



## Green Patenting Efficiency of Higher Educational Institutions in India

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Considering the present state of the global environment, it is imperative for academic institutions to prioritise the promotion of sustainability. The potential challenges faced by rapidly developing economies such as India can be addressed through the implementation of innovative and science-driven approaches such as the creation of green technologies. The present investigation aimed to analyse the prevailing patterns of environmentally sustainable technologies. To evaluate the efficiency of the leading 50 higher educational institutions according to NIRF 2022, this study employed data envelopment analysis. The results indicate that 16 universities have made noteworthy advancements in the creation of technologies that foster environmental sustainability. Furthermore, leading academic institutions collectively filed 1217 patents.

**Keywords:** Green Patenting, Patenting Efficiency, Green Patent Efficiency, Environmentally Sustainable Technologies, Third Mission

The exacerbating impacts of climate change have caused the degradation of worldwide ecological circumstances, culminating in an unparalleled predicament of sustainability. Ensuring sustainability is an imperative priority that cannot be compromised, and the implementation of science-based solutions, such as green technologies, may aid in mitigating ecological degradation in rapidly growing economies such as India.<sup>1</sup> This assertion posits that it is incumbent on all individuals within a given society to engage in the process of transitioning towards sustainable practices. The urgent need for sustainable development and the consequent importance of innovation raise legitimate concerns about the responsibility of universities to undertake research duties in addressing sustainability crisis.<sup>2</sup> The execution of innovative initiatives presents advantages not only to universities but also to industries. The latter are currently experiencing considerable pressure as a result of swift technological developments and abbreviated product life cycles and are therefore seeking sustainable alternatives. Consequently, there is increasing demand for collaboration between industries and universities

to augment innovation and attain a competitive edge.<sup>3</sup> Concurrently, academic institutions, through the creation of innovative and highly desirable information, fund their investigative pursuits, procure assets, and serve as tangible stimulants for financial progress<sup>3</sup>. Throughout history, collaborations between universities and industry have played a significant role in the development of a novel 'third mission' for universities, which has continued to evolve over time.<sup>4</sup> The objective of this mission is to make a valuable contribution to both the economy and society by generating and disseminating research findings, promoting partnerships with industry and government, converting research outcomes into commercial products, and fulfilling wider societal obligations.<sup>4</sup> The conventional strategy adopted by universities to accomplish their third mission entails leveraging technology to facilitate the dissemination of research outcomes including patents, licencing, spinoffs, and entrepreneurship.<sup>3</sup> However, the discretion of faculty members is a determining factor in the disclosure of research findings to universities for technology transfer purposes.<sup>5</sup> Universities have responded to the sustainability crisis by establishing novel research prospects that concentrate on sustainability science.<sup>6</sup> Sustainability science

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strives to offer resolution through the amalgamation of interdisciplinary investigations, inventive methodologies, and cooperative alliances among scholars. The concept of sustainability science has been identified as an underlying objective for promoting innovation within the framework of the third mission, as highlighted by various scholars<sup>7</sup> and there is a noticeable trend among higher education institutions to create new and long-lasting technologies.<sup>8, 9</sup> However, the evaluation of the efficiency of innovation in generating sustainable technologies, as indicated by patents, has been underexplored. Prior research has primarily concentrated on quantifying the number of patents produced,<sup>10</sup> sustainable patents generated, and research efficiency in patent production.<sup>11</sup> This study assesses the efficiency of green patent generation by leading institutions in India. This pursuit appears to be crucial, as India offers a compelling research environment for investigation owing to its categorisation as a lower-middle-income nation that obtains more than 50% of research funding from public sources or governmental institutions.<sup>11</sup> In light of the significant investment in public funds for academic research in India, it is crucial to understand how resources are utilised and mobilised to produce academic patents that promote regional development, public outreach, and sustainable research. This understanding is essential for assessing the effectiveness of resource allocation and utilisation in achieving sustainable outcomes. The aim of this study is two-fold: first, to investigate the recent trend of environmentally sustainable technologies that have been filed, and second, to employ data envelopment analysis as a means of evaluating the efficiency of the leading institutions. This study aims to provide empirical evidence of a university's role in promoting sustainability and identifying potential sources of inefficiency. The findings indicate that 16 universities demonstrated a satisfactory degree of efficiency in the development of environmentally sustainable technologies.

### **University Third Mission**

The third mission of the university pertains to its formal obligation to engage with society through scientific means.<sup>12</sup> The aforementioned definition suggests a change in the university paradigm that emphasises the amalgamation of science, technology, and society to address societal concerns through

technology transfer. This process entails deliberate collaboration between academic and non-academic partners.<sup>13</sup> Academic institutions often employ diverse strategies for technology transfer to establish connections with the industry. These approaches may encompass activities such as industrial gatherings, symposia, advisory services, and commissioned researches.<sup>3</sup> Furthermore, academic institutions have the ability to establish laboratories, incubators, and research centres; engage in collaborative research endeavours and entrepreneurial pursuits; and exchange personnel with industries, patenting, licencing, spinoffs, and the creation of start-up companies. Expanding upon the third mission, the notion of co-creation to achieve sustainability has been amalgamated and promoted as an extra mission to address crises related to sustainability.<sup>6, 7</sup> The proposed methodology entails the utilisation of five distinct channels, namely knowledge management, technical demonstration and projects, technology transfer and economic development, reforms of the built or natural environment, and socio-technical experimentation, with the aim of collaboratively creating sustainable solutions<sup>14</sup>. The third mission is a dynamic and evolving concept that encompasses the resolution of sustainability crises in society.

### **University Patenting and Efficiency**

Recently, there has been a significant surge in research efforts focused on improving resource utilisation through the effective execution of a university's three missions.<sup>11,14</sup> The widely held perception is that the primary goals of universities are the pursuit of scholarly research and the dissemination of knowledge through teaching. Consequently, several academics have researched the efficiency of pedagogy in higher education.<sup>14</sup> Scholars have investigated the effectiveness of both pedagogy and scholarly inquiry.<sup>15, 16</sup> The key inputs that drive research and development (R&D) initiatives in academic institutions include the number of faculty members, research funding, research facilities, full-time equivalent of R&D personnel, quality of student enrolment, and student enrolment numbers.<sup>11,15,17,18</sup> The primary outcomes encompass the number of postgraduate scholars, the number of published works, patents, citations, and other related factors.<sup>11,15,17,18</sup> Finally, the university's third mission was limited research. In our study, the inputs were restricted to funds, while the outputs were limited to

green sustainable patents, which are environmentally sustainable technologies, due to data limitations. Universities are frequently examined as foundations for innovation in numerous academic enquiries regarding patenting. The use of patents as a means of transferring technology has been extensively studied by management scholars.<sup>5,9-11</sup> However, developing countries have paid little attention to this research area. Patents measure the tangible effects of innovation on economic growth and technological progress.<sup>19,20</sup> Academic institutions' patenting endeavours are susceptible to changes in their socioeconomic milieu. The Bayh-Dole Act, enacted in the 1980s in the United States, serves as an illustration of a policy aimed at encouraging the commercialisation of academic research through the provision of incentives for university patenting; this model has been adopted by other nations.<sup>22</sup> In the Indian context, studies have focused on the research performance of technical institutions with a specific emphasis on their patents or publication outputs.<sup>10</sup> To understand the drivers of patenting an econometric model to understand the various factors that impact the behaviour of academic researchers in India.<sup>23</sup> A comparative analysis across multiple scientific departments at the Indian Institute of Technology (IIT) Roorkee, situated in India.<sup>24</sup> Patenting endeavours of academic institutions in the realm of environmentally sustainable technologies.<sup>9</sup> The effectiveness of research outcomes, specifically patents and publications, in the Indian Institutes of Technology (IITs) was conducted<sup>11</sup>. Nevertheless, the study did not prioritise the assessment of patenting efficiency in relation to sustainable technology.

### Methodology

The World Intellectual Property Organization's Patentscope is a platform that facilitates access to patent information filed under the WIPO, either directly or in the national or regional offices of 152 contracting states.<sup>25</sup> The Patentscope platform features a specialised tool known as the "Green Patent Inventory", which is based on the International Patent Classification (IPC) system.<sup>26</sup> This tool offers a wide-ranging compilation of patent applications related to various areas of alternative energy production, transportation, energy conservation, waste management, agriculture and forestry, administrative regulatory or design, and nuclear power generation.<sup>26</sup> Patentscope provides a comprehensive range of data

encompassing application identification numbers, application filing dates, publication dates, IPC codes, and the appellations of applicants, inventors, and abstracts. Institutions included in the top 50 rankings under the National Institutional Ranking Framework (NIRF) 2022 were evaluated.<sup>27</sup> This can be attributed to the framework's inclusion of provisions for the recognition and management of intellectual property rights. The focal point of observation in this research pertains to applications submitted by a university or its intellectual property office. The analysis pertains to applications that have been filed domestically, internationally, and under the Patent Cooperation Treaty, covering the period 2015 to 2022. The categorisation of a document as a university patent depends on certain conditions, such as its submission through the university's channels, its corresponding orthographic variation, its submission by the university's technology transfer office, or its collaborative application with other entities. The assessment of a patent's relevance to research was based solely on International Patent Classification (IPC) codes associated with sustainable environmental technologies. It is pertinent to acknowledge that a solitary patent has the potential to be allocated multiple International Patent Classification (IPC) codes, leading to the convergence of technological domains. To address this issue, we assigned patents to their corresponding technological domains, leading to an increased number of entries compared with the factual count of patents. This methodology has also been implemented in cases in which collaborative applications have been detected among academic institutions. This study was conducted in a series of consecutive stages.

### ESTs

Phase 1: Data were collected from all patents filed by the institutions. The researchers independently searched for the names of each of the 50 institutions in the patent scope database and retrieved the results for the period between 2015 and 2022. The data obtained were subsequently considered for further analysis. The resulting output consists of more than 14,169 lists.

Phase 2: the compiled data underwent processing using the software "OpenRefine" for the purpose of grouping spelling variations and excluding universities that fall outside of the top 50 institutions. In addition, duplicate entries were removed as described in a

previous study. Approximately 7000 patent filings have been recorded over nearly eight years.

Phase 3: Over 500 IPC codes pertaining to ESTs were gathered from the Green Patent Inventory, which was established within the patent scope framework presented in Table 1. These codes were then cross-referenced with the IPC provisions listed in patent application entries using Microsoft Excel. It is noteworthy that, for the purpose of analysis, only IPC entries featuring at least one green code were considered. As a result, 1217 patent filings related to ESTs were identified across the top 50

institutions.

#### NIRF and DEA Assumptions

Phase 4: To perform DEA analysis aimed at computing efficiency, it is imperative to acquire data pertaining to input variables. The present investigation identified the input variables as capital expenditure funds and recurring expenditures, which were classified as research and development.<sup>11</sup> The output variables were green patents, specifically ESTs filed, obtained from previous stages. Scholars have previously recognised a time lag between input and output variables,<sup>28</sup> whereby the manifestation of an

Table 1 — Environmentally sound technologies- IPC codes

Field	Technology	IPC codes
Alternative energy production	Bio-fuels	C10L3/00, F02C 3/28
	Fuel cells	H01M4/86-4/98, 8/00-8/24,12/00-12/08, H01M 4/86-4/98,H01M4/86-4/98,H01M 8/00-8/24, 50/00-50/171,H01M 12/00-12/08,C10B 53/00,C10J
	Harnessing energy from manmade waste	C10L 5/00,C10L 5/42, 5/44,F23G 7/00, 7/10, C10J 3/02, 3/46,F23B 90/00,F23G 5/027,B09B 3/00,F23G 7/00,C10L 5/48,F23G 5/00, 7/00,C21B 5/06,D21C 11/00,A62D 3/02,C02F 11/04, 11/14,F23G 7/00, 7/10,B09B 3/00,F23G 5/00,B09B,B01D 53/02, 53/04, 53/047, 53/14, 53/22, 53/24, C10L 5/46,F23G 5/00
	Hydro energy	E02B,9/00-9/06,E02B,9/08,F03B,F03C,F03B,13/12-13/26,F03B 15/00-15/22,B63H 19/02, 19/04,F03G 7/05
	Wind energy	F03D,H02K 7/18,B63B 35/00,E04H 12/00,F03D 13/00,B60K 16/00,B60L 8/00,B63H 13/00
	Solar energy	F24S,H02S,H01L 27/142, 31/00-31/078,H01G 9/20,H02S 10/00,H01L 27/30, 51/42-51/48,H01L 25/00, 25/03, 25/16, 25/18, 31/042,C01B 33/02,C23C 14/14, 16/24,C30B 29/06,G05F 1/67,F21L 4/00,F21S 9/03,H02J 7/35,H01G 9/20,H01M 14/00,F24S,F24D 17/00, 18/00,F24D 3/00, 5/00, 11/00, 19/00,F24S 90/00,F03D 1/04, 9/00, 13/20,F03G 6/00,C02F 1/14,F02C 1/05,H01L 31/0525,H02S 40/44,B60K 16/00,B60L 8/00,F03G 6/00-6/06,E04D 13/00, 13/18,F22B 1/00,F24V 30/00,F25B 27/00,F26B 3/00, 3/28,F24S 23/00,G02B 7/183,F24S 10/10,F24T,F01K,F24F 5/00,F24T 10/00-50/00,H02N 10/00,F25B 30/06,F03G 4/00-4/06, 7/04,F24T 10/00-50/00,F24V 30/00-50/00,F24D 11/02,F24D 15/04,F24D 17/02, 18/00,F24H 4/00,F25B 30/00,F01K 27/00,F01K 23/06-23/10,F01N 5/00,F02G 5/00-5/04, F25B 27/02,F01K 17/00, 23/04,F02C 6/18,F25B 27/02,C02F 1/16,D21F 5/20,F22B 1/02,F23G 5/46,F24F 12/00,F27D 17/00,F28D 17/00-20/00,C10J 3/86,F03G 5/00-5/08
Transportation	Vehicles in general	B60K6/00, 6/20, B60W 20/00,F16H 3/00-3/78, 48/00-48/30, H02K 29/08, H02K 49/10,B60L 7/10-7/22,B60L 8/00,B60L 9/00, B60L 50/50-58/40,F02B 43/00,F02M 21/02, 27/02, B60K 16/00, H02J 7/00
	Vehicles other than rail vehicles	B62D 35/00, 35/02, B63B 1/34-1/40,B62K,B62M 1/00, 3/00, 5/00, 6/00
	Rail vehicles	B61
	Drag reduction	B61D 17/02
	Marine vessel propulsion	B63H 9/00, B63H 13/00, B63H 19/02, 19/04, B63H 16/00,B63H 21/18, B64G 1/44
Energy conservation	Storage of electrical energy	B60K 6/28,B60W 10/26, H01M 10/44-10/46, H01G 11/00, H02J 3/28, 7/00, 15/00
	Power supply circuitry	H02J ,B60L 3/00,G01R,C09K 5/00,F24H 7/00,F28D 20/00, 20/02
	Low energy lighting	F21K 99/00, F21L 4/02 ,H01L 33/00-33/64, 51/50 H05B 33/00
	Thermal building insulation, in general	F03G 7/08, B60K 6/10, 6/30 ,B60L 50/30
	Waste management	Waste disposal

(contd.)

Table 1 — Environmentally sound technologies- IPC codes (*contd.*)

Field	Technology	IPC codes
	Treatment of waste	A61L 11/00, A62D 3/00, 101/00, G21F 9/00, B03B 9/06, B09C, D21B 1/08, 1/32, F23G
	Reuse of waste materials	A43B 1/12, 21/14, B22F 8/00, C04B 7/24-7/30, C04B 18/04-18/10, C05F
	Recovery of plastics materials from waste	B29B 17/00, B62D 67/00, C08J 11/04-11/28, C10G 1/10, C10L 5/46, 5/48, C22B 7/00-7/04, 19/30, 25/06, D01G 11/00, D21C 5/02, H01J 9/50, 9/52, H01M 6/52, 10/54
	Pollution control	B01D 53/14, 53/22, 53/62, B65G 5/00, C01B 32/50, E21B 41/00, 43/16, E21F 17/16, F25J 3/02
	Air quality management	B01D 53/00-53/96, F01N 3/00-3/38, B01D 53/92, F02B 75/10, C21C 5/38, C10B 21/18, F23B 80/02, F23C 9/00, 23G 7/06, F01N 9/00
	Control of water pollution	B63J 4/00, C02F, C05F 7/00, C09K 3/32, B63B 35/32, E02B 15/04, E03C 1/12, C02F 1/00, 3/00, 9/00, E03F, G21C
Agriculture / forestry	Forestry techniques	A01G 23/00
	Alternative irrigation techniques	A01G 25/00
	Pesticide alternatives	A01N 25/00-65/00
	Soil improvement	C09K 17/00, E02D 3/00
Administrative regulatory or design aspects	Commuting, e.g., hov, teleworking	G06Q, G08G
	Carbon/emissions trading, e.g. pollution credits	G06Q
	Static structure design	E04H 1/00
Nuclear power generation	Nuclear engineering	G21, G21B, G21C, G21D
	Gas turbine power plants using heat source of nuclear origin	F02C 1/05

Source: IPC Green Inventory

effect is contingent upon the duration between the initiation of an action and its realisation, despite the presence of only one input and one output. To investigate this phenomenon, a correlation analysis was performed on research and development funds over an 8-year time frame, yielding a significant correlation. The aforementioned discovery implies that opting for 2015 research expenditure instead of 2013 would result in comparable results. The data were averaged to mitigate any inaccuracies that may have arisen due to temporal lags, as observed in prior research.<sup>28, 29</sup> The data were prepared in accordance with the guidelines outlined.<sup>30</sup>

Phase 6: To perform DEA, an output-oriented methodology predicated was employed on the notion of enhancing output while not preserving the current input level. The variable return to scale was used to measure technical efficiency (TE). The present research utilises a benchmarking package within the R software for analytical objectives.

## Results

The top institutions filed a total of 1217 patents; the filing trend has been on the rise since 2016, with a

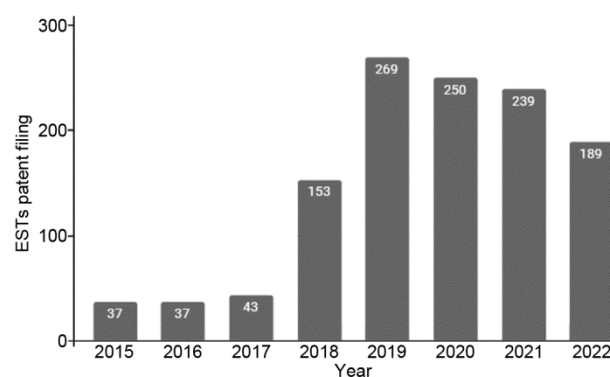


Fig. 1 — Recent ESTs patent filing trend of top 50 institutions

significant increase in 2019 as presented in Fig. 1. Table 2 presents the number of top institutions that have filed environmentally sustainable technology patents over the past eight years. Most of the patents were filed by Chandigarh University (248), followed by Amity University (121) and IIT Madras (117). These three institutions filed more than 100 patents over an 8-year period, years and 47 institutions had filed for less than 100 years. The average number of patents filed by the institutions accounted for 24; however, no environmentally sustainable technologies

Table 2 — Patents filed and efficiency score of higher educational institutions

Higher educational institutions	ESTs	Efficiency score	Bias corrected efficiency score
Chandigarh University	248	1	0.6
Amity University	121	0.494	0.314
Indian Institute of Technology, Madras	117	0.472	0.29
Indian Institute of Technology, Delhi	88	0.355	0.237
Indian Institute of Technology, Bombay	85	0.675	0.427
S.R.M. Institute of Science and Technology	76	0.306	0.201
Indian Institute of Technology, Roorkee	43	0.175	0.114
Indian Institute of Science	36	0.221	0.152
Indian Institute of Technology Kanpur	33	0.177	0.12
Indian Institute of Technology Guwahati	32	1	0.586
Siksha 'O' Anusandhan	30	0.201	0.132
Vellore Institute of Technology	26	0.105	0.065
Indian Institute of Technology (Banaras Hindu University) Varanasi	24	0.185	0.127
National Institute of Technology Karnataka, Surathkal	20	0.119	0.075
Kalasalingam Academy of Research and Education	60	0.242	0.16
Indian Institute of Technology, Kharagpur	22	0.151	0.103
Kalinga Institute of Industrial Technology	17	0.069	0.047
Birla Institute of Technology & Science – Pilani	16	0.762	0.444
Anna University	13	0.403	0.24
Saveetha Institute of Medical and Technical Sciences	11	1	0.534
Manipal Academy of Higher Education, Manipal	10	0.118	0.076
National Institute of Technology, Tiruchirappalli	10	0.04	0.027
Indian Institute of Technology (Indian School of Mines)	9	0.036	0.024
Indian Institute of Technology Hyderabad	7	0.136	0.087
Indian Institute of Technology Ropar	7	0.189	0.115
National Institute of Technology Rourkela	7	0.028	0.018
Amrita Vishwa Vidyapeetham	5	0.062	0.044
Institute of Chemical Technology	4	0.087	0.054
National Institute of Technology Warangal	5	0.102	0.064
Panjab University	5	0.268	0.152
Shanmugha Arts Science Technology & Research Academy	5	0.034	0.021
Jawaharlal Nehru University	4	0.119	0.072
All India Institute of Medical Sciences, Delhi	3	0.05	0.035
Indian Institute of Technology Indore	3	0.055	0.038
Indian Institute of Technology, Gandhinagar	3	0.04	0.025
Banaras Hindu University	2	0.042	0.027
Calcutta University	2	0.014	0.009
University of Delhi	2	0.019	0.013
Aligarh Muslim University	1	0.004	0.003
Bharathiar University	1	0.019	0.014
Indian Institute of Science Education & Research, Kolkata	1	0.032	0.021
Indian Institute of Science Education & Research, Pune	1	0.038	0.026
Indian Institute of Technology, Mandi	1	0.012	0.007
Savitribai Phule Pune University	1	0.014	0.01
Jamia Millia Islamia, New Delhi	0	0	0
Jadavpur University	0	0	0
Homi Bhabha National Institute	0	0	0
Indian Institute of Science Education & Research, Mohali	0	0.007	0.005
Osmania University	0	0	0
University of Hyderabad	0	0	0
Total	1217	-	-
Average	24.34	0.19354	0.1191

were filed at Jamia Milla Islamia, Jadavpur University, Homi Bhabha National Institute, Indian Institute of Science Education and Research, Osmania University, or the University of Hyderabad.

The efficiency scores of the 50 institutions are presented in Table 2. This score was determined by considering output orientation and variable returns to scale, which basically speak about the technical efficiency of the units that were evaluated for efficiency analysis. Decision making units that achieve a score equivalent to 1 are considered efficient, whereas units that achieve a score less than 1 are regarded as inefficient in producing the desired outputs.

According to the efficiency scores presented in Table 2, only three institutions are efficient in generating environmentally conscious technology. These universities are Chandigarh University, the Indian Institute of Technology Guwahathi, and the Saveetha Institute of Medical and Technical Sciences. These benchmarks serve as models for creating the greatest number of environmentally conscious technical patents with the greatest amount of input available. The non-parametric study, on the other hand, indicates that the remaining 47 institutions are inefficient. This suggests that these institutions can improve their levels of environmentally friendly technologies with existing inputs available to them. Ineffective management is almost certainly the primary contributor to such inefficiency. To extend this interpretation, the average efficiency score reveals that the 14 universities are either above or near the average efficiency score of 0.1935. The nearby university with the highest score was the Birla Institute of Technology and Science, followed by the Indian Institute of Technology in Bombay, Amity University, and the Indian Institute of Technology in Madras. Filtering below the average indicates that 36 institutions are levelling off compared to institutions that are above the average. These institutions must place greater emphasis on the production of environmentally sustainable technologies.

It is interesting to note that calculating the score after bias correction reveals to all universities that their output of environmentally sustainable technologies needs to be improved because all efficiency scores are lower than one. The average efficiency score is 0.119, indicating that 16 universities have achieved a commendable level of efficiency. Chandigarh University, Indian Institute of Technology Guwahathi, and Saveetha Institute of Medical and Technical

Sciences are the three institutions that have improved their rankings the most. On the other hand, 34 institutions are regarded as having efficiency below average or worse than average. The Indian Institute of Technology at Kanpur and the Indian Institute of Technology at Banaras Hindu University are the two institutions that were found to have a rating that was greater than the average after bias corrections were applied. As a result, it is fair to claim that 16 universities are above average or have focused on generating environmentally friendly technologies and combating climate change.

### Conclusion

There are several restrictions on the current investigation. One limitation of this approach is that it focuses solely on the trends over the past eight years. The principal rationale for this is that the inputs and factors considered were accessible for only a limited duration. An additional constraint was that the analysis was restricted to a sample of 50 institutions. The sustainable patent output variable was limited to encompassing only patent applications, excluding granted patents. The research utilised the database of the World Intellectual Property Organization for data collection, as opposed to relying on the databases maintained by either the European Patent Office or the United States Patent and Trademark Office. The fact that the efficiency assessments only included technical efficiency scores and did not include overall technical efficiency scores limits the computation of scale efficiency. Further studies should include additional variables. It should be noted that the funds allotted are not only for generating green technologies but that the demarcation itself is challenging to address. This study highlights the presence of innovation opportunities that industries can leverage as alternatives to innovation. Over the past eight years, there has been a significant increase in the development and implementation of environmentally sustainable technologies. The integration of sustainable science into a university's third mission aligns with the objective of identifying institutions that can effectively contribute to society and the environment. The evaluation of EST effectiveness among leading institutions was predicated on publicly accessible data. The discernible disparities in efficacy scores indicate that managerial inefficiencies in input utilisation are responsible for the observed inefficacy. Notably, funds are not exclusively allocated to

research on green operations. Nevertheless, it is imperative for institutions to enhance their desired outcomes to cater to society's needs.

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