Adoption of Supercritical Fluid Technology in a Developing Country

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Supercritical fluid technology is a green technology. Most developed countries have benefited economically and environmentally from adopting such technology in the manufacturing sector. Some developing countries, such as the Philippines, struggle to embrace such technology due to their challenges. In this policy analysis, (1) an in-depth review of the trends and applications of supercritical technology globally and locally was conducted; (2) some facilitating and restraining factors in the adoption of supercritical technology in the Philippines were determined; (3) impacts of supercritical technology in the economy, industry, and the society was discussed; and (4) recommendations on the policies involving labor and employment, human resources development and education, government policies, and research and development were provided as a result of the policy analysis that sheds light on how to correct a paradox that leads to a rethinking of several aspects of technological adoption in the Philippines. The policy analysis shows that businesses' low-level technological adoption level observed in developing countries is a reasonable response to various circumstances. They face physical and human capital accumulation obstacles, poor business abilities, and ineffective government ability. For instance, unraveling the tremendous potential progress of bringing countries nearer to the technology boundary is not as easy as offering more incentives for research and development. Pushing nearer the border would compel realistic and ambitious policies that overcome several technical constraints.

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INTRODUCTION

Climate change is one of the most severe perils of public well-being. These will affect everyone; however, climate change will have the most devastating effects on poor and marginalized people (Roa et al., 2020). Climate change has been linked to several significant environmental emissions (e.g., noise pollution, light pollution, soil pollution, water pollution, air pollution, thermal pollution, and radioactive contamination). Hence, to help address climate change without compromising the economy, it is vital to innovate and introduce alternative green technologies that provide a minimum environmental effect for products with specific customized properties. High-pressure technologies have produced various processes, leading to new products with unique features (Cansell et al., 2004; Knez et al., 2019). Supercritical fluid (SCF) technology is one of the most advanced technologies that create various excellent and promising processing technologies because of its physicochemical properties. The thermophysical properties of the medium, which is the SCF, can be changed by simply changing the operating temperature and pressure. It also has outstanding thermal transmission characteristics that can be used with virtually no environmental impact compared to the conventional poisonous or potent emission of greenhouse gases (Knez et al., 2019).

Ambitious targets for greenhouse gas and waste recycling reduction are needed to reduce the significant degree of climate change. These targets ensure that by the mid-century, the move toward a 'circular' low carbon economy is significant and supports the United Nations Sustainable Development Goals

KEYWORDS

developing country, Philippines, policy analysis, supercritical fluid technology

(UN SDG No. 13). (OECD, 2016). This change affects all facets of the economy and culture and will be encouraged by technological innovation and adoption Fields(OECD, 2016). Therefore, if their pledge is to be met, it is essential to consider how emerging innovations are adopted in practice. Increasing adoption of global technologies in developing countries must involve significant research and policy advice because domestic capacities are necessary for absorbing technology. Not only the lack of expertise but also the lack of business dimensions is a fundamental barrier if manufacturing innovation undergoes fixed costs, thereby requiring growing specialization in economies of scale. Technology returns are considered extremely high, but countries' investment appears to be tiny, suggesting that this crucial growth channel for productivity is underexploited (Cirera and Maloney, 2017). The introduction of technology must also be backed up by suitable policies and actions that improve the transition from technological acceptance to corporate diffusion, as has been the case in countries such as the Republic of Korea and China (UNIDO, 2015). In the Philippines, the adoption of supercritical technology is motivated by the long-term goal set by the government called "Ambisyon Natin 2040" (Our Goal 2040). This green technology could support one of its goals, providing a long and healthy environment for every Philippine citizen (NEDA, 2016a). There is also an incumbent policy framework of the Philippine government that could help in the adoption process of this technology which includes (1) a comprehensive national strategy of top priorities; and (2) the comprehensive national industrial strategy (DTI-BOI, n.d.).

In this policy analysis, (1) an in-depth review of the trends and applications of supercritical technology globally and locally was conducted; (2) some facilitating and restraining factors in the adoption of supercritical technology in the Philippines were determined; (3) impacts of supercritical technology in the economy, industry, and the society were discussed; and (4) recommendations on the policies involving labor and employment, human resources development and education, government policies, and research and development were provided as a result of the analysis that sheds light on how to redress some paradox which leads to rethinking many aspects of technological adoption in the Philippines. It must also be noted that the policy recommendation or model appropriate for a developing country such as the Philippines may differ from that of another developing country, much more of a developed or advanced country.

SUPERCRITICAL FLUID TECHNOLOGY

A supercritical fluid (SCF) is any substance whose pressure and temperature are above its critical point when distinct liquid and gas phases do not exist but below the pressure necessary to compress it into a solid (Padrela et al., 2009). They can diffuse through porous solids such as gas, exceeding mass transfer limits that impede the transport of liquids through such materials (Kiran and Sengers, 1994; Schlosky, 1989). Supercritical fluids are far superior to gases in their capacity to dissolve substances such as solids or liquids (Cansell et al., 2004). Commonly used solvents for SCF extraction are carbon dioxide (CO_2), methane, propane, water, propylene, ethylene, acetone, methanol, and ethanol (Kavčič et al., 2014). Supercritical fluid extraction using CO_2 has been identified as a green technology (Das et al., 2017). It is a versatile and clean solvent with liquid-like density and gas-like diffusivity in the supercritical phase. With these properties, supercritical carbon dioxide makes it an excellent substitute for toxic chemical solvents (Deshpande et al., 2011). Some popular SCFs have properties that make them appealing for a wide range of operations. Supercritical fluid can create new, better, clean products and processes (Caputo et al., 2013; Hauthal, 2001; Sengers et al., 2000).

Various studies have shown that supercritical fluid extraction (SFE) technology is easier to use, environmentally benign, and has a lower extraction temperature when compared to other alternative technologies (e.g., liquid-liquid and solid-liquid extraction) (Baldino et al., 2017; Cansell et al., 2004; Grijó et al., 2018; Lang and Wai, 2001; Phelps et al., 1996; Rubi et al., 2019; Zhou et al., 2021). SFE has been widely used to extract bioactive compounds and nutrients from different types of food processing by-products, including polyphenol antioxidant bioactive substances from fruit processing by-products (Kelly et al., 2019), carotenoids from vegetable wastwres, and marine microalgae (Abrahamsson et al., 2018; de Andrade Lima et al., 2019), as well as polyunsaturated fatty acids from marine fish by-products (Kuvendziev et al., 2018). SFE can be employed alone or in conjunction with other extraction technologies (Fink and Beckman, 2007; Knez et al., 2018; Misra et al., 2017; Zabot et al., 2018; Zhong et al., 2018; Zhou et al., 2021), such as mechanical pressing, to extract phenolic compounds and oils from olive kernels and increase extraction efficiency, therefore conserving the biological activity of the extracted chemicals (Misra et al., 2017). More details about the applications of SFE are discussed in the later section.

On the other hand, there are some drawbacks to utilizing SCF. These drawbacks include the requirement of elevated pressure, which is energy-intensive and requires a relatively high investment cost (Baldino and Reverchon, 2018; Knez et al., 2019). Another thing is that it requires unusual operating conditions due to complicated phase behavior (Schlosky, 1989). When all factors are considered, SCF has certain limits. However, its benefits exceed its drawbacks, and further advancements are predicted to become an essential and valuable resource in the chemical industries for various applications in the following years (King, 2002).

TRENDS IN SUPERCRITICAL FLUID TECHNOLOGY

Globalization that operates through investment, the flow of people and ideas, products, and services is motivated by the broad use of digital technology. It is the driving force and factor for many of these changes in power and influence (OECD, 2016**.** This section will review the history of supercritical fluid and compare it to modern supercritical fluid technology in application scenarios. The growing trend of supercritical fluid technology will also be analyzed.

Global Trends

A bibliometric analysis was conducted to illustrate how supercritical fluid technology evolved and became popular worldwide (Fig. 1 to 4). Due to its updated bibliometric data lists and the analysis tool feature (Afgan and Bing, 2021; Lasda Bergman, 2012; Meho, 2019), Scopus was preferred over Web of Science and Google Scholar. The most interconvertible and representative keywords were utilized to obtain accurate quality and a more comprehensive array of bibliometric data. The search was narrowed down using the advanced search feature of Scopus with the Boolean string: "(ALL ("supercritical fluid" OR "supercritical technology" OR "supercritical fluid technology"))." Researchers in different studies have previously drawn similar approaches (Afgan and Bing, 2021; Darko et al., 2017; Zuo and Zhao, 2014). While keeping the settings of Scopus search as "Title, Abstract, Keywords," search attempt was implemented as of December 2020, resulting in a total of 126,331 documents, including articles belonging to various fields outside the current research domain.

It is remarkably fascinating to know that researchers have been toiling on supercritical fluid technology for a long time. This section presented global trends based on the publication in supercritical fluid technology from 1953 to 2020. Based on the annual publication trend, the first publication was done in 1953 (Fig. 1). The subsequent publication came after nine years (in 1962). A significant number of publications happened in 1983 and continued to rise until 2020. These publications presented a revolution in the field of supercritical fluid technology. The number of annually published articles was 4743, 5471, 6135, 6552, 6838, 7241, 7661, 8311, 8771, 9684, and 10834 from 2010 to 2020, respectively. The publication trend al 3 so depicts the enormous growth in the previous ten years ascribed to awareness, globalization, and rapid urbanization towards adopting supercritical technology. This observation also shows the possible rise of supercritical technology in the era and the associated demands of society towards sustainability. China, the United States of America, and Japan ranked highest among the top 3 publications produced by a country (Fig. 2). These publications are relative to the adopters of supercritical technology. As expected, supercritical fluid technology is primarily used in chemical engineering and chemistry (Fig. 3). It can be recalled that supercritical fluid was first discovered and used by chemists and later applied to industries by chemical engineers. Since then, this technology has been employed in several applications and has gained popularity worldwide. Over the years, the technological transition has profoundly impacted economies and societies (OECD, 2016). As the planet faces many challenges, including climate change, aging, and the exhaustion of natural resources, new or better solutions for new problems will be needed. The future dynamics of technological change and science and technology developments will shape these socio-ecological demands (OECD, 2016)**.**

Collaboration analysis through co-authorship was performed using the VOSviewer tool (http://www.vosviewer.com) and the Scopus database (Fig. 4). size indicates the number of documents published in a country (e.g., an immense size has the most significant number of documents). The color of the nodes expresses the country cluster. Links connect countries where one nationality co-authors the other nationality. The closer the two countries are to each other, the stronger their relatedness. The two top publishers, the US and China, have very close ties or strong collaborations in terms of publication in SCF technology. Surprisingly, top publishers in Southeast Asian countries, namely Malaysia and Vietnam, have close ties to Middle East countries, namely Saudi Arabia and Iran.

Local Trends

Local trends are discussed in this section to show some margins of technology adoption using bibliometric analysis and some available data in the literature and databases. The same method as in the "Global Trends" section was used in generating the data (Fig. 5 to 7). The search was narrowed down using the advanced search feature of Scopus with the Boolean string: "(ALL ("supercritical fluid" OR "supercritical technology" OR "supercritical fluid technology")) AND (LIMIT-TO (AFFILCOUNTRY, "Philippines"))." A similar string was used for other Southeast Asian countries (Fig. 5). While retaining the settings of Scopus search as "Title, Abstract, Keywords," search attempt was conducted as of December 2020 stemming to a total of 74 documents, including articles that belong to varied fields outside the current research domain.

Based on the bibliometric analysis, the Philippines has adopted supercritical fluid technology since 1997 (Fig. 5). It is nice to know that, generally, there is an increasing publishing trend in the Philippines. However, comparing the total publications made from 1989 (the year since Singapore made the first publication) with other Southeast Asian countries, we are left behind by Malaysia, Thailand, Indonesia, Singapore, and Vietnam (Fig. 6). The growth trend of Philippine publications is still low compared to other top Southeast Asian countries, especially Malaysia, which showed a dramatic increase from 2004 to 2020. Most applications of supercritical fluid technology seemed to consistently lie in the field of chemistry and chemical engineering (Fig. 7).

APPLICATIONS OF SUPERCRITICAL FLUID TECHNOLOGY

Supercritical fluid (SCF) technology applications include extraction, particle formation, impregnation of aerogels, and chemical and biochemical reactions. In extraction, collecting compounds or fractionating total extracts (Hrnčič et al., 2018; Lack and Simándi, 2001) is one of the principal advantages of using supercritical fluid (SCF) technology. Gases (e.g., propane) can help isolate or fractionate parts and adjust process parameters. Carbon dioxide (CO_2), which is not polar, is the most widely used SCF. A polar co-solvent (e.g., ethanol) has to be combined with supercritical carbon dioxide ($scCO_2$) to improve its solubility (Knez et al., 2019). Overall, applying SCF on laboratory and industrial scales is very promising for removing material from solids or liquids. (Rubi et al., 2019) used supercritical fluid technology in extracting the andrographolide from *Andrographis paniculate*. Supercritical carbon dioxide and other co-solvents (ethanol and water) showed promising results when used in the extraction process. They provided additional development in the extraction of biochemical compounds using green chemistry (Fig. 8). SCF technology is primarily valuable for pharmaceutical industries such as Unilab Industries and Pascual Laboratories, Incorporated, which are situated in the Philippines.

Fine particles from supercritical solutions obtain the rapid expansion of supercritical solution (RESS). As the SCF solution is extended under lower pressure, the solution is dissolved in a high-pressure fluid precipitate. The most significant benefit of RESS is that there is no need for traditional solvents. A straightforward scale-up is based on understanding the primary hydrodynamic and thermodynamic data (Diefenbacher and Türk, 2002). Several applications are currently linked to active compound encapsulation.

Aerogels have various applications, exhibiting very different technological and chemical characteristics (Akimov, 2003). To state a few: catalysts, isolators, condensers, cosmetics, microelectronics, medical applications, or supplies for active ingredients in the pharmaceutical and food industries (Knez et al., 2019). The impregnation method is intensified by using the unique properties of sophisticated energy and raw materials with substantial savings. Supercritical aerogel impregnation requires applying medicine to the aerogels already ina dried state (Fig. 9) (Braga et al., 2008). The technique is typically used to facilitate the breakdown and absorption of low-water-soluble drugs. The supercritical solution's pressure, temperature, hydrodynamics, composition, and depressurization rate affect these processes (Gurikov and Smirnova, 2018).

SCF can be used as a reactant in chemical reactions. Specific chemical reactions are carried out in SCF media to achieve products of high added value (Fig. 10). These were already introduced on the industrial scale (Munshi and Bhaduri, 2009). Ethylene polymerization to polyethylene was one of the first SCF-technology chemical applications identified accidentally in 1933 (Lutz et al., 2016). The supercritical water (SCW) dissociation constants are comparatively strong. The dielectric constant of SCW is reduced with increased pressure and temperature. For acid-catalyzed reactions like the Friedl-Crafts

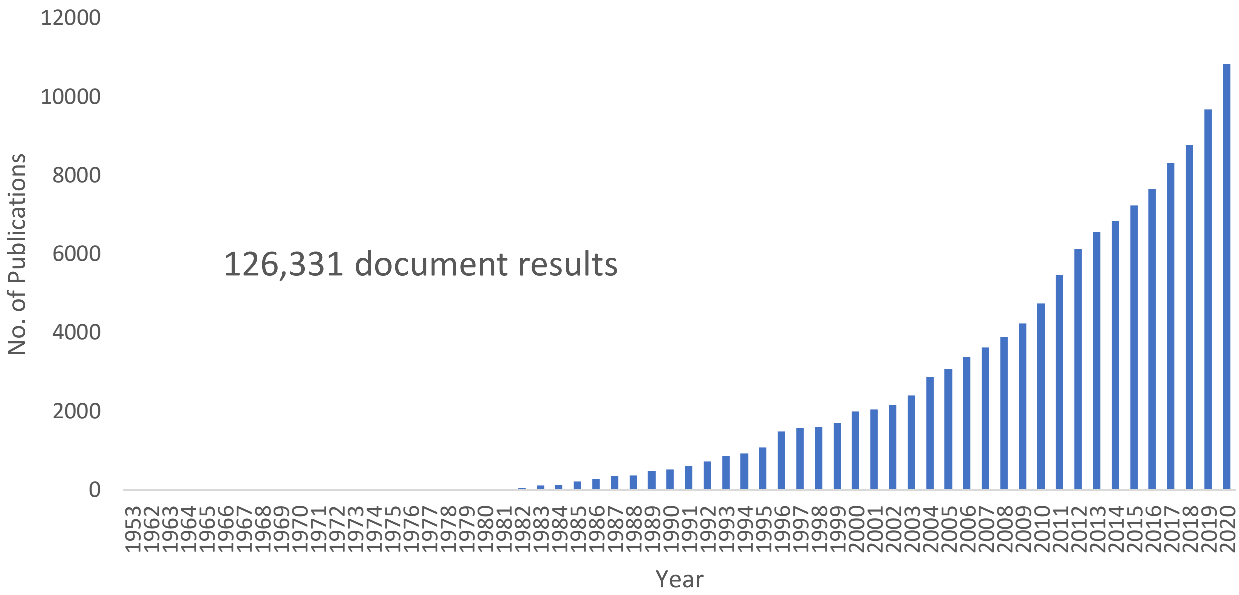

Figure 1: Number of documents published globally per annum on supercritical fluid technology from 1953 to 2020 using the Scopus database.

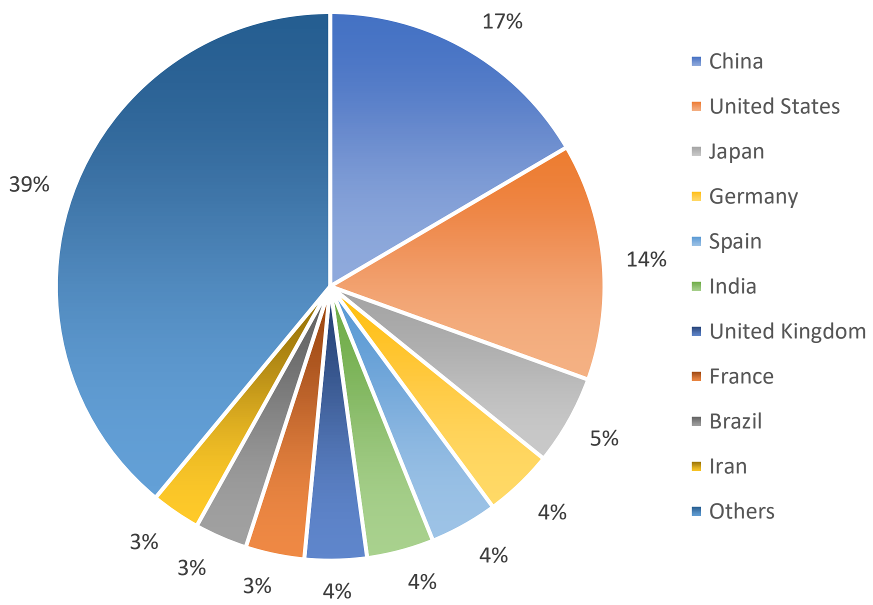

Figure 2: Using the Scopus database, published documents (global) distribution by territory on supercritical fluid technology from 1953 to 2020.

hydrolytic and alkylating reactions of esters and lower SCW polarity, the high-dielectric constant can be used well (Knez et al., 2019).

Reactions in enzyme-catalyzed non-aquatic solvents have become a crucial research area because of certain enzymes' high selectivity and activity in organic solvents and SCF. Improvement in non-aqueous solvent substrate solubility might have higher rates of reaction. SCF is, therefore, a promising non-aquatic solvent community. Green chemicals have become increasingly popular through the industrial interest in new environmentally-friendly solvent schemes (including SCFs, solvent fluorine, water, solvent-free systems, and ionic liquid) (Ghaffari-moghaddam et al., 2015; Hobbs and Thomas, 2007; Kavčič et al., 2014).

Applications of Supercritical Fluid Technology in the Philippines

It is best to look for possible sectors or areas where bibliometric analysis applies supercritical fluid technology in the Philippines. Scopus database was used in the study using the Boolean string, "(ALL ("supercritical fluid" OR "supercritical technology" OR "supercritical fluid technology")) AND (LIMIT-TO (AFFILCOUNTRY, "Philippines"))." The data retrieved from the database was then analyzed using an analysis tool provided by Scopus (Fig. 11). Most applications of supercritical fluid technology seemed to lie consistently in the field of chemistry and chemical engineering (Fig. 11). It is also good to know that supercritical fluid technology has a significant contribution to the energy sector, where carbon footprint can be reduced. In the Philippines, the first coal-fired powered plant to employ SCF technology is the San Buenaventura Power Ltd. Co. SCF

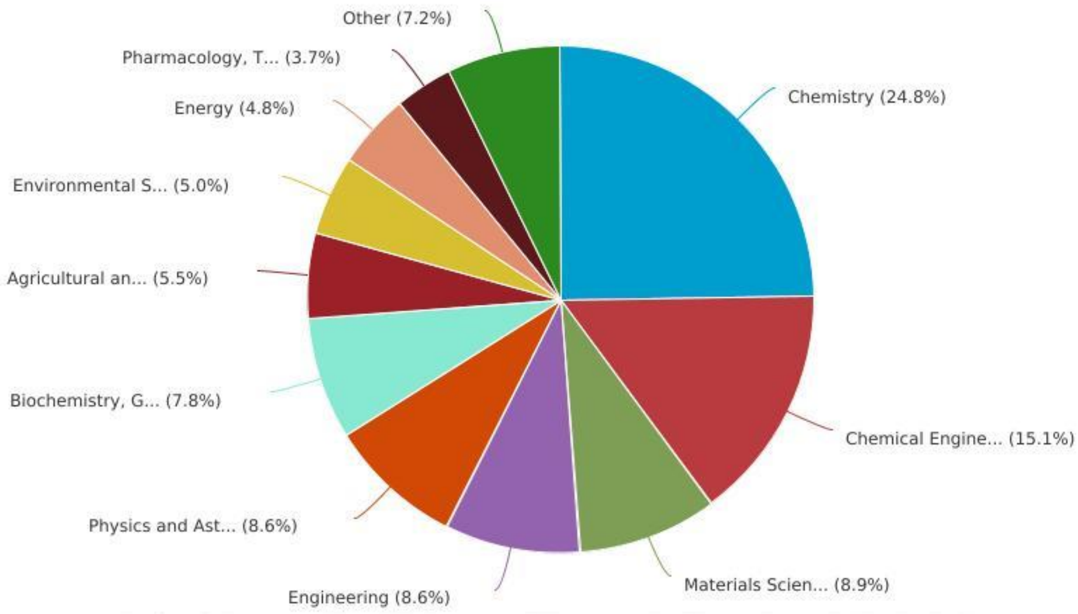

Figure 3: Global distribution of publications under supercritical fluid technology by subject/area from 1953 to 2020 using the Scopus database.

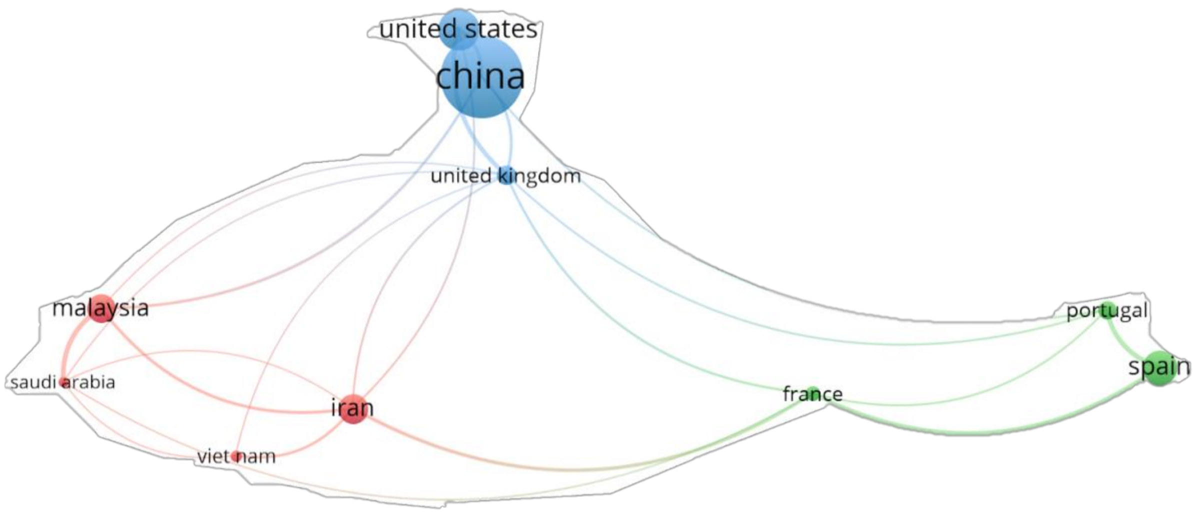

Figure 4: Collaboration analysis through co-authorship of top publishers in the field of supercritical fluid technology performed using the VOSviewer tool.

technology can decrease fuel consumption and pollution in coal-fired power plants.

Future Perspective and Challenges

Over organic solvent technologies, supercritical fluid technology provides significant advantages. Demands for new solvents have risen because of solid environmental concerns and rises in organic solvent price rates. More contemporary goods are also challenging in all fields of human life with unique features, high purities, and low energy consumption because of lower process temperatures (Brunner, 2010). Thus, advancements in supercritical technology opened new opportunities for inexpensive, environmentally safe methods for substances and goods.

Substantial progress in analysis, engineering, scale-up, and economic issues regarding the implementation of that technology at the industrial level was made by the accumulated expertise gained in the fields of SCF extraction technology (de Melo *et al*., 2014). However, many SFE investigations are not organized, so a route from feedstock to products is designed (Rasheed *et al*., 2021). In this regard, future research quality with a cradle-to-gate perspective is needed (Gwee *et al*., 2020; Rasheed *et al*., 2021).

ADOPTION OF SUPERCRITICAL FLUID TECHNOLOGY

Adoption of and proliferation of technology would be as critical as creating new technologies and should encourage the broad adoption of the best technologies available for efficient use of

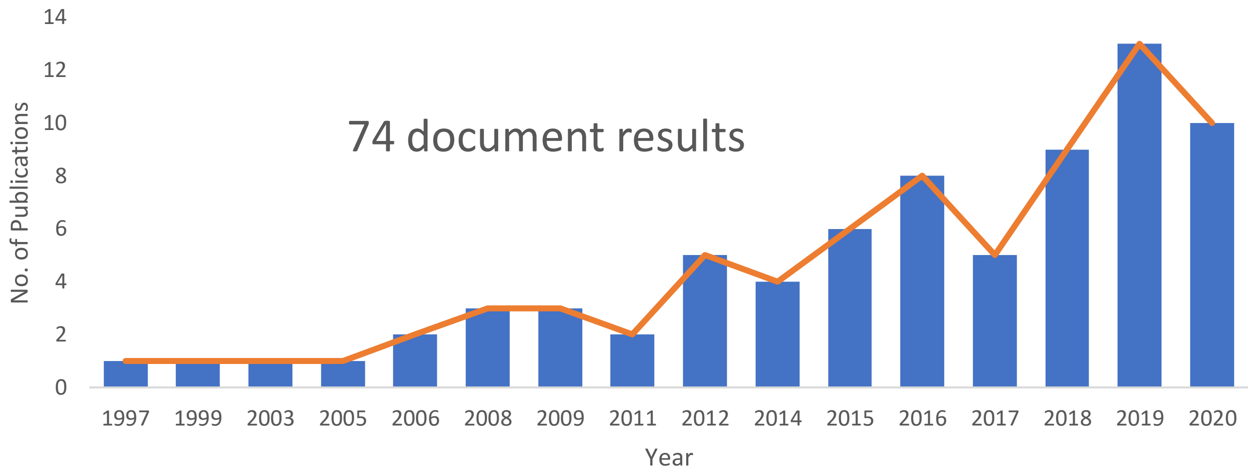

Figure 5: Number of documents published in the Philippines per annum on supercritical fluid technology; started from 1997 to 2020, using the Scopus database.

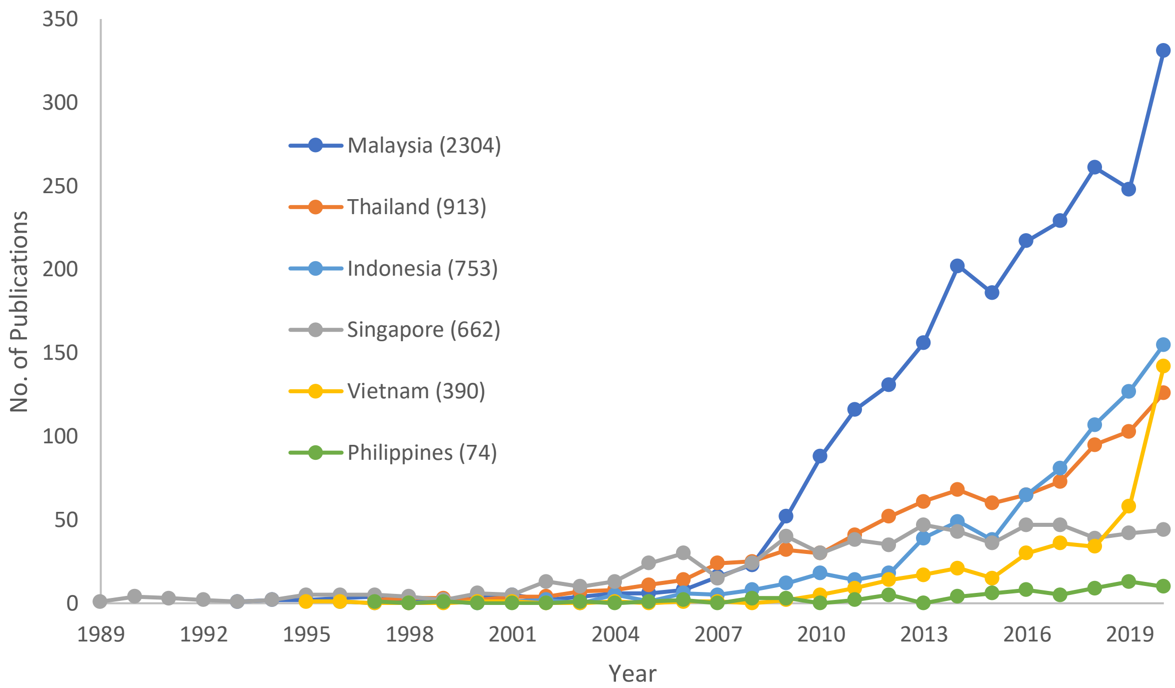

Figure 6: Trends of top five publishers in Southeast Asia on supercritical fluid technology from 1989 to 2020 using the Scopus database.

resources (OECD, 2016). This section discusses a theory on technology adoption cycles that can promote factors, challenges, and limitations in adopting and disseminating supercritical fluid technology in the Philippines.

Facilitating Factors

Any factor which promotes and stimulates public education in a fertile environment is described as facilitating factors or facilitators. In driving – or dissuading – eco-innovation, the market and organization of markets are critical. Market demand is influenced by policy agenda changes that describe the environmental impacts of the customer's goods and services. In such situations, politicians must correct stereotypes to build the right atmosphere in the market (UNIDO, 2015).

Barriers and Constraints of Adoption

Three barriers or constraints may occur in the full adoption of the supercritical technology in the Philippines: (1) weak corporate capacity for meaningful adoption, (2) general lack of critical innovation and complementarity with adoption, and (3) weak government capacity in managing the increased complexity and reach of the innovation and adoption policies of the last two barriers. The study specifically attempts to find common ground in methodological traditions in analyzing these three barriers, which often clash in both philosophical and political fields. One of its kind is the standard neoclassical tradition, which, to over-simplify, sees innovation policy as significant remediation of innovation-induced market failures (UNIDO, 2015).

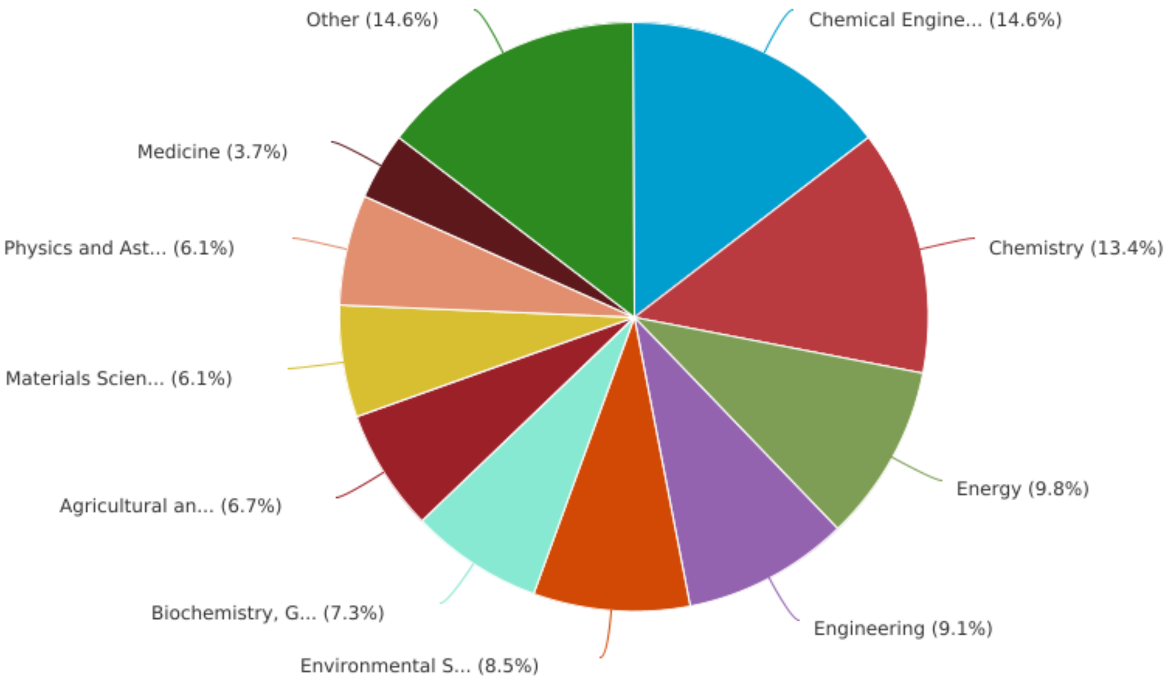

Figure 7: Publication distribution on supercritical fluid technology in the Philippines by subject/area from 1997 to 2020 using the Scopus database.

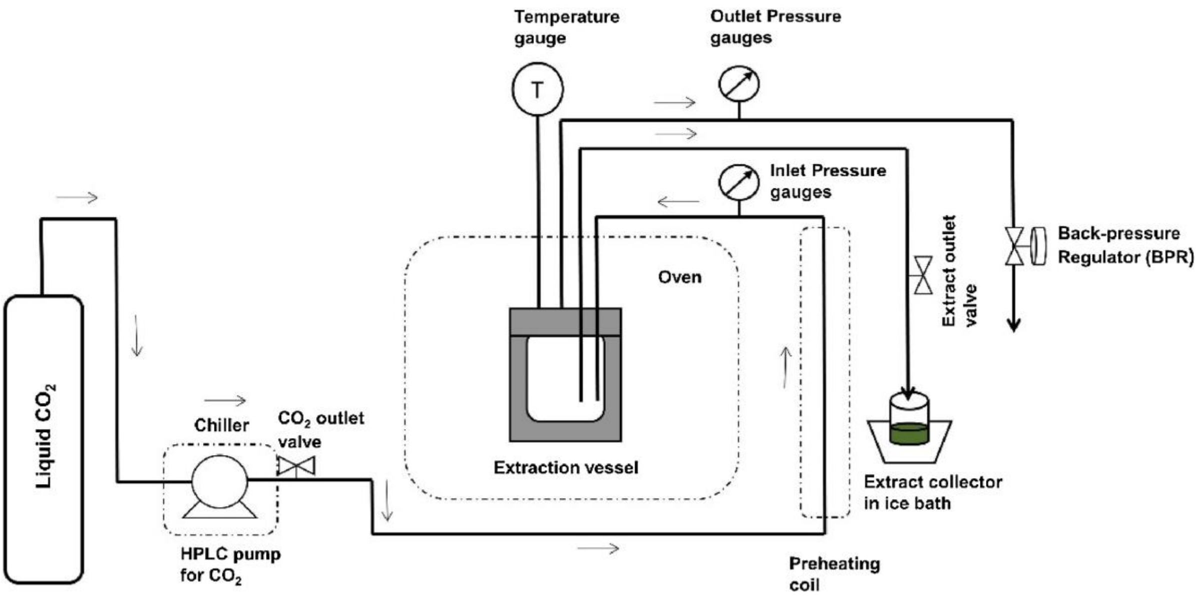

Figure 8: Schematic diagram of the extraction apparatus utilizing supercritical carbon dioxide with other co-solvents (Rubi et al., 2019).

A common mistake is that since many can use their expertise, a person who invests in innovation or discovers new technology to introduce to a country may not enjoy the full benefits of investment. Others will take advantage of investment without costs. Several policy instruments, such as R&D (research and development) grants and tax incentives, matching grant funds, and establishing non-market institutions like public research institutes and universities, have been used to address the failure (UNIDO, 2015).

IMPACTS OF THE SUPERCRITICAL FLUID TECHNOLOGY

Technological change is a significant megatrend, constantly being reshaped, often dramatically by the economy and society. In terms of form, knowledge base, and application, the technology spectrum is vast and expansive, and it interacts complexly and co-exultantly with economies and societies. Such circumstances create tremendous confusion about technological change's possible paths and impacts and provide opportunities to shape and implement technology for industries, governments, and people. In this respect, many forms of technology evaluations may provide helpful feedback, such as trend analyses, assessments, estimates, and foresight exercises (OECD, 2016).

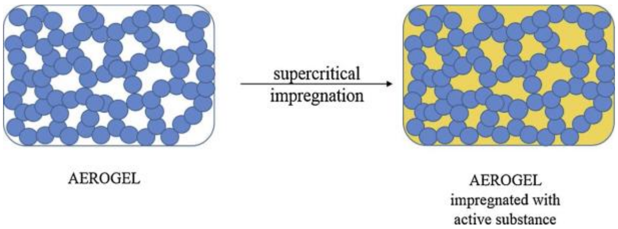

Figure 9: Schematic presentation of supercritical impregnation process (Munshi and Bhaduri, 2009).

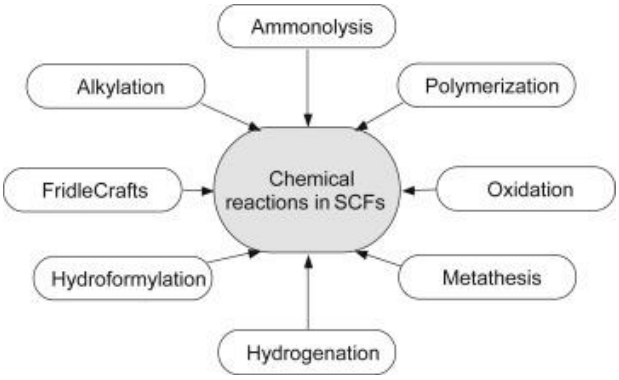

Figure 10: Chemical reactions in supercritical fluids on an industrial scale (Munshi and Bhaduri, 2009).

Economy
Considering the extent of use or publication related to supercritical technology in Southeast Asia, Malaysia has the highest number of published journals compared to the Philippines, which placed sixth (Fig. 12). It can also be observed that the top publishers have higher GDP (Growth Domestic Product) per capita than the Philippines, which is related to the economic status of a country (Fig. 13). It can be said that Southeast Asian countries with higher economic stature are more open to embracing technological innovation from other countries to gain more economically and environmentally. The number of publications associated with supercritical technology fluid utilization directly relates to the GDP (Fig. 14). Interestingly, both parameters have an increasing trend. These findings may relate to the openness of the Philippines to adopt the new technology opting to diffuse such technology in expansive space fully.

Industry and Manufacturing
The adoption of supercritical fluid technology can significantly impact the manufacturing sector in the agricultural and services sectors; manufacturing industries have higher income, wages, and output multipliers. Manufacturing comprises over half of the industrial sector in the Philippines and represents almost a quarter of the nation's gross domestic product (GDP). The manufacturing industry expanded by 10.5% in 2013 from an annual growth rate of 5.4% in 2012 (NEDA, 2016a). Furthermore, the manufacturing sector facilitates stronger inter-industry and inter-sectoral ties, productivity, technological growth, and innovation. As such, the development of the manufacturing industry boosts the diversification, demand, and upgrading for higher value-added services in the industry and manufacturing sectors.

Preliminary findings from the 2016 Annual Survey of Philippine Business and Industry (ASPBI) show that 6,208 establishments with TE of 20 and over operate in the formal business sector (Fig. 15). More than half of the total number of companies constituted the top 10 sectors in the industry (53.9 %). Possible adopters of

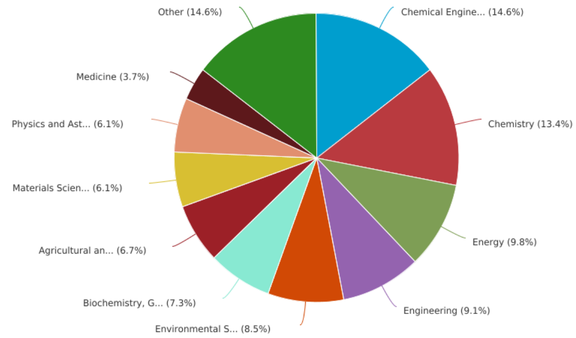

Figure 11: Publication distribution on supercritical fluid technology in the Philippines by subject/area using the Scopus database.

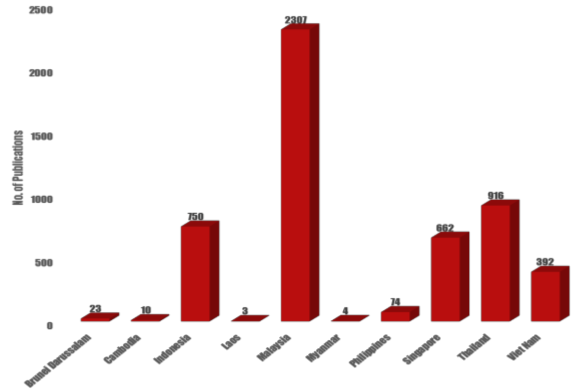

Figure 12: Number of documents published in the Southeast Asian Region on supercritical fluid technology from 1989 to 2020 using the Scopus database.

supercritical fluid technology are in the food and plastic products industry, which combines 20.2%. The National Capital Region (NCR) has the highest number of establishments among the 18 regions, with 2,256 or 36.3% of the total (Fig. 16). With 1,634 establishments (26.3 %), CALABARZON placed second (PSA, 2019). The most technological access is attributed to NCR. Hence, technology adoption may arise in this region and eventually provide a significant impact that may be observed when SCF is fully adopted.

Furthermore, the possible estimated size of adoption in value output is approximately 48% assuming that food, beverages, refined petroleum products, and dairy products were all manufactured using the SCF technology (Fig. 17) (PSA, 2019).

Supercritical coal-fired power stations are a type of coal-fired power station used for modern design. They differ from conventional coal-fired power stations because the water acts as a supercritical fluid, meaning it is not a liquid or a gas (Di Gianfrancesco, 2017). This technique has shown that less carbon is used to heat the same amount of water as is usually required in a typical coal-fired plant (Yadav and Mondal, 2021). This supercritical fluid technology also dramatically increases the thermal efficiency of the plant. In the Philippines, the first coal-fired power plant to use supercritical technology is the SBPL (San Buenaventura Power Ltd. Co., Mauban, Quezon) Power Plant in 2019, with a capacity of 500 megawatts (Fig. 18) (Cinco, 2020). Increased operational effectiveness contributes to decreased fuel and air pollution, including carbon dioxide, and advanced coal-fired power technologies such as supercritical technology (Di Gianfrancesco, 2017). This scenario indicates

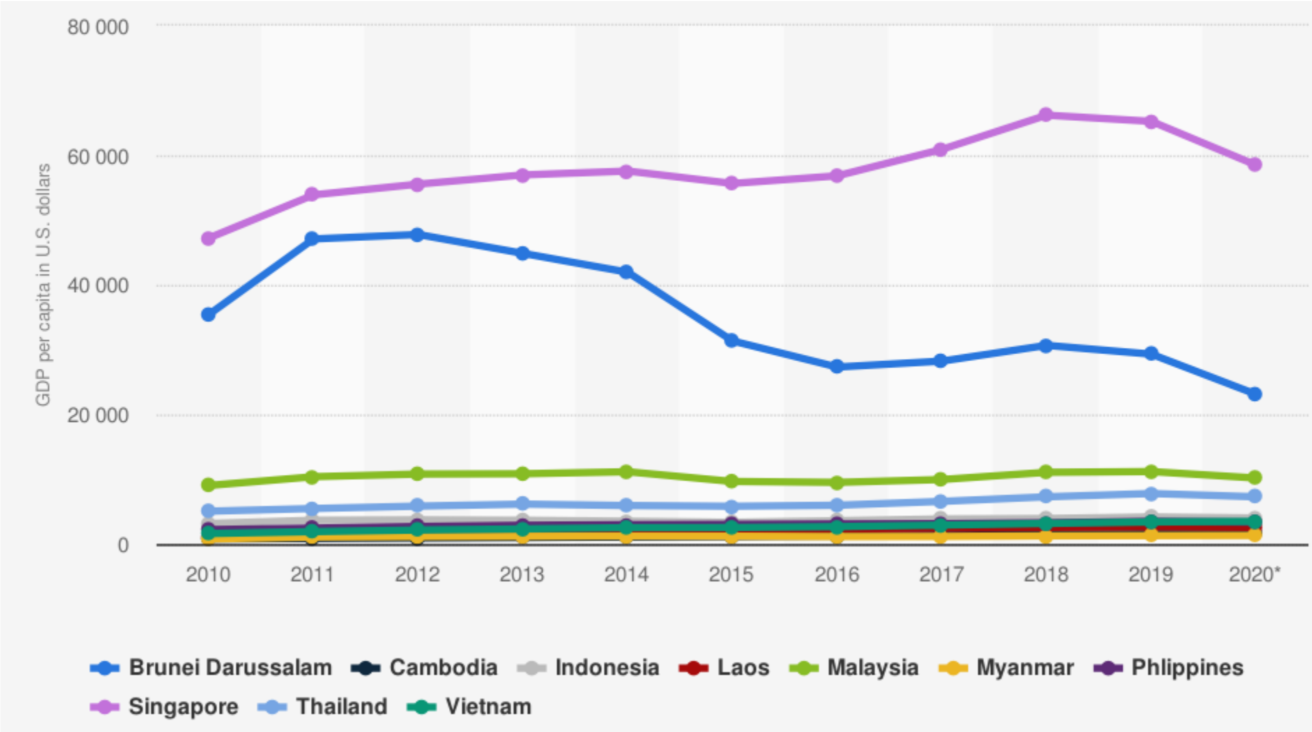

Figure 13: Gross domestic product (GDP) per capita in current prices from 2010 to 2020 (IMF, 2020)

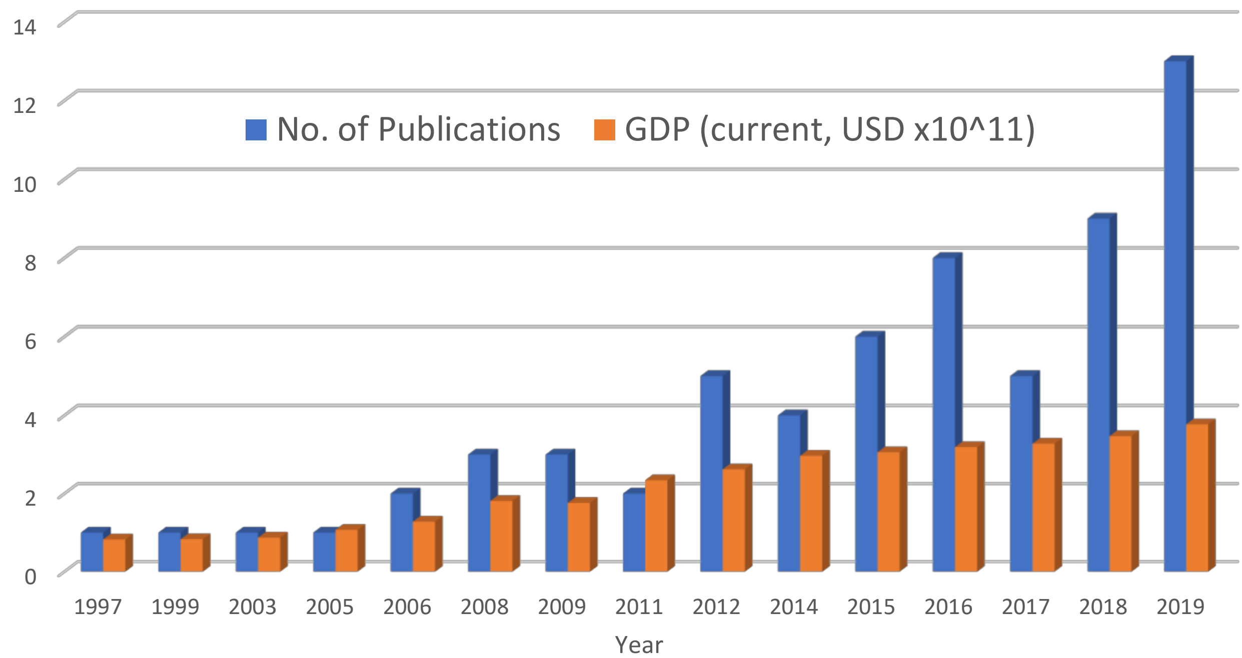

Figure 14: Number of documents published, and the Annual Gross Domestic Product in the Philippines on supercritical fluid technology from 1997 to 2020.

that the energy sector is starting to appreciate the advantages of having supercritical fluid technology in its system.

Education and Research and Development

Those most involved in research belong to the top universities that are globally competitive and ready to embrace new technologies. This finding is based on the number of published documents related to supercritical fluid technology (Fig. 19). The University of the Philippines published the most significant \number of related documents with 27, followed by the De la Salle University with 19. Supercritical fluid (SCF) technology applications are made in the laboratory, which include extraction and chemical and biochemical reactions.

Society

The organization of markets and business dynamics play a role in pushing or dissuading eco-innovation that has an essential impact on people's lives. Demand for new goods and the incremental environment integration in existing products have led to eco-innovations being embraced and disseminated (Rehfeld *et al.*, 2007). Market demand was also influenced by policy agenda changes that determine what consumers expect from the environmental impact of products and services. Incentives were created to reuse metal elements in buildings, for example, by higher prices for metal items (UNIDO, 2015).

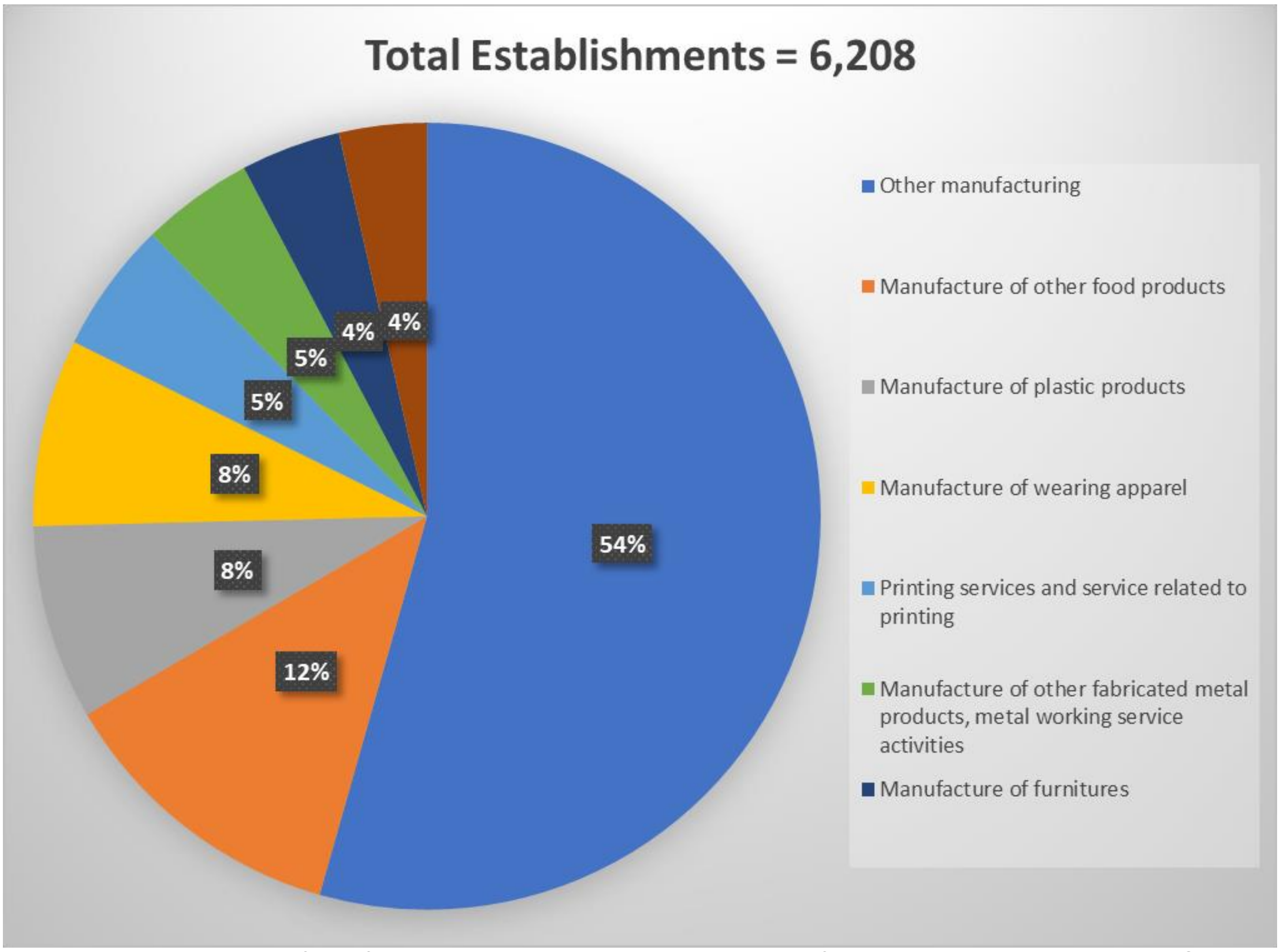

Figure 15: Percent distribution of manufacturing establishments with total employment of 20 and over by industry group 2016 (PSA, 2019).

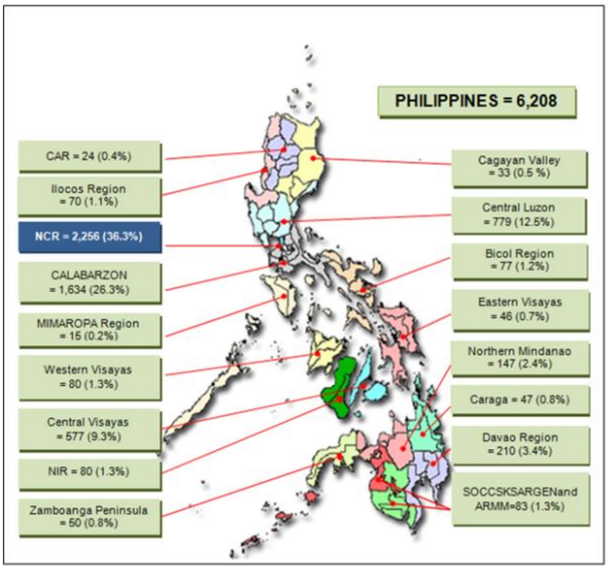

Figure 16: Regional distribution of manufacturing establishments with total employment of 20 and over (PSA, 2019).

POLICY DIRECTIONS AND RECOMMENDATIONS

Government Policy and Laws

Government policy directions are crucial in the adoption and diffusion process of technology. The Philippine government has formulated an agenda to support the United Nations Sustainable Development Goals (UN SDG) or the "Agenda 2030" (NEDA, 2016a). Considering some policy directions, let us enumerate some strategies or frameworks that the government has established to support the manufacturing sector that could affect labor and employment, human resource development, education, research and development, and innovation.

The Comprehensive National Industrial Strategy (CNIS) (Fig. 20 and 21) links and incorporates agriculture, manufacturing, and services, focuses on supply chain gaps, and intensifies industry participation in global value chains (DTI-BOI, 2020). Strategic actions include green industries, innovation, and R&D activities, human resource development, infrastructure investments, aggressive promotion and marketing programs, and SME (small and medium enterprise) development to address the high cost of logistics, power, and shipping; and automation and streamlining of government regulations and procedures affecting business actions (DTI-BOI, n.d.).

Another driver in the adoption of supercritical fluid technology in the Philippines is environmental laws. Major environmental laws include the Republic Act 9003 or the Ecological Solid Waste Management Act of 2000, Republic Act 9275 or the Philippine Clean Water Act of 2004, Republic Act 8749 or the Philippine Clean Air Act of 1999, Republic Act 6969 or the Toxic Substances, Hazardous and Nuclear Waste Control Act of 1990, and Presidential Decree 1586 or the Environmental Impact Statement (EIS) of 1978 (EMB, n.d.). With the motivation of the Philippines to address the climate change issues, the manufacturing sector will be obliged to use an alternative green technology such as supercritical technology.

Research and development (R&D) play a crucial role in innovation in the high-tech industries, while the adoption of

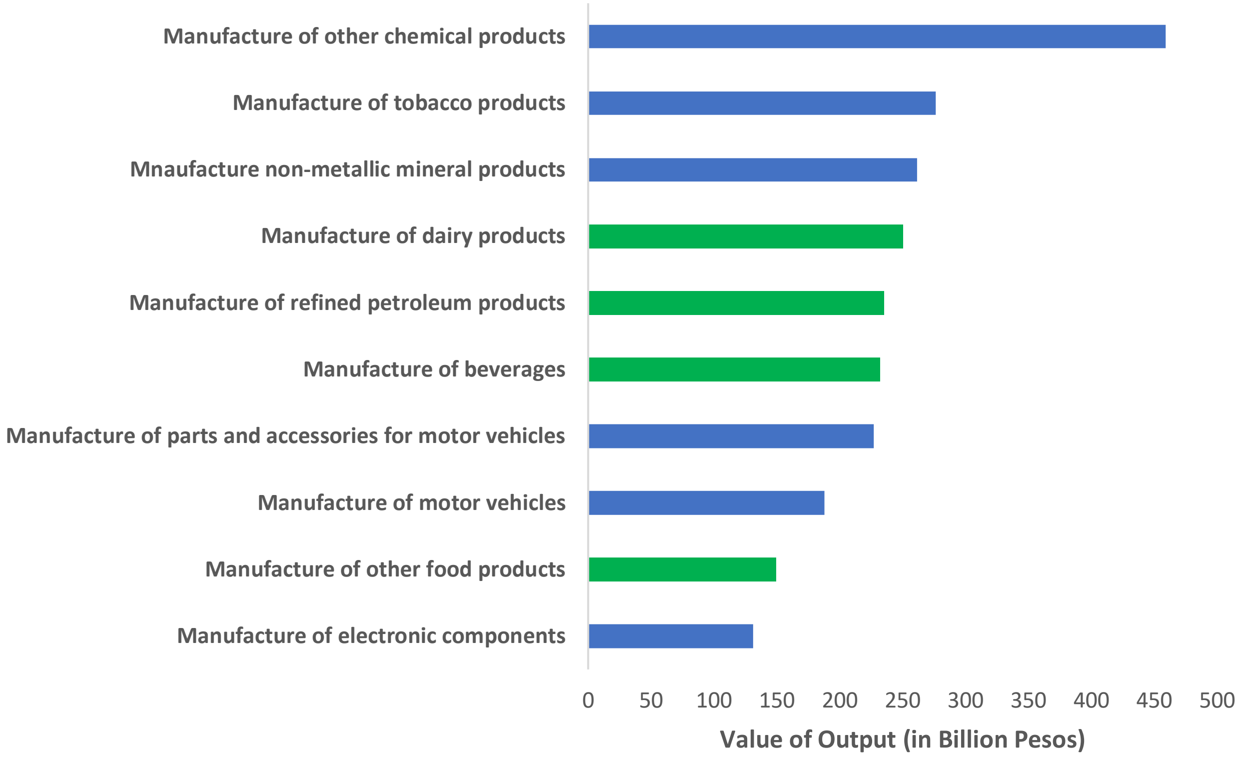

Figure 17: Top grossers in output value for manufacturing establishments with total employment of 20 and over by industry group (PSA, 2019). Sectors in green bars are possible adopters of supercritical fluid technology.

Figure 18: The 1st Supercritical Coal-Fired Power Plant in the Philippines by San Buenaventura Power Ltd. Co., with a capacity of 550 MW located in Mauban, Quezon (Cinco, 2020).

established knowledge and technology by other industries is becoming broad. The National Economic and Development Authority (NEDA), in cooperation with other government agencies, such as the Department of Science and Technology (DOST), has formulated a policy plan to leverage STIs in outcomes are being monitored, including (1) creative capacity for knowledge and technology generation, acquisition, and adoption enhanced; (2) STI utilization in the investments in

achieving this objective (Fig. 22). These government agencies will help accelerate and promote technology adoption and incite innovation to promote STIs in the country. The four sub-sectorqe

technology-based startups, enterprises, and spin-offs increased; and (3) open collaboration among actors in the STI ecosystem strengthened; agriculture, industry, and services sectors improved

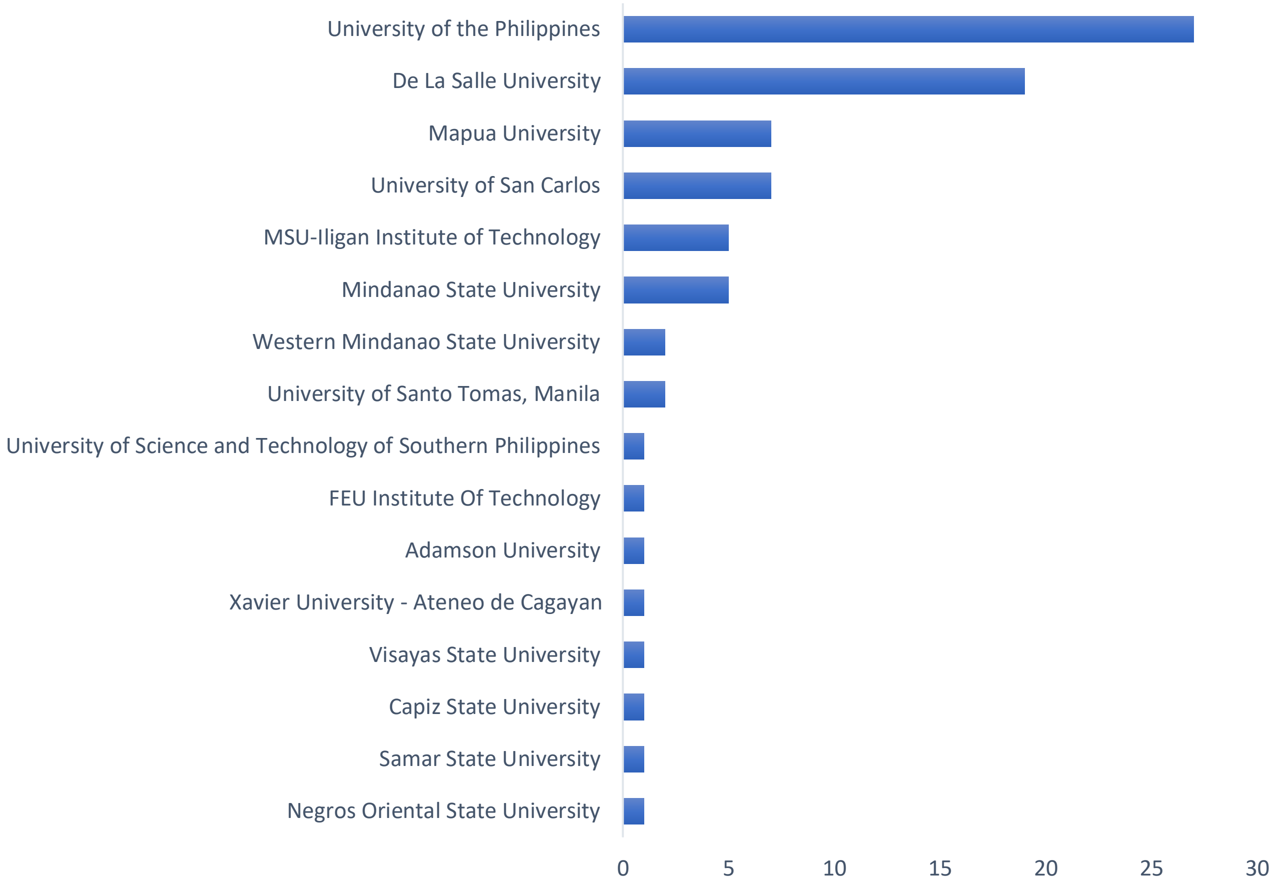

Figure 19: Research involvement of different academe/research institutions to supercritical fluid technology using the Scopus database.

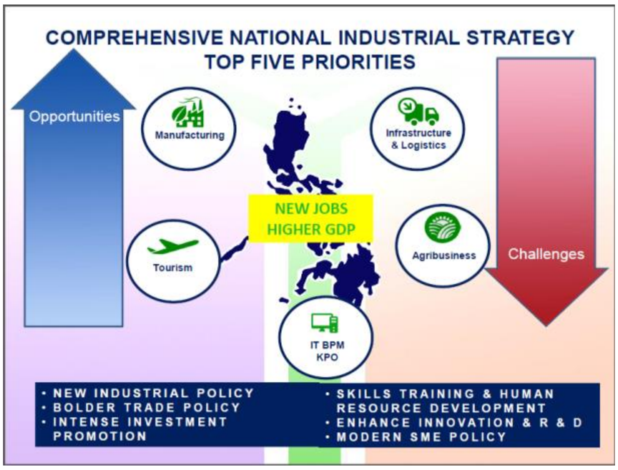

Figure 20: Comprehensive national industrial strategy on top five priority sectors (DTI-BOI, n.d.)

(Fig. 22) (NEDA, 2016b). This framework also covers human resource development and education.

Policy Recommendations

Much policy and research advice have been centered on the growing interest in adopting foreign technologies in developing countries, especially domestic capabilities, to absorb technology. A fundamental challenge is the lack of expertise and the absence of the market. Innovation in the manufacturing sector is subject to fixed costs; therefore, increased specialization is needed in economies of scale (UNIDO, 2015). Thus, the increased adoption and diffusion of new green technologies, such as supercritical fluid technology, is essential. Future adoption of technology would require increased organizational capabilities and domestic skills (OECD, 2016).

The trade and investment, industry representation and infrastructure, business-enabling, and macroeconomic policies must complement innovative technologies and industrial policies to promote competitiveness in a country (Fig. 23). These policies must be accompanied by a more radical macroeconomic strategy and more strategic investment policies to be incorporated into the global valuation chain (GCV). Additional policies are essential to tackle trade-offs and maintain an equilibrium between fiscal, environmental, and social aspects.

CONCLUSIONS

This study highlights the vital importance of developing such untapped adoption of supercritical fluid technology and examines why a developing country, the Philippines, is doing too little to achieve it compared to other countries. The process of developing companies and countries' capabilities, particularly sophisticated management practices, brings analytical discipline and economic rigor. The rational response of firms, especially in the manufacturing sector, is vital to meet a variety of constraints that hinder the build-up of physical and human capital, low marketability, and poor government capacities. It is not straightforward to unlock the tremendous potential growth of countries moving closer to the technological frontier, which includes the adoption of supercritical fluid technology. Both facets of society headed up by the government must make great efforts. In conclusion, the adoption by companies of new technology such as supercritical fluid technology is a crucial feature of productivity growth and, thus, economic development.

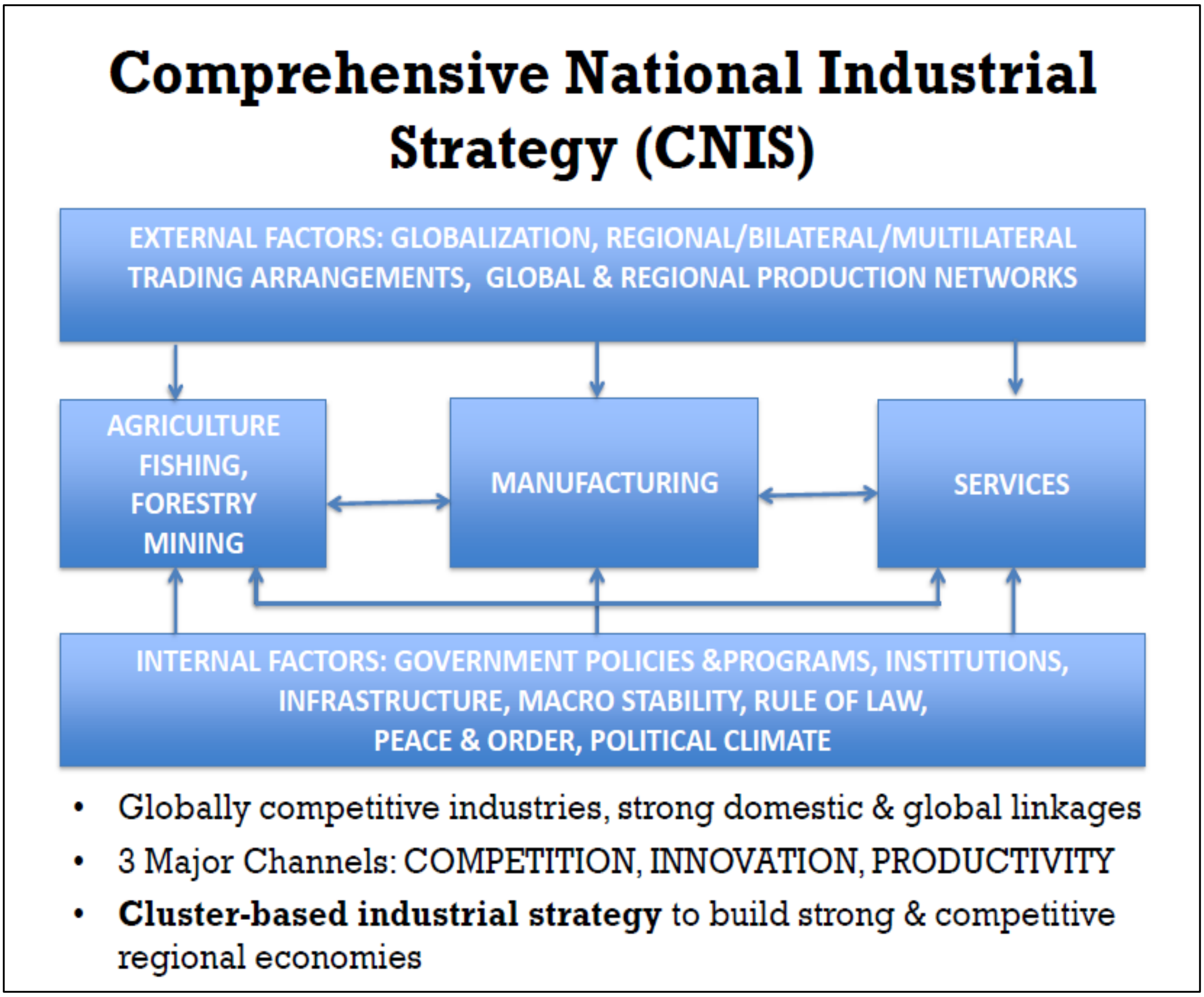

Figure 21: Comprehensive national industrial strategy flow chart (DTI-BOI, n.d.)

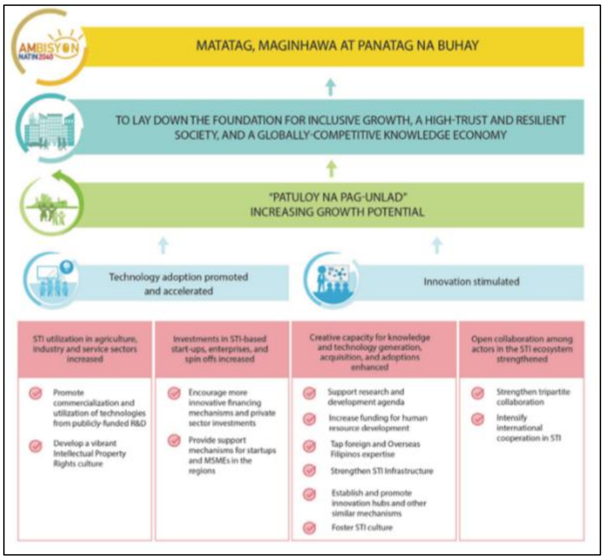

Figure 22: Strategic Framework to Leverage Science, Technologeqeqwy, aand Innovation (NEDA, 2016b).

proportions for inclusive economic growth is a potential opportunity for developing countries to draw on a vast amount of global know-how and technological knowledge to adopt what has already been invented.

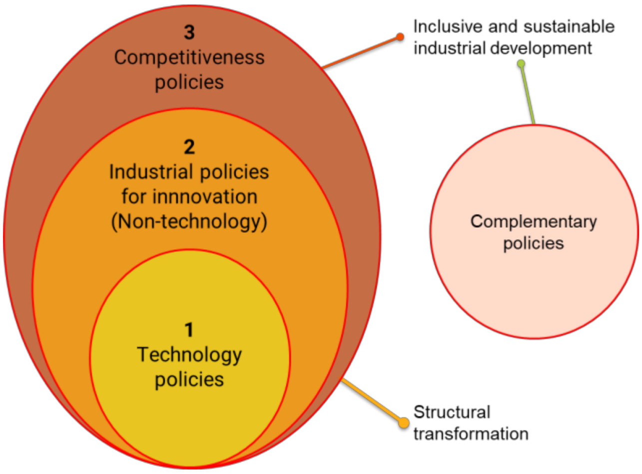

Figure 23: Policies targeting inclusive and sustainable industrial development (UNIDO, 2015).

CONFLICTS OF INTEREST

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CONTRIBUTIONS OF INDIVIDUAL AUTHORS

Prof. Alvin B. Culaba triggered the concept and supervised Engr. Juvyneil Cartel in preparing and revising the manuscript. Engr.

Asuncion Raquel T. Casio helped collect and analyze the data and review the manuscript.

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