addition to the need to prevent commercial use within the borders of Bangladesh in order to protect public order and ethics, a number of other issues have been left out of patent protection, including innovation.

A registrar office will be there to issue or cancel patents of any single inventor or joint inventors of a technical innovation under the proposed law.

https://www.thedailystar.net

CHINA

R&D investment in 2012-2021

Researchers China's manufacturing sector saw an increase in research and development (R&D) investment during the 2012-2021 period, the Ministry of Industry and Information Technology (MIIT) said. Investments in the sector's R&D rose from 0.85 per cent in 2012 to 1.54 per cent in 2021, Wang Wei, an MIIT official, said at a press conference. In 2021, the R&D investment of China's specialized and sophisticated enterprises that produce new and unique products reached 10.3 per cent, according to Wang.

The manufacturing sector is also seeing an improvement in its innovation system. A total of 23 manufacturing innovation centers have been set up by the central government or co-established by the central and local governments. Industrial enterprises with an annual business turnover of at least 20 million yuan ($2.96 million) saw the share of the revenue brought by the new products in total business revenue increase from 11.9 per cent in 2012 to 22.4 per cent in 2021, according to Wang.

https://www.chinadaily.com.cn

State-owned enterprises invest more in R&D

China's centrally administered state-owned enterprises (SOEs) invested more in research and development (R&D) to boost innovation-driven growth in the first half of 2022, official data showed. The central SOEs' total expenditure on R&D amounted to around 378.62 billion yuan (about $56.1 billion) in the first six months, an increase of 19.7 per cent over the same period of last year, said the State-owned

Assets Supervision and Administration Commission (SASAC) of the State Council.

The R&D input of the central SOEs has maintained a double-digit growth during the first six months, and the R&D investment intensity of those companies increased by 0.12 percentage points year on year, according to the SASAC. The SASAC data also showed that the combined revenue of China's central SOEs stood at 19.2 trillion yuan in the January-June period, an increase of 12 per cent year on year. Their net profits came in at 1.09 trillion yuan, up 6.1 per cent from the year earlier.

https://www.chinadaily.com.cn

INDIA

Establishment of BIMSTEC Technology Transfer Centre

The Union Cabinet chaired by the Prime Minister Shri Narendra Modi has approved a Memorandum of Association (MoA) by India for the establishment of Bay of Bengal Initiative for Multi-Sectoral Technical and Economic Cooperation (BIMSTEC) Technology Transfer Facility (TTF) was signed by the BIMSTEC member countries at the 5th BIMSTEC Summit held at Colombo, Sri Lanka on 30th March, 2022.

The main objectives of the BIMSTEC TTF are to coordinate, facilitate, and strengthen cooperation in technology transfer among the BIMSTEC Member States by promoting the transfer of technologies, sharing of experiences and capacity building.

The TTF shall facilitate transfer of technologies among the BIMSTEC Member States, amongst other things, in the following priority areas Biotechnology, Nanotechnology, Information and Communication Technology, Space technology applications, Agricultural technology, Food processing technology, Pharmaceutical technology automation, New and renewable energy technology automation, New and Renewable energy technology, Oceanography, Nuclear Technology Applications, E-waste and solid waste management technology, Health Technologies, Technologies pertinent to Disaster Risk Reduction and Climate Change Adaptation.

The TTF shall have a Governing Board and the overall control of activities of the TTF shall be vested in the Governing Board. The Governing Board shall consist of one nominee from each Member State.

The expected outcomes of the BIMSTEC TTF are:

i. Databank of technologies available in BIMSTEC Countries,

ii. Repository of information on good practices in the areas of technology transfer management, standards, accreditation, metrology, testing and calibration facilities,

iii. Capacity building, sharing of experiences and good practices in development, and

iv. Transfer and use of technologies among the BIMSTEC countries.

https://pib.gov.in

Report on digital banks

A report from the National Institution for Transformation India (NITI Aayog) makes a case and offers a template and a roadmap for a licensing and a regulatory regime for digital banks. It focuses on avoiding any regulatory or policy arbitrage and offers a level playing field to incumbents as well as competitors.

The report recommends a carefully calibrated approach, comprising the following steps:

1. Issue of a restricted digital bank licence (to a given applicant, the license would be restricted in terms of volume/value of customers serviced and the like).
2. Enlistment (of the licensee) in a regulatory sandbox framework enacted by the Reserve Bank of India.
3. Issue of a "full-scale" digital bank licence (contingent on satisfactory performance of the licensee in the regulatory sandbox, including salient, prudential and technological risk management).

The report also maps prevalent business models in this domain and highlights the challenges presented by the "partnership model" of neo-banking—which has emerged in India due to a regulatory vacuum and in the absence of a digital bank licence.

The methodology for the licensing and regulatory template offered by the report is based on an equally weighted "digital bank regulatory index." This comprises of four factors—(i) entry barriers; (ii) competition; (iii) business restrictions; and (iv) technological neutrality. The elements of these four factors are then mapped against the five benchmark jurisdictions of Singapore, Hong Kong, United Kingdom, Malaysia, Australia, and the Republic of Korea.

https://www.pib.gov.in

FDI equity inflows in R&D sector

In the calendar year (C.Y.) 2021, India attracted USD 343.64 million in Foreign Direct Investment (FDI) equity inflow, a 516 per cent increase over the previous C.Y. 2020. (USD 55.77 million). In the Research and Development (R&D) industry, FDI is allowed via a 100% automatic route, subject to any applicable laws, regulations, security requirements, and other restrictions. Following Telangana and Haryana in order of FDI Equity recipients in R&D for C.Y. 2021 is Karnataka. Telangana, Karnataka, Haryana, Andhra Pradesh, and Tamil Nadu all experienced growth of more than 250 per cent in C.Y. 2021 compared to C.Y. 2020.

With a 40% share of all FDI Equity in R&D, Singapore leads Germany (35%) and the United States in terms of R&D investment during the C.Y. 2021. (11 per cent). Additionally, the FDI equity inflow from a number of nations, including Germany, Mauritius, France, Singapore, Oman, and the United States, increased by more than 200 per cent from the previous C.Y. 2020.

Daimler Truck Innovation Center was the top FDI Equity inflow recipient company in R&D during the C.Y. 2021 with 35% share of the total FDI Equity in R&D, followed by Aragen Life Sciences Private Limited (34%), and Stelis Biopharma Private Limited (21%).

These trends indicate a robust and growing R&D sector, which would benefit the economy by driving innovation, increasing productivity, thereby leading to a higher economic growth.

https://www.thestatesman.com

INDONESIA

Formal registration of tech and game companies

The Ministry of Communication and Information Technology of the Republic of Indonesia (Kominfo) had issued regulation no. 5 of 2020 on Penyelenggara Sistem Elektronik Swasta (PSE) or Private Electronic System Providers. This regulation is imposed to local as well as foreign tech enterprises operating in the Republic of Indonesia, which include game companies, who are (1) providing services within the territory of the Republic of Indonesia, (2) doing business in the Republic of Indonesia, and/or (3) whose electronic system is used and/or offered in the territory of the Republic of Indonesia.

There are four main objectives of the regulation: (1) establishing a system of all Public Sector Enterprise (PSEs) operating in the Republic of Indonesia; (2) maintaining the Republic of Indonesia's digital space; (3) protecting public access on digital platforms; and (4) creating a fair system between the domestic and foreign PSEs, including in terms of tax collection.

According to the PSE website run by the Kominfo, there are currently 8,276 private PSEs that are registered, consisting of 8,069 domestic PSEs and 207 foreign PSEs. Some of the big names who have registered to the website are Google, YouTube, Search Engine, Playstore, Ragnarok Online, Valorant, PUBG Mobile, Mobile Legend, Roblox, and Google Maps. There are companies and games that have not yet registered to Kominfo's database, including Opera, LinkedIn, PayPal, Amazon.com, Alibaba.com, Yahoo, Bing, Steam, Epic Games, Battle.net, Origin, Counter-Strike: Global Offensive, and Dota 2. The failure to comply will be met with the following steps: a formal warning, a monetary fine, and an access termination.

The new regulation provides an opportunity to obtain information on the number of gaming companies that operate in the country. In a report launched by the Kominfo, there is a demand for more opportunities and jams for local game publishers to increase their experience. By tracking the gaming companies currently active in the country, the government can promote more game jams between the local and foreign game companies, or fund internship opportunities to major game studios. The registration requirement may also promote fairness in terms of tax issues in the gaming industry. Currently, foreign companies are yet to contribute to the country's tax revenue as compared to the local gaming companies.

On the other hand, the regulation may potentially disrupt the current games market in the Republic of Indonesia. In terms of privacy, developers will be required to provide the government access to their users' personal data, which may violate one's rights to data protection. Furthermore, there is a lack of clarity in Article 14 point 3 in the PSE regulation. It states that an enterprise would be prone to lawsuits if certain contents are considered "disturbing public order," without providing further information on what this entails. This may hinder game development projects that are already under way and ultimately affect the prepublic of Indonesia's growing games industry. Global game companies could be deterred from investing and publishing games in Indonesia as the games could be banned without detailed reasons or due to fear that the companies have to compromise their users' private data.

https://nikopartners.com

MALAYSIA

Rules on tax treatment of R&D expenditures

The Inland Revenue Board of Malaysia has published an updated public ruling explaining the rules relating to qualifying research and development (R&D) expenditures for tax incentive deductions. The businesses residents in Malaysia that undertake the R&D activity may be able to claim tax incentives on their qualifying R&D expenditures in the form of a single deduction or double deduction. To qualify for a double deduction, the expenditure must be incurred for an "approved" qualifying R&D activity.

The updated ruling includes some clarifications from the previous editions of the guidance. For instance, it specifies that any cash contribution or payment for the use of services that are capital in nature will not qualify for a double deduction (noting, as examples, the purchase of plant equipment, buildings, or vehicles for research purposes). Among other updates, the new public ruling also states that effective from 1 January 2021, no double deductions will be permitted if the payments for R&D expenditures undertaken outside Malaysia constitute more than 30% of the total allowable R&D expenditure.

https://mnetax.com

Centre to boost 4IR

The Malaysian Government announced the establishment of the Centre for the Fourth Industrial Revolution (C4IR), an independent centre within the World Economic Forum, to support the achievement of Malaysia's overarching vision under its 4IR Policy launched in 2021, as well as the Malaysia Digital Economy Blueprint. The new centre aims to accelerate technology adoption that will help secure a more equitable, inclusive, and sustainable growth for Malaysia as the economy recovers from the COVID-19 pandemic.

The establishment of this centre, also the first in Southeast Asia, highlights the Malaysian Government's commitment to prioritizing technology as a key catalyst for economic growth and post-pandemic recovery, as well as supports its aspiration to be a regional leader in the digital economy.

The "C4IR" will be a part of the Forum's global networks for multi-stakeholder cooperation to realize the benefits of emerging and innovative technology. Through its current network of centres globally, the C4IR is pioneering an agile

and human-centred model of tech-focused policy development and implementation. The C4IR will be officially set up and officiated by Malaysia's Prime Minister in the second half of 2022. The C4IR establishment was announced on behalf of the Malaysian Government by the Malaysia's Minister of Finance, on the sidelines of the World Economic Forum Meeting held from 23 to 26 May 2022.

Malaysia's Minister of Finance stated that the country is accelerating its digital transformation journey, and its ability to leverage 4IR technologies such as artificial intelligence, nanotechnology, renewable energies, and quantum computing will be one of the leading drivers for the nation's sustainable, resilient, and inclusive economic growth in the decades to come.

https://opengovasia.com

PHILIPPINES

Patent fee waivers

The Intellectual Property Office of the Philippines (IPOPHL) has launched programs to assist female inventors and female-led micro-, small-, and medium-sized enterprises (MSMEs) in protecting their intellectual property (IP). In a virtual launch, the IPOPHL-Bureau of Patents Director Lolibeth R. Medrano said the Juana Patent and Juana Design Incentive Protection programs seek to promote the registration of IP and improve IP awareness, particularly for women. "The Juana Patent and Juana Design programs are envisaged to assist women inventors, designers, and entrepreneurs (in) protecting their intellectual creations by (offering an) incentive package for invention, utility model (UM), and industrial design (ID) applications," Ms. Medrano said. The goal is to "promote gender inclusivity and enhance national innovation. IP is one of the areas where female participation can be greatly enhanced," she added.

According to the IPOPHL, the program will waive fees for up to 50 patents, 150 UMs, and 150 ID applications for applicants that qualify for the program. "Waiving the fees for application, publication and substantive examination, the new program will provide women inventors and innovative, women-led MSMEs and startups with application savings from P2,700 for IDs and UMs up to about P5,100 for patents," IPOPHL said. IPOPHL also signed a memorandum of agreement with the Department of Trade and Industry (DTI) to promote the programs.

The IPOPHL said those interested in the incentives must have been in business for at least one year, with a limited financial capacity. An applicant must also not have previously availed or funding under the Republic Act 7459 or the Philippine Inventors and Inventions Incentives Act. Enterprises whose principals apply for the program must have no more than 20 employees.

"IPOPHL's programs highlight the role of IP as a valued asset and business tool for entrepreneurs. Protecting IP goes hand in hand with the DTI's objective of shaping a culture of innovation and creativity. Again, we reiterate that we don't want to just create MSMEs. We want to create smarter and higher-value MSMEs," Trade Secretary Ramon M. Lopez said. "As the pandemic deepened risks to vulnerable groups like women, the (program) comes at an opportune time to help them bounce back from the livelihood losses and economic challenges from the pandemic. By helping them capitalize on their ingenuity and protect their IP, we are also fulfilling our commitment to do more in empowering women to spur innovation in the country," the IPOPHL Director General, Rowel S. Barba said.

https://www.bworldonline.com

Rules for geography-based intellectual property

The Intellectual Property Office of the Philippines (IPOPHL) has drafted the implementing rules and regulations on geographical indications (GI)—which essentially identify a good to a specific locality—in a bid to strengthen the protection of these products in the country. The regulations, drafted by the Bureau of Trademarks, aims to fulfill the recognition of GIs as "protectable" intellectual property under the law. It will also fulfill the obligation of the Philippines as a member of the World Trade Organization to provide reciprocal rights and GI protection to other members.

In a recent statement, the IPOPHL said the draft defines geographical indicators (GI) as "any indication which identifies a good as originating in a territory, region or locality, where a given quality, reputation, or other characteristic of the good is essentially attributable to its geographical origin and/or human factors." The IPOPHL, citing the draft, said it is important to protect GIs since it is vital in the competitive advantage of local and indigenous products. The protection for a GI is not subject to a certain period and will remain valid unless its registration is canceled.

Under the draft, registrants will have the rights to prevent their products from being misused by other stakeholders, such as a false representation that a good actually comes from somewhere else, among other cases. The GIs in the Philippines are protected under the trademarks section of the Intellectual Property Code of 1997. The popular Guimaras Mangoes and the Tau Sebu "T'nalak," registered as collective marks, are identified as potential GIs.

Other possible examples are Bicol Pili, Davao Pomelo, Cordillera Heirloom Rice; Camiguin "Lanzones;" Davao Cacao; Kalinga Coffee; Antique's Bagtason Loom; Aurora's Sabutan Weave; Samar's Basey Banig; Basilan and Zamboanga's Yakan cloth; and, most recently, the Masbate beef and Baguio Strawberry.

https://business.inquirer.net

REPUBLIC OF KOREA

R&D Spending

The Republic of Korea placed second in the research and development (R&D) spending as a portion of its gross domestic product (GDP) among major developed countries in 2020, but its tepid growth in recent years call for more policy support,

a report said. The Republic of Korea's R&D expenditures reached 93.1 trillion won ($75.4 billion) in 2020, accounting for 4.81 per cent of the GDP, according to a recent report by the Federation of Korean Industries (FKI), the country's largest business lobby. This made the Republic of Korea the biggest R&D spender among 36 out of 38 member countries of the Organization for Economic Cooperation and Development (OECD) trailing only Israel, whose R&D portion came to 5.44 per cent, the report said.

Chile was excluded from the finding due to limited available data. Costa Rica was also excluded from the report because it joined a Paris-based organization last year.

The report also found that the Republic of Korea's R&D portion jumped 2.54 percentage points last year from 2001, a nearly fivefold increase compared with the OECD average of 0.53 percentage point.

Large companies spent 71.3 trillion won, representing a bulk of the expenditures, while 21.6 trillion won was spent by the government or other public entities. The R&D spending, however, has remained stalled at the average of around 7.5 to 8.0 per cent in the past decade, retreating from the average 11.4 per cent for 2001-2010.

In 2018, the Republic of Korea ranked far below the OECD average in earnings from intellectual property royalties versus the R&D spending, with the percentage coming to 9.9 per cent, compared with the OECD's 27.7 per cent. The FKI called for a stronger policy support for large enterprises, whose R&D spending makes up more than half of all the corporate R&D investments.

"The corporate R&D investment has a greater positive effect on the total factor productivity than government or public R&D," the report said. "It is necessary to revitalize domestic R&D by strengthening tax support for large corporations that are leading the private sector R&D," it said.

https://m.koreaherald.com

R&D investment-to-sales ratio in semiconductor companies

The market research firm IC Insights said that the Republic of Korea's semiconductor companies' R&D investment was equivalent to 8.1 per cent of their sales last year, whereas the figure was 16.9 per cent, 12.7 per cent, 11.5 per cent and 11.3 per cent in the case of the U.S., Chinese, Japanese, and Taiwanese semiconductor companies, respectively. From 2011 to 2021, the annual R&D spending in the global semiconductor sector increased from $50.8 billion to $80.5 billion. U.S.-headquartered companies increased their R&D investment-to-sales ratio from 54.5 per cent to 55.8 per cent.

In non-Japan Asia, the ratio jumped from 18 per cent to 29.5 per cent in that period. The Republic of Korea's companies' R&D spending, $9.9 billion, accounted for 11.9 per cent of the global total in 2021. On the other hand, the ratios of the European and Japanese companies fell from 11.6 per cent and 15.9 per cent to 8.1 per cent and 6.6 per cent from 2011 to 2021, respectively. Still, the absolute amount of R&D investment of the companies in the industry in the Republic of Korea is relatively smaller. Intel's R&D investment amounted to $15.2 billion in 2020, when Taiwanese companies' was $11.7 billion.

http://www.businesskorea.co.kr

THAILAND

Digital economy

Thailand's Deputy Prime Minister and Chair of the DE Fund Executive Committee, General Prawit Wongsuwan, has set the direction of the country's Digital Economy and Society Development Fund (DE Fund) for 2023, with the goal of enhancing the Thai people's economic and social development capacity through digital technology. The DE Fund Management Committee acknowledged the Fund's performance, which can be carried out as planned because progress has been made and nearly 100 per cent of the money has been disbursed for projects funded from the Fiscal Year 2019 to date, particularly for projects funded in the Fiscal Year 2019.

The committee discussed and approved the Long-Term Action Plan (B.E. 2023-2027), which included the Fund's Operational Plan and Budget for the Fiscal Year 2023 as a guide for future operations. They have also collaborated on the creation of a general funding policy framework. The seven areas for the Fiscal Year 2023 are:

- Education for the new generation in the digital age
- Digital Government and Infrastructure
- Proactive Agriculture with Digital Innovation
- Digital Technology in the Future
- Health Technology
- Security in the digital world
- Digital environment saves

Thailand Smart City is utilizing innovative technologies to improve the efficiency and effectiveness of city management and services in seven areas: intelligent environment, intelligent economy, intelligent transportation, intelligent energy, intelligent citizens, intelligent living, and intelligent public administration.

The DE Fund is currently considering projects that request funding for the Fiscal Year 2022 under the cap of 2,500 million baht. After the proposal was closed, over 600 projects were submitted. The Fund has formed a working group of specialists from various sectors to select a digital development project that is compatible with the country's development context and can provide visible results. The outcomes of the annual sponsored projects will be made public on the Digital Economy and Society Development Fund's website.

https://opengovasia.com

Funding support key R&D projects

The Thai government is set to tap into the Global Partnership Fund and Competitiveness Fund as tools to draw foreign investments in high technology and targeted industries. Luxmon Attapich, advisor to the president of the Thailand Science Research and Innovation (TSRI), which

handles the Global Partnership Fund, recently discussed with the Board of Investment (BoI) using existing funds as a tool to draw foreign investments. The BoI agreed to use its Competitiveness Fund, worth 10 billion baht, to support the R&D projects that can be developed to commercial scale.

The Global Partnership Fund was established in 2020 to strengthen national science, research and innovation; create opportunities for the development of science, research, and the basic infrastructure of innovation; and support collaboration and networking between domestic and foreign research institutions.

The fund is supported by the government's annual budget through the TSRI, and is supervised by the National Higher Education Science, Research and Innovation Policy Council. It offers three main groups of projects—competitiveness enhancement, research excellence, and environment and sustainable development.

The TSRI plans to allocate 17.1 billion baht in the fiscal year 2023 to support R&D projects, an increase of 2.85 billion from 14.2 billion in the fiscal year 2022.

Thailand spent 193 billion baht on R&D in 2019, an increase of 5.9 per cent year-on-year. Of this amount, 23 per cent or 43.8 billion baht came from the government sector, while the private sector spent 77 per cent or 149 billion baht. The top three industries with the most R&D investment were food, petroleum, and finance and insurance. The government has a targeted spending on R&D to reach two per cent of the GDP in 2027.

https://www.bangkokpost.com

VIET NAM

IT, telecoms development trends

Cloud computing services, artificial intelligence (AI), the Internet of Things (IoT), 5G technology, fixed broadband internet, and blockchain technology are expected to lead the information technology and telecommunications sector in Viet Nam in the time ahead, according to a recent survey. The survey, conducted by the Vietnam Report JSC, revealed that technology companies are investing in core and fundamental technologies to serve digital transformation.

Cloud computing services in Viet Nam are forecast to develop with better security than physical servers, helping organizations and businesses increase productivity and save machinery and infrastructure expenses. The country's cloud computing market is predicted to grow by some 26 per cent annually, the fastest pace in Southeast Asia and much higher than the global average of 16 per cent.

Meanwhile, about 66.67 per cent of enterprises are applying AI to their digital transformation process. Capable of managing and optimizing infrastructure and customer support, AI is expected to access all businesses in the future. The survey also found that the rate of firms using the IoT in 2022 has reached 86.67 per cent, an increase from 66.67 per cent in 2021.

The 5G technology is also believed to be part of the IT and telecommunications sector's future. Its contribution to Viet Nam's GDP will reach 7.34 per cent by 2025 as projected by the Institute of Information and Communications Strategy under the Ministry of Information and Communications (MIC). The application of 5G services will help telecoms enterprises boost the use of AI and IoT in smart city building and business operations, and meet digital users' demand for high-definition videos, virtual reality, and augmented reality.

According to the MIC's Authority of Telecommunications, telecoms network infrastructure has been expanded to 100 per cent of communal-level localities. The 2G, 3G, and 4G mobile networks have covered 99.8 per cent of the population while 5G has been piloted in 16 provinces and cities.

By the end of 2021, there were nearly 71 million mobile broadband subscribers and 18.8 million fixed ones, respectively rising 4 per cent and 14.6 per cent from 2020. Internet traffic in Viet Nam also surged by over 40 per cent in 2020. The development of broadband networks is said to have created new spaces for businesses in the post-pandemic recovery period, especially opportunities for telecoms service suppliers to fuel growth in the future.

Regarding blockchain, this is a technology enabling safe transmission of data on the basis of a complicated data encoding system. It has developed beyond the financial and monetary sector to enter many different social aspects. Thanks to its development potential, blockchain is opening up chances for the technology - telecommunications industry, according to the report.

https://en.vietnamplus.vn

Vietnamese startups attract millions of US dollars

According to the Viet Nam Innovation and Technology Investment Report published by the National Innovation Center of the Ministry of Planning and Investment and Do Ventures, Viet Nam ranks third in Southeast Asia (after Singapore and Indonesia) in terms of the number of invested startup projects and the value of capital invested in start-ups.

In early 2022, many startups in Viet Nam also lured millions of US dollars from foreign funds.

SoBanHang: In March 2022, SoBanHang, a management application for small business households and online retailers, raised $2.5 million from FEBE Ventures, Class 5, Trihill Capital and others.

SoBanHang was developed by two brothers Bui Hai Nam and Bui Hai Long to help small businesses and business households create online stores and manage orders. Mr. Bui Hai Nam was once the CEO of Lazada Viet Nam, while his brother Bui Hai Long used to be the Chief Analyst and CTO of the supermarket chain Landers Superstore in the Philippines. The capital will help SoBanHang focus on products and develop new features to support sellers in a more comprehensive way.

Infina: In February 2022, Infina platform announced that it had successfully raised $ 6 million in a seed round

from six foreign investors, including Sequoia India's Surge program, Y Combinator incubator, Saison Capital Ventures, Starling Ventures, Alpha JWC, and AppWorks. Some of the other investors participating in this round have invested in similar startups and fintech models in other markets. Infina is an investment and accumulation platform focused on the Vietnamese market. Users have a wide range of investment options ranging from fixed income products to fund certificates, and stocks.

OpenCommerce Group: In late February 2022, cross-border e-commerce company OpenCommerce Group (OCG) announced it had raised $7 million in a Series A funding round. Headquartered in Hanoi with representative offices in San Francisco (USA) and Shenzhen (China), OCG provides whole-package support services for online sellers with low costs and limited risks. More than two years after its launch, the platform has helped more than 86,700 people from 195 countries do their e-commerce business globally, reaching $670 million in the GMV value. The company's technology ecosystem currently consists of three key products: ShopBase, PrintBase, and PlusBase.

Mio: In early 2022, Mio, an e-commerce platform announced via social networks, a funding of $8 million in the Series A round, bringing the total capital raised by the company since its establishment to $9.1 million. The new investors include Jungle Ventures, Patamar Capital, Oliver Jung, GGV, Venturra, Hustle Fund, iSEED SEA and Gokul Rajaram. Established in June 2020, Mio is a trading platform for buying and selling agricultural products and FMCG for tier two and three cities in Viet Nam. The criteria that the startup sets for commodity products on its platform are consistent quality, affordable price, and next-day delivery.

Timo: Timo digital bank in 2022 raised $20 million from Square Peg, an investment fund with experience in supporting and investing in Fintechs such as FinAccel and Airwallex, along with the participation of investment funds Jungle Ventures, Granite Oak, Phoenix Holdings, and other angel investors.

Established in 2015, Timo provides digital banking products related to payment and processing banking requests without the need for customers to visit physical branches. Users can even open a bank account without going to a bank for fulfilling the registration procedures. Notably, Tech in Asia says that Timo is aiming to be licensed as a digital bank in Viet Nam.

Jio Health: In early March 2022, Jio Health—a healthcare startup based in Viet Nam—announced the completion of a series B funding round worth $20 million led by Singapore-based investment fund Heritas Capital. Other investors include Fuchsia Ventures, Kasikorn Bank Group, and existing investor Monk's Hill Ventures.

Jio Health was founded in 2014 with the goal of using modern technology to provide affordable healthcare on demand. Through a smartphone application, this platform helps doctors and nurses to visit and care for patients more conveniently anytime and anywhere. The company currently has 150 general care providers on its platform.

https://vietnamnet.vn

ASIA-PACIFIC

AUSTRALIA

Solar-powered carbon capture systems

A technology has been developed by a carbon dioxide capture company called AspiraDAC, with its first customer, global financial infrastructure company Stripe. The first generation product was developed in collaboration with the University of Sydney. It will be followed by a second generation unit made by utilizing additive manufacturing processes.

When it comes to the engineering of the machine, it is built around a sponge-like substance produced at the University of Sydney that traps CO_2 molecules when air travels through it. Fans suck air into the sponge-filled canisters, and heat is used to extract pure CO_2, which **may be piped and stored underground**. The best feature of this technology is that the solar panels that cover the units like an A-frame tent provide all of the power.

https://interestingengineering.com

CHINA

Low-temperature ignition for diesel soot elimination

Using conductive metal oxides as catalysts, researchers have developed an electrification strategy aimed at decreasing the ignition temperature of soot. Relevant results were published in *Nature Catalysis*. This research was conducted by Prof. Zhang Jian's group at the Ningbo Institute of Materials Technology and Engineering (NIMTE) of the Chinese Academy of Sciences (CAS) and Prof. Zhang Zhaoliang's group of the Jinan University.

Catalytic soot combustion is the most efficient after-treatment technology for reducing diesel soot particulate emissions, which can trigger severe health and environmental problems. However, urban diesel vehicles idle frequently in traffic with exhaust temperatures reaching from 100°C to 200°C only, which is too low for catalytic soot combustion to occur. Aiming at realizing soot ignition at low temperatures, researches at NIMTE and Jinan University designed an electrification strategy for soot combustion. Typical conductive metal oxides with excellent oxidation resistance and conductivity were employed as catalysts.

According to the researchers, 53 per cent of the soot in the mixtures was combusted within only a few minutes at <75°C. The performance achieved was far superior to that achieved from a conventional thermal catalytic soot combustion, generally with T_{50} (the temperature at which 50 per cent of soot is converted) >300°C. Thus, the dependence of electrification on contact conditions is much weaker than that of a conventional thermal process.

In regard to energy demand, an electrification process consumes considerably less energy than a thermal process, with an energy-saving rate of one to two orders of magnitude. In addition, two key mechanisms for the performance were illuminated, electrically driven release of lattice oxygen from catalysts accounts for the rapid soot ignition at low temperatures, while the opposite electrostatic fluidization between the conductive catalyst and soot particles is responsible for the catalyst-soot contact efficiency improvement.

The electrification process has achieved a breakthrough in the ignition temperature for soot combustion, presenting a prospective strategy to solve the common issue of all automotive after-treatment at low exhaust temperatures. Promisingly, this strategy could be integrated into vehicle design, especially that of hybrid electric vehicles, by virtue of onboard electric power systems.

https://phys.org

INDIA

Environment-friendly fuel engine technology for vehicles

Researchers from the Indian Institute of Technology (IIT) Delhi's Department of Energy Science and Engineering (DESE), Indian Oil Corporation (IOC R&D), and Ashok Leyland Ltd. have developed a technology that enables a diesel-powered automotive vehicle to run in flex fuel mode, that is, either 100 per cent diesel or Dimethyl Ether (DME) plus Diesel mode. The project was funded by the Department of Science and Technology (DST). Using this technology, the researchers converted a diesel-powered automotive vehicle into a flex fuel vehicle on a pilot basis. This flex fuel technology-based vehicle DOST was jointly flagged off on 8 April 2022 at IIT Delhi by the officials. While the flex fuel engine technology that uses DME was developed by the IIT Delhi, the IOC R&D undertook the endurance and field trials tests and developed the dedicated engine oil with the technical support of Ashok Leyland.

The major highlights of the technology developed by the IIT Delhi, IOC R&D, and Ashok Leyland are:

- Flex Fuel Vehicle Technology (Vehicle can run both modes: either 100 per cent diesel or DME-Diesel mode)
- The transition of diesel trucks from conventional diesel to DME as an alternative fuel (First phase as Flex Fuel Vehicle; Second Phase as dedicated 100 per cent DME/alternative fuelled vehicle)
- Less or negligible smoke, soot, Particulate Matter (PM) emission
- Lower noise with smoother engine or vehicle operation
- Improvement in transient engine performance
- Enhancement of energy security
- Sustainable environment as there is a substantial reduction in Greenhouse Gas Emission

https://news.careers360.com

Material that can absorb greenhouse gas

Researchers at the Indian Institute of Chemical Technology (IICT), Hyderabad have computationally designed a hybrid material that can capture methane and also act as a catalyst to convert it to high purity hydrogen. The team has succeeded in computationally designing this hybrid material that can also simulate a process of capturing carbon dioxide in situ and convert it to high purity hydrogen from

non-fuel grade bioethanol. The team has developed a facility, where they can test this material and push for innovative technology in carbon capture.

The new facility developed by the researchers is a dual operational fixed cum fluidized bed reactor system (FBR) that can carry out enhanced steam methane reforming (SESMR) for high purity H2 production based on the modeling and preliminary experimental studies.

https://www.indiatoday.in

Converting CO_2 into eco-friendly methane

Indian scientists have developed an affordable metal-free catalyst that can convert carbon dioxide to methane by simply absorbing visible light. The research that's currently ongoing would help reduce CO_2 into value-added products like methane, where it can be used for clean fuel as well as applications in fuel cells as a hydrogen carrier.

CO_2 reduction can be done in a variety of ways such as photochemical, electrochemical, photoelectrochemical, photothermal etc. A photochemical process makes use of the solar energy as a renewable source. However, for a photo-catalyst to convert CO_2 into other applications, you need light-harvesting properties, charge carrier, separation proficiency, and the presence of a proper electronically aligned conduction band, so the endeavour to turn carbon dioxide into methane selectively and effectively is a challenging endeavour. Only some specific catalysts are able to do so and most of them contain metal counterparts that are toxic and expensive.

To overcome this, researchers from the Jawaharlal Nehru Centre for Advanced Scientific Research –an autonomous institute of the Department of Science and Technology, Government of India – have created a metal-free porous organic polymer that absorbs visible light to catalyze the CO_2 reduction reaction, turning it into methane.

They've developed a donor-acceptor assembly using a C-C coupling to form a stable conjugated microporous organic polymer, which was used as a heterogeneous catalyst. The keto group present in the phenanthraquinone moiety acted as a catalytic site in contrast with other conventional metal-based catalysts, where the metal counterpart carries out the CO_2 reduction reaction.

During a catalysis process, the first chemical dubbed conjugated microporous polymer could update carbon dioxide on its surface due to its high CO_2 intake capability at a room temperature and turn it into methane. The push-pull effect between the electron-rich donor and the electron-deficient acceptor caused efficient electron-hole separation, enhancing electron transfer kinetics and assisting in efficient catalysis.

https://www. indiatimes.com

CO_2 capture from power plants

The Indian Institute of Technology (IIT) Guwahati has partnered with National Thermal Power Corporation (NTPC) Limited to design and develop a highly energy-efficient plant for carbon dioxide capture from power plants. In a communiqué, the IIT Guwahati has stated that this technology, which works on flue gas using a newly activated amine solvent (IITGS), consumes up to 11 per cent less energy as compared to the commercial activated MDEA (Monoethanolamine) solvent, and up to 31 per cent less energy compared to the benchmark MEA (Monoethanolamine) solvent.

This indigenous technology was developed by a research team led by Bishnupada Mandal, from the Department of Chemical Engineering, IIT Guwahati. It has the potential to save a lot of foreign exchange for the nation. Bishnupada Mandal, Department of Chemical Engineering, IIT Guwahati, said, "The increase in anthropogenic CO_2 emissions is one of the reasons attributed to global warming. Extensive research efforts are being made by the scientific community to overcome this global challenge that includes modifications to existing technologies through efficiency improvement for CO_2 capture."

According to the IIT Guwahati, the outcomes of this project will benefit oil, natural gas, biogas industries, and petroleum refineries. This project, through its research and education, will support and strengthen the UNs Sustainable Development Goals (SDGs) as well. After the successful completion of test studies, the pilot plant has been shifted to NTPC's NTPC Energy Technology Research Alliance(NETRA) facility. The IIT Guwahati Team and the NTPC Limited are in the process of patenting the technology. This development has the potential to impact and combat global climate change. The next phase of the study will involve the testing of the pilot-pant using industrial flue gas.

The MEA and other proprietary solvent-based technologies are available for CO_2 capture in the chemical industry. This technology is utilized in coal and gas-fired power plants, mainly to produce food-grade CO_2 in small quantities (compared to CO_2 capture in power plants). However, the IIT Guwahati claims the process is energy-intensive, if adopted for large-scale CO_2 capture in power plants. It has developed an energy-efficient amine-based process for CO_2 capture from flue gas.

https://www.telegraphindia.com

JAPAN

Converting CO_2 to formic acid

The photoreduction of CO_2 into a transportable fuel like formic acid (HCOOH) is a great way of dealing with CO_2's rising levels in the atmosphere. To aid in this mission, a research team from Tokyo Tech chose an easily available iron-based mineral and loaded it onto an alumina support to develop a catalyst that can efficiently convert CO_2 into HCOOH with 90 per cent selectivity!

The scientists developed the photocatalytic systems that could reduce CO_2 with the aid of sunlight. Such a system consists of a light-absorbing substrate (i.e., a photosensitizer) and a catalyst that can enable the multi-electron transfers required to reduce CO_2 into HCOOH.

In a recent study published in *Angewandte Chemie*, the team adopted a simple impregnation method to synthesize their catalyst. They then used the iron-loaded Al_2O_3 material for photocatalytic reduction of CO_2 at room temperature in the presence of a ruthenium-based (Ru) photosensitizer, an electron donor, and a visible light of wavelength over 400 nanometer. The results were quite encouraging; their system showed 80-90 per cent selectivity towards the main product, HCOOH, and a quantum yield of 4.3 per cent (which indicates the system's efficiency).

This study presents a first-of-its-kind, iron-based solid catalyst that can generate HCOOH when accompanied by an effective photosensitizer. It also explores the importance of a proper support material (Al_2O_3) and its effect on the photochemical reduction reaction.

https://www.eurekalert.org

Carbon capture system claims 99 per cent efficiency in ambient air

Researchers from the Tokyo Metropolitan University have developed a new compound that can reportedly remove carbon dioxide from ambient air with 99 per cent efficiency and at least twice as fast as the existing systems.

The Direct air capture (DAC) technologies usually remove carbon dioxide by piping air or exhaust through some kind of filter or catalyst, including magnetic sponges, zeolite foam or materials made of clay or coffee grounds. Other carbon capture technologies bubble the air through a liquid, which can either absorb the CO_2 or cause it to separate out into solid crystals or flakes.

The new compound falls into the last category, which is known as liquid-solid phase separation systems. While studying a series of liquid amine compounds, the Tokyo Metro team discovered a compound called isophorone diamine (IPDA), which was particularly effective at capturing carbon dioxide.

In tests, the team found that the IPDA was able to remove more than 99 percent of CO_2 from the air with a concentration of 400 parts per million (ppm) – about the level currently in the atmosphere. This process also happened much faster than other carbon capture techniques, removing 201 millimoles of CO_2 per hour, per mole of the compound. That is at least twice as fast as the other DAC lab systems, and far faster than the leading artificial leaf device.

The pollutant separated out into flakes of a solid carbamic acid material, which could be removed from the liquid relatively easily. If need be, it can be converted back into gaseous CO_2 by heating it to 60 °C (140 °F), which also releases the original liquid IPDA ready for reuse. Whether the carbon is kept as a solid or a gas, it can still be stored or reused in industrial or chemical processes.

The new system shows promise but, of course, there is always the question of scale. Humanity belches about 30 billion tons of carbon dioxide into the atmosphere every year, and the world's largest direct air capture plant currently removes about 4,000 tons a year. It feels a little like bailing water out of a sinking ship with a shot glass. The researchers on the new study are now working on improving the system and investigating how the captured carbon could best be used.

https://newatlas.com

Recycling of CO_2 and drug development

Researchers at the Institute for Chemical Reaction Design and Discovery (ICReDD) at Hokkaido University have formulated a technique that has the potential to assist in the recycling of waste carbon dioxide (CO_2) while also creating molecules beneficial for drug development. The team guided by Professor Tsuyoshi Mita applied an electrochemical technique wherein an electron was incorporated into either the CO_2 molecule or to the other molecule in the solution, rendering it much easier for them to react with each other. This study marks a particularly huge breakthrough since CO_2 is used to conduct a traditionally challenging type of transformation with unparalleled efficiency. When the specific conditions are met, electrons can be shared between numbers of atoms in a molecule by what is known as an aromatic system.

These systems are particularly stable and hard to break, but the new technique formulated at ICReDD can dearomatize, or break these stable aromatic systems by incorporating CO_2 into the molecule using electricity. This method has the potential to recycle CO_2 as well as produce high value-added dicarboxylic acids from basic starting materials, solving two issues simultaneously.

Before the actual experiments, the researchers from the ICReDD screened numerous heteroaromatic compounds by assessing their reduction potentials, which is a measure of how a compound will react when exposed to an electric environment. The results allowed the scientists to detect potentially reactive compounds and perform targeted electrochemical experiments. They show that a wide range of substrates that display highly negative reduction potentials can very efficiently experience this extraordinary dearomative incorporation of two CO_2 molecules.

https://www. azocleantech.com

REPUBLIC OF KOREA

Low-temperature DeNOx catalyst for reducing emission

At the Extreme Materials Research Center, which is a part of the Korea Institute of Science and Technology(KIST), a research team of Dr. Kwon, Dong Wook, and Dr. Ha, Heon Phil announced the development of a high-durability low-temperature catalyst material for selective catalytic reduction (SCR); it can reduce NOx into water and nitrogen, which are harmless to the environment and the human body.

The team successfully developed a composite vanadium oxide-based catalyst material that significantly limited the formation of poisonous ammonium sulfate by suppressing the adsorption reaction between the active sites and sulfur dioxide. A catalyst interface engineering technique was used in which molybdenum and antimony oxides were added to the vanadium-based catalyst.

The developed vanadium oxide-based composite catalyst material has significantly increased catalytic life when exposed to sulfur dioxide at 220°C, with the time to reach 85 per cent of the initial performance delayed by about seven times as compared to that in a conventional catalyst. The developed catalyst is also energetically efficient due to increased low-temperature activity, which significantly lowers the burden of NOx treatment without reheating the exhaust gas. As a result, it is possible to reduce air pollutant treatment costs if the developed catalyst is applied to industrial sites in the future.

After completing the laboratory-scale reactor experiment, the team installed a pilot demonstration facility at the Kumho Petrochemical's Yeosu 2nd Energy Cogeneration Power Plant to test using actual flue gas. The KIST-Kumho Petrochemical team aims to establish plant facilities by 2022 after deriving an optimal operation plan by evaluating and verifying the driving variables of the demonstration facility for about ten months.

https://phys.org

SINGAPORE

Storing CO_2 below ocean floor sediments

Scientists from the National University of Singapore (NUS) Department of Chemical and Biomolecular Engineering have shown the first-ever experimental proof of the steadiness of CO_2 hydrates in oceanic sediments — a vital step in rendering this carbon storage technology a practical reality. The team's results — part of a project financially supported through the Singapore Energy Centre — were first reported in the scientific journal *Chemical Engineering Journal*.

Using a specially engineered laboratory reactor, the NUS researchers demonstrated that CO_2 hydrates can stay stable in oceanic sediments for up to 30 days. Soon, the team says, the same technique can be used to verify the stability of CO_2 hydrates for longer periods of time. At low-temperature and under high-pressure environments formed by the ocean, CO_2 can be stored within water molecules, creating an ice-like substance. These CO_2 hydrates develop at a temperature just above the freezing point of water and can store nearly 184 m^3 of CO_2 in 1 m^3 of hydrates. The presence of massive volumes of methane hydrates in similar sites globally and their safe existence offers a natural analogy to support the theory that CO_2 hydrates will stay stable and safe if deposited under deep-oceanic sediments. The researchers state that this technology could ultimately be transformed into a commercial-scale process, allowing nations like Singapore to efficiently sequester over two million tons of CO_2 per annum as hydrates to comply with the emission reduction targets.

Working with specially engineered equipment, Prof Linga and his team recreated the environments of the deep ocean floor, where temperatures range between 2 °C to 6 °C, and the pressures are 100 times greater than what is encountered at sea level. Developing a macro-scale reactor that could sustain such conditions was difficult and is one of the reasons why experiments to verify the stability of CO_2 hydrates were not formerly possible.

The NUS researchers surpassed this challenge using an in-house developed pressurized vessel, fitted with a silica sand bed, which mimicked ocean sediments. The researchers were able to create solid hydrates on top and within the silica sand bed, and modified the pressurized vessel to imitate the oceanic environment to view the stability of the formed solid CO_2 hydrates in sediments. Under pressurized settings, the hydrates were monitored for 14 to 30 days, and were found to exhibit a high level of stability.

This hydrate technology would enable nations to sequester large quantities of carbon emissions in deep-ocean geological formations on top of how it is presently stored in saline aquifer formations and depleted oil and gas reserves.

https:// www.azocleantech.com

EUROPE

AUSTRIA

Molybdenum, sulphur key to converting CO_2 into methanol

RResearchers at the Vienna University of Technology (TU Wien) have developed a solution that allows for the production of liquid methanol from carbon dioxide using a catalyst material made of sulphur and molybdenum. The new technology is already patented and in the process of being brought to an industrial scale, is meant to sequester CO_2 from the exhaust gas stream of large industrial plants.

"To convert carbon dioxide, catalysts based on copper have often been used so far," Karin Föttinger, one of the scientists involved in the project, said in a media statement. "However, they have the disadvantage that they are not robust. If there are certain other substances in the exhaust gas stream besides carbon dioxide, for example, sulphur, the catalyst quickly loses its activity. It is said that the catalyst is poisoned." Given this situation, Föttinger and her team set out to find a better material.

The group was able to show that catalysts based on sulphur and molybdenum fulfills these requirements. Special additional elements, such as manganese, ensure that carbon dioxide, which is actually very unreactive, is activated and converted. By choosing such additional elements, the properties of the catalysts can be precisely adapted to the desired area of application. In this way, methanol can now be produced from waste gases containing CO_2.

https://www.mining.com

DENMARK

Decarbonization technology for waste-to-energy plant

Danish researchers have demonstrated that it is possible to remove most of the carbon dioxide (CO_2) from the emissions of a waste incinerator, and by demonstrating the viability of the process, the researchers believe that they have developed a key technology in the fight against climate change. A pilot plant has been

operational in Copenhagen for several months and a novel gas monitoring technology has enabled the optimization of plant efficiency.

Researchers from the Technical University of Denmark (DTU) are, therefore, working with a highly innovative waste incineration plant in Copenhagen to develop a process, which will be able to capture carbon dioxide (CO_2) from its emissions. The project is utilizing advanced gas analyzers from the measurement product manufacturer Vaisala to measure the carbon capture efficiency and, therefore, carbon capture utilization and storage (CCUS) viability.

The researchers have developed a pilot plant to remove CO_2 from the emissions of the incinerator at the Amager Bakke Waste-to-Energy Plant, which is one of the largest combined heat and power (CHP) plants in the northern Europe, with the capacity to treat 560,000 tonnes of waste annually. Developed by the Copenhagen-based waste management company ARC (Amager Ressourcecenter), which is jointly owned by five Copenhagen-area municipalities, the CHP plant features a number of innovations including a rooftop artificial ski slope, which is a part of an outdoor activity centre known as CopenHill.

The pilot plant was developed to capture CO_2 from the emissions of processes such as wastewater treatment, biogas production, anaerobic digestion, and waste incineration. However, the researchers are also investigating the ways in which CO_2 can be both captured and utilized. Prior to its installation at the Amager Bakke, the pilot carbon capture plant was operated at a wastewater treatment plant. "The technology itself is not new," explained Jens Jørsboe, a researcher from the DTU, "However, the focus of our work has been to lower the cost of carbon capture, so that it can become economically feasible."

Exhaust gas from the Amager Bakke incinerator is passed through an electrostatic precipitator (ESP) to remove particulates, nitrous oxide (NOx) compounds are removed by selective catalytic reduction (SCR), and a scrubber removes oxides of sulfur. High levels of CO_2 remain in the flue gas and the main purpose of the pilot carbon capture plant is to investigate the feasibility of its capture. To achieve this, the gas is passed upwards through a column packed with beads and a monoethanolamine (MEA) solvent which scrubs the CO_2 from the gas. The solvent is then passed to a desorber, which removes the CO_2, which is now almost pure, and regenerates the MEA for re-use. As a research project the produced CO_2 is currently still vented to the air; but on a commercial basis, there are many different industrial applications, in which CO_2 can be utilized. For example, CO_2 can be reacted with hydrogen in the Sabatier process to produce methane (a gas fuel) and water, at an elevated temperature and pressure, in the presence of a nickel catalyst. This can be a green method for manufacturing fuel if the hydrogen is generated by electrolysis using renewable energy – from solar, biogas, or wind power for example.

https://www.gasworld.com

NETHERLANDS

Prototype EV scrubs CO_2 from air

A student team from the Eindhoven University of Technology has built a prototype electric passenger car that removes and stores carbon dioxide from the air as it rolls down the roads, with the aim of capturing more CO_2 than is emitted during a full lifecycle of a vehicle. The project is the seventh for the TU/ecomotive students, following 2018's Noah concept and the Luca from 2020. The challenge for the Zem (EM-07) team was to build a carbon net-zero electric vehicle.

The team created a monocoque and body panels using additive manufacturing techniques to reduce material waste and produce "as little CO_2 emissions as possible," while also making use of recycled plastics, which can be shredded and re-used for other projects. The use of recycled plastics continues inside, along with sustainable materials like pineapple leather. Polycarbonate is the material of choice for the windows instead of glass, which the team says is better for the environment. And a modular infotainment system, modular electronics, and modular lighting were installed as well, which can all be reused in other products.

The fact that the Zem is an electric vehicle means that zero carbon dioxide is emitted while it's being driven around. As the focus of this project was the car's carbon footprint and recyclability, the details on the drivetrain are scant but the students have mentioned that there are nine 2.3-kWh modular battery packs installed, there's a 22-kW motor, and there's "an old Audi differential with a relatively high gear ratio to increase the torque.

What looks like a fairly standard grille to the front actually flows to the direct air capture technology – for which the students are seeking a patent – that scrubs the air as the vehicle moves along. The team claims that up to two kg of CO_2 could be removed for every 20,600 km (12,800 miles) traveled per year at around 60 km/h (37 mph). Though this isn't a great deal on its own, if the technology were to be rolled out to the millions of cars on the road around the world, then it has the potential to make a real contribution to the decarbonization efforts.

The Zem's filter currently fills to capacity after 320 km (200 miles), and the thinking is that such filters could be cleaned using green energy and the captured CO_2 stored in a tank as an EV is topped up at charging stations, and then reused to capture the next batch. What happens to the captured CO_2 after drop-off isn't clear – though we have seen some interesting projects recently that show potentials in dealing with such things, including using captured CO_2 to make more eco-friendly concrete, creating synthetic fuels and plastics from simple chemical building blocks and even putting the fizz in bubbly water.

https://newatlas.com

UK

Supercapacitor device helps reduce CO_2 emissions

Scientists have built a low-cost device capable of selectively capturing carbon

dioxide gas while charging. When it ejects, the CO_2 can be distributed in a controlled manner and accumulated to be reused or disposed of. A supercapacitor device is the size of a two-pence coin and is created in part from sustainable materials such as coconut shells and seawater.

The supercapacitor, developed by scientists at the University of Cambridge, could help fuel carbon capture and storage innovations at a much cheaper price. Every year, approximately 35 billion tons of CO_2 are discharged into the air, and the alternatives to avoid these emissions and resolve the climate crisis are desperately needed. The most sophisticated carbon capture technologies are currently energy-intensive and costly.

A supercapacitor is made up of two electrodes, one positive and one negative in charge. The group tried interchanging from a negative to a positive voltage to broaden the charging time from previous trials in works led by Trevor Binford. This increased the ability of a supercapacitor to capture carbon.

The results are reported in the journal *Nanoscale*.

https://www.azom.com

NORTH AMERICA

USA

Technology to reduce heavy-duty diesel emissions

The Southwest Research Institute (SwRI®) demonstrated the effectiveness of its patented and award-winning Catalyzed Diesel Exhaust Fluid (CAT-DEF™) technology during the WCX™ World Congress Experience in Detroit, which took place from 5 to 7 April. The internally funded advancement successfully reduced the heavy-duty diesel engines' nitrogen oxide (NOx) emissions to meet the California Air Resources Board (CARB) 2027 standards.

CAT-DEF, which stands for Catalyzed Diesel Exhaust Fluid, is an SwRI-developed catalyst- and surfactant-modified diesel exhaust fluid (DEF) solution. Today's diesel engines use selective catalytic reduction (SCR), an advanced emissions control system, to abate NOx emissions. The DEF is injected into the exhaust stream and ideally decomposes to form ammonia, which reacts with NOx on the SCR catalyst to form N_2 and H_2O.

Although the current process is relatively efficient at temperatures greater than 250°C, at temperatures below 250°C, the urea-derived deposits form within the after-treatment system. These deposits severely limit low-temperature NOx conversion and increases fuel consumption as high-temperature engine operations are required to remove the deposits. The SwRI's novel technology decreases the NOx and carbon dioxide emissions for diesel engines by significantly reducing the undesirable deposit formations in exhaust systems.

"Although DEF technology has been utilized for more than a decade, the highest emissions control efficiencies could never be realized due to DEF's tendency to create potentially harmful deposits in the exhaust system, particularly when the engine is operated at low loads and temperatures," said Dr. Charles E. Roberts Jr., the director of SwRI's Commercial Vehicle Systems Department. "A combination of surface-active agents and heterogenous catalysts blended into CAT-DEF reduces deposits by 90% with potential reductions up to 98%."

Using internal fundings, the SwRI engineers studied the technology's effectiveness for reducing NOx emissions at the new standards set by CARB – known for enacting stricter standards than the Environmental Protection Agency – through a head-to-head comparison of diesel engines operated with and without the CAT-DEF.

https://www.eurekalert.org

Carbon capture technology to remove 99 per cent of CO_2 from air

The University of Delaware engineers have demonstrated a way to effectively capture 99 per cent of carbon dioxide from air using a novel electrochemical system powered by hydrogen. It is a significant advance for carbon dioxide capture and could bring more environmentally friendly fuel cells closer to the market. The research team, led by UD Professor Yushan Yan, reported their method in *Nature Energy*.

Fuel cells work by converting fuel chemical energy directly into electricity. They can be used in transportation for things like hybrid or zero-emission vehicles. Yushan Yan, the Henry Belin du Pont Chair in Chemical and Biomolecular Engineering, has been working for some time to improve hydroxide exchange membrane (HEM) fuel cells, an economical and environmentally friendly alternative to traditional acid-based fuel cells used today. But HEM fuel cells have a shortcoming that has kept them off the road – they are extremely sensitive to carbon dioxide in the air. Essentially, the carbon dioxide makes it hard for an HEM fuel cell to breathe. This defect quickly reduces a fuel cell's performance and efficiency by up to 20 per cent, rendering the fuel cell no better than a gasoline engine. Yan's research group has been searching for a workaround for this carbon dioxide conundrum for over 15 years.

The research team's results showed that an electrochemical cell measuring two inches by two inches could continuously remove about 99 per cent of the carbon dioxide found in air flowing at a rate of approximately two liters per minute. An early prototype spiral device about the size of a 12-ounce soda can is capable of filtering 10 liters of air per minute and scrubbing out 98 per cent of the carbon dioxide, the researchers said.

Scaled for an automotive application, the device would be roughly the size of a gallon of milk, Setzer said, but the device could be used to remove carbon dioxide elsewhere, too. For example, the UD-patented technology could enable lighter, more efficient carbon dioxide removal devices in spacecraft or submarines, where ongoing filtration is critical.

https://scitechdaily.com

New Catalyst Could Clean Natural Gas Engine Emissions

A newly developed catalyst with a unique, atomic-sized "rafts" does a better job than the current technologies for cleaning up emissions from natural gas engines. Natural gas-powered technologies might become cleaner and more practical for trucks, off-road vehicles, and equipment powertrains as a result of the research, which was published in *Nature Catalysis*. Researchers created palladium (Pd) oxide catalyst "rafts" that are bound together by single platinum atoms. Their catalyst cleans up natural gas and makes the catalytic process more tolerant of water vapor, lowering the quantity of unburned methane released.

While natural gas engines produce roughly 25 per cent less carbon dioxide and particle pollution than gasoline or diesel engines, they still emit unburned methane because their exhaust emission's catalytic converters are inefficient at low temperatures. This new technology was shown to operate at ahigher reaction rates than the existing technologies.

"The improvements in energy efficiency have to go hand in hand with the aftertreatment technologies," said Yong Wang, the Voiland Distinguished Professor at the Washington State University's (WSU) Gene and Linda Voiland School of Chemical Engineering and Bioengineering. He is also one of the paper's corresponding authors. "Currently, combustion from methane to generate power is not able to use the most efficient combustion technology. So it works, but there is room for further improvement in that efficiency."

The researchers from the WSU and the University of New Mexico (UNM) headed the team, which included partners from the United States, the European Union, and China. While not as widely used in the U.S., natural gas engines are commonly used in vehicles worldwide, especially in China, Iran, and India. Because they're less polluting than diesel engines, they are often used in trucks and buses in urban areas. Natural gas-powered engines are also used in the gas industry to run thousands of compressors that pump natural gas to people's homes.

However, these natural gas-powered vehicles emit unburnt methane because their exhaust emission's catalytic converters are not efficient at low temperatures. The more efficiently the engines work and the cleaner they burn, the lower the exhaust temperatures become, and the poorer the catalysts perform at cleaning up pollutants. Unburnt methane from an engine, in particular, is a potent greenhouse gas that is about 25 times worse than carbon dioxide, contributing to climate change.

Furthermore, one of the byproducts of methane combustion is water, and the conventional catalysts are "notoriously bad" when it comes to working in the presence of water, said Wang. The cleaner-burning fuel ends up working against itself in removing pollutants. Compared to the typically used catalysts made of Pd oxide nanoparticles, the rafts that the researchers developed provided better tolerance to water vapor with improved reactivity.

"The strongly bound platinum (Pt) can serve as a nucleation site for added metal atoms," said Abhaya K. Datye, a professor in the UNM's Department of Chemical and Biological Engineering and one of the corresponding authors of this study. "Using trapped Pt atoms, we were able to demonstrate the formation of Pt as well as Pd oxide two-dimensional rafts which modify the oxidation state and reactivity of the active phase."

"Our theory calculations suggested that the raft does not readily dissociate water, thus inhibiting the adverse effects of water poisoning in the catalysis of methane oxidation," said Hua Guo, a professor in the UNM Department of Chemistry and Chemical Biology.

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Catalyst that can turn carbon dioxide into gasoline

A new catalyst, invented by Matteo Cargnello, a chemical engineer at Stanford University and his colleagues, moves toward this goal by increasing the production of long-chain hydrocarbons in chemical reactions. It produced 1,000 times more butane – the longest hydrocarbon it could produce under its maximum pressure – than the standard catalysts given the same amounts of carbon dioxide, hydrogen, catalyst, pressure, heat and time. The new catalyst is composed of the element ruthenium – a rare transition metal belonging to the platinum group – coated in a thin layer of plastic. Like any catalyst, this invention speeds up chemical reactions without getting used up in the process. Ruthenium also has the advantage of being less expensive than other high-quality catalysts, like palladium and platinum.

Cargnello and his team describe the catalyst and the results of their experiments in their latest paper, published in the journal *Proceedings of the National Academy of Sciences*. Cargnello and his team took seven years to discover and perfect the new catalyst. The hitch: The longer the hydrocarbon chain is, the more difficult it is to produce. The bonding of carbon to carbon requires heat and great pressure, making the process expensive and energy intensive.

In this regard, the ability of the new catalyst to produce gasoline from the reaction is a breakthrough, said Cargnello. The reactors in his lab would need only greater pressure to produce all the long-chain hydrocarbons for gasoline, and they are in the process of building a higher pressure reactor.

https://news.stanford.edu

Scrubbing carbon dioxide from factory emissions

Carbon dioxide can be harvested from smokestacks and used to create commercially valuable chemicals thanks to a novel compound developed by a scientific collaboration led by an Oregon State University (OSU) researcher. Published in the *Journal of Materials Chemistry A*, the study shows that the new metal organic framework, loaded with a common industrial chemical, propylene oxide, can catalyze the production of cyclic carbonates while scrubbing CO_2 from factory flue gases. The new, three-dimensional,

lanthanide-based metal organic framework, or MOF, can also be used to catalyze cyclic carbonate production from biogas, a mix of carbon dioxide, methane and other gases arising from the decomposition of organic matter.

"We've taken a big step toward solving a crucial challenge associated with the hoped-for circular carbon economy by developing an effective catalyst," said chemistry researcher Kyriakos Stylianou of the the OSU College of Science, who led the study. "A key to that is understanding the molecular interactions between the active sites in MOFs with potentially reactive molecules."

An MOF is an inorganic-organic hybrid, a crystalline porous material made up of positively charged metal ions surrounded by organic "linker" molecules, in this case lanthanide metals and tetracarboxylate linkers. The metal ions make nodes that bind the linkers' arms to form a repeating structure that looks something like a cage; the structure has nanosized pores that adsorb gases, similar to a sponge. The MOFs can be designed with a variety of components, which determine an MOF's properties.

Lanthanide-based materials are generally stable because of the relatively large size of lanthanide ions, Stylianou said, and this is true with lanthanide MOFs as well, where the acidic metals form strong bonds with the linkers, keeping the MOFs stable in water and at high temperatures. This is important because the flue gases and biogas are hot as well as moisture rich. The lanthanide MOFs are also selective for carbon dioxide, meaning they're not bothered by the presence of the other gases contained by industrial emissions and biogas.

"We observed that within the pores, propylene oxide can directly bind to the cerium centers and activate interactions for the cycloaddition of carbon dioxide," Stylianou said. "Using our MOFs, stable after multiple cycles of carbon dioxide capture and conversion, we describe the fixation of carbon dioxide into the propylene oxide's epoxy ring for the production of cyclic carbonates." Cyclic carbonates have a broad range of industrial applications, including polar solvents, precursors for polycarbonate materials such as eyeglass lenses and digital discs, electrolytes in lithium batteries, and precursors for pharmaceuticals.

https://www.google.com/phys.org

Polymer membrane improves efficiency of carbon dioxide capture

Researchers have developed a new membrane technology that allows for more efficient removal of carbon dioxide (CO_2) from mixed gases, such as emissions from power plants. "To demonstrate the capability of our new membranes, we looked at mixtures of CO_2 and nitrogen, because CO_2/nitrogen dioxide mixtures are particularly relevant in the context of reducing greenhouse gas emissions from power plants," says Rich Spontak, co-corresponding author of a paper on the work. "And we've demonstrated that we can vastly improve the selectivity of membranes to remove CO_2 while retaining relatively high CO_2 permeability."

"We also looked at mixtures of CO_2 and methane, which is important to the natural gas industry," says Spontak, who is a Distinguished Professor of Chemical and Biomolecular Engineering and a Professor of Materials Science & Engineering at the North Carolina State University. "In addition, these CO_2-filtering membranes can be used in any situation in which one needs to remove CO_2 from mixed gases – whether it's a biomedical application or scrubbing CO_2 from the air in a submarine."

The research team, from the U.S. and Norway, addressed this problem by growing chemically active polymer chains that are both hydrophilic and CO_2-philic on the surface of existing membranes. This increases the CO_2 selectivity and causes relatively little reduction in permeability.

"In short, with little change in permeability, we've demonstrated that we can increase selectivity by as much as about 150 times," says Marius Sandru, co-corresponding author of the paper and senior research scientist at SINTEF Industry, an independent research organization in Norway. "So we're capturing much more CO_2, relative to the other species in gas mixtures."

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Air pollution control in the Republic of Korea

Enabling Technology and Regulatory Policies to Support SMEs

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Abstract

Air pollution is a serious issue that has major detrimental impacts on people's health and quality of life. Effectively addressing air pollution is complex due to the variety of pollutants' sources, the complexity of measurement and oversight, as well as the need to not place unreasonable burdens on businesses. To effectively reduce air pollution and its origins, governments must enact and enforce enabling technologies and regulatory policies, which will correctly incentivise and support small and medium-sized enterprises (SMEs) in their efforts to reduce their emissions of air pollutants. This article provides an overview of the recent air pollution trends and the policies in the Republic of Korea, and the practical steps the government has taken, focusing on technology and regulatory policies that assist SMEs in decreasing their emissions, and discusses the enabling policies that support air pollution reduction by SMEs.

Introduction

Air pollution is the biggest environmental risk to human health, and annually, it causes about one in every nine deaths. Air pollution is estimated to cause around seven million premature deaths annually through diseases such as lung cancer, respiratory diseases, heart diseases, and strokes, with 4.2 million of these premature deaths each year due to outdoor air pollution (WHO, 2016). Air pollution also impacts people's health indirectly as people spend less time outdoors, or exercise less when the pollution levels are high. Air pollution has even been found to threaten the mental health of individuals living in areas with high concentration of air pollutant particulates (Yang et al., 2021). Nine out of ten people reside in areas that exceed the WHO recommended guideline limits of air pollutant levels and is particularly severe in some of the world's fastest-growing urban areas. Although some air pollution is a result of naturally occurring events such as volcanic activities or airstream movement of sand particles, human activity is the predominant cause of air pollution, primarily through the burning of fossil fuels.

As Asia undergoes rapid economic development, air pollution levels have also risen, with 70% of the global air pollution related deaths now occurring in the Asia Pacific region (UNEP, 2022). In 2016, the welfare losses in South Asia was the equivalent of 7.4% of the region's gross domestic product (GDP), and in East Asia and the Pacific, the equivalent welfare loss was 7.5% of the regional GDP (World Bank Group & IHME, 2016). The enhancement of air quality has a major potential to greatly improve the wellbeing of millions of people residing in Asia and the Pacific region. The decoupling of air pollution and other environmental damages, such as climate change from economic growth is vital to ensure long-term prosperity and quality of life for all. The failure to achieve this will result in continued massive detrimental impacts, which will undermine sustainable development growth pathways. Even though air pollution is a multifaceted problem, and is difficult to effectively address due to the variety of the sources of the pollutants, based on the complexity of measurement and oversight, as well as the regionality dimension of the issue, decisive actions must be taken.

This article provides an overview of recent air pollution trends and the policies in the Republic of Korea, and the practical steps the government has taken to address the problem. It aims to provide insights for the executives of small and medium scale enterprises (SMEs), as well as the government decision makers, on the types of policies that help create an enabling environment to reduce air pollution without placing unreasonable burdens on businesses. By outlining technology trends, successful regulatory management practices and disseminating useful information regarding air pollutant reduction policies and methods, this article seeks to contribute to overcoming the serious issue of air pollution through mutually beneficial engagements with the SMEs.

Air pollution in the Republic of Korea

The Republic of Korea faces some of the highest level of air pollution in the Organization for Economic Co-operation and Development (OECD) and the total deaths due to air pollution has been estimated to be about 40,000 per year (Farrow et al., 2020). Improving the air quality has emerged as a major national priority, with increasing numbers of citizens demanding urgent action to reduce air pollution levels and the exposure of vulnerable groups such as children and the elderly. The negative effects of air pollution in the Republic of Korea are likely to become more severe in the future as the country has a rapidly aging population. The Republic of Korea currently has the lowest birth-rate in the world, with its fertility rate falling to 0.81 in 2021. By the year 2050, the population aged 50 or older is forecasted to be almost 60% of the population, and the population aged 70 or older is forecasted to be over 30% (UN, 2022). Older people are more vulnerable to diseases caused by air pollution, such as strokes, heart disease, lung

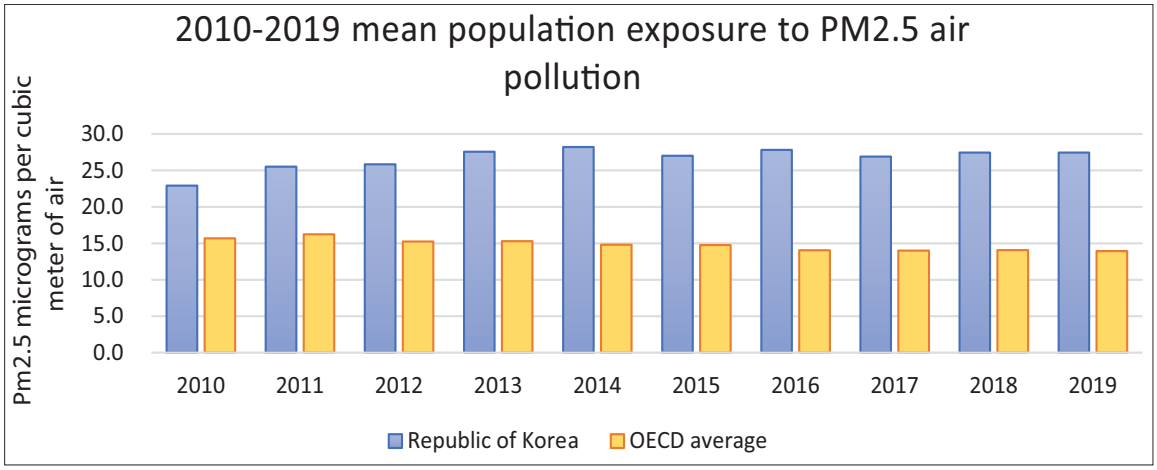


Figure 1: 2010-2019 mean population exposure to PM2.5 air pollution (OECD, 2022)

cancer and respiratory diseases. Increasing urbanization will also increase the severity of the air pollution's negative impacts as air quality tends to be lower in cities. In 2021, 81.4% of the Republic of Korea's population lived in urban areas, and by 2050 this figure is expected to rise to 86.4%.

Policy changes to address air pollution

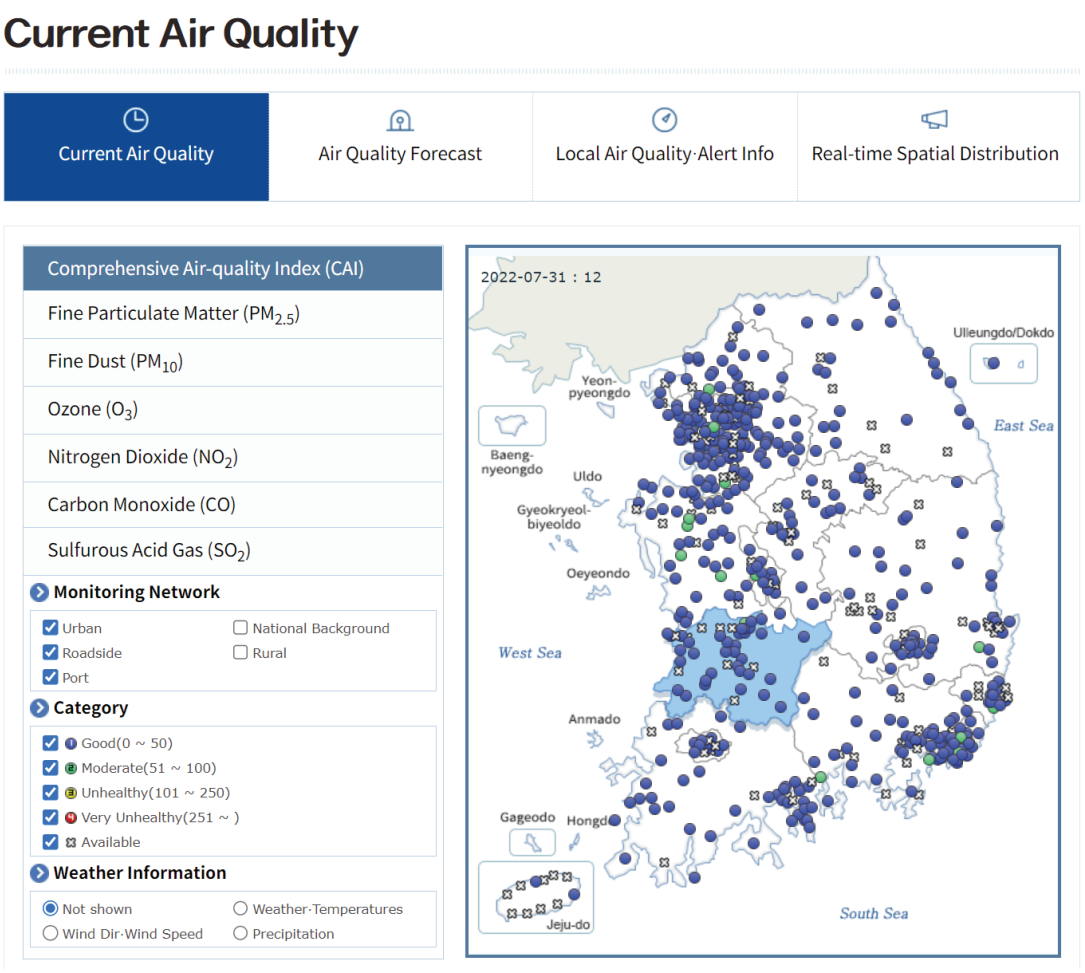
The government of the Republic of Korea has enacted a diverse range of policy measures to address air pollution. The country operates an Air Pollutant Emission-Cap Management System, which sets a maximum quantity of air pollutants to be emitted annually in each area. In cases of a business exceeding their assigned limit, a charge is levied and if a business's emissions are below their allocation, the remainder may be transferred to alternative sites of business or the unused allocation can be saved until the next year (KECO, 2022). The Republic of Korea also introduced increased support for early scrapping for old diesel vehicles and limitations on the areas where they are allowed to drive as a part of a policy to phase-out such vehicles (Ministry of Environment, 2018). This supported the uptake of newer lower emission vehicles such as those powered by electricity or liquefied petroleum gas (LPG).

In 2019, the government designated low air quality as a social disaster and established The National Council on Climate and Air Quality (NCCA), which was chaired by former diplomat and United National Secretary-General Ban Ki-moon (Office of the President, 2019). The NCCA's first focused on taking immediate actions that could bring near instantaneous benefits. In the second stage of its operation, the council began evaluating longer horizon solutions to address the problem, considering policy options that require medium-to-long-term discussions and planning (Jung, 2019). The council carried out seasonal management measures to significantly reduce the air pollution levels during periods of severely low air quality, such as from March to May in which the air quality levels are particularly low mainly due to air currents transporting pollutants from China to the Korean peninsula. The NCCA also fulfilled a vital role in carrying out polices that were led by engagements with the general public, as citizens presented their perspectives through the discussions of the national policy participation group. This helped in deciding the policies and the implementations to be made in accordance with the public consensus. The NCCA broadly succeeded in achieving its stated objectives and helped to boost national air quality with its seasonal monitoring system, which enabled the central government to enforce more stringent air pollutant emission limits during periods of elevated air pollutant concentration. The NCCA was terminated in April 2021, having completed its term limit of two years.

The government of the Republic of Korea has also taken active steps to raise awareness and transparency regarding air quality levels. Public awareness and understanding helps in promoting a cleaner environment and enhances the trust of the public in the responses of the government's policy. The Real-Time Air Quality information portal operated by Air Korea provides data on nationwide outdoor air quality nationwide, displaying data in an easy-to-understand way. The portal promotes the safety and health of Korea's citizens by informing the public when the outdoor air pollution is dangerously high, so that they can refrain from outdoor activities. It additionally helps citizens comprehend the impact of long-term policy changes on air quality levels. The National Air Emission Inventory and Research Center (NAIR) was also established with the goals of intensifying research and internal and external collaboration, communication, and organizational capabilities, and building expertise (NAIR, 2022).

Electricity generation sector

The electricity generation sector in the Republic of Korea uses the biggest amount of fossil fuels, and thus is the largest domestic source of air pollutants. For the dual objectives of reducing air pollution and mitigating climate change, the Republic of Korea has been taking



Source: Air Korea https://airkorea.or.kr/eng/currentAirQuality?pMENU_NO=68

Figure 2: Air Korea Real-Time Air Quality information portal.

measures to expand its renewable electricity generation capacity as an alternative to the consumption of fossil fuels. Over the past five years, the gross renewable electricity generation has increased from 27,928 gigawatt hours (GWh) in 2017 to 39,102 GWh in 2021, which is an increase of 40% (KEPCO, 2022). Despite this major increase, renewable energy stills makes up a small portion of the total electricity generated, under 7% of total GWh generated in 2021. Coal remains the largest source of electricity followed by liquefied natural gas (LNG) and nuclear energy (primarily from pressurized water reactors). The Republic of Korea has gradually strengthened the production and performance standards of its coal power plants and promoted technological or process changes to lesson air pollution from coal powered electricity generating stations. This has resulted in the coal power plants installing flue gas desulphurization and other emission control technologies, which have reduced their emissions (UNEP, 2019). The government also reviewed and modified the tax system for fossil fuels used to generate electricity, raising the tax on the use of coal and lowering the tax on the use liquefied natural gas (LNG). This positively altered the incentive structure of electricity generating plants, encouraging the electricity generating plants to use more LNG as an alternative to coal, resulting in air pollutants being emitted from the energy sector. Despite these policy changes and the use new technologies, coal power plants are still major sources of local pollution, therefore, during periods of high air pollution, such as in the early spring period, the operations of coal power plants are reduced.

The changes of policy directions between the different administrations has added an increased uncertainty to the energy sector and its emissions, as different Presidents aim to move the electricity sector in divergent directions during their five-year terms. For example, the previous Moon Jae-in stated its goal to phase out nuclear power and closed some nuclear power plants ahead of schedule, but the newly elected Yoon Suk-Yeol administration is seeking to increase the use of nuclear power domestically, as well as expand the exports of the nuclear power related supplies, and increase the nuclear plant projects overseas. A greater policy consistency across different administrations would help the Republic of Korea meet its air pollution and climate change mitigation targets.

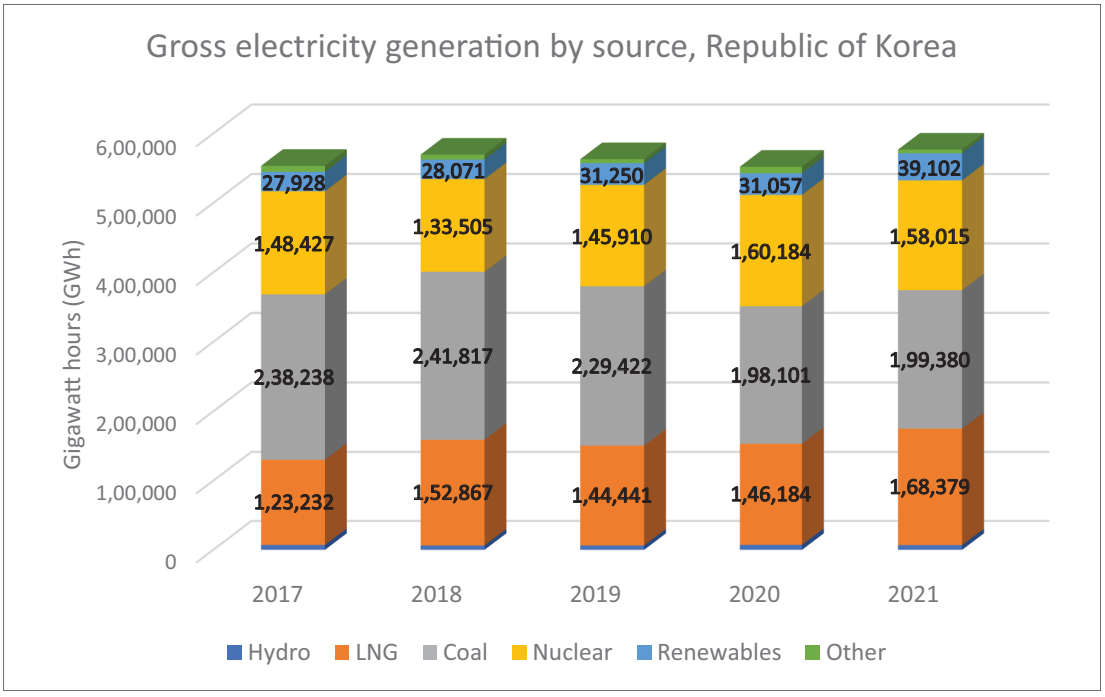


Figure 3: Gross electricity generation by source in the Republic of Korea, 2017-2021.

Small and medium-sized enterprises (SMEs)

The government of the Republic of Korea has taken active steps to decrease air pollutant emissions from businesses of all sizes. Larger companies received more direct supervision as they account for almost 65% of emissions, but the government also undertook a diverse range of measures to assist SMEs reduce their emissions as well. The number of inspection teams has risen greatly, with particular attention given to enterprises that are based in urban areas. Financial support for SMEs to support them in reducing their air pollutant emissions was made available through expanded regional and local public sector budgets. A heightened financial support for SMEs with yearly air pollutant emissions lower than ten tonnes was provided. For the installation of equipment and facilities that reduce air pollution, SMEs may be eligible and apply for "Environmental Improvement Loans" (Ministry of Environment 2018). These low-interest loans of up to five billion Korean won (about 3.8 million USD) are to be repaid to the Ministry of Environment over four years at a fixed interest rate, with a three-year grace period to ensure that the loan payments are not too cumbersome for the enterprises. This funding allowed businesses to take practical action to reduce their air pollution impact, which would not have been possible due to their financial constraints. From 2021, a more stringent exhaust inspection system was also carried out. The scope of a regular inspection for diesel vehicles was expanded to include more diverse types and classification of vehicles emitting gases such nitrogen oxides. Targeted loans and funding for the installation of catalytic converters in vehicles used by SMEs such as trucks, cars, and forklifts, as well as for electrical generators used on business sites, made emission reduction possible in a way that was mutually beneficial for both the SME owners as well as the overall welfare of the society.

Expert help of professionals were made available to the SMEs to assist them in reducing their air pollutant emissions. Local governments worked with the experts from the Korea Environment Corporation (KECO), the Korea Environmental Industry and Technology Institute (KEITI), and the National Institute of Environmental Research (NIER), to create teams to give information, advice, and technical support to SMEs. These teams were designed according to industry type to ensure that had the best knowledge and approach in assisting the SMEs. This customization enabled credible engagement between the public and the private sectors as the teams had deep understanding of the enterprises they were issuing support to. The expert advice and technical support focused on pragmatic and realistic steps that the SMEs could take to reduce air pollution from their production and operational processes. The overall reduction strategies by industry type plans were devised, taking into consideration the unique characteristics of the industry type. Information and guidance were also provided to the SMEs regarding purchasing options of new vehicles and equipment, which emit fewer pollutants or none at all. The use of hybrid and electric cars was expanded through tax structures, which subsidized the purchase of environmentally friendly options.

Transparency is a vital factor in the creation and implementation of successful policies to address air pollution. In the context of

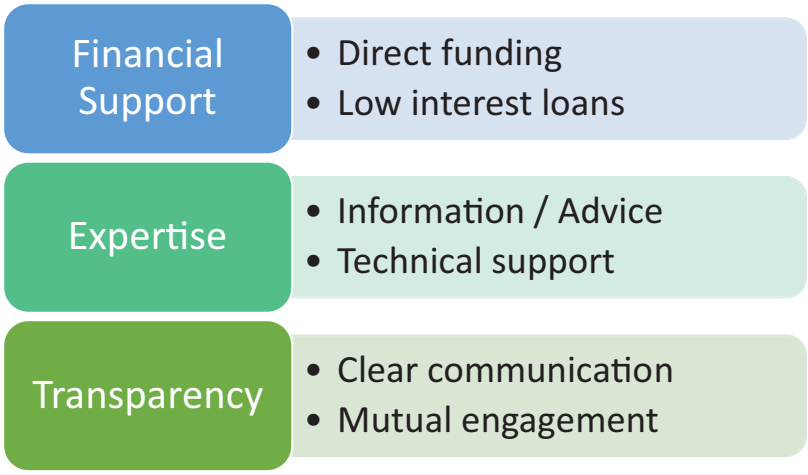


Figure 4: The three pillars for successfully assisting SMEs reduce air pollution.

the Republic of Korea, the authorities attempted to make their intentions and requirements of the businesses clear from an early stage, so that enterprise operators had a clear understanding of what was expected of them and what supports they could avail. Periodic evaluations of the enactment of the created reduction plans take place to ensure that the reduction plans are working effectively and being engaged with by businesses. Information regarding the basic charges and the required standards were communicated well in advance of enforcement to give SMEs a clear timeline of the regulatory changes. Real-time disclosure of the results of inspections began in December 2019 to enhance openness and public trust in regulatory procedures. To increase the overall credibility of the environmental regulatory frameworks, the authorities addressed the oversight blind spots in areas such as construction sites and prohibited incinerations.

There are various obstacles still present in the Republic of Korea that bars SMEs from effectively reducing their negative environmental impacts. While many processes and procedures have been simplified and streamlined, significant bureaucratic hurdles still remain for SMEs in relation to the environmental regulation compliances. Due to their limited technical and human resource capacity, the administrative burden of current issue-specific permits is still relatively high for SMEs in the Republic of Korea, therefore, to address this the authorities are considering replacing multiple permits with general binding rules according to an SME's sector. Sector specific general binding rules have been utilized in many OECD countries to make compliances more straightforward for SMEs.

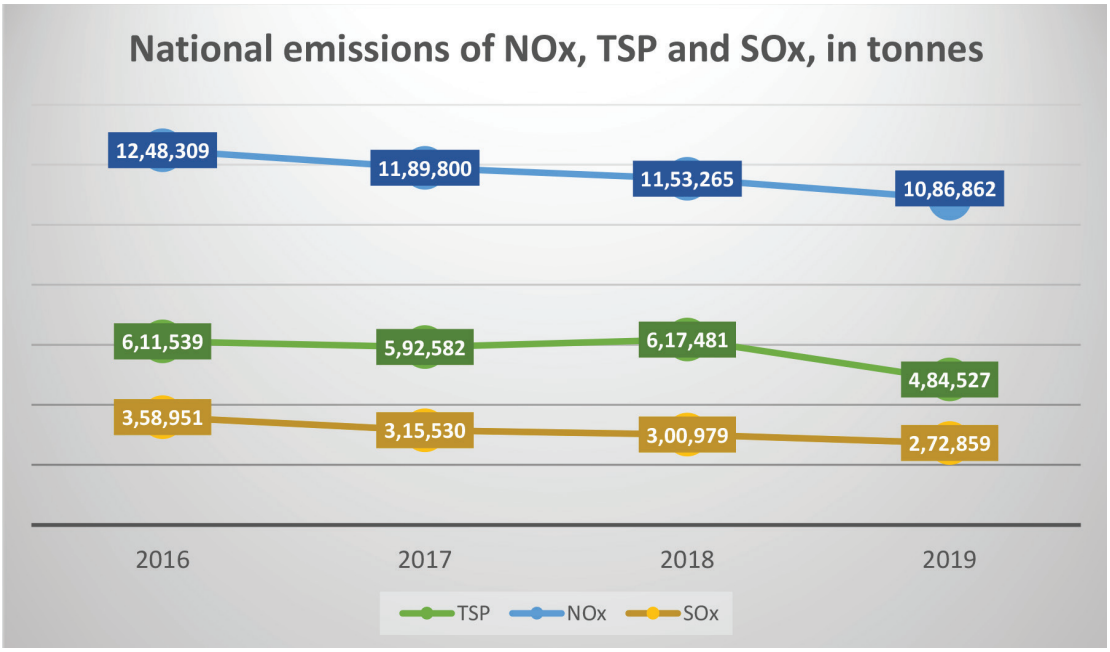
Results of air pollution policy changes

The policies introduced by successive governments of the Republic of Korea have helped reduce emissions from national sources, but the overall level of emissions is still high due to factors such as the large size of the country's industrial sector and the high number of vehicles in its densely populated urban areas. The Air Pollutant Emission-Cap Management System has shown some success in reducing air pollutant emissions through the real time collection of data from emission monitoring devices at business sites. The Air Pollutant Emission-Cap Management System targets the air pollutants such as nitrogen oxides (NOx), sulphur oxides (SOx), and total suspended particulates (TSP). In 2016-2019, the emissions of both NOx and SOx continually decreased year by year. Over the same period, the TSP levels decreased overall as well, expect for a spike of emissions in 2018.

The levels of Particulate Matter (PM10) and PM2.5 exposure in the Republic of Korea are extremely high and an enhanced policy to address this has been taken by the national government, as well as by the regional and local authorities. Policies such as bolstering the monitoring f emissions for factories and other production sites, and increased regulation of deteriorated diesel vehicles have resulted in lower emissions than a nonpolicy action baseline. However, PM2.5 and PM10 exposure levels remain high particularly in the Seoul Capital area, where over half of the Republic of Korea's 50 million population reside. The total national emissions for PM2.5 and PM10 have dropped comparatively between 2016 and 2021, yet there was also a sharp rise in emissions of both air pollutants in 2018 due to the large increase of fossil fuel combustion by the industrial sector.

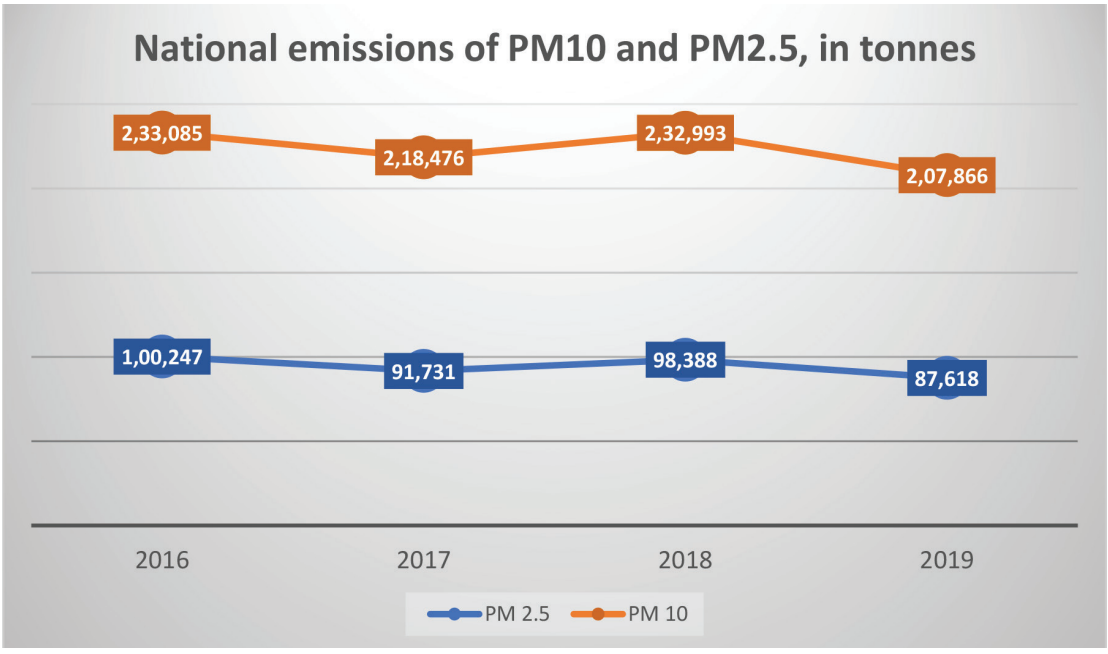
Regional cooperation

The air quality in the Republic of Korea is also strongly affected by the air pollutant emissions from other countries in the region, particularly China (Kim, 2019). For a more effective impact on increasing air quality levels in the Republic of Korea, regional cooperation is essential. The Korean government recognizes this and has initiated diplomatic measures to deepen mutually beneficial collaboration with China



Source: National Air Emission Inventory and Research Center, 2022.

Figure 5: National emissions of NOx, TSP, and SOx in tonnes, 2016-2019, Republic of Korea.



Source: National Air Emission Inventory and Research Center, 2022.

Figure 6: National emissions of PM10 and PM2.5, in tonnes, 2016-2019, Republic of Korea.

to reduce air pollution in East Asia. Over the past twenty years environmental ministerial meetings have occurred annually to discuss environmental policy issues such as regional air pollution and climate change. Environment ministers from both the countries have also announced a strengthening of cooperation to manage and decrease air pollution. The Republic of Korea currently promotes international joint research mitigating air pollution in the Northeast Asia in cooperation with China (NIIER, 2019). In the joint research project for Long-range Transboundary air Pollutants in Northeast Asia (LTP),

researchers from the Republic of Korea and China co-operate to use remote monitoring equipment for the Northeast Asia to analyze the air quality, seeking to improve the air quality in the region. Such a bilateral cooperation improves the comprehensive understanding about the causes and the origins of air pollution, while such cooperation also maintains communication and knowledge sharing among the various stakeholders.

International cooperation is also crucial to reduce air pollution for disseminating knowledge regarding technology and the responses of effective policies. The Republic of Korea also works in partnership with the United Nations Environment Programme (UNEP), sharing its experience and learning the best practices with regions experiencing low air quality to combat air pollution globally (UNEP, 2021). The UNEP partners with many countries in the Asia-Pacific region to support the development of national and subnational action plans and policies on air quality, and they also provide assistance in lowering emissions from major sectors such as industry and transport.

Enabling policies for SMEs

In order to effectively reduce air pollution and its origins, governments must enact and enforce enabling technology and regulatory policies that correctly incentivize and support small and medium scale enterprises (SMEs) in their efforts to reduce their air pollutant emissions. Given their environmental and economic importance, SMEs have the potential to be major drivers of green and sustainable growth, so careful consideration of policies that impact them is paramount. The manufacturing sector SMEs account for a significant portion of the world's resource consumption, pollution, and waste generation, and thus it is essential to enact policies that enable and strongly encourage them to reduce their adverse environmental impacts (Koirala, 2018). To not do so would be a major missed opportunity to improve the air quality through public and private sector cooperation.

A key issue is balancing the efficacy of legal requirements and oversight procedures that ensure that environmental goals are met without impeding the functioning of the SMEs through excessive compliance costs (OECD/Economic Research Institute for ASEAN and East Asia 2018). The continuation of one-size-fits-all approaches when designing and implementing environmental regulations can be a major drawback to SMEs as they do not operate on a substantive scale as larger enterprises, for which compliances to rules and regulations are less arduous. Regulations need to be designed with thorough attention to the SME sectors and the unique aspects of the local market in which they operate. The simplification of regulatory compliances is one of the first steps authorities should take to create an enabling environment for SMEs to reduce their air pollutant emissions. To streamline a regulatory system, regulators should introduce sector specific general binding rules as a substitute for multiple permits schemes, which create avoidable administration burdens for SMEs.

Regulatory impact analyses are an important tool for the environmental regulation of enterprises. To enhance the quality of regulatory oversight and to ensure that the created regulations are based on sufficient rigorous scientific foundations, it should be mandatory for regulators to carry out regulatory impact analyses. A regulatory impact analysis assesses the need for goals and feasibility for any new or reinforced regulation, and necessitates that regulators comprehensively compare various alternative regulatory options. They are highly beneficial as they clearly illustrate the inherent trade-offs between different policy options and regulatory proposals (Trnka, 2020). They also increase transparency by clarifying the reasons why a government intervenes in a private sector's business operations, which consequently raises the possibility of active compliance by the enterprises being regulated. This is especially important in the context of regulating SMEs to evaluate how the changes in the regulations and enforcements would affect their competitiveness and overall profitability.

Governments must ensure that it is practical for SMEs to utilize new air pollution reduction technologies. The advancements in air pollution reduction have, and will continue to take place. However, unless these new technologies are feasibly and rapidly adopted by SMEs, a meaningful reduction in the emission of air pollutants by SMEs will likely not occur. It is the responsibility of legislative and regulatory bodies to create enabling policies that facilitate speedy and widespread adoption of air pollution reduction technologies by SMEs. Increased use of air pollution reducing technologies, such the installation catalytic converters and flue gas scrubbers, are not possible without the government playing an active and facilitatory role in their adoption. Governments must be more stringent and dynamic in engaging with the SMEs in their technology adoption strategies into the future and provide the vision and funding for policies to be successful. A national budget funding should be specifically allocated for air pollution control measures for SMEs. SMEs must also engage with their local and regional authorities for effective coordination, and actively seek information regarding technological solutions and financial support for the reduction of their emissions of air pollutant.

Governments should also consider alternative and new policies to utilize SMEs in improving national air quality. SMEs can be supported to increase the number of trees in urban areas, which helps reduce air pollution levels. Trees absorb harmful airborne particles, so local authorities in various countries have taken measures to extend urban forests. While most trees will be planted at a large scale, SMEs can still be utilized to increase the total number of trees in cities. Local authorities can provide funding for businesses, landowners, building owners, etc. to plant trees on small unused patches of land. Generally, these patches of land are too small for other purposes, so it will result in a win-win situation for the property owners and the local authorities seeking to expand the number of trees in urban areas.

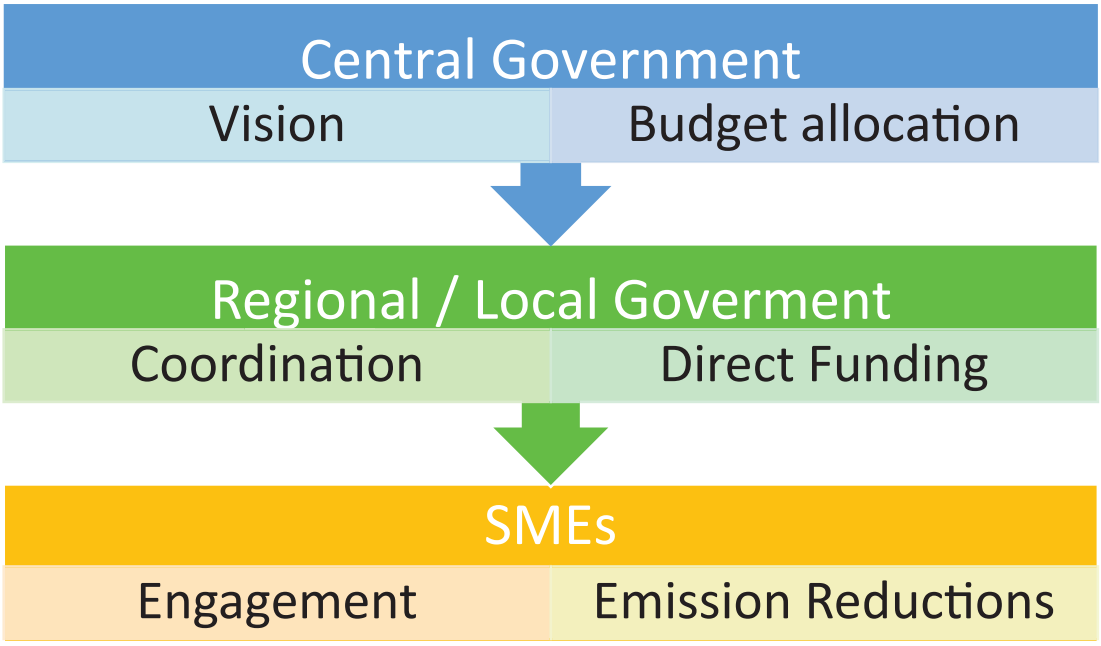


Figure 7: Process for effectively supporting SMEs in reducing air pollution.

Conclusion

The Republic of Korea has taken various measures to reduce air pollutant emissions from national sources, including from SMEs. By providing an overview of its recent air pollution trends and policies, this article aims to contribute to spreading practical knowledge for governments to take measures to improve air quality. Air pollution continues to be the greatest environmental threat to human health and wellbeing, and overcoming it requires innovation and change from all actors from the public sector, private sector, and civil society. An enabling environment for air pollution reduction by SMEs through technology adoption and regulatory measures must be actively created by governments in collaboration with SMEs. SMEs must play their role in reducing air pollution and be actively supported by governments in doing so. Through the three pillars of financial support, expertise, and transparency, the national, regional, and local authorities need to enact innovative and viable measures for controlling air pollutants. Regulatory frameworks need to move away from one-size-fits-all approaches, but be designed with consideration of the unique country and sector specific circumstances of SMEs. The air pollution control policies must not place unreasonable burdens on the operations of SMEs so that they can continue to be competitive. The managements of the SMEs must also actively cooperate with the regulatory authorities to reduce air pollution for the overall benefit of society, which will ensure cleaner air for the current and future generations.

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Overcoming Barriers to Clean Cooking in Thailand: A Quantitative Assessment

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Abstract

In many developing countries, people rely on inefficient stoves fuelled by biomass, coal and manure for cooking. The fine particulates ($PM_{2.5}$) emitted from these stoves not only harm human health, but they also disrupt climate systems. Unfortunately, economic, technological, social and institutional barriers have often slowed the widespread adoption of cleaner stoves or fuels. Several studies have offered qualitative assessments of these barriers. However, for those assessments to be factored into modelling studies that governments increasingly use to inform policy, quantitative evaluations of the impacts of different barriers are much needed. This paper uses the case of Thailand to offer a quantitative assessment of how much key barriers affect the diffusion of improved stoves and fuels. It shows that the combined effects of economic, technological, social and institutional barriers are significant—slowing diffusion rates by between 60 and 70 per cent. The paper further demonstrates that the social and institutional barriers—which are not typically included in modelling scenarios—are of comparable or greater size than the technological and economic barriers. The study concludes that countries such as Thailand would be well advised to focus more on creating enabling environments that support institutional coordination across relevant agencies; create consistency in policy objectives; and invest in awareness raising and encourage public comments on alternatives to traditional stoves or dirty fuels.

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Introduction

Every year, approximately 7 million people worldwide die sooner than they should from air pollution. For many casual observers, the understandable reaction to this troubling statistic is that curbing outdoor air pollution in cities requires more attention. However, a closer look at the data reveals that a sizable proportion of the 7 million premature deaths come from *indoor air pollution* in rural areas (WHO 2014). Simply stated, air pollution is not solely an urban phenomenon. In addition, in many rural areas the main source of indoor air pollution is residential energy use for cooking and heating. Across many developing countries, people burn biomass, coal, and dung in inefficient cookstoves that emit particles that damage health, deepen poverty, and warm the climate (WHO 2016).

A sizable body of research has estimated the impacts of cookstoves as well as the potential benefits from the widespread adoption of possible solutions. Several studies have also documented the challenges of adopting improved cookstoves or shifting to cleaner fuels or energy sources. In contrast, fewer studies have sought to document how much different barriers delay the adoption of improved stoves or cleaner fuels as well as what enabling reforms could help overcome those barriers. The main goal of this article is to fill this gap in understanding by looking at the case of cookstoves in Thailand.

The remainder of this article is divided into six sections. The next section looks more closely at the cookstove issues and its multiple adverse impacts. The third section describes possible solutions. A fourth section examines potential barriers. A fifth section estimates the impacts of those barriers on the diffusion of cleaner technologies and fuels. The sixth section

focuses on how Thailand has sought to overcome those barriers and the additional efforts that could help make more progress in the future. The final section concludes the discussion with a review of findings, policy recommendations, and the way forward.

The problem and its Impacts

Much of the world depends on cooking and heating from biomass-based fuels. In fact, the World Health Organisation (WHO) reports that globally 64 percent of the world's population relies on fuels derived from biomass (WHO 2016). Other studies underline the heavy reliance on these fuels: the amount of biomass fuel needed annually for basic cooking can reach up to 2 tons per family in some countries (The World Bank 2011). The dangers of this dependence are also well documented. Indoor smoke from the combustion of these fuels in frequently poorly ventilated areas poses a serious health risk. In fact, in 2016 almost 3.2 million premature deaths were attributable to household air pollution (WHO 2014).

The dependence on these fuels also has wide-ranging impacts on the other dimensions of development. Because approximately 90% of air pollution-related deaths occur in middle- and low-income countries, indoor air pollution threatens to undermine poverty alleviation (UNEP APCAP and CCAC 2019). In addition, since women and children typically spend more time indoors and are more exposed to smoke, they also tend to suffer more from its adverse impacts. This is implied in figures that underline the fact that 600,000 children under the age of 5 die annually worldwide from indoor and outdoor air pollution. Work showing that air pollution has been identified as a health hazard to prenatal children echoes a similar point (UNICEF 2016). There are also other ripple effects that amplify these gender impacts. For instance, the time it takes to collect biomass fuels such as firewood and the time it takes to cook on old, thermally inefficient cookstoves also often take time away from the women to do other things. Some studies have collected information on these monthly fuel use and collection times (Urmee and Gyamfi 2014).

The effects of indoor air pollution also may have implications for climate change. The combustion of biomass not only involves clearing land and forests that reduces carbon sinks, but the combustion of biomass-fuels also leads to emissions of the fine particulate ($PM_{2.5}$) that contains black carbon. Black carbon is a short-lived climate pollutant (SLCPs) that absorbs heat in its relatively brief atmospheric lifetime (weeks as opposed to decades or centuries associated with longer-lived greenhouse gases). Though difficult to compare because of its difference in chemical composition, some suggest black carbon is more powerful than carbon dioxide (CO_2). On a regional level, black carbon can also affect cloud formation and intensify rainfall patterns in regions that are already suffering from perturbations to the climate. Finally, when black carbon is deposited on ice and snow, it can reduce the brightness of surfaces and their capacity to reflect sunlight, accelerating the melting of glaciers in regions such as the Arctic and the Himalayas (UNEP APCAP and CCAC 2019). It is therefore not surprising that the IPCC Special Report on Global Warming of 1.5°C shows that mitigation of SLCPs and CO_2 are critical to achieving the Paris Agreement goals (IPCC 2018).

Solutions

The upside of many of the adverse impacts in the previous section is that solutions can also deliver multiple benefits. In fact, there are few interventions that could do more for making good on the Sustainable Development Goals (SDGs) than transitions to cleaner fuels and technologies in residential energy. The recognition of these benefits has led to many different types of solutions (USAID 2017).

One of the solutions involves the use of more efficient or improved cookstoves. The realization of this potential has led the market for more efficient stoves to expand greatly over the past thirty years. Some of the more frequently involve installing fans that help burn biomass more efficiently or offer design features that have similar intended effects. There are also stoves that rely on solar panels and heat-retention cookers that obviate the need for burning biomass in the first place.

A second set of options involves shifting to cleaner gaseous fuels. In this case, there can be a transition to liquefied petroleum gas stoves that burn cleaner than traditional cookstoves. Similarly, some governments and communities are turning more to biogesters, which can convert manure and other forms of waste into biogas that can be used for cooking as well as other residential energy purposes.

A third set of solutions involves transitions to electricity. While this option arguably has the potential to mitigate the effects of indoor air pollution, its impacts on climate change depend upon the sources of electricity. If the electricity comes from coal-fired power plants, then it might export some of the air pollution to regions where power is generated and cancel out the climate benefits in the process.

In all of the above cases, there is unlikely to be a single best universally acceptable clean cooking solution. The selection of appropriate stoves and fuels is almost by definition context-appropriate. Because of the need to find a good fit between the solutions and the context, careful consideration of how different technological and fuel improvements work within different enabling environments is critical to overcoming barriers to their widespread adoption.

Barriers

Another way of looking at the how to design an effective enabling environment involves understanding the barriers preventing their adoption. There are, in fact, several types of barriers that could impede shifts in this sector. For the sake of simplification, this section describes four such categories: 1) technical; 2) economic; 3) social; and 4) institutional. Before detailing each category, it merits highlighting that these are not perfectly watertight divisions between the groupings; there is some overlap across the categories (Rosenthal et al. 2018; Vigolo, Sallaku, and Testa 2018;

Sharma and Jain 2019; Thoday et al. 2018; Dendup and Arimura 2019; Khandelwal et al. 2017).

Technological barriers involve both the technology that is used in the stove itself as well as the supportive technology needed for the stove to operate effectively. Issues that fall under this category therefore include poorly designed stoves that could hinder the transition to an improved stove or one that runs on cleaner fuels. To illustrate, cookstoves that do not fit existing pots are likely to be a non-starter for many users. Another issue is lack of trained local maintenance and manufacturers who would be needed to quickly repair a dysfunctional stove or provide replacement parts (Kshirsagar and Kalamkar 2014; Vigolo, Sallaku, and Testa 2018; Chalise et al. 2018).

A further set of barriers involve the economics of purchasing a new stove and cleaner fuels. Arguably the chief economic barrier is the initial cost of purchasing a stove. Depending on the technology, the initial investment can be several times higher than the less clean alternatives. A similar set of constraints involves relatively greater costs of cleaner fuels. Especially if a user is shifting from what can be no- or low-cost biomass to a gaseous fuel, changes in costs can prove prohibitive. Yet another economic barrier pertains to government subsidies for dirty fuels such as coal or kerosene, which can artificially deflate costs and discourage transitions to less-polluting alternatives.

Social barriers focus on the willingness of users to accept a new stove or improved fuels. Under this category, some of the main challenges include reluctance to abandon traditional cooking practices that can, for instance, alter the flavour of foods. In some instances, the desire to retain certain tastes has led users to keep on using two or more stoves, with the smokier version reserved for some dishes. Another issue that comes under the social category is the lack of public awareness of the health hazards of indoor air pollution; while knowledge of these impacts is increasing, the severity of these effects continues to be an important blind spot for some users and communities. Additional social considerations entail sufficient access to sales outlets for cleaner stoves and fuels and engagement in decision making processes.

Finally, there are a set of institutional barriers that revolve around how governments work—or fail to work—to craft policies facilitating shifts to cleaner technologies and fuels. Some of the arguably more difficult institutional challenges involve lack of coordination among relevant ministries and agencies in the design and implementation of relevant policies. In many cases, clean cooking is a concern that falls between the cracks of agencies with energy, environment, and health mandates. A similar hurdle involves the shortage of administrative capacity: especially at the local level, governments may lack the human and financial resources to devote to conceiving and then rolling out solutions. Insufficient monitoring of policy effectiveness is a related problem. Resource-constrained agencies may lack the staff or resources to follow up on whether a specific intervention is working. This may result in a lack of constancy in policy objectives over time—an issue that was particularly salient in the case of Thailand.

The case of Thailand

As noted previously, both the kinds of solutions and the enabling programmes supporting their implementation are context-specific. This section reviews some of the efforts implemented in Thailand to help support shifts to sustainable cooking. These efforts have enjoyed varying degrees of success due, in part, to the barriers mentioned previously. It should nevertheless be underlined that the way these barriers appear resemble, but are not mirror images of, the more general descriptions in the previous section.

To understand those barriers, it helps to start by outlining some important background factors in the sector. A key piece of that background is that, although fossil fuels and electricity are currently the main energy sources for cooking in Thailand, more than 10 million households use the kinds of pollution-intensive charcoal cookstoves that can threaten health and cause other development challenges (Ministry of Energy Thailand, n.d.). Because Thailand is predominantly an agricultural country and has an abundance of biomass, the government has supported household and community-scale biomass energy production technology. These efforts have, at times, gained momentum because the rising fuel costs have encouraged users to turn to these stoves.

One of the early efforts that Thailand's government made to support cleaner cookstoves came in 2008 with the High Efficiency Cookstove Development and Manufacturing Project or High Efficiency Cookstove (Mahasetthi Cookstove). The Mahasetthi Cookstove was smaller and lighter than traditional cookstoves; in addition, it had a high heat capacity of around 1,000–1,200^{0} C for cookware (pots) ranging from 16 to 32 inches in diameter that were heated with an average thermal efficiency of 29%. Yet another advantage was that the high-efficiency stoves could save 30–40% more than traditional cookstoves, and reduce the cost of firewood and charcoal up to THB 500–600 per household per year (Nantasiriporn et al., n.d.). Perhaps most importantly, because of its greater efficiency the Mahasetthi stove would generate less smoke or toxic gases and thereby lessen strains on health (Ministry of Energy Thailand, n.d.). The Mahasetthi stove therefore filled many of the criteria one would expect to overcome the technical and economic barriers.

Interestingly, there was also recognition from Thailand's Ministry of Energy that simply having a stove that was technically and economically feasible would not be enough. Instead, there was an effort to create policy incentives that could spread production techniques to communities and thereby generate self-sustaining businesses, jobs and greater awareness. Toward that end, Thailand's government set a target of production and use of 1.5 million cookstoves within 5 years from 2008 onwards. The project further set up 30 community-level production centres and learning centres as well as promoted

e-commerce marketing and sales training (Ministry of Energy Thailand, n.d.). In many ways, these design features demonstrated that relevant government agencies were aware of the potential challenges beyond a technically sound stove with reasonable price.

After the Mahasetthi project concluded in 2008 and 2011, some of the institutional and social barriers began to become more challenging. One of the reasons that they became more problematic is that Thailand's Ministry of Energy shifted gears in its approach to the issue—though retaining a small budget to support the Mahasetthi project at the sub-district level and the community energy network as well as running a website on the higher-efficiency stoves (Ministry of Energy Thailand 2021; Bureau of the Budget Thailand 2021). The main change was a greater emphasis on renewable energy sources and allocating a larger portion of its budget to such programmes. With the course change and reduction in government support for improved stoves, several of the businesses manufacturing the more efficient stoves encountered higher costs for raw materials, a lack of skilled workers, and an inability to fulfil local demand, which ultimately forced them to close. These challenges also led to reductions in the production and use of high-efficiency cooking stoves (Ruchuwararak et al. 2013).

The shift in policy that brought the institutional and social barriers to the surface was part of a larger effort to support more renewable forms of energy. More concretely, from approximately 2011 the government's policy concentrated more on the use of renewable energy under the Alternative Energy Development Plan (AEDP). The AEDP sought to boost the use of renewable energy by 25% (2011-2021) of all energy, with a non-negligible proportion of consumption from biomass of up to 3,630 megawatts (43.24 percent) of all renewable energy receiving some forms of support. The Department of Alternative Energy and Efficiency, Ministry of Energy was tasked with overseeing the AEDP. The department worked to enable communities and households to generate their own energy and to change to clean alternative energy sources, but without an emphasis on the previous stoves (Twarath 2012).

More recently, Thailand reversed course again, returning to the previous emphasis on cleaner stoves. As fuel and cooking gas have become more expensive, the Minister of Energy has begun encouraging people to use high-efficiency cookstoves. The high-efficiency stoves have been viewed as appropriate and useful in rural areas or by food sellers who need to use the stove constantly (though not condominiums or closed households). In addition, the government has made an emphasis on including energy-saving labels on high-efficiency gas stoves, fumigation stoves (green stoves), and induction stoves that conserve gas and energy.

This most recent turn in strategy has also nonetheless generated some criticism that helps point to some of the social and institutional difficulties. Most notably, some observers have suggested that government recommendations to use high-efficiency stoves during moments of high fuel prices is inconsistent with more recent programmatic objectives. Moving forward, the same critics have contended that the government should have measures to manage and control the price of energy rather than develop and promote cookstoves, including high-efficiency stoves. Therefore, it was difficult to encourage its increased use in household cooking ("Director-General of the the Department of Alternative Energy").

Assessing current barriers

While the policies and programmes reviewed previously have made some headway, there are arguably several challenges that still exist to making cleaner stoves and fuels mainstream. To date, much of the work on the size of those challenges has focused on qualitative assessments as in the previous section. Such assessments are extremely valuable; they capture the richness of many of the issues that often require a careful eye and on-the-ground grasp of stakeholder needs. At the same time, a possible drawback of relying chiefly on qualitative descriptions is that they are difficult to incorporate into energy and air pollution models that are often used to inform environmental policy decisions. At the risk of simplification, those models are best suited to integrate quantitative data on issues such as the timing and diffusion rates of new technologies.

For this article, then, the authors aimed to quantitatively assess the magnitude of the four types of barriers for Thailand. To make such an assessment, the authors combined assessments from two different techniques: expert surveys and literature reviews.

The first technique consisted of a survey of approximately 30 experts and policymakers who were selected because of their knowledge of clean cooking in Thailand and other Southeast Asian countries. The survey asked respondents questions about how much each type of barrier could slow the diffusion of technologies.

For each survey response and each type of barrier, survey respondents were asked how much they felt the barrier in question would slow the diffusion of two different options: cleaner stoves and cleaner fuels and/ or types of energy. The responses were associated with the possible magnitudes of the different effects that are presented in Box 1.

After applying the numerical coding to all of the responses for all of the technologies, a numerical average or mean was calculated from all of the responses for each type of barrier for each kind of solution. To provide an example, equation 1 provides the notation for this calculation for the institutional barriers.

$$\bar{x}_{inst-expert\ survey} = \frac{\sum_{i=1}^{n} r}{n} \quad (1)$$

$\bar{x}_{inst\text{-}expert\ survey}$ = *Average magnitude of the institutional barrier based on the expert survey*

r = *Coded response based on the explanation above*

n = *Number of responses*

The next step was then combining the average assessments from the survey

Box 1: Assumptions about the size of effects

- If the response was "no effect," then this response was coded as a "0" or 0%.
- If the response was "small (slowing the transition to cleaner technologies by between 1% to 10%)", then this was coded as "0.05" or 5% as this was the midpoint between 1% to 10%.
- If the response was "moderate (slowing the transition to cleaner technologies by between 11% to 20%)", then this was coded as "0.15" or 15% as this was the midpoint between 11% to 20%.
- If the response was "significant (slowing the transition to cleaner technologies by more than 20%)", then this was coded as "0.25" or 25% as this was a conservative high-end estimate on the maximum amount a barrier could slow diffusion. In theory, this "0.25" or 25% estimate also makes sense because it would suggest that, if all four types of barriers were rated as "significant" for a given solution, then it would lead to a 100% slowing of the diffusion, or lack of progress in the rollout, of the solution.

with assessment from a literature review. For converting the literature review assessment into concrete figures, the authors used the same coding scheme as used in the expert survey. More concretely, if a barrier were judged to be "small," then it would be coded as 0.05 or 5%; a barrier that was judged to be moderate was coded as 0.15 or 15%; and so on and so forth.

In determining the relative magnitude of the barriers based on the literature review, the authors used the descriptive criteria in Table 1 below. Though admittedly subjective, the criteria aimed to base the assessment on how frequently and directly a barrier was mentioned, as well as how significant it appeared to be when it was referenced.

The authors then focused on estimating the size of the barriers from the literature review. For converting the literature review assessment into concrete figures, the authors used the same coding scheme as the expert survey. That is, if a barrier were judged to be "small," then it would be coded as 0.05 or 5%. A barrier that was judged to be moderate was coded as 0.15 or 15%, and so on and so forth.

Once the average magnitude for each type of cooking alternative and barrier was calculated from the expert survey and the literature review, the figures were combined. To arrive at a figure that combined the expert survey and literature review, the authors decided to use a weighted average of the expert survey mean and literature review assessment. For the weighted average, the expert survey was given a slightly higher weight of 0.6 and the literature review assessment was given a slightly lower weight of 0.4 (see equation 2 for notation). This weighting scheme was intended to reflect the belief that the expert survey should get slightly more weight, since most of the literature was focused not specifically on the relevant barriers but rather on a range of issues. In addition, some of the surveyed studies in the literature review come from countries or regions outside of the focus region. Finally, it is likely that the literature review reflected an assessment of barriers that is at least somewhat dated, given the amount of time it takes

Table 1: Descriptive criteria for coding the barriers

Indicator	Description
No effect	The barrier is not mentioned in the literature.
Small	The barriers are mentioned indirectly and/or briefly in the relevant literature, but they are not a focal point. Moreover, when they are mentioned, they appear to have limited impact on the diffusion of solutions. For example, in the case of a "social" barrier for the introduction of a specific new measure, the relevant literature mentions in passing the need to raise awareness of the benefits of this new measure, but does not discuss the barrier in much detail beyond noting the need for greater awareness.
Moderate	The barriers are mentioned directly once or twice in the literature, but their impact on the diffusion of solutions appears to be modest. For example, in the case of a technical barrier to the introduction of a new measure, the relevant literature mentions its potential for introduction and diffusion, and elaborates on why targeted efforts to increase the availability of the proposed technology are needed to advance this new measure.
Significant	The barriers are mentioned directly and repeatedly in the literature, and their impact on the diffusion of solutions is likely to be significant. For example, in the case of institutional barriers to the introduction of certain new measures, the relevant literature focuses on the need for greater coordination between different sectors and ministries in order to make any progress in implementing the technology.

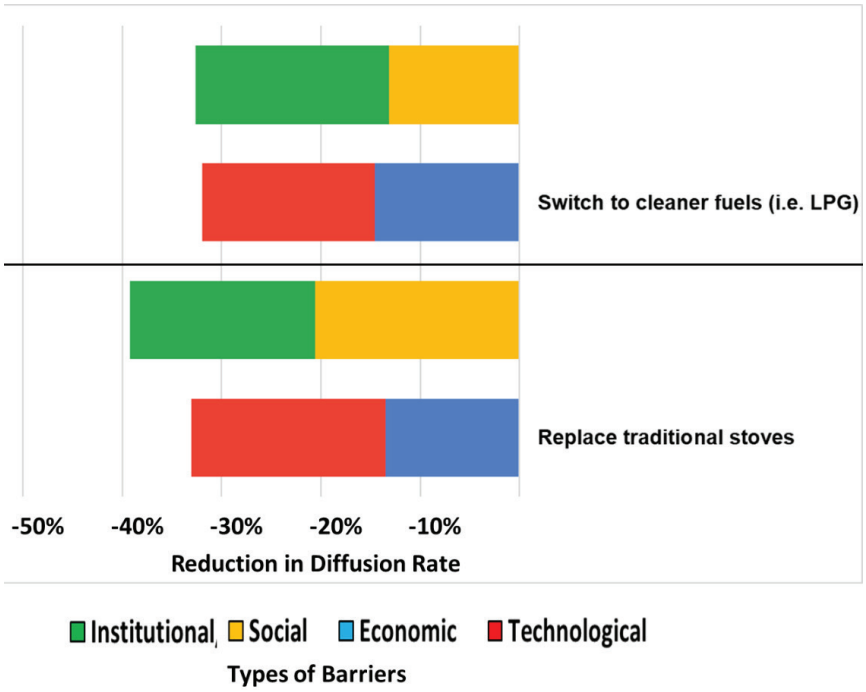

Figure 1: The effects of different barriers on diffusion rates of clean fuels and improved stoves

to develop a published article. The survey responses were likely to be more recent (see Equation 2).

$$b_{inst} = .6(\bar{x}_{inst-expert\ survey}) + .4(x_{inst-lit\ review}) \quad (2)$$

$x_{inst\text{-}expert\ survey}$ = *Average magnitude of the institutional barrier based on the expert survey*

$x_{inst\text{-}lit\ review}$ = Average magnitude of institutional barrier based on the literature review

b_{inst} = Magnitude of institutional barrier

After combining the expert survey and literature review assessments, it is possible to determine how much the different kinds of barriers slowed the diffusion of clean cooking in Thailand. The results of that assessment for both cleaner stove technologies and shifts to cleaner fuels are illustrated in Figure 1. Those results are interesting for at least three reasons.

First, they suggest that in all cases the implementation barriers are significant. In the case of shifting to cleaner fuels, the sum of the barriers implies a 60% reduction in the diffusion rate; in the case of shifts to improved stoves, the sum of the barriers implies more than 70% reduction in the diffusion rate.

Second, the magnitude of the economic and technological barriers and the institutional and social barriers is significant. For shifting to cleaner fuels, the sizes of the economic and technological barriers and the institutional and social barriers are almost the same. For shifts to improved stoves, institutional and social barriers are notably greater (by about 20 percent) than the economic and technological barriers. This is important because it is precisely the institutional and social barriers that are often not factored into models.

Third, though the interpretations of slowing diffusion may vary, one way of looking at the results is factoring in the delays in the introduction of new technologies or cleaner fuels. Those delays could amount to between 6 and 7 years over a ten-year period (the time period mentioned in the expert survey). Further, between 50% and 60% of those delays are due to institutional and social issues, which could be addressed with additional efforts to raise awareness and provide training (for the social barriers) and build capacities and enhance coordination (for the institutional barriers).

The way forward

This article examined the potential for and the constraints on clean cookstoves and fuels to reduce air pollution and mitigate climate change in Thailand. It underlined that while there has been a significant amount of research on both the potential and the related constraints, few studies have systematically analysed how much different barriers influence the diffusion of solutions. This omission is particularly worrying for institutional and social barriers, which do not naturally lend themselves to measurement needed for the kinds of data-driven modelling that increasingly informs air pollution and climate change policy. The article then underlined the need for greater efforts to include these often less visible barriers into modelling scenarios. In doing so, it illustrated that these barriers are often of greater magnitude than the more easily quantified technological and economic barriers in Thailand.

The next logical question that follows from this assessment is: What can be done to

overcome these barriers in Thailand? The simple solution is to focus more energy in improving the enabling environment for clean cooking and fuels in Thailand. This simple statement requires a little more unpacking to make it more helpful for policymakers.

Some more specific suggestions entail increasing efforts to enable coordination across relevant government agencies on residential energy. The possible consequences of such coordination could, in turn, be more consistency in programmatic targets and objectives and greater efforts to sustain programmes where there appears to be significant momentum. A related consequence of greater coordination and consistency might also be regular evaluation of programme effectiveness and impact. These assessments could help in refining objectives and adapting to the changing scenarios on issues such as fuel prices.

Many of the above recommendations focus chiefly on institutional as opposed to social issues. To address some of the social issues, deepening efforts to raise awareness of sustainable alternatives is a clear need. A related need is to offer clearer explanations for shifts in policy, while also eliciting inputs from affected communities before policy changes. Both the above efforts could be pursued with greater cooperation with academic institutions and civil society. Both efforts could also inform how to support sustainable business models for cleaner stoves or fuels that build self-sustaining markets for such interventions.

While the article has shed some light on the magnitude of the often underappreciated barriers and the possible reforms to help overcome them, it is not free from limitations. Some of these limitations involve the methods for assessing barriers. The approach used herein, for instance, places a cap on the maximum size of different barriers at "slowing diffusion at 25%" per type of barrier. For further iterations of this work, one might look at ways to expand this cap. A second limitation is that some of the descriptions of the barriers are not perfectly consistent with the experiences in Thailand. More concretely, policy consistency appears to be a significant issue in Thailand, but is only one of many institutional challenges used in the analytical framework in this article. A third shortcoming of the article is that many of the barriers within and across categories are in fact related to each other. For example, the lack of awareness of the different technological options is related to both social and technological hurdles. Future work could look more closely at the interactions between the barriers.

A final area where additional research could prove useful pertains to the costs of overcoming some of the institutional and social barriers. There is a rich and extensive literature on transaction costs, which can provide insights into what it costs to develop and implement public policies. Drawing on that literature can shed much-needed light on what it could, for instance, cost a policymaker to institute some of the enabling reforms discussed earlier in this section. Coupling those cost estimates with the data from the modelling studies, as well as from the analysis of the barriers, may also open eyes to the sizable benefits from strengthening policies and institutions to promote the diffusion of other kinds of air pollution solutions in a wide range of contexts.

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Networks and Databases related to Air Pollution Control

Regional Emission inventory in ASia (REAS)

The Regional Emission inventory in ASia (REAS) is a data repository, which provides past emission data for the Asian region. The first version of REAS (REASv1.1) accounted for the actual emissions of SO2, NOx, CO, NMVOC, black carbon (BC), and organic carbon (OC) from fuel combustion and industrial sources between 1980 and 2003, and the projected ones in 2010 and 2020. The inventory was updated as the REASv2.1 for the period between 2000 and 2008 and the datasets of the Regional Emission inventory in Asia for Persistent Organic Pollutants (REAS-POP) 1.0 focusing on polycyclic aromatic hydrocarbons (PAHs) in the Northeast Asia were also developed. The current latest version, REASv3.2.1, provides a long historical emission inventory between 1950 and 2015 in the Asian region. It provides data for emissions of SO_2, NO_x, CO, NMVOC, PM_{10}, $PM_{2.5}$, BC, OC, NH_3, and CO_2 from 1950 to 2015 from the East, the Southeast, and South Asia. It includes the emission sources such as fuel combustions in power plants, industry, transport, and domestic sectors; industrial process; and agricultural activities (fertilizer application and livestock).

https://www.nies.go.jp/REAS/index.html#general%20info

WHO Air Quality Database

The WHO air quality database compiles data on the ground measurements of annual mean concentrations of nitrogen dioxide (NO_2), particulate matter of a diameter equal or smaller than 10 µm (PM10) or equal or smaller than 2.5 µm (PM2.5), which aim at representing an average for a city or a town as a whole, rather than for individual stations. Both groups of pollutants originate mainly from human activities related to fossil fuel combustion. The WHO database is updated regularly every two to three years since 2011, and the fifth update was released in April 2022. It currently hosts data on air quality for over 6000 human settlements in more than 100 countries. The data compiled in this database is used as an input to derive the Sustainable Development Goal Indicator 11.6.2, the air quality in cities, for which WHO is the custodial agency.

https://www.who.int/data/gho/data/themes/air-pollution/who-air-quality-database

Asia Pacific Clean Air Partnership

Air pollution is recognized as a public health and environment crisis. In the Asia Pacific, there have been several intergovernmental and voluntary cooperation frameworks and initiatives working on air pollution with varying focus, functions, and scope in terms of membership. There was also a growing body of evidence on the status, impacts, and solutions of air pollution generated by different scientific bodies and research institutes in the region. There was a need to set-up a coordination mechanism to bring together different frameworks and initiatives to maximize synergies and to consolidate available evidences to identify the most effective solutions to reduce emissions of pollutants and improve health and wellbeing. The Asia Pacific Clean Air Partnership (APCAP) was established in 2015 as a mechanism and platform to promote coordination and collaboration among various clean air initiatives in the Asia Pacific. The APCAP aims to serve as a mechanism for better coordination and collaboration of clean air programs in the region; provide a platform to generate and share knowledge on air pollution initiatives, policies, and technologies in the Asia Pacific region; and strengthen institutional capacity, provide technical assistance on air quality management; and support air quality assessments to identify solutions for clean air.

https://www.unep.org/asia-and-pacific/asia-pacific-clean-air-partnership

Acid Deposition Monitoring Network in East Asia (EANET)

Acid deposition can cause various effects on ecosystems through acidification of soil and water as well as damage to buildings and cultural heritage through corrosion of metals, concrete, and stone. In order to assess the adverse effects of acid deposition on an ecosystem, it is necessary to identify the dose-effect relationship of acid and eutrophic substances in the environment. It is also important to quantify the effects on ecosystems, estimate the necessary amount of reduction of emissions of harmful gases that cause acid deposition, and consider the most cost-effective policy options. The determination of emission reduction target may require the identification of the threshold level of acidic and eutrophic substances that do not cause any adverse effect on ecosystems. Acid deposition is not limited by national boundaries and, therefore, cooperation at the regional and international levels is required to effectively address this problem. In Europe, it was successfully achieved through the activities under the Convention on Long-Range Transboundary Air Pollution (CLRTAP). The Acid Deposition Monitoring Network in East Asia (EANET) was established as a regional cooperative initiative to promote the efforts for environmental sustainability and the protection of human health in the East Asian region.

https://www.eanet.asia/about/background/

Clean Environment and Planetary Health in Asia (CEPHA) network

The Clean Environment and Planetary Health in Asia (CEPHA) network aims to enhance inter-sectoral interdisciplinary engagement to co-create lasting partnerships that will help instigate a clean environment transformation in Asia (India, China, Thailand, Malaysia, and neighbouring countries) through low-carbon development, focusing on innovative solutions that can provide multiple health, environmental, and socioeconomic benefits. The CEPHA network engages with researchers, citizens, policymakers, the health sector, industry, and other stakeholders through systems-based participatory methods to develop lasting partnerships to tackle environmental pollution. Another objective

of the CEPHA network is to identify "what works," knowledge gaps, key challenges, and barriers/enablers in developing/prioritizing innovative solutions that can provide multiple benefits. The CEPHA network strengthens international cooperation and knowledge exchange on environmental pollution control and planetary health across Asia. The CEPHA network builds the capacity and the capability of the stakeholders in Asia and widens their participation across sectors and socioeconomic groups. The activities of the CEPHA network focus on generating resources and research income through joint research grant applications.

http://cepha.in/

Climate and Clean Air Pollution

The Climate and Clean Air Coalition is a voluntary partnership of governments, intergovernmental organizations, businesses, scientific institutions, and civil society organizations committed to improving air quality and protecting the climate through actions to reduce short-lived climate pollutants. The partners include states, IGOs, and NGOs. It also has a network of actors from civil societies carrying out actions on the ground. The global network includes hundreds of states and non-state partners, and hundreds of local actors carrying out activities across economic sectors. In 2012, the governments of Bangladesh, Canada, Ghana, Mexico, Sweden, and the United States, along with the United Nations Environment Programme (UNEP), came together to initiate efforts to treat short-lived climate pollutants as an urgent and collective challenge. Together, they formed the Climate & Clean Air Coalition to support fast action and deliver benefits on several fronts at once, which include climate, public health, energy efficiency, and food security. Today, the Coalition brings together hundreds of experienced and influential stakeholders from around the world to leverage high-level engagement and catalyse concrete actions in both the public and private sectors.

https://www.ccacoalition.org/en

Tech Events

2022

Oct 27 – 28
Ho Chi Minh City, Viet Nam
ASEAN Wind Energy 2022
Contact: Kathy Xi
Tel: +86 151 2112 8297
Email: Kathy@leader-associates.com
https://www.aseanwindenergy.com/

Nov 9 – 10
Akita City, Japan
Global Offshore Wind Summit (GOWS)
Contact: Global Offshore Wind Summit-Japan 2022 Desk
Email: gows-j2022@jbn.jtb.jp
https://gows-j.com/

Nov 14–15
Manila, Philippines
ASEAN Clean Energy Week
Contact: Cheryl Yu
Tel: +86 137 9522 9971
Email: Cheryl@leader-associates.com
https://www.aseancleanenergyweek.com/

Nov 18–20
Singapore
2022 8th International Conference on Robotics and Artificial Intelligence (ICRAI 2022)
Contact: Ms. Carrie Li
Tel: +86-18008065167
Email: icraiconf@outlook.com
http://icrai.org/

Nov 22–24
Bangkok, Thailand
2022 4th Asia Conference on Material and Manufacturing Technology (ACMMT 2022)
Contact: Ms. Jane Li
Conference Secretary
Tel: +1-669-900-4528 / +86-28-87577778
Email: acmmt_conf@163.com
http://www.acmmt.org/

Nov 29–Dec 1
Tokyo, Japan
2022 International Conference on Emerging Technologies for Communications
Contact: The Korean Institutes of Communications and Information Sciences (KICS)
#06296, 3F, 32-3, Nonhyeon-ro 38-gil, Gangnam-gu, Seoul, Republic of Korea
Tel: 82-2-3453-5555; Fax: 82-2-539-5638
Email: ictc@kics.or.kr
https://ictc.org/

Dec 12–14
Hyderabad, India
14th Asian Conference on Machine Learning (ACML 2022)
Access: https://www.acml-conf.org/2022/cfp.html

Dec 17–18
Dhaka, Bangladesh
3rd International Conference on Sustainable Technologies for Industry 4.0 (STI 2022)
Contact: Conference Secretariat
Tel: +8801733588677, +8801716539541
Email: sti@green.edu.bd
https://fse.green.edu.bd/sti-2022/

Dec 17–19
Osaka, Japan
2022 5th Artificial Intelligence and Cloud Computing Conference (AICCC 2022)
Contact: Mr. Paul Choo
Conference Secretary
AICCC 2022 conference secretary
Email: aiccc.contact@gmail.com
http://www.aiccc.net/

Dec 28–30
Bangkok, Thailand
2022 5th Asia Conference on Machine Learning and Computing
Contact: Cherry Chan
Conference Secretary
Tel: +86-28-86512185
Email: acmlc@iacsitp.com
http://www.acmlc.org/

2023

Jan 06–08
Changsha, China
9th International Conference on Renewable Energy Technologies (ICRET 2023)
Contact: Amber Tseng
Conference Secretary
Tel: +86-28-8777-7577
Email: icret@young.ac.cn
http://icret.org/

Feb 10–11
Chennai, India
9th GoGreen Summit & Expo
Contact: 9th GoGreen Summit & Expo
Tel: +91 89256 49674
Email: gogreen@bioleagues.com
https://gogreen.bioleagues.com/

Mar 03–05
Harbin, China
2023 the 7th International Conference on Innovation in Artificial Intelligence (ICIAI 2023)
Contact: Ms. Ashley Liu
Conference Secretary of ICIAI
Tel: +86-13980894300
Email: iciai2018@vip.163.com
http://www.iciai.org/

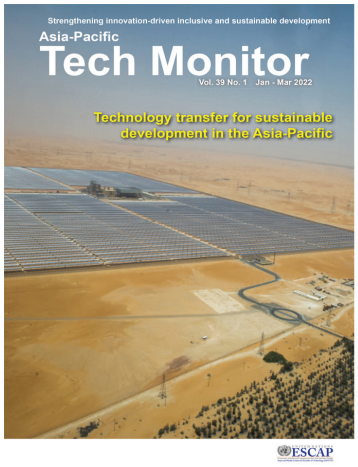
Mar 10–12
Singapore
2023 The 7th International Conference on Green Energy and Applications
Contact: Evelyn Koh
Secretary of ICGEA 2023
Email: icgea_secretary@163.com
http://www.icgea.org/

Mar 24–26
Singapore
2023 4th Asia Conference on Renewable Energy and Environmental Engineering (AREEE 2023)
Contact: Nancy Liu
Conference Secretary
AREEE Conference Secretariat
Tel.: +86-28-86512185
Email: areee@iacsitp.com
http://www.areee.org/

Mar 27–29
New Delhi, India
8th Smart Cities India Expo
Contact: Prateek Kaushik
Vice President
Exhibitions India Group
C-103, Okhla Industrial Estate
Phase III, New Delhi - 110 020, India
Mob: +91 98999 81610
Email: prateekk@eigroup.in
https://www.smartcitiesindia.com/

Apr 14 – 16
Tianjin, China
2023 8th Asia Conference on Power and Electrical Engineering (ACPEE 2023)
Contact: Ms. Amber Cao
Tel: +852-30506862
Email: acpee@vip.163.com
https://www.acpee.net/

Apr 27 – 29
Seoul, Republic of Korea
2023 Asia Conference on Blockchain Technologies (ACBT 2023)
Contact: Mia Hu (Conference Secretary)
Tel: +86-19136119387
Email: acbt@academic.net
http://www.acbt.org/



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