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STRIDES – A STUDENTS' JOURNAL OF SHRI RAM COLLEGE OF COMMERCE
ISSN 2581-4931 (PRINT)

Shri Ram College of Commerce is well known for its academic excellence and dedicated approach towards dissemination of knowledge in the academic world. The college appreciates the role of research in education and is committed to developing an inclination towards research in both faculty and students. In this pursuit, the college has taken the initiative to launch a new Journal named 'Strides – A Students' Journal of Shri Ram College of Commerce'.

ABOUT THE JOURNAL

It is a double blind reviewed bi-annual Journal launched exclusively to encourage students to pursue research on the contemporary topics and issues in the area of commerce, economics, management, governance, polices etc. The journal provides an opportunity to the students and faculty of Shri Ram College of Commerce to publish their academic research work.

PUBLICATION POLICY

Shri Ram College of Commerce is committed to upholding the high academic standards. Therefore, the Committee On Publication Ethics (COPE) follows a 3-Stage Selection Process while approving a paper for publication in this Journal. The policy is as follows:

Stage-1. Screening of Plagiarism

To maintain high academic standards, academic ethics and academic integrity each research paper received by COPE (Committee On Publication Ethics) is sent for screening of plagiarism on "Turnitin". The committee adheres to the maximum tolerance limit of 25%.

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Stage-2. Double Blind Review

The journal adheres to a rigorous double-blind review policy. Each research paper received by COPE is sent for review to the *Referee* (Subject Expert). The reports submitted by the *Referees* are sent to the respective students for improvement (if any, suggested by the *Referees*). After reporting all the suggestions recommended by the *Referees*, the revised and improved version of the papers are re-submitted by the students to the COPE.

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The following guidelines are to be carefully adhered by the students before final submission of the manuscript. The submitted manuscripts not conforming to the following guidelines are not taken into consideration for any further processing.

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Format of the article on the front page should be:

a) Title
b) Name(s) of the student(s) and mentor along with their details
c) Abstract
d) Keywords

Abstract

The abstract should capture the essence of the article and entice the reader. It should typically be of 100 -150 words, and in Italics.

Font type and word limit

The research paper is to be typed on A-4 size paper with single line spacing. The complete length of the paper should not exceed 5000 words including endnotes and references. The font size should be 12 and font style should be Times New Roman.

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The Journal adheres to the APA (American Psychological Association) Referencing Style, Sixth Edition. Students must refer to the APA Referencing Guidelines to ensure conformance to this reference style. For further information you may visit the following link - http://www.apastyle.org

Endnotes

Endnotes should be serially arranged at the end of the article well before the references and after conclusion.

Table, Figures, Graphs

The first letter of the caption for table, figure, graph, diagram, picture etc. should be in capital letter and the other words should be in small letter - e.g. Table-1: Demographic Data of Delhi, Figure-1: Pictorial Presentation of Population etc.

MANUSCRIPT SUBMISSION GUIDELINES

Soft Copy: The soft copy of the manuscript should be sent through e-mail to the editor at strides@srcc.du.ac.in and cc to principaloffice@srcc.du.ac.in.

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Declaration

As part of the submission process, the student and mentor needs to declare that they are submitting original work for the first publication in the Journal and that their work is not being considered for publication elsewhere and has not already been published elsewhere. Again, the paper should not have been presented in any seminar or conference. The scanned copy of duly signed declaration by the students and their respective mentors has to be emailed along with the research paper.

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The student(s) remain the whole and sole author of their respective research papers published in 'Strides – A Students' Journal of Shri Ram College of Commerce' and hold its copyright. Also, the 'author' is wholly and solely responsible for plagiarism caught after publication (if any). The Editor, Referees, Mentors, COPE, SRCC, Printer, Publisher and Printing Press shall not be responsible for any plagiarism.

AWARD

The authors of best three papers from every Issue are awarded – First Prize, Second Prize and Third Prize on the SRCC Annual Day.

Principal's Message

The mission statement of the college signifying the existence and its road map to the achievement of its vision, reads as:

"To achieve and sustain excellence in teaching and research, enrich local, national and international communities through our research, improve skills of alumni, and to publish academic and educational resources"

To achieve and promote excellence in publications and applied research, the college has taken the initiative to launch a new journal exclusively to publish students' research papers and articles. It will be an add-on to the enriched catalogue of college publications and academic literature.

The Journal has provided an opportunity to the students of our college to focus on research. Since the students were not opened to the research methodologies at the undergraduate level, they were mentored by experienced faculty of our college. Simultaneously, their articles were also reviewed by the referees and tested for plagiarism before publication. After reporting all the suggestions recommended by the referees, the articles were revised and then finally published. The college had successfully released the foundation issue of the Journal **"Strides - A Students' Journal of Shri Ram College of Commerce, Volume 1, Issue 1, 2016-17"** on the occasion of 91st Annual Day of the College held on 13th April, 2017. The Journal was released by **Shri Prakash Javadekar, Honb'le Union Minister of Human Resource Development, Government of India.**

I would like to congratulate the students whose papers are published in this issue of the journal and simultaneously encourage all the students to contribute their research papers and articles for the successive issues of the Journal.

Best wishes for their future endeavors.

Prof. Simrit Kaur
Principal

Editor's Message

Shri Ram College of Commerce is well known for its academic excellence and dedicated approach towards dissemination of knowledge in the academic world. The college appreciates the role of research in education and is committed to developing an inclination towards research in both faculty and students. In this pursuit, the college has taken the initiative to launch a new Journal named 'Strides - A Students' Journal of Shri Ram College of Commerce' to encourage students to pursue research under the guidance of the faculty of Shri Ram College of Commerce.

It is a bi-annual Journal launched exclusively to publish academic research papers and articles by the students on contemporary topics and issues in the area of commerce, economics, management, governance, policies etc.

In order to maintain the high standards of publication, COPE (Committee On Publication Ethics) has been constituted. The COPE shall be the apex authority to take all the decisions related to the publication of research papers and articles in Strides. The decision of COPE shall be final and binding.

To maintain the high academic standards, academic ethics and academic integrity, a rigorous process of double blind review of research papers is followed along with screening of plagiarism of each manuscript received by the COPE

for publication. The research work published in Strides is original and not published or presented at any other public forum.

The foundation issue of the Journal **"Strides - A Students' Journal of Shri Ram College of Commerce, Volume 1, Issue 1, 2016-17"** was successfully released on 91st Annual Day of SRCC held on 13th April, 2017 by **Shri Prakash Javadekar, Honb'le Union Minister of Human Resource Development, Government of India.**

The successive Issues of 'Strides - A Students' Journal of Shri Ram College of Commerce' shall be bi-annually released.

I congratulate all the students whose research papers are published in this Issue of Strides and express my sincere thanks to their mentors and referees.

Dr. Santosh Kumari
Editor

STRIDES - A STUDENTS' JOURNAL OF SHRI RAM COLLEGE OF COMMERCE

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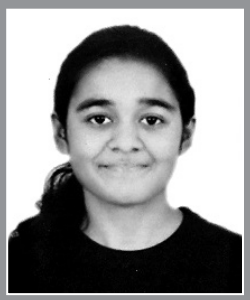
RESEARCH PAPERS

Agrophotovoltaics: Towards a New Path of Energy-cum-Food Generation



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ABSTRACT

The paper discusses an innovative approach of agricultural mechanism- food production along with energy generation which benefits farmers economically and provides a new scope of development and revival in Indian Agriculture. According to the studies, it provides far reaching benefits to the agricultural sector when compared to the traditional and conventional methods of farming. The data and statistical figures reflect the scale of crop production being enhanced due to implementation of the agrophotovoltaics system through experiments conducted at grape farming lands in India as well as in the arid regions. The paper also mentions the cost benefit analysis as well as the critical approach of adopting the mechanism through various aspects of economy and environment. Moreover, the achievements in India towards the mechanism till now have also been discussed along with a focus on establishing the system all over the country with the available resources and technology. Apart from the food generation capacity, the mechanism also provides for a comprehensive use of solar energy, which is

a renewable resource, in order to fulfill the increased demand of energy in the country.

INTRODUCTION

Agrophotovoltaics refers to the innovative idea of developing the same area of land for solar energy generation as well as for agricultural production through photovoltaic methodology. It is also known as agrivoltaics. The idea was originally being conceived by Adolf Goetzenberger and Armin Zastrow in 1981. Since 2004, this technique has been extensively tried and implemented in Japan and later in many countries of Asia and Europe. The idea implies the co-existence of solar panels and crops in the fields and thus, facilitating sharing of solar light for both energy production and food production. Harvesting crops and solar energy together on a single shared land provides a promising and efficient solution for India's land and water scarcity problems. Thus, the method facilitates better crop productions in arid and semi-arid regions.

The two essential requirements for human beings are energy and food production. Due to the rapidly increasing population, demands for these two resources are also increasing at a greater pace. In order to fulfill the present as well as future requirements of these resources, the role of agrovoltaics has been discussed and proved through various research and experiments conducted worldwide. These experiments reflect the great potential of this the technique in enhancing farmer's income and in improving their livelihood. Since, the mechanism involves participation of a renewable resource i.e. sun, it can be used at a varied scale enormously. Agrivoltaics works extensively well for the shade resistant plants. Some plants with such potential functioning crops are hog peanut, alfalfa, yam, taro, cassava, sweet potato and lettuce. Also, it has been found that agrivoltaics is most beneficial for summer crops because of the microclimate created by sun and its solar energy effects on earth's surface along with the temperature conditions, specifically for equatorial land. Agrivoltaics system has effects in terms of three aspects that directly affect plant growth and reproduction, which are air temperatures, direct sunlight, and lastly water vapor in atmosphere. Photovoltaic panels help to provide shade to the land in which it is installed, which in turn results in comparatively cooler temperatures during day and warmer temperatures in night than the traditional farming which has open sky planting system i.e. without any upper shade system. Also, a lower vapor pressure deficit in the agrivoltaics system is observed which reflects that there is more moisture present in the air because of those panels.

EDGE OVER TRADITIONAL FARMING

"Many of us want more renewable energy, but where do you put all of those panels? As solar installations grow, they tend to be out on the edges of cities, and this is historically where we have already been growing our food," says Greg Barron-Gafford, a lead author of Nature Sustainability (Science Daily, 2019, para.2). A recent study in Nature found that current croplands are the "land covers with the greatest solar PV power potential" based on an extensive analysis of incoming sunlight, air temperature, and relative humidity (Science Daily, 2019, para.3).

The Fraunhofer experts in there researches mentions that the costs of agro PV installations are expected to fall in the near future because of the economies of scale and learning effects. Also, they are already cost competitive with the small rooftop solar panels. PV system owners could also gain an additional source of income from energy storage on the arable land specifically or from the rising use of electric vehicles in agriculture. The advantages of agroPV use reportedly go beyond increased crop yields. The innovative method provides a substantial edge over the conventional methods of farming in various aspects along with environmental sustainability. The mechanism provides the varying benefits such as prevention of wind and soil erosion because of the implementation of panels in the fields which will be strong enough to hold the soil firmly. Solar plants can also provide shade for livestock, thus facilitating spacious use of field for livestock farming since livestock farming is itself an additional source of income for farmers. It can prove to be the improved pollinator habitats. It enhances increased market opportunities for shade tolerant crops like grapes, making the crop production economically viable and feasible. A study by **Sustainable Energy Technologies and Assessments** explores the viability of agrivoltaics system deployment on the grape farms already existing in India. The economic value of these farms deploying the proposed systems may increase more than fifteen times as compared to conventional farming, because of the shade tolerance capability of the grape plant. It has a very important effect on power generation which gets increased over 16000GWH electricity amount which in turn reflects the potential of meeting energy needs and demands of more than 15 million people. Through this estimation, one can analyze the enhanced value of land, which will in turn provide good economic utility to the farmers. Grape based agrivoltaics can be implemented in rural areas to enable village electrification effectively. Thereby, fulfilling and solving the electricity crisis in rural parts of the country, which lack in terms of financial resources.

Since the plants are on elevated platform, there is no need of any additional waterproofing since the pots/containers are not in contact with the roof (Unlike traditional rooftop gardens where additional water proofing may be required). Some of the other benefits include protection against extreme temperatures, extreme frost, and heat waves and also protects from hail. It provides soil hydrometric sunlight, and plants physiological needs might be controlled via innovative sensors and swing PV. The method facilitates increased pasture fields production on dry, unirrigated farmlands. Renewable energy production and farming are a winning combination. Solar energy can be harvested forever, providing farmers with a long term source of income i.e. throughout the year. The solar heat collectors can be used to dry crops and warm homes, livestock buildings and greenhouses.

CHALLENGES TO THE TECHNIQUE

Though the method has far reaching advantages, yet few challenges appear to take place as a result of implementation. The most important among them is that the adoption of such technique requires deployment of heavy financial resources i.e. a huge investment is required which increases the cost of production.

Also, the technology does not work for sunshine addicted crops. Shade resistant crops are not typically grown in industrial agricultural systems. For instance, wheat crops do not fare well in a low light environment, meaning they would not work with agrivoltaics. Agrivoltaics do not yet work with greenhouses. Greenhouses with half of the roof covered in panels were simulated, and the resulting crop output reduced by 64% and panel productivity reduced by 84%. Also, the swarm of elevating solar plants may increase humidity ratio and can also attract and favor the growth of parasitic plants. It also possesses a negative visual impact on natural landscape since the plants are highly visible from a great distance.

Thus, a viable solution is needed to overcome the challenges faced in implementing the technology, among which the first priority is to make sure of the availability of the financial resources to the farmers so that the benefits could be reaped. It could be done through government initiatives either through private public partnerships or through public investments, as well as private sector participation is also required in order to get a good performance.

EFFECTIVE IMPLEMENTATION IN INDIA

Agrophotovoltaics lies as the solution for a global energy transformation, increasing world energy demand, negative global warming effects, and global

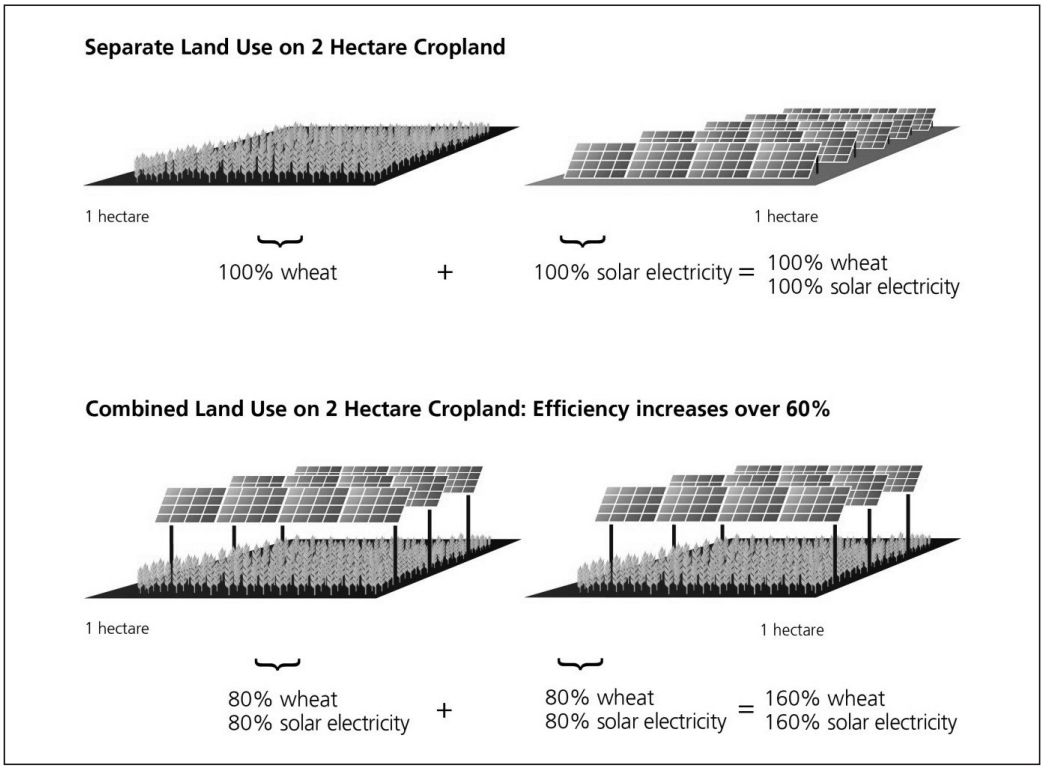
water scarcity. It tends to offer a promising investment to farmers and new opportunities for ecologically sustainable livelihoods. For the fulfillment of the mentioned purposes, various studies and researches are conducted in various countries as well as India. The technology has a great potential in India.

The **Fraunhofer Institute,** the largest institute for solar energy system in Europe has been conducting an experiment near Lake Constance, Germany and has now shown that both uses i.e. crop generation and energy generation are compatible. In the first year, they found that the combination of solar energy and agriculture has made the land 160% more productive. Along with that, it is also resource efficient and it reduces competition for land and additionally opens up a new source of income for farmers.

Similarly, a study by **Max Trommsdorff of Fraunhofer ISE** made this compatible analysis for Indian agricultural system also. The Maharashtra State Power Generation Company (Mahagenco) performed setting up 10MW of agricultural solar PV. It included the creation of green house and poly house sheds in their experiments. Mahagenco expresses to increase the height of solar module erecting structures so as to facilitate the provision of extra space beneath the modules which can be used for horticulture, floriculture and some other allied activities. The ply houses for sheds established along with the solar panels can be given for earning and operational activities to the agro-developers, co-operative organizations, farmers and also to the unemployed youth in the rural areas for commercial house farming. Meanwhile, shifting over system would help to save huge sums of money and would help in generating income for farmers nationwide, according to a research by the Institute for Energy Economics and Financial Analysis (IEEFA). In Maharashtra, there is a good potential for implementing the mechanism in arid and semi-arid regions of the state. It demonstrated the shading impacts on crops as discussed above and also about the less evaporation with results of up to 40% higher yield for tomatoes and cotton crops. In certain cases, the results yielded nearly double the efficiency for the region. Besides less evaporation and lower temperature, harvesting the rain water with PV modules also plays a significant role. It is possible to collect and store rainwater from the top surface of PV modules in the system. Therefore, rain-water harvesting system in the developed solar panel system has also been designed. This water harvesting system contains of rectangular sheet water collector channels, underground water conveying PVC pipes and an underground water storage tank of 1 lakh liter capacity. Apart from this, the utilization of power generated indigenously by solar panels to run solar water pumps for irrigation lowers the dependency

on government's electricity supply or diesel generators which tremendously causes pollution. Among the various benefits, one is the ability to save water resource as demonstrated by **CAZRI** that water left from cleaning solar panels can be used for crops below panel area. However, Agrophotovoltaics are still at an early stage of development, hence they are still under technical progress and quality improvements. Nevertheless, the system shows an incredible potential in meeting environmental needs and solving its varied concerns. It helps in achieving both sustainable agriculture and rural development.

Figure: Pictorial Presentation of Increased Capacity



Source: GREENOMICS WORLD

(Agrophotovoltaics or Agrovoltaics – The Future of Modern Farming)

The importance and requirement for renewable energy has been steadily increasing in India than ever before because it serves as a solution for the insufficient non-renewable energy resource, which is not being capable to fulfill demands of such a rapidly increasing population. Among the renewable energy resources, solar energy has proved to be the most widely used because of its

enormous availability in a country like India, with such a climate appearing in Thar Desert. Photovoltaic based electricity generation shares a major portion of renewable energy generation in India now-a-days. Another essential reason behind the use of solar energy is that fossil fuels are being exhausted rapidly. Energy generation through biomass or bio-plants is claimed to be a possible substitute or a solution to the incapability of fossil fuels, yet land area required for biofuels largely exceeds cropland area of planet. Biofuels extracted from cereals or oil crops are generally produced by ethanol pathway or trans-esterification methods. Also, estimations are there that a hectare land of cereals will be sufficient to manufacture bioenergy which can allow a car to run up to 18,000 km and it can also run up to 22,000 km, if most efficient trans-esterification method is used. **ICAR** researches shows that the low efficiency of photosynthetic process of most energy crops which is about 3% will not be able to cope up with increased energy demands. In contrast, commercially available photovoltaic panels have an efficiency of 12-15% and can constantly and thoroughly supply future energy needs of India.

INDIA'S APPROACH AND FUTURE PROSPECTS

In a country like India, which has the second largest extent of arable land in the world- almost 395 million acres and world's largest extent of irrigated croplands where 58% population is dependent on agriculture directly or indirectly, agrivoltaics can give an excellent performance. Using such a vast stretch of land, India can effectively implement the mechanism. In its approach, Central Arid Zone Research Institute (CAZRI) established a one acre 105kwp pilot project in Jodhpur in 2017. Later on, it also added a 25kwp project at its regional research center in Bhuj, Rajasthan. The structural parameters for installation of solar panels are slightly different from that in a conventional solar power plant. Installation of such systems in farmers' field may fetch additional income from sale of electricity in addition to crop production. At CAZRI, Jodhpur, 105 kW capacity solar plants has been established with three experimental designs, which are- PV arrays of one row PV module and 3 m interspaces between arrays; PV arrays of two row PV modules and 6 m interspaces between arrays and PV arrays of three row PV modules and 9 m interspaces between arrays. Such projects, installed at isolated sites are also being conducted by Amity University in Noida.

After installation, it was its rainwater harvesting potential which attracted attention. The rainwater collection efficiency of CAZRI Jodhpur has increased by 69.2% according to PV Magazine. This research published in 2017, also looks at the potential of agrivoltaism for vineyards in India. About 49% land area of a

solar PV-installation system can be used to cultivate crops, which is otherwise left as fallow for no use throughout the year. Some of the selected crops are mungbean, mothbean, clusterbean, isabgol, cumin, and chickpea. Apart from these, medicinal plants e.g. Aloevera, sonamukhi, sankhpuspi etc. can also be grown. All these crops are generally low heighted crops and require less amount of water and thus are suitable for AgroPV system.

India is looking forward to double its agricultural sector income by 2022. In its efforts, latest practices and experiments can be seen at India's second AgroPV session at **Renewable Energy India Expo, Sep 2019.** The expo was a more of an industrial nature exhibition where some of the prestigious policy-makers, decision-makers, influencers, techno experts and professionals from across the globe met to discuss the global challenges prevailing all over the world, reforms, and technological advancements and to develop a roadmap for seamless growth in this field. This was a packed session entitled-'Agrophotovoltaics- Harvesting sun for food and power'. International participants were also present to explore future business opportunities for investments in India in combining farming and solar energy generation. There were projects and presentations explained by various sector experts and consultants hailing from CAZRI, AMITY, Next2Sun, Astron Solar Power regarding the ongoing research as well as commercial projects under implementation in India. At last, Informa Markets in India (Formerly UBM India) in this session, succeeded in conducting the 13th edition of Renewable Energy India (REI) Expo from 18th to 20th September 2019 at the India Expo Center, Noida, Uttar Pradesh.

The future 14th epic edition of REI Expo scheduled to be held during 10th to 12th December 2020 is expecting to attract over 800+ Exhibitors, 40,000+ trade visitors and multiple Country Pavilions.

CONCLUSION

The increasing growth of land-based solar photovoltaic energy generation can create a land use conflict with agricultural production. Fortunately, this issue can be resolved using the concept of agrivoltaics, which is co-development of land area for both solar PV and agriculture. Also, fossil fuels are continuously being depleted with their simultaneous negative consequence on environment. This demands a greater use of renewable energy source to enable to internalize current externalities and disable the carbon generation in environment. The value of solar generated electricity coupled to shade-tolerant crop production created an over 30% increase in economic context from farms using the

agrivoltaic systems instead of conventional agriculture. It has been postulated that agrivoltaics would be beneficial for summer crops as they create the side effect of heat and water flow control.

Among the benefits, there are sort of serious challenges to be faced in working of this mechanism. First of all, the major issue is the investment requirement in the system as its implementation involves huge cost. The system is not fit for taller crops of more than 5-6 feet such as wheat, millet and jowar. Other challenges could be the crop damage form heavy falls of water during cleaning of solar PV modules, uprooting of plants due to repairs of underground wiring.

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HISTORY OF THE JOURNAL

The idea to launch this Journal was discussed in December 2016 by the former Officiating Principal, **Dr. R. P. Rustagi** with **Dr. Santosh Kumari,** the Editor of the Journal. Since the idea appealed to **Dr. Santosh Kumari**, she took the initiative to contribute to SRCC by creating this new academic research Journal and took the responsibility for its Creation, Registration, License and ISSN (International Standard Serial Number) etc. along with *Editorship*. Therefore, **Dr. Santosh Kumari, Assistant Professor in the Department of Commerce, Shri Ram College of Commerce** was appointed as the Editor of the Journal vide. Office Order – SRCC/AD-158/2017 dated March 14, 2017. She meticulously worked hard in creating the concept and developing the structure of the Journal. She introduced the concept of COPE (Committee On Publication Ethics) to maintain the high academic standards of publication.

On behalf of SRCC, **Dr. Santosh Kumari** made every effort in seeking License from Deputy Commissioner of Police (Licensing), Delhi to register the Journal at "The Registrar of Newspapers for India, Ministry of Information and Broadcasting, Government of India". The paper work for seeking license started under the former Officiating Principal, **Dr. R.P. Rustagi** on March 27, 2017. The foundation Issue of the Journal "**Strides – A Students' Journal of Shri Ram College of Commerce, Volume 1, Issue 1, 2016-17**" was successfully released on the 91st Annual Day of SRCC held on April 13, 2017 by **Shri Prakash Javadekar, Honb'le Union Minister of Human Resource Development, Government of India**. The title of the Journal got verified and approved by the Registrar of Newspapers for India, Ministry of Information and Broadcasting, Government of India on April 21, 2017. On September 1, 2017, **Prof. Simrit Kaur** joined SRCC as Principal and signed each and every legal document required for further processing and supported **Dr. Santosh Kumari**.

On December 18, 2017, the College got the license "**License No. - DCP / LIC No. F. 2 (S / 37) Press / 2017"** to publish 'Strides – A Students' Journal of Shri Ram College of Commerce'. Due to change of Printing Press, the License got updated on March 09, 2018. On April 26, 2018, the SRCC Staff Council unanimously appointed **Dr. Santosh Kumari as the 'Editor of Strides**' for the next two academic years.

On April 27, 2018 (The Foundation Day of the College), **Dr. Santosh Kumari** submitted the application for the registration of the Journal. On May 04, 2018, the SRCC received the '**Certificate of Registration**' for ***"Strides – A Students' Journal of Shri Ram College of Commerce"*** and got the **Registration No. DELENG/2018/75093** dated May 04, 2018. ***On behalf of Shri Ram College of Commerce, it was a moment of pride for Dr. Santosh Kumari to receive the 'Certificate of Registration' on May 04, 2018 at the Office of Registrar of Newspapers for India, Ministry of Information and Broadcasting, Government of India (website - www.rni.nic.in).***

On May 07, 2018, **Dr. Santosh Kumari** submitted the application for seeking ISSN (International Standard Serial Number) at "ISSN National Centre – India, National Science Library, NISCAIR (National Institute of Science Communication and Information Resources). Weblink - http://nsl.niscair.res.in/ISSNPROCESS/issn.jsp". Finally, the College received the International Standard Serial Number "**ISSN 2581-4931 (Print)**" **on June 01, 2018.**

We are proud that this journal is an add-on to the enriched catalogue of SRCC's publications and academic literature.

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