

Name of the Teacher: Dr. Deepa

Designation Assistant Professor

Department: Physics

Sr. No.	Session	Name of the Collaborative activity (quality initiatives)	Name of the collaborating institution	Nature of the collaboration	Outcomes
1.	2017-18 To 2018-19	Computational Study on SWCNTs and their hybrids and follow-up analysis	Shizuoka University, Shizuoka, Japan	Research	Published work
2.	2018-19 Till date	Computational Study on Carbon Nanostructures and follow-up analysis	Kwansei Gakuin University, Japan	Research	Computational results
3.	2015-16 till date	UGC Faculty Fellowship and follow-up activities	NIT, Kurukshetra	Research	Published work, Thesis work and award of Ph.D.
4.	2015-16 till date	Computational Study on SWCNTs and their hybrids and follow-up analysis	Panjab University, Chandigarh	Research	Published work
5.	2018-19 till date	Computational Study on Carbon Nanostructures and follow-up analysis	JNCASR, Bangalore	Research	Published Work
6.	2018-19 Till date	Computational Study on Carbon Nanostructures and follow-up analysis	Lawrence Berkeley National Laboratory, USA	Research	Published Work
7.	2016-17 till date	Computational Study on Carbon nanostructures and follow-up analysis	International Association of Advanced Materials, headquarters in Sweden	Research	Published Work
8.	2019-20 Till date	Computational Study on Carbon nanostructures and follow-up analysis	University College Dublin, Ireland	Research	Published work
9.	2017-18 till date	Computational Study on Carbon nanostructures and follow-up analysis	Indian Statistical Institute, Kolkata	Research	Computational Analysis
10.	2018-19 till date	Simulation Study on use of Carbon nanostructures as electrodes in batteries	Virginia Commonwealth University, USA	Research	Computational Analysis
11.	2022-23 till date	Computational Study on Carbon nanostructures and follow-up analysis	IIT, Roorkee	Research	Work in progress
12.	2022-23	Drafting of Junior Netball Policy of Newzealand	Netball Federation of Newzealand	Policy Draft	Policy in effect
13.	2016-17 Till date	Optics, Photonics & Lasers	International Frequency Sensor Association (IFSA)	International Program Committee member of	Annual Conference OPAL

Signature of the teacher.....

Department of Nanotechnology for Sustainable Energy,
School of Science and Technology,
Kwansei Gakuin University,
Gakuen 2-1, Sanda City, Hyogo 663-1337, Japan
Telephone +81 79 565 9751 Facsimile +81 79 565 9729

August 23, 2018

Prof. Dr. Katsunori WAKABAYASHI

Professor,

*Department of Nanotechnology for Sustainable
Energy, School of Science and Technology,
Kwansei Gakuin University*

Gakuen 2-1, Sanda, Hyogo 669-1337 Japan

Phone +81-79-565-9751

E-mail: waka@kwansei.ac.jp

Dr. Deepa Sharma
Assistant Professor
Department of Physics
SUS Government College,
Matak-Majri,
Haryana, India

Dear Dr. Deepa Sharma

We are very pleased to invite you as a short-term visiting researcher to Department of Nanotechnology for Sustainable Energy, Kwansei Gakuin University from 1st April 2019 to 30th September 2019.

The collaboration research title is "First Principles Calculations on Graphene and related topological nanostructures".


For this collaboration, we also cooperatively apply to the research fellowship program supported by the Matsumae International Foundation.

Please return the Statement of Acceptance with your signature, which indicates your acceptance of our invitation and agreement.

In case, the proposed travel schedule doesn't suit you, you may propose another. Your contribution in our work on Computational Study on Carbon Nanostructures is quite significant and our remote collaboration will however continue as before irrespective of your acceptance for visit.

We look forward to seeing you in Hyogo.

Sincerely yours,
Katsunori Wakabayashi



Statement of Acceptance

I accept the contents of the letter of Dr. Katsunori Wakabayashi, Professor of Kwansei Gakuin University, and agree to apply the research fellowship program supported by the Matsumae International Foundation.

/signed/ _____
/typed/ Deepa Sharma

Date:

NATIONAL INSTITUTE OF TECHNOLOGY
KURUKSHETRA-136119

No. Ph/2015/3938

Dated: 26.06.2015

From

Deepa
Asstt. Professor,
Deptt. of Physics,
SUS Govt. College, Mataki-Majri (Gudri)

To

The Deputy Registrar (GA&L),
National Institute of Technology,
Kurukshetra.

Subject: Joining Report for the post of Teacher Fellowship (UGC)

In response to my appointment letter No. ~~Estt. #~~ F.No. 27-57/2014 (TF-NRC)
dated 30-3-2015 I accept the terms and conditions of the appointment and report
myself for duty with effect from 26-06-2015 (FN/AN).

Supervisor of Ph.D.
Vijay Singh
(A. Name 26/6/15)

Yours faithfully,

Deepa

Dated: 26-06-2015

(Through: Head of Deptt./Section).

[Signature]
26/6/15

Copy to: -

1. Deputy Registrar (Accounts), NIT, Kurukshetra.
2. Head of Deptt./Section.
3. Estate Officer.

4. Dean (Acad.)

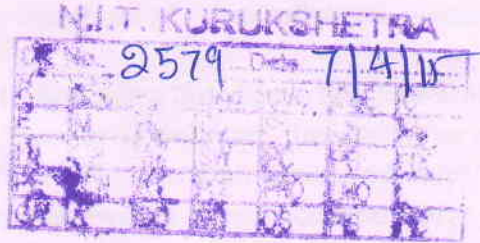


40/15
7/4/15

F. No. 27-57/2014 (TF/NRCB)

March, 2015

The Principal,
Pt. Chiranji Lal Sharma
Govt. PG College,
Sector-14,
Karnal
Haryana



30 MAR 2015

Sub: - Award of Teacher fellowship to Mrs. Deepa Bhargava, Assistant Professor Department of Physics, Pt. Chiranji Lal Sharma Govt. PG College, Sector-14, Karnal, Haryana for completing Ph.D from National Institute of Technology, Kurukshetra in two years under FIP Scheme during 12th Plan period-reg.

Sir,

I am directed to refer to the letter No. **GCK/1761** dated **03/12/2014** on the above subject and to convey the approval of the U.G.C. for award of Teacher Fellowship to Mrs. Deepa Bhargava, Assistant Professor Department of Physics, of your College for completing Ph.D from National Institute of Technology, Kurukshetra under Faculty Improvement Programme for the period of two years from the date of his joining as teacher fellow.

The guidelines for the scheme for 12th Plan (Available on UGC website www.ugc.ac.in) including the following Terms and conditions, are to be followed strictly.

1. The teacher will continue to receive full salary from the parent College during the period of teacher fellowship.
2. A teacher fellow will be eligible for reimbursement of actual contingency expenditure subject to a maximum of Rs.15, 000/- (Rupees Fifteen Thousand only) per year. The accounts for contingency grant and audited Utilization Certificate may be submitted to UGC.
3. Grants towards Contingency for the Teacher Fellowship for the first year will be paid to the research Centre/place of research of the Teacher Fellow on receipt of the Joining Report duly signed by Registrar/Principal/Research Guide of the University/College. The 2nd year's Contingency grant will be paid on receipt of Utilization Certificate for the 1st installment of grant duly signed by the Registrar/Principal/Research Guide of the University/College and item-wise statement of expenditure for the 2nd year.
4. The salary of the substitute teacher, appointed by the College in place of a teacher selected for award of Teacher Fellowship, will be paid by the UGC. The College will make a fresh appointment of a substitute teacher in accordance with the prescribed procedure of UGC, in the minimum pay scale prescribed for an Assistant Professor (with no increments). If the substitute teacher is appointed on a pay scale higher than the minimum pay scale of an Assistant Professor, the grant towards the salary of the substitute teacher will be restricted by the UGC to the minimum scale and the balance

SA
7/4/15

Dr. Meena Jaggi for further work

29/6/15

Received on 24.06.15

amount will be met by the respective College or by the respective State Government. If the post vacated by the Teacher fellow is filled by transfer or depufation, such a substitute's salary will not be reimbursed. The substitute teacher must be appointed on a full time basis.

In case it is not possible to appoint a Substitute Teacher at the initial stage, or, if the appointment of a Substitute Teacher is delayed, then lectures may be arranged on the basis of honorarium of Rs.1,000/- (Rupees One Thousand only) per lecture, subject to a maximum of Rs.25,000/- (Rupees Twenty Five Thousand only) per month. Approval of affiliating University / State Government will not be necessary. However, all efforts should be made for the early appointment of a Substitute Teacher.

The Commission will not pay the salary of the substitute teacher if appointed on a part time basis, unless there are substantial reasons for same. The substitute teacher will not be entitled to yearly increments. The substitute teacher would also be entitled for salary for the extended period of the Teacher Fellow.

5. Grant towards salary of the substitute teacher (If appointed) will be paid to the College where the Teacher Fellow was working (parent institution) immediately before joining Teacher Fellowship on receipt of the month-wise details salary statement.
6. The supervisor/guide of the Teacher Fellow must give a 'progress report' after half the period of fellowship is over. In case of a negative report given by the Supervisor/Guide, the fellowship to the Teacher Fellow may be withdrawn by the UGC.
7. If a Teacher Fellow fails to complete his/her Ph.D./M.Phil Programme and leaves it midway, he/she has to refund the entire amount paid to him/her by the UGC during his/her Teacher Fellowship (Contingency grant + salary paid to the substitute teacher during the tenure of fellowship).

The College is requested to make appointment of substitute teacher immediately so that the related courses can run regularly.

Yours faithfully,

(Jitendra)
Education Officer

Copy to: -

1. Mrs. Deepa Bhargav, Assistant Professor Department of Physic, Pt. C.L. Sharma Govt. PG College, Sector-14, Karnal Haryana
2. The Registrar, Kurukshetra University, Kurukshetra.
3. The Director of Higher Education/Commissioner of Collegiate Education, Government of Haryana, Panchkula (Haryana).
4. The HoD, Department of Physic, Kurukshetra University, Kurukshetra.
5. The Registrar, National Institute of Technology, Kurukshetra (Haryana) - 136 119.

DR(Head)
07.04.15

Dean Acad
06/4/15

(A.B. Bhatt)
Section Officer

To inform the concerned scholar and request her to prepare assist in preparing the required case.

F. No. 27-57/2014 (TF/NRCB)

March, 2015

The Principal,
Pt. Chiranji Lal Sharma
Govt. PG College,
Sector-14,
Karnal
Haryana

Sub: - Award of Teacher fellowship to Mrs. Deepa Bhargava, Assistant Professor Department of Physics Pt. Chiranji Lal Sharma Govt. PG College, Sector-14, Karnal, Haryana for completing Ph.D from National Institute of Technology, Kurukshetra in two years under FIP Scheme during 12th Plan period-reg.

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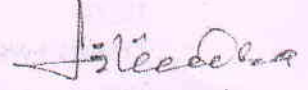
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Yours faithfully,



(Jitendra)

Education Officer

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2. The Registrar, Kurukshetra University, Kurukshetra.
3. The Director of Higher Education/Commissioner of Collegiate Education, Government of Haryana, Panchkula (Haryana).
4. The HoD, Department of Physic, Kurukshetra University, Kurukshetra.
5. The Registrar, National Institute of Technology, Kurukshetra (Haryana) - 136 119.

Encl. No. GCK/2015/2637 Dt. 25/4/15

(A.B. Bhatt)

Section Officer

Copy sent to the Principal, C.C. College at present
Anabala Devi for n. action as Mrs. Deepa Asst. Prof (Physic) is working in your college at present



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References (37)

Cited by (4)



Spectrochimica Acta Part A: Molecular and Biomolecular Spectroscopy

Volume 246, 5 February 2021, 118985



Effect of conjugation on the vibrational modes of a carbon nanotube dimer

Deepa Sharma^{a, b, c}, Swastika Banerjee^d, Swapan K. Pati^e, Neena Jaggi^f

^a Department of Higher Education, Government of Haryana, India

^b Deenbandhu Choturam University of Science & Technology, Murthal, Haryana, India

^c Shaheed Udham Singh Government College, Matak-Majri, Haryana, India

^d Lawrence Berkeley National Laboratory, Berkley, CA, USA

^e Jawaharlal Nehru Centre for Advanced Scientific Research, Bangalore, India

^f National Institute of Technology, Kurukshetra, Haryana, India

Received 25 May 2020, Revised 2 September 2020, Accepted 21 September 2020, Available online 26 September 2020, Version of Record 6 October 2020.



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Keya Dharamvir
Professor (superannuated)

Phone: 91-172-253-4471 (O)
-254 1741 (Phy O)
FAX: 91-172-2783336
E-mail: keya@pu.ac.in

23.05.2019

Subject : Recommendation for Dr. Deepa Sharma, WISTEMM applicant

I am glad to provide this recommendation in support of Dr. Deepa Sharma who has been associated with me for a number of years. I have had the opportunity to interact with and observe her closely during our collaborative research work on SWCNTs and their hybrids. We have co-authored a chapter in the Encyclopedia of Nanoscience and Nanotechnology published by American Scientific Publishers. I find her clarity of thought remarkable.

Her knowledge and understanding of fundamentals of Physics are excellent, providing the adequate background for research in a highly challenging area. The quality of her research publications speak for themselves. She has a number of research papers in journals of international repute to her credit, some of the work having been done when she had very little research facility while working in a college devoted to teaching alone. In addition, she has several conference proceedings and has attended a number of conferences giving her a good exposure.

She is systematic in her approach and works in a focused manner when given a specific task. She has used density functional techniques in her Ph.D. thesis and is quite thorough with the programs she has used. I believe she has the capability to quickly pick up other programs of similar nature.

During her teaching career, she helped organize seminars and conferences. I have had the opportunity to watch her during these events as a visitor. She has shown exceptional patience with students who approached her with a variety of problems. Combining this quality with her academic competence and proficiency in English, I feel she will prove to be an excellent teacher at any locale.

Deepa is an alert worker and has shown a lot of initiative. She has often helped me in my Non-profit organization working for popularization of science. She has shown ability and keenness to go beyond the work assigned to her. She works well in a team and I expect her to be able to provide effective leadership in later years.

In accordance with Dr. Deepa Sharma's research capabilities and teaching acumen, I highly recommend her for the fellowship she has applied for. She will be an asset to both teaching and research activities.

Keya Dharamvir,

Professor (superannuated) and

General Secretary, Society for Promotion of Science & Technology in India (a Non-Govt. organization devoted to popularization of Science)

Address: #229, Sector4 MDC, Panchkula 134 114, Haryana, India

Mob. +91 9478000088

Addl. E-mail: keyadv@gmail.com, spsti.info@gmail.com

From: **IAAM-International Association of Advanced Materials** <contact@iaamonline.org>

Date: Fri, Nov 25, 2016 at 5:04 PM

Subject: Congratulations: IAAM-International Association of Advanced Materials, Sweden

To: <bhargava.dp@gmail.com>

International Association Of Advanced Materials

Dear [deepa sharma](#),

Welcome to the International Association of Advanced Materials

Your membership Number: 76332911282

The benefits of this offer include:

- You will get a lifetime IAAM membership complimentary which normally costs around 800 Euro.
- In conferences sponsored by IAAM, you will get discounted registration under IAAM members.
- FREE listing in, and access to, the online IAAM Member.
- First-to-know status for IAAM meeting programs and calls for papers.
- Regional forums for interaction through IAAM Sections.
- Regularly receive Advanced Materials Letters (www.vbripress.com/aml) and Advanced Materials Proceedings (www.vbripress.com/amp).

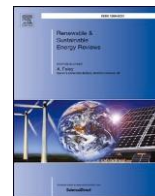
We look forward to receiving your expertise to fulfill the objectives of the association and welcome you [in](#) our upcoming cruise congresses.

With best regards,

Tina Henson

International Association of Advanced Materials

Mjärdevi Science Park, Teknikringen 4A



Advancements in net-zero pertinency of lignocellulosic biomass for climate neutral energy production

B.K. Nahak^a, S. Preetam^a, Deepa Sharma^{b,c}, Mikael Syväjärvi^d,
Dana-Cristina Toncu^{a,d}, Ashutosh Tiwari^{a,*}

^a Institute of Advanced Materials, IAAM, Gammalkilsvägen 18, Ulrika, 59053, Sweden

^b Department of Higher Education, Government of Haryana, India

^c Shaheed Udham Singh Government College, Matak-Majri, Haryana, India

^d School of Chemistry, University College Dublin, Belfield, Dublin 4, Ireland

ARTICLE INFO

Keywords:

Lignocellulosic biomass
Climate neutral production
Sustainable bioenergy
Enzyme technology
Net-zero energy

ABSTRACT

The lignocellulosic biomass is one of the most abundantly perennial available natural resources for green energy production. The heterogenous organic and inorganic composite structure of lignocellulosic biomass comprises numerous morphologies, particle size and properties. The cellulose, hemicellulose, lignin, and other organic components with acetyl groups, minerals, and phenolic compounds are found in the biomass as principal ingredients. This review article describes the use of lignocellulosic biomass as sustainable source of energy in solid, liquid and gas with its readiness level in climate neutral energy production. The efficacy of various used physical, chemical, and biological treatments on biomass are discussed with their effect on biomass during conversion of energy sources. Further, the properties of derived energy generations to solid, liquid and gas are described in comparison to commercially used fuels to create a measurable standardization towards their sustainable functions. Data from India's case-study is analyzed in the light of new programs encouraging net-zero utility of lignocellulose biomass.

1. Introduction

The increase of the global economy, development, and population over the last decades has been significantly reliant on the consumption of the planet's limited fossil fuels for power generation [1,2]. It was found that continuous CO₂ emissions are one of the primary causes of climate change. It began to rise during the industrial revolution, implying that developed countries such as the United States, which made an initial transition to a fossil fuel-based economic system, show an outsized part in contributing to climate influences, as illustrated in Fig. 1 [3]. Likewise, low- and middle-income countries have reduced shared historical emissions and per capita emissions. In order to effectively reduce emissions, we need to understand from where the emissions first come from. As shown in Fig. 1, greenhouse gas emissions (GHG) occurred from energy sector is around 73.2%, agricultural, forestry and land use contribute 18.4%, landfills and wastewater comprising contribute 3.2% and industrial waste contribute 5.2% [4,5]. It is clear from this breakdown that a range of sectors which contribute to GHG emissions. Out of which energy and agriculture waste contribute

in a large amount. To deal with this, primary energy needs can be encountered with utilizing alternative and renewable energy fuels, assisting in the present energy crisis declaration.

The numerous renewable energy sources, counting wind, solar, and hydropower energy are on the rise to meet rising energy demands [6]. The benefits of these energy resources include reduced greenhouse gas emissions, decreased reliance on foreign fuels, and creating economic growth through manufacturing and installation jobs. Despite the fact that these technologies are sophisticated enough to meet current energy demands, they do have their limitations. The primary disadvantage of these technologies is their geographical location, as sun, wind, and water energy are irregular in nature, preventing residents of various regions from utilizing these renewable energy sources. Considering the geographically suitable locations for renewable technologies, the additional aspects, such as animal lives, nature preservation, etc. might hinder implementation of renewable energy technology at optimized locations.

Biofuels are commonly defined as liquid, gas, and solid fuels that are derived primarily from renewable sources. Currently, a variety of fuels

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E-mail address: director@iaam.se (A. Tiwari).

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Available online 21 April 2022

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(ethanol, butanol, biodiesel, and bio-hydrogen) can be produced from these renewable energy sources [7,8]. The switchgrass, rice, and wheat straw are good examples of lignocellulosic biomass (LBs) that can be utilized to produce biofuels including bioethanol, biodiesel, and biogas. Recently, this biofuel sector has gained traction globally because of (i) being available as sustainable and renewable sources (ii) having eco-friendliness, hence mitigating GHG emissions (iii) having abundant availability in nature (iv) creating economic boost to rural people. In this respect, various attempts are made to judicious use of LBs as sustainable sources of energy in decentralized means and generate sustainable energy.

The different methods reported for conversion of LBs into different energy sources are thermal degradation, chemical leaching, microbial and enzyme degradation. Although practice of the use of biomass in energy is very limited and it appears essential to investigate intensively for value addition, pollution control and economic enrichments. In the light of the above developments, the present study describes the different properties, and sources of LBs in the first half. Further sections exemplify various pretreatment methods and their advantages, disadvantages with possible solutions to the problems. Finally, a brief

description of policies and reforms that have been implemented in India to promote biofuel production are discussed, as well as the status of commercialization of lignocellulos biomass.

Today, there is an exponential rate of publications, and this systematic review provides a good understanding of novel approaches available for sustainable energy production and thereby it will rapidly contribute to the climate urgency mitigation. This critical review deals with the efficient and cost-effective road map of lignocellulosic biomass for the processing and energy conversion. Additionally, development in enzymatic processing and sustainable energy systems is also summarized. Finally, it provides an important perspective of prospective orientation in terms of commercialization.

2. Lignocellulose biomass

The lignocellulosic biomass (LB) is one of the most abundantly available natural resources on a global scale. The majority of LBs are derived from plants and are composed of cellulose, hemicellulose, lignin, and other important compounds. Additionally, LBs could be found in various plants such as rice husk, sugar cane bagasse, straw,

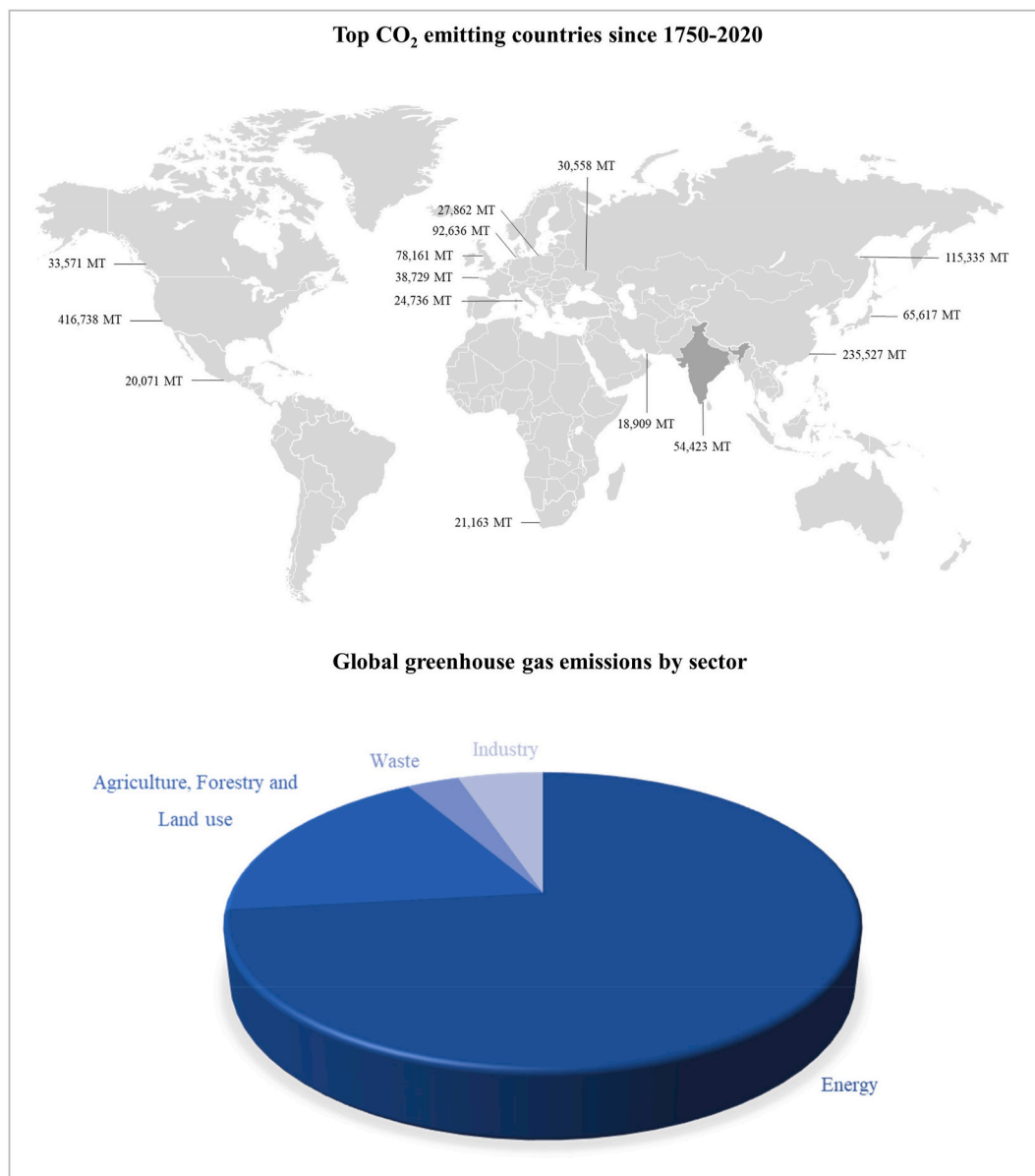


Fig. 1. The statistical data of top fifteen CO₂ countries since year 1750–2020 and the greenhouse gases emitted by per sector occurred in 2016.

bark, coconut husk, sawdust, leaf litter etc. Among the many, LBs-based biomass options, only a few have nutritional value for conventional uses such as fodder, while others are dumped and exploited as crude energy sources [8]. As a result, their disposal, dumping, and burning contribute to a number of major environmental and marine issues. Thus, converting LBs to energy products is a prudent use of this plentiful carbon-neutral renewable resource, as well as a step toward reducing carbon dioxide emissions and atmospheric pollution [9]. Economically, LBs are more affordable than crude oils. Thus, utilizing LBs as a source of energy not only improves financial situations, but also considerably aids of the governments in preserving reserve fuels reserve for supply and pollution reduction.

2.1. Classification of lignocellulosic biomass

Agricultural wastes (crops and sugarcane bagasse), forest leftovers, and woody crops are the three main sources for lignocellulosic feedstocks.

2.1.1. Agricultural residues

Biofuels can be made from a wide range of agricultural wastes, such as maize stover, straw, wheat straw, and bagasse. These biofuels are considered sustainable as they are being used from crop wastes and do not compete with crops from land fields. Cellulosic ethanol can be made from agricultural wastes using a biochemical process that comprises of pretreatment, hydrolysis, and fermentation. Alternatively, waste can be gasified to create syngas and converted into liquid fuels using catalysts.

2.1.2. Forestry residues

There are two main types of forestry resources that are used in production of biofuels: (i) remaining of wood harvestings such branches, leaves, roots, are such source (ii) complementary felling which describes the variance between the extreme sustainable harvest level and the real harvest needed to meet wood claim.

2.1.3. Herbaceous woody energy crops

To provide feedstocks for fuel production, various types of energy crops could be grown in marginal land (location that is unsuitable for food growth). For instance, perennial grasses are being studied as potential new sources of energy (miscanthus, switchgrass, eucalyptus, poplars, and robinia). In order to provide continuous supply to the processing plants, these crops can be grown under ideal conditions and harvested over long seasons [2].

2.2. Physico – chemical characteristics of lignocellulose biomass

The LBs have varied shape, particle size, and other features because of their heterogeneous composition, which includes both organic and inorganic substances. Cellulose, hemicellulose, and lignin are the most common organic ingredients, but there are also trace amounts of acetyl groups, minerals, and phenolic compounds. Silica, silicate, and metal oxides are the primary inorganic components. They have highly complicated non-uniform three-dimensional structures, in which the organic polymer's part is structured based on the kind and relative composition of the organic components that are already present. The stability and resistance to environmental degradation are attributed to the synergistic combination of cellulose, hemicellulose, and lignin shown in Fig. 2. Hydrogen bonds often link cellulose and hemicellulose, while covalent bonds hold lignin together. The lignocellulose's resistance to enzymatic and chemical degradation is also attributed to their crystallinity, size, shape, and hydrophobicity, among other things. Structure and chemical method are commonly used for lignocellulosic biomass conversion to nanocellulose. Table 1 lists a few samples of LBs with data on their composition and other useful characteristics.

Hence, during conversion of LBs into value added products the integrated approach of chemical, physical, and biological are explored. Some of them are used for removal of physical impurities and activation,

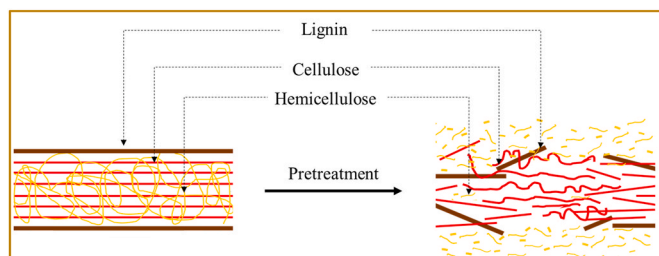


Fig. 2. Graphical demonstration of lignocellulosic biomass polymers; cellulose, hemicellulose, and lignin.

Table 1

Types of lignocellulosic biomass and their chemical composition [10].

Lignocellulosic Biomass		Cellulose (%)	Hemicellulose (%)	Lignin (%)
Hardwood	Poplar	50.8–53.3	26.2–28.7	15.5–16.3
	Eucalyptus	54.1	18.4	21.5
Softwood	Pine	42.0–50.0	24.0–27.0	20.0
	Spruce	45.5	22.9	27.9
Agricultural Waste	Wheat Straw	35.0–39.0	23.0–30.0	12.0–16.0
	Barley Hull	34.0	36.0	13.8–19.0
	Barley Straw	36.0–43.0	24.0–33.0	6.3–9.8
	Rice Straw	29.2–34.7	23.0–25.9	17.0–19.0
	Rice Husks	28.7–35.6	12.0–29.3	15.4–20.0
Grasses	Sugarcane Bagasse	25.0–45.0	28.0–32.0	15.0–25.0
	Grasses	25.0–40.0	25.0–50.0	10.0–30.0
	Switchgrass	35.0–40.0	25.0–30.0	15.0–20.0

however, other ones are used for production of energy producing chemicals in solid, liquid, and gaseous state.

2.2.1. Cellulose

Cellulose is a long-lasting polymer made of glucose bonded together by long linear chains. The β -1,4 linkages connect the (1,4)-D-glucopyranose units, and the molecular weight is about 100,000 [11]. There are intermolecular hydrogen bonds that hold together 40–50% of the cellulose molecules in plant biomass, but these molecules tend to create intramolecular and intermolecular hydrogen bonds as well, enhancing cellulose's stiffness and making it extremely intractable in most organic solvents. Crystalline and amorphous regions coexist in nature as bundles of cellulose molecules that form microfibrils [12,13].

2.2.2. Hemicelluloses

Glucuronoxylan, glucomannan, and other polysaccharides are prevalent heterogeneous polymers consisting of hemicellulose. Arabinan, galactan, and xylan are components of grass and straw; mannan is found in hardwood and softwood hemicellulose [14]. These sugars comprise the backbone of the cell wall, with the majority of them being made up of xylan and mannan [15]. All three galactans and arabinans are found in the hemicellulose category. The β -1,4-linked backbone structure, which is unique to the equatorial area, is shared by both species. One of the most important components in hardwoods is glucuronoxylan, which is short for O-acetyl-4-O-methyl-glucurono- β -D-xylan. Linkages in the polymer's backbone are comprised of β -1,4-xylopyranose molecules. An average molecular weight of less than 30,000 Da makes up one-fourth of the biomass from woody plants, and this is known as hemicellulose. Cellulose and hemicellulose adhere firmly to the surface of each cellulose microfibril using noncovalent attractions. Until quite recently, hemicelluloses were assumed to be intermediary products in cellulose production [16].

2.2.3. Lignin

Lignin makes about 10–25% of the total weight of the plant's

biomass. These phenyl-propane polymers, which are mostly connected by ether bonds, form the bulk of the polymer, which has an extremely lengthy chain of building blocks. The lignin acts as a glue by attaching polymers to cellulose and hemicellulose, and this is filling up the gaps between them. It can be found in all kinds of plant material. It is called “aside product” in the bioethanol making process since it is a “residue”. Cell wall component binding phenyl-propane, methoxy groups, and noncarbohydrate polyphenolic material comprise the Lignin, a complex and massive polymer made up of several phenyl groups and polypropane and methoxy groups [17]. In lignin, the most important building unit is phenyl-propanes, which have three carbon atoms connected to six carbon atom rings. The I, II, and III methoxyl groups are linked to rings and designated as O, I, and II phenyl-propanes. Each of these categories is based on the plant origin on which it is derived. The three major structural components (structures I, II, and III) occur in plants and wood.

3. Role and impact of pretreatment

Pre-treatment is critical when it comes to recovering lignin-based biomass’s cellulose component, as opposed to starches. Lignocellulosic biomass must be thoroughly pre-treated to break down the lignin barrier before enzymatic hydrolysis may convert it to fermentable sugars. This is important before working with lignocellulosic biomass. Fermentable sugar may be made from nearly all agricultural lignocellulosic materials, including wood, by employing several pre-treatment processes [19]. When setting the stage, this data points to many previous pre-treatment options for various feedstocks. Among the prospective pre-treatment categories for bio-energy generation are those that have already been commercialized. To attain the greatest level of fermentation activity, it is important to preserve the hemicellulose fractions in order to maximize the quantity of fermentable sugar while minimizing carbohydrate loss. It is also important to avoid creating inhibitors from degradation products and utilize an efficient and cost-effective technique.

The factors as mentioned earlier must be completely addressed to get the maximum result of interest. There are several techniques to break down biomass by hydrolysis. It can be done physically, chemically, or biologically [18–21]. These pretreatments methods are used to make the LBs prone by simplify, hydrolyze, solubilize, and separate the organic components for biochemical degradation to produce energy releasing compounds. Pretreatment processes can be mechanical, physicochemical, and chemical methods. It includes physical milling, microwave treatments, steam heating, treatment from ammonia and supercritical carbon dioxide, SO₂, water pretreatment, wet oxidation, Ozonolysis, and acid hydrolysis are all methods of alkaline hydrolysis. The applicability of LBs used in energy sources will also be determined by advancements in LBs following pretreatment technology, according to this prediction. The illustrative impact of physical treatment on a representative LBs is illustrated in Fig. 3.

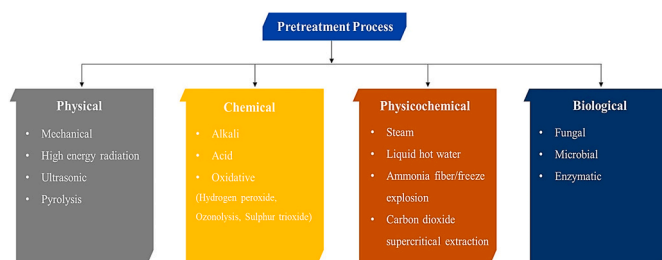


Fig. 3. Different types of pretreatments used in the preretirement process of lignocellulose biomass.

3.1. Physical methods

3.1.1. Mechanical pretreatment

The sheer power generated using mechanical procedures to break the inflexible pattern of lignocellulose and these lines further improve the accessibility of synthetic, microorganisms, and compounds to cellulose and hemicellulose. This treatment performs to comminution of polymer in order to enhance a surface area, reactivity, reduces that size, shape and segregation of the lignocellulosic biomass [22]. Understanding recalcitrance and predicting hydrolysis for lignocellulosic biomass conversion is important for its processing. The operation involves the use of different mechanical technique such as chipping, grinding, and milling. The basic explored milling tools are two-roll mill, ball mill, vibro energy mill, colloid mill, hammer mill, and wet disk mill. The efficiency of milling is further improved by modifying medium like using acid, enzymes and microbial treatments [23]. The impact of different mills has each their own advantages and limitations and thus may be used on the basis of applications in term of duration and type. Similarly, the disk milling generates fibers more effective after enhancing the hydrolysis of cellulose than hammer milling [24]. The power of mills are important criteria for properties of final particle size derived by LBs like the final particle size is 3–6 mm during comminution by using power 30 kWh per ton of LBs. This cycle can bring about a positive reaction, however the prerequisite of a higher energy request makes it an expensive expansion to anaerobic assimilation process. These days this pretreatment is applied to low lignin content herbaceous plants. For instance, wheat straw, knoll and different substrates pre-treated by expulsion crushing, cutting, and ball processing cannot just altogether decrease the size of the substrate and level of polymerization, yet in addition diminish the lignin content from 38.5 to 54.43% [25].

3.1.2. High-energy radiation

The 1,4-glycosidic linkages in LBs are cleaved by high-energy radiation, like cellulose, increasing the precise surface area, decreasing crystallinity, and increasing the degree of polymerization, hydrolysis, and depolymerization. This is similar to what happens to cellulose. Ultrasound, ultraviolet, electron beam, pulsed electrical field, gamma radiations, microwaves, and infrared are among of the high-energy radiations employed in the processing of LBs. Sometime the radiation on LBs is performed in integration of enzyme hydrolyzed fermentation like electron beam irradiated of 80 kGy at 0.12 mA and 1 MeV on rice straw with yield of 52%. Similarly, the pretreatment on wheat straw by gamma-radiation yielded glucose through enzymatic hydrolysis with yield. Although the radiation is very useful, but it is too costly in large scale applications along with specific nature as well as environmental and safety concerns [26–28].

3.1.3. Pyrolysis

In this process, the biomass is thermo-chemically converted into energy sources at elevated temperature >300 °C. The pyrolysis of LBs can affect be influenced by fluctuating temperature and air in the environment such as with excess air, partial air, and no air. At reduce temperature, low volatile products are formed due to a slower rate of decomposition. At elevated temperatures, the LBs disintegrate rapidly into gaseous compounds and residual char. Fast pyrolysis, flash pyrolysis, and conventional pyrolysis are all types of pyrolysis. Rather than burning the volatile organic compounds for energy, the residual char is treated with water or a mild acid to increase its carbon content so that fermentation can occur during the process of making bioethanol. Fan et al. has reported that the pyrolysis product of pretreated biomass on successive mild acid hydrolysis from 1.0 N H₂SO₄ at 94 °C gives reducing sugar with conversion efficiency of 80–85% [29]. Similarly, Rabou et al. observed the generation of transferable fuels from biomass by pyrolysis through a biomass-to-liquids route into to syngas as well as high-quality Fischer-tropsch fuels [30]. The reaction mechanism also varies with temperature: at lower temperature below 575 K free radical

are formed, between 575 and 725 K breaking of glycosidic bond occurs, and above 725 K rearrangement and substitution take place [31]. It is the primary route by which biomass is thermo converted into fuels and chemicals.

Further, Kong et al. studied the use of numerous bioresources derived molecules and additional wastes as precursor materials including glucose, sucrose, gelatin, chitosan, rice husk, hemp, wheat straw and sugar cane bagasse for pyrolysis at inert environment. Finally, they concluded that the biomass-derived graphene-like carbon materials have high surface area, interconnected pore, electrochemically stable surface, proper electrical conductivity etc. which are suitable for the supercapacitor, catalysts, and fuels [99].

3.1.4. Gasification

The gasification step of the LBs feedstocks to syngas takes place at high temperatures (800–1500 °C) inside gasifier. The feedstocks are partially oxidized because of a lower concentration of oxygen than the stoichiometric need. Oxygen is supplied to gasifier as carrier like air, pure oxygen, water steam. Compared to other process, gasification is more efficient as it can change all carbon content present in biomass into gaseous compounds. However, one of the key limitations of this process is formation of tar. This tar can be classified into three categories primary, secondary and tertiary. Primary tars are formed from pyrolysis of cellulose, hemicellulose and Lignin; the secondary and tertiary tars are produced from numerous complexes. Finally, the syngas composition depends on many changes such as temperature, residence time, pressure, catalyst used, equivalence ratio, and type of feedstocks and gasification technology that is being implanted [133,134]. Wood has been commonly used feedstock in the gasification process. It was observed that latter condition is the most appropriate optimization for syngas fermentation. N₂ can be seen as key syngas component when air was used as gasifying carrier in addition to H₂, CO₂, CO and CH₄. This can be one of the major topics for researchers in biomass gasification process to reduce the presence of CH₄.

Unlike gasification of coal, syngas produced from biomass is consider to be pure. As it involves very less amount of nitrogen, sulphur, heavy metals, and have high hydrogen to carbon ratio, results in low emissions. Yet, significant number of submicron particles, particularly soot, might exist in syngas after gasification of biomass. Soot is an aerosol product produced due to incomplete combustion. In industries, process like combustion and pyrolysis occurs simultaneously with the gasification, and among all this individual reaction process continuous soot is being formed. These soot's can be classified into two categories, soot generated from solid fuels and gas fuels. The properties of the soot depend on biomass components (cellulose, hemicellulose and lignin), which makes it significantly different. It was found in literature that approximately 10% volatile matter end up as soot in a furnace, and approximately 0.1 kg of pyrolysis oil transformed into soot in a EFG [144]. Moreover, in solid soot, the Alkali and Alkaline Earth Metals (AAEMs) that are liberated into gas phase plays role of as catalyst to dimensive soot formation, which is another important difference from the gaseous soot. These generated biomass soot also cause some disadvantages during the lignocellulose conversion process. It blocks the pipeline and poison the catalysts in the downstream device, which causes some serious consequences. Thus, it becomes very important to control the soot formation. Some of the ways through to minimize soot formation within the gasifier, is by reducing benzene and hydrocarbon since they are important sources for PAHs and soot [145]. Another way is by collecting the soot after gasification, and including thermo-catalytic treatments in secondary reactors and physical separation by cyclones, filters or electrostatic precipitators.

3.1.5. Ultrasonic pretreatment

Ultrasonic vibrations can disturb lignocellulose construction due to occurrence of extremely high energy and vulnerability. The exhibition of ultrasonic pretreatment is firmly connected with lignocellulose type,

ultrasonic recurrence, force, and length. Regularly the ultrasonic recurrence causes an effective pretreatment, yet the pretreatment proficiency won't increment any longer when the recurrence is more noteworthy than 100 kHz as per the investigation of Bussemaker [102]. When ultrasonic pretreatment is combined with chemical pretreatment, for example, 20 kHz intensity with 1.0 N NaOH solution eliminate lignin up to 80–100% from cabbage, peanut husks etc. [103].

3.2. Chemical methods

3.2.1. Alkali pretreatment

The alkaline treatment of lignocellulosic agricultural residues employs bases such as NaOH, KOH, NH₄OH, Ca(OH)₂, NH₃ and (NH₄)₂SO₃. This action with alkali is conditional on the lignin level and generally applied for high lignin content lignocellulose feedstocks. Alkaline pretreatment dissolves the crosslinking between the various polymer matrices found in lignocellulosic biomass, increasing porosity swelling, structural deformation of lignin, partial crystallization of cellulose and hemicellulose fractional solvation are all factors to consider, as well as internal surface area, degree of polymerization and crystallinity [32].

By dissociating lignin from the rest of the lignocellulosic biomass' carbohydrate components using alkali pretreatment, the carbohydrate fractions become more readily available. Pretreatment of alkali at ambient temperature and pressure requires hours or even days. In comparison to acid pretreatment, alkali pretreatment results in less sugar degradation, and numerous alkaline salts, such as caustic salts, can be recovered or regenerated with relative ease. To increase the output of biogas from lignocellulosic biomass such as wheat straw, rice straw, corn stover, and woody materials like sunflower stalks, the most thoroughly investigated and well-known addition is sodium hydroxide (NaOH). The NaOH has been shown to boost the digestibility of hardwoods from 14 to 55% by lowering the lignin concentration from 24 to 50% [33].

Alkali pretreatment has the effect of saponifying and cleaving lignin-carbohydrate bonds, hence helping to remove lignin from the lignocellulosic matrix heterogeneous matrix and making cellulose more enzyme-accessible. For the most part, alkali pretreatment works better on wood, herbaceous crops, and agricultural leftovers with less lignin than on softwoods with a lot of lignin [34]. Acetyl and other uranic acid replacements on hemicellulose that decrease enzyme availability to the cellulose surface can be removed with alkali pretreatments, according to research [35,36]. The NaOH pretreatment of wheat straw improved lignin solubilization and cellulose and hemicellulose hydrolysis, resulting in an increase in biogas output. Handling of wheat straw with 0.25 mol NaOH and Na₂CO₃ at 0 °C for 6 h separately can attain the solid dissolution efficiency of 86.7% and 91.1% respectively [37].

Pretreatment with lime (calcium oxide, CaO) or calcium hydroxide (Ca(OH)₂) eliminates amorphous materials such as lignin and hemicellulose, growing the crystallinity index. Azzam and Nasr observed that pretreatment of sugar bagasse with 4% CaO (g/g VS) at 200 °C completed the digestion after 8 days and produced 70% of the methane within three days [38]. This resulted in the conclusion of CaO pretreatment [39]. Dong et al. conveyed that KOH has not been frequently used due to its high cost relative to NaOH and Ca(OH)₂ [40]. The KOH, on the other hand, provides environmental benefits because its waste stream may be utilized as a fertilizer [40]. Even though, NaOH generates Na⁺ ion inhibition, due to cost-effectiveness it is utilized for pretreatment of lignocellulosic biomass. Additionally, use of an integrated recycling technique enhanced the generation of biogas. As a result of this technique, environmental pollution from waste Na⁺ disposal may be reduced, and the requirement for pretreatment may be eliminated.

3.2.2. Acid pretreatment

Acidic chemicals were established reagents involved in the release of fermentable sugars by destroying glycosidic bonds in lignocellulose and dissolving cellulose, hemicellulose and lesser extent to lignin. This pretreatment can be carried out at elevated temperatures (e.g., 230 °C)

in the presence of concentrated acid (30–70%) or dilute acid (0.1–0.4%). For dilute acid pretreatment, mainly sulfuric acid (H_2SO_4), hydrochloric acid (HCl), nitric acid (HNO_3), phosphoric acid (H_3PO_4), acetic acid, and maleic acid have been utilized. While concentrated acid is quite successful at hydrolyzing cellulose, it is extremely poisonous, caustic, and dangerous. As a result, concentrated acid pretreatment requires specialized reactors for lignocellulosic material pretreatment, making it an energy- and cost-effective procedure. To make acid pretreatment economically viable, acid must be recovered from lignocellulosic materials following pretreatment. Thus, lignocellulosic materials have been successfully pretreated with dilute acid. Sulfuric acid is frequently employed as a pretreatment agent because it has the ability to hydrolyze up to 100% of the hemicellulose into its constituent sugars. Pretreatment with diluted sulfuric acid increases the methane output of sugar bagasse by 166% after 15 min at 121 °C with 2% acid. Dilute acids primarily contribute to a high degree of lignin disruption and considerably increase cellulose's sensitivity to microbial degradation and enzymatic hydrolysis [41]. Extreme conditions of temperature or acidity does not result in methane generation.

The other acids, such as HCl and H_3PO_4 , have been investigated as well. Pretreatment with HCl at 1 M acid concentration at ambient temperature, rise the biogas production from coconut fiber by 76 and 32%, respectively. On the other hand, even at an 80% concentration at 100 °C for 30 min, acetic acid unable to dissolve lignin. Further, accumulation of 2% HNO_3 to 35% acetic acid, facilitate removal of around 80% of the lignin. Hydrochloric acid can partially substitute HNO_3 , but low HNO_3 concentrations may necessitate a longer treatment time. Pretreatment with dilute acid is not usually efficient in increasing biogas output from lignocellulosic biomass. Even though pH neutralization is required prior to adsorption of prepared materials, the process generates enormous amounts of gypsum, which raises disposal issues. Dilute acid pretreatment is used to make a variety of ethanol fermentation inhibitors, including phenolic compounds and carboxylic acids. Acetic acid can be transformed directly to biogas via the AD process. Phenolic compounds' inhibitory properties are determined by their concentration and physiochemical characteristics. The acid pretreatment must be carefully selected to avoid or restrict inhibitor generation. Despite the fact that acid pretreatment can considerably improve the digestibility of cellulose, it is more expensive than other pretreatment procedures such as steam explosion or lime treatment. Since high venture, operating, and administration budgets, functioning constraints, and environmental effects limit the commercial viability of dilute acid pretreatment.

3.2.3. Oxidative pretreatment

Lignocellulosic feedstocks can be designed using oxidizing agents such as hydrogen peroxide, ozone, oxygen, or air [42,43]. This process turns lignin into acids. Because these acids could act as fermentation inhibitors, they must be removed. Degradation of lignocellulosic compounds damages the hemicellulose fraction, and much of the hemicellulose in the complex is destroyed, making it unusable for fermentation [44].

3.2.3.1. Hydrogen peroxide. The most often employed oxidizing agent for increasing the biological conversion of lignocellulose to bio-ethanol is hydrogen peroxide. The *in situ* production of hydroxyl radical ($\text{OH}\cdot$) occurs during H_2O_2 pretreatment due to variations in H_2O_2 concentration/chemical component. The hydroxyl radical ($\text{OH}\cdot$), which is significantly more powerful than peroxide, induces lignin hydrolysis and the formation of low molecular weight products, as well as an increase in hemicellulose and cellulose hydrolyzes. The production of inhibitors can occur when the lignin is oxidized to produce soluble aromatic mixes from the inorganic material Sugars, which are lost in the oxidative pretreatment process because H_2O_2 is a non-selective oxidant. H_2O_2 partially break down the polymers therefore biodegradation process by bacteria increases. When oxidizing agents are used, soluble lignin

compounds are formed, which hinder hemicelluloses and cellulose from being converted to ethanol. Yang et al. investigated rice husk pretreatment with hydrogen peroxide and biological therapy (*Pleurotus ostreatus*) [45]. As a result, the lignin degradation of the biomass content of the lignocellulosic feedstocks increases significantly. The concentration of H_2O_2 should be monitored during H_2O_2 pretreatment because an increased H_2O_2 concentration of 4% has been found to prohibit the anaerobic digestion due to the poisonousness hydroxyl ions for methanogens. Study suggests that 2–8% (w/w) H_2O_2 with 10% NaOH (w/w) at 90 or 120 °C for 12 h on hybrid poplar, results in the decrease lignin content by 9–63% [104]. The H_2O_2 alone may not be effective in treating complexes that are highly non-biodegradable. This is why other pretreatment procedures like alkali/acid hydrolysis and microwave irradiation are usually combined with hydrogen peroxide for improved treatment results.

3.2.3.2. Ozonolysis. Ozone may break down lignin and hemicellulose in a variety of lignocellulosic materials, including poplar sawdust, wheat straw, bagasse, peanut, pine, and cotton straw [46,47]. In disparity to other chemical behaviors, ozonolysis does not leave dangerous residues and increases the treated material's in-vitro digestibility. Lignin was the sole component to break down, with hemicellulose and cellulose intact. When 60% of the lignin in wheat straw was eliminated by ozone pretreatment, the rate of enzymatic hydrolysis enhanced five times. When poplar sawdust was subjected to ozonolysis, the enzymatic hydrolysis yield changed from 0% to 57%, while the amount of lignin was decrease from 29 to 8%. Euphrosine-Moy et al., However, ozonized 45% moisture moistened poplar sawdust and discovered oxalic and formic acids as the principal compounds in the aqueous extract as the treated material's primary products [48]. For the most part, the ozonation studies were carried out using hydrated fixed beds, which produce more powerful oxidations than aqueous or acetic acid suspensions [47]. The lignin degradation appears to be affected by ozone strength, action time, and pH. Study suggest that 8.87 g/g ozone treatment on wheat straw, result in a glucose production of 0.057 mg/mL [105], which later enhanced 5 times due to increasing treatment time up to 6 h, where cellulose and lignin content reduced, according to FTIR-ATR spectra. The lignin removal ratio of coffee husks increases with pH 7.0 to 11 with the ozone intensity and treatment time were reduced to 14.2 min in compare to 32.5 min [106]. This shows that lignin removal was better with ozone pretreatment under alkaline circumstances.

3.2.3.3. Microthermal technique. Brodeur et al. investigated the Pretreating biomass such as rice straw with sulphur trioxide in a technique called sulphur trioxide microthermal explosion (STEX) [58]. After being agitated for 7 h at 50 °C/atm with biomass suspended over a solution of oleum and sodium hydroxide (1% w/v), the solids are obtained by washing them [50]. A saccharification yield of 91% was achieved using rice straw pretreatment under the aforementioned conditions. Heat created by the sulphur trioxide–straw interaction causes an internal explosion, resulting in the rapid enlargement of air and water from the biomass's interior, increasing structural alterations and pore volume while also partially removing hemicellulose and lecithin [50,51]. Due to its corrosiveness sulphur trioxide will be a major challenge in this method.

3.3. Physiochemical process

3.3.1. Steam pretreatment

Steam pretreatment, often known as a steam explosion, is the widely studied and utilized physiochemical technique to pretreatment of biomass. This process involves treating lignocellulosic biomass with high-pressure saturated steam at a temperature of 160–260 °C and a pressure of 0.69–4.83 MPa for a few seconds to a few minutes. The hemicellulose hydrolysis, and the material explosive decompression

occurs due to the rapid release of pressure. Explosive decompression removes hemicelluloses from microfibrils, and lignin is only partially removed by the steam explosion. However, melting and depolymerization or repolymerization reactions redistribute it on the fiber surfaces.

During pretreatment, hemicellulose, which contains the majority of carbohydrates, is solubilized in liquid. Lignin undergoes a change at high temperatures, increasing the likelihood of cellulose being hydrolyzed. Hemicellulose is expected to be hydrolyzed by acids during the steam explosion process, resulting in the release of xylose and glucose monomers. The use of acid catalysts (H_2SO_4 , CO_2 , SO_2) reduces time and temperature, improves hemicellulose sugar recovery, reduces inhibitory chemical generation, and effectively improves solid-surface hydrolysis [52,53]. With a steam explosion pretreatment at 215 °C and 2 MPa for 5 min, almost 80% of the lignin in pineapple leaf fibers could be eliminated [107]. Furthermore, 90% hemicellulose in reed was decreased after 15 min of pretreatment at 200 °C and 3.4 MPa, resulting in a significant rise in cellulose content from 64.48 to 81.3% [108]. During biogas production, Aski et al. observed methane yield up to 147% with utilization of steam-exploded rice straw [109]. In comparison to other pretreatment methods, steam explosion pretreatment utilizes less chemicals, doesn't dilute the sugars produced excessively, and consumes less energy while requiring no recycling or environmental expenditures.

3.3.2. Liquid hot water pretreatment

Pretreatment utilizing liquid hot water is a hydrothermal technique that do not require the accumulation of chemicals in the pulp industry or in the manufacturing of bioethanol. Regardless of the nomenclature used, all of these processes are a form of hydro-thermolysis. Higher poly- and oligosaccharide synthesis is achieved using this method's lower temperatures and dry matter content (around 1–8%). Up to 15 min of water-biomass contact is achieved at temperatures ranging between 200 and 230 °C. During biomass hydrolysis, hot water cleaves the hemiacetal links, releasing acids and facilitating the breaking of ether bonds in biomass [54]. A steam explosion pretreatment uses steam to retain water in a liquid state at a high temperature (100–103 °C). Liquid hot water pretreatment does the same thing. The HMW pretreatment leads to the hydrolysis of hemicellulose and the elimination of laminin, as per Yang and Wyman, by reducing the temperature to which fermentation inhibitors are generated while increasing the availability of cellulose in the biomass [49]. The Liquid hot water (LHW) pretreatment configurations varied with co-current, counter-current, and flow-through reactors methods. Higher surface area of cellulose is sensitive to microorganisms and enzymes for degradability and LHW is found to be highly effective. Sunflower stalks, miscanthus and grass, paper tube residuals, sugar bagasse, and microalgae have all been used to increase methane manufacture from lignocellulosic biomass. Pretreatment of rice straw with LHW increases methane output by 22% over untreated rice straw. The chemical composition and structural characteristics of lignocellulosic biomasses have a large impact on LHW efficiency and the optimal pretreatment conditions. As a result of LHW's utilization of low temperatures, less degradation products are created, and final washing or neutralization is not necessary. Unlike acid-based pretreatments, it does not necessitate the use of expensive corrosive-resistant reactor materials. Because LHW uses water as a pretreatment solvent, it can be used on a broad scale. Water functions as an acid at high temperatures and to stop the production of inhibitors during LHW pretreatment, the pH can be kept neutral by adding certain bases such as NaOH. The downsides of LHW pretreatment include more energy-intensive downstream processing due to the enormous amounts of water involved.

Venkatachalam et al. managed to optimize water extraction of fuels and fine chemicals from *Prosopis juliflora*, a weed tree native to South Americas. They obtained the best production of bio-oil (3.65%) and biomass to water loading 20.13% w/v. They attained enlargement of bio-oil yield and minimization of biochar yield at temperature 300.14 °C, reaction time 75.12 min and biomass to water loading 19.19 %w/v with a maximum bio-oil yield of 3.34% and minimum biochar

yield of 29.74% [100].

3.3.3. Ammonia physicochemical method

Ammonia fiber explosion is a method of physicochemical pretreatment in which lignocellulosic biomass is reacted to liquid ammonia at raised temperatures and pressures for an extended time before the pressure is quickly lowered. It's comparable to steam explosion pretreatment, except it's done at room temperature (<90 °C), whereas AFEX is done at greater temperatures. Pretreatment with AFEX has been used to increase the rate of fermentation of a range of herbaceous crops and grasses, as well as lignocellulosic materials. In the AFEX and ARP processes, lignocellulosic material is exposed to ammonia ensuing in swelling and phase change of the cellulose crystallinity and elimination of lignin. In a typical AFEX process, biomass is exposed to anhydrous liquid ammonia at a concentration of 1–2 kg ammonia/kg dry biomass (ratio of 1:1 to 1:2) for 10–60 min at temperatures 60–90 °C with pressures more than 3 MPa [55]. For approximately 30 min, the biomass and ammonia combination are cooked to the required temperature in a closed vessel under pressure. After approximately 5 min of maintaining the correct temperature, the vent is abruptly opened to explosively alleviate the pressure. The rapid release results in the evaporation of ammonia, decreasing the system's temperature [56]. The distribution of lignin is unaffected by AFEX pretreatment, but the structure of the lignin is significantly changed, ensuing enhanced water-holding capacity and digestibility. As a result, AFEX is ineffective against lignocellulosic biomass that has a high.

Currently, AFEX has been shown to be operative in the pretreatment of lignocellulose with little lignin content. The lignin degradability of barley straw [55] and cornstover [57] was determined to be between 24% and 1.3%. Furthermore, by addition of hydrogen peroxide might boost the glucose production; the greatest sugar yields from gigantic reed and Miscanthus, respectively, were 424.6 g/kg and 485.0 g/kg [110,111].

The AFEX pretreatment procedures have various advantages, including: i) The capability to decrease, improve, and recycle the ammonia used in both AFEX and ARP makes feasible for an industrial procedure; ii) Ammonia pretreatments exhibit a high degree of selectivity for lignin reactivity, and the AFEX/ARP hydrolysate is well-matched with fermentation organisms without conditioning; iii) Within 20 min of processing, ARP delignifies 70–85% of maize stover lignin and eliminates 40%–60% hemicellulose while keeping the cellulose intact; iv) In comparison to other physicochemical procedures, the low temperature (<100 °C), pH (<12.0) and small residence time utilized in AFEX and ARP largely eliminate the production of fermentation inhibitors; v) Ammonia costs roughly one-fourth the price of H_2SO_4 , meaning that AFEX preparation is less expensive than DAP; and vi) residual ammonia could assist as a nitrogen [58,59]. Apart from the benefits, there are several drawbacks to using the AFEX process, including: i) They are not effective for pretreatment of lignocellulosic biomass having rich lignin content, such as newsprint (18–30% lignin) and softwoods; ii) The cost of ammonia is mostly associated with the manufacturing process and its significant application; and iii) Environmental worries about the ammonia odor have increased [60].

3.3.4. Carbon dioxide supercritical extraction

The CO_2 (SC- CO_2) demonstrate increasing digestibility of lignocellulosic biomass by operating at a lesser temperature than steam explosion and maybe at a cost-effective than ammonia explosion. At temperatures above its critical point, a supercritical fluid is a gaseous fluid compressed to a liquid-like density. The SC- CO_2 is applied at a high pressure to biomass (1000–4000 psi) tank in this procedure [61,62].

The vessel is kept for an amount of time and heated to the necessary temperature [63]. The CO_2 molecules can flow through the same microscopic pores as water and ammonia molecules due to identical in size with them. It is assumed that dissolved Carbon dioxide in water produce carbonic acid, which accelerates the hydrolysis of

hemicellulose and cellulose. The release of compressed gas results consequential high the accessible surface area of biomass due to its structural disruption [64]. A rise in pressure allowed CO₂ molecules to penetrate the crystalline structures more quickly, resulting in more glucose being produced following the explosion. The CDE pretreatment is also appealing because of the cost-effective CO₂ solvent, toxins absence, the high solids capacity, and the utilization of moderate temperatures that preclude any considerable breakdown of monosaccharides by the acid [65]. Research suggests that CO₂ explosion to steam and ammonia explosion for the processing of recycled paper and sugarcane bagasse, where CO₂ explosion was comparatively cheaper than explosion of ammonia [66]. The excessive cost of equipment capable of withstanding the high-pressure conditions associated with this CDE pretreatment, on the other hand, is a significant barrier to its widespread use. Because CO₂ explosions are carried out at low temperatures, they do not result in sugar deterioration, as is the case with steam explosions, which are carried out at high temperatures. Additionally, the effects on the carbohydrate components of biomass are unknown.

3.4. Biological pretreatment

Bacterial activity, fungi, and enzymes are used to classify biological pretreatment methods. The most frequent way for increasing biogas generation in anaerobic digestion is to apply a fungal biological pretreatment. Biological pretreatment methods, in contrast to physical and chemical pretreatment approaches, look to be a promising technology with various advantages, including low energy inputs, no chemical requirements, and an environmentally acceptable operating method [67] and mild climatic conditions to ensure that fewer inhibitors are produced, which could harm anaerobic digestion. However, the treatment's applicability in commercial applications has been limited due to the lengthy pretreatment process and the need for a substantial amount of room to do it. It also necessitates meticulous monitoring of growing conditions [68]. Microbes require a particular amount of carbs for biological pretreatment, resulting in carbohydrate rivalry between pretreatment and downstream biogas production. Biological pretreatment improves biogas generation by increasing cellulose accessibility by removing as much lignin as possible to boost digestibility and minimize carbohydrate loss during anaerobic digestion of feedstocks. Fig. 4 depicts a schematic of biological pretreatment. Lignin is a heterogeneous, alkyl aromatic polymer found in plant cell walls that is made up of three aromatic alcohols with varying degrees of methoxylation. It is degraded by a far smaller number of organisms than cellulose. Furthermore, most

lignolytic fungi not only dissolve/consume lignin, but also hemicellulose and cellulose [69,70]. Therefore, biological pretreatment having technological and monetary challenges and makes it economically less attractive.

3.4.1. Fungal pretreatment

Biological pretreatment is the process of changing the composition of lignocellulosic biomass (physical and chemical) using wood-degrading fungi like white-rot, brown-rot and soft-rot, which make it more acquiescent for the enzymatic digestion. Due to the higher resistance of cellulose to fungal assault than other components, fungi that preferentially decay lignin and hemicellulose while consuming less cellulose have been studied using fungal pretreatment. This kind of fungal pretreatment results in higher cellulose digestibility, which is advantageous for AD treatments. Pretreatment of fungal cultures must take place in a sterile atmosphere. Although brown-rot fungi predominantly target cellulose, white and soft-rot fungi attack both cellulose and lignin and with white rot fungi consider better in producing biogas. White-rot fungi degrade lignocellulosic materials most efficiently. By cultivating fungi on rice husks, Potumarthi et al. explored the immediate pretreatment and saccharification of rice husk by white-rot fungus (*Phanerochaete chrysosporium*), successfully delignifying the rice husk [71]. This suggests that fungal pretreatment using white-rot fungus could be a suitable way to reduce the operational costs of washing and removing inhibitors during traditional pretreatment procedures. When *C. subvermispora* was processed ATCC 96608 used to treat yard clippings for 30 days at a moisture level of 60% without forced aeration, the methane output increased by 154%.

Vasmara et al. also reported that *C. subvermispora* effectively delignified wheat straw. Biological pretreatment should consider the reduction of cellulose loss owing to fungal metabolism. After 10 weeks of pretreatment, *C. subvermispora* demonstrated the least cellulose loss and the maximum sugar output of up to 44% [72]. Various processing parameters impacting biological pretreatment, such as incubation time, incubation temperature, and inoculum concentration, were optimized. Delignification of lignocellulosic biomass via biological pretreatment could be an efficient way for increasing enzymatic hydrolysis and thus getting more methane gas. When compared to untreated samples, a pretreatment combination of leaves and hay in a specified ratio, such as 1:2, resulted in a 15% higher biogas manufacture.

3.4.2. Microbial pretreatment

Unlike fungal pretreatment, which is largely focused on lignin degradation, a microbial association often has a high capacity for cellulose and hemicellulose degradation. Microbes selected from natural habitats perform microbial consortia pretreatment on decaying lignocellulosic biomass as the substrate. Chen et al. established MEG microbial system for lignocellulosic biomass pretreatment via multigeneration selection, which increased cotton stalks biogas output by 25% during a seven-day period at 35.2 °C [73]. Combination of garden waste manure, maize fodder fungi and biofibers does not increase the biogas production. Amin et al. created a thermophilic microbial community using materials from various sources [66,74]. The partnership blended distillery effluent with cassava leftovers and processed them for 12 h at a temperature of 55 °C, releasing 96% more methane than untreated wastes. For the biological pretreatment screened groups from natural environments, pure yeast and cellulolytic bacteria (microbial powder) were used. The microbial powder was applied at room temperature for 15 days to autoclaved maize straw, resulting in a 75% increase in methane output and a 34.6% reduction in digestion time. During microbial group for pretreatment, lignocellulosic sterilization is not required which makes it beneficial.

3.4.3. Enzymatic pretreatment

Hydrolytic enzymes were utilized to improve biogas generation before to or during anaerobic digestion of lignocellulosic material.

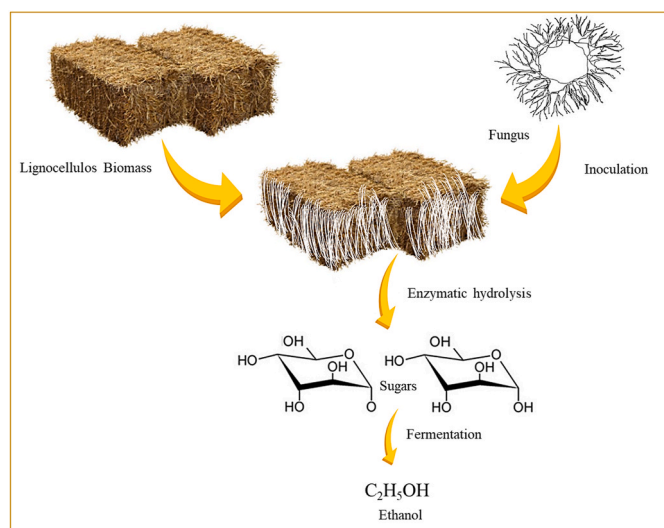


Fig. 4. The biological pretreatment of lignocellulose biomass.

Cellulase and hemicellulose enzymes are commonly used for hydrolysis of lignocellulosic biomass. Because of its high cost and minor increase in biogas output, enzymatic pretreatment is rarely used. However, a research study discovered that pretreatment of pulp and paper sludge with mushroom compost extract containing laccase and carboxymethylcellulose activity increased methane generation by 34.2%, and this technique looks promising given the 4-h pretreatment time and cheap cost of enzyme use. Ensiling for biogas production was researched by Vervaeren et al. but it was found that ensiling had no meaningful effect on biogas yield [75]. Biological pretreatments are, on average, less effective than chemical pretreatments and have a longer retention duration. As a result, more research is needed to solve certain major issues like cost, selectivity, and efficiency in order to make biological pretreatments more commercially viable. When compared to raw biomass, enzyme-assisted hydrolysis promotes the solubilization of cell wall elements, allowing for an increase in biogas production. Cellulase, endogalacturonase, protease, and esterase, as well as a combination of them, were applied to three microalgae and incubated for 24 h at 50 °C. The *Rhizoclonium* algae were treated with five different enzymes (amylase, protease, lipase, xylanase, and cellulase), and the largest methane synthesis (145 ml CH₄/g TS) occurred when a combination of the enzymes was used (20% of each enzyme). As the enzyme mixture was applied to *Rhizoclonium* pretreatment, however, methane production increased by 31% and 21%, respectively, as compared to the volume of methane produced by samples treated with sonicated

Table 2

Summary of advantages and disadvantages of pretreatments used for lignocellulosic biomass [127].

Sl. No.	Type of Pretreatments	Advantages	Disadvantages
1	Mechanical Comminution	Reduces cellulose crystallinity	Power consumption usually higher
2	Steam Explosion	Causes hemicellulose degradation and lignin transformation, Cost-effective	Less disruption of the lignin-carbohydrate matrix and generates microorganisms' inhibitory compounds
3	Ammonia Fibre/freeze Explosion (AFEX)	Increase accessible surface area, removes lignin and hemicellulose to an extent, does not produce inhibitors for downstream processes	Inefficient for high lignin biomass
4	CO ₂ Explosion	Increase accessible surface area; cost-effective, does not cause formation of inhibitory compounds	Does not modify lignin or hemicellulose
5	Ozonolysis	Reduces lignin content, does not produce toxic residues	A large amount of ozone required Expensive
6	Acid Hydrolysis	Hydrolyzes hemicellulose to xylose and other sugars, Alter lignin structure	High-cost, Equipment corrosion Toxic substances
7	Alkaline Hydrolysis	Removes hemicellulose and lignin Increase accessible surface area	Long residence times, Salt formation and incorporation
8	Organosolv	Hydrolyzes lignin and hemicellulose	Solvents drainage required, evaporated, condensed and recycled, high cost
9	Pyrolysis	Produces gas and liquid products	High-temperature, Ash production
10	Pulsed Electrical Field	Ambient conditions, Disrupts plant cells Simple equipment	Process needs more research
11	Biological	Degrades lignin and hemicellulose low energy requirements	Rate of hydrolysis is very low

Rhizoclonium [76]. Table 2 defines the advances in pretreatment of lignocellulosic biomass for bioenergy production. Important challenges and perspectives are summarized for better understanding of pretreatments type and their advantages [127].

4. Roadmap to conquer the pretreatments

4.1. Minimizing the inhibitors spawning during pretreatment process

Generation of inhibitors in the lignocellulose bioenergy process is one the major challenge. Studies show that inhibitors occurred during pretreatment process decreases the lower lignin content and can be overcome by implementing strategies, like detoxification, optimizing culture procedures, selection of anti-toxic microbes, and utilization of genetically engineered microbe's having resistant characteristics against inhibitors [128]. Low-lignin contain feedstock, bean-straws and banana-stems contribute a high influence on the renewable bioenergy production. Furthermore, introducing better feedstocks which contain less lignin and hemicellulose can be another way of decreasing recalcitrance and preventing the release of inhibitors. Hydrothermal pretreatment reduces the recalcitrance of *Miscanthus* grass and wheat straws [129]. As in solution, relatively low amounts of furan-aldehydes and phenols were observed. Physico-chemical pretreatments such as extrusion, liquid hot water, ammonia fiber explosion, CO₂ explosion etc. found to be efficient in reducing inhibitor release [130].

4.2. Bioconversion proficiency

To address the constraint of lignin bioconversion, a number of novel methods have been established, like lignin re-utilization and the manufacture of lignin-derived additives. Valorization and reductive catalytic fractionation (RCF) are effective ways to alter lignin to a limited range of products. A number of studies has recently been demonstrated which aim to develop genetically modified bacteria that promote the conversion of lignin into useful compounds (polyhydroxyalkanoate and lipid) [131,132]. Altogether, these proposed methods could be used to maximize the yield product of lignocellulosic biomass while reducing the capital investment in lignin pretreatment. Many other potential strategies for enhancing production and value of biofuel through biomass conversion explored, like lignin valorization microbes engineering, RCF formulations etc. It was revealed that reducing the inhibitory action of accumulated volatile fatty acids increased biohydrogen generation. Furthermore, it has been reported that adding biochar to the mix can help with lignocellulose bioconversion by increasing cellulolytic enzyme activity. Since the use of lignin-derived additions boosted bio-hydrogen production yield, reduced treatment costs, and had detrimental effects on the environment, extensive research is required to make low-cost, ecologically sustainable lignin-derived biochar replacements.

5. Production of biofuel from lignocellulosic biomass

Lignocellulosic biomass such as rice husk, wheat straw, sugar bagasse, corn stalk, etc. are the agricultural wastes that are generated in millions of tons per year as a result of the production and processing of the agricultural crops. The unutilized biomass is either dumped into landfills or water bodies resulting in environmental pollution. The uncontrolled burning of lignocellulosic biomass also leads to greenhouse gas emission. With increasing energy demands besides, increasing population and environmental concern have encouraged the as a sustainable energy.

Biofuel eliminates the generation of greenhouse gas emission and serves as an efficient alternative to fossil fuels. Fossil fuels are a non-renewable source of energy and require a longer possesses for their formation. Many researchers have studied and reported the use of lignocellulosic biomass for the production of biofuels. The fermentation

of lignocellulosic feedstocks leads to the generation of bio-ethanol which is mixed with the normal fuel in order to decrease the air pollution while the anaerobic digestion of lignocellulosic biomass, which serves as the vehicle fuel or kitchen fuel for cooking food thereby decreasing the total carbon and greenhouse gas emission into the environment [101]. On the basis of nature of the state of the biofuel, it can be categorized as liquid fuel (bio-ethanol), gaseous fuel (biogas) and solid fuel (palletization of lignocellulosic biomass as a crude source of energy).

5.1. Liquid fuel

Pretreatment, hydrolysis, and fermentation are the three major procedures in the synthesis of bioethanol from LBs. The first step is pretreatment of lignocellulosic waste carried out to breakdown the complex molecular structures of biomass into simple sugars and alter its microscopic and macroscopic size, shape, and chemical composition all contribute to the efficiency with which carbohydrates may be hydrolyzed into fermentable sugars [65]. Fermentation by biomass hydrolysis is carried out either by naturally or genetically modified microorganisms and polysaccharides are converted into monomeric sugars. On a fundamental level, in lignocellulosic biomass, the cellulose present is structured into microfibrils, each of which would include up to 36 glucan chains as well as thousands of glucan residues, and with approximately 3–6 nm in diameter. Cellulose is the β-linked glucose polymer that can be hydrolyzed into glucose either chemically or by cellulolytic enzymes while hemicellulose is a branching sequence of xylose and arabinose which contains glucose, galactose, and mannose and is readily digested by bacteria to produce ethanol [77].

The significant fraction of lignocellulosic biomass is to be developed for example zero-waste added value in the woods and agricultural wastes, consist of arabinose and xylose, recombinant ethanologenic bacteria for biomass fermentation. The bacteria and yeasts produced by the recombinant ethanologenic strains are effective to co-fermenting pentoses and hexoses into the ethanol and other significance compounds at excellent yield, enhancing the economic viability for bio-ethanol production [78,79]. Distillation combined with adsorption and filtering, along with drying using lime/salt, are being used to extract ethanol from fermentation broth. The lignin, enzyme, organism debris, leftover cellulose and hemicellulose, and the distillation process used to purify ethanol can be recovered as solid fuel or converted into value-added coproducts [80].

Transportation-storage and the blend wall, which is the maximum amount of ethanol that can be blended into fuel without reducing fuel efficiency, are two important hurdles in achieving biofuel ambitions (Table 3). Another significant disadvantage is that the majority of motor vehicles in use in the country like India are not flexible enough to accommodate flex fuel. Even though the concept for engine modification isn't really new, key crucial point is making the engines, as well as the supply chain, available in India and tuning the engine for Indian conditions. As a result, there has been a significant rise in investor interest in this sector, implying rapid growth in annual ethanol production capacity from 3550 million liters to 6000–7000 million liters in the next three years. Thus, sophisticated technology for domestic ethanol production in blending sectors, as well as diversifying lignocellulosic biomass,

Table 3
Showing comparative representation of methane and ethanol production based on biomass type.

Sl. No.	Biomass	Methane Production ⁶⁵		Ethanol Production ⁷⁷⁻⁸⁰	
		Yield (Kg/Tonne)	Energy (MJ)	Yield (Kg/Tonne)	Energy (MJ)
1	Maize crop residue	208.80	10440.00	338.12	9061.616
2	Wheat straw	174.96	8748.00	304.94	8172.392
3	Rice straw	167.04	8352.00	328.64	8807.552
4	Sugarcane crop waste	148.32	7416.00	334.96	8976.928

environmental benefits of biofuel, import bills, and more R&D into drop-in biofuels, as well as economic understanding, must be increased for the public.

5.2. Gaseous fuel

To achieve the energy requirements of an expanding population, fossil fuels like crude oil, natural gas, and coal have been over-exploited for transportation and home use, resulting in fast resource depletion. Fossil fuels are non-renewable energy sources that need a longer time to produce and contribute to greenhouse gas emissions thereby, polluting the environment. Biofuel has evolved as a renewable, sustainable, and ecologically acceptable source of energy. Production of biogas by the biological decay of agricultural, industrial, animal and municipal solid waste is carried out by the heterogeneous microorganism's, which leads to the decomposition of complex organic matter into simple sugars in an oxygen-free environment known as anaerobic digestion. Deublein et al. stated that biological decomposition of lignocellulosic biomass takes place via synergistic action of multiple carbohydrate-active enzymes, this results in the creation of complex organic components like as carbohydrates, lipids, and proteins, which are then broken down to generate methane and carbon dioxide as shown in Fig. 5 [81]. Cellulose and hemicellulose are linked via glycosidic bonds that are broken down by the action of glycosidic hydrolases. Additionally, polysaccharide esterases aid in their operation by removing methyl, acetyl, and esters, allowing glycosidic hydrolases to act on hemicellulose.

Guillen et al. phenolic revealed that in addition to ligninolytic enzymes, lignin breakdown can be accelerated further by the activity of alcohol oxidase and other enzymes found in *Pleurotus eryngii* that oxidize a variety of primary alcohols containing the aromatic ring [82]. Lignocellulosic biomass is the largely generated agricultural waste can be utilized for methane gas production through anaerobic digestion which otherwise causes environmental pollution if remain untreated. Biogas composition and amount of generation depend largely on the source of feedstock, the chemical composition of the substrate, operational parameters and the technology used. The gas is said to become combustible when the methane percentage reaches at least 45% [83]. Edlmann et al. found that the colorless biogas consists of a mixture of methane (50–70%), carbon dioxide (20–40%) and traces of other gases such as hydrogen sulfide, ammonia, hydrogen, nitrogen, carbon monoxide, oxygen, siloxanes, and water vapors, etc [84,85].

5.3. Solid fuel

Biochar is a low-cost carbonaceous compound produced via pyrolysis in a low-oxygen atmosphere or hydrothermal carbonization at high pressure from a range of waste biomass, for example, sewage sludge/manure, agricultural waste, and food waste. Biochar does offer a number



Fig. 5. Diagrammatic representation of anaerobic digestion from lignocellulosic waste.

of benefits, including a large surface area, a large pore volume, long-term stability, and surface enriched functional groups, which means it can be used in a lot of different ways. Biochar is useful for: a) soil remediation by immobilizing various inorganic compounds from gaseous, aqueous, or solid phases [86,87] b) increased soil-nutrient interactions, soil fertility, and agricultural production and c) carbon sequestration through greenhouse gas emission reductions [88] d) waste water treatment due to its effective elimination of heavy metals and organic compounds, as well as fostering the growth of soil microbes important for nutrient absorption [89–91]. Several researchers have discovered that biochar may be used to remove antibiotics, agrochemicals, polycyclic aromatic hydrocarbons (PAHs), volatile organic compounds (VOCs), polychlorinated biphenyls, and aromatic dyes [92]. Engineering adjustments like as carboxylation, magnetization, and amination, according to Rajapaksha et al. can improve the pollutant removal effectiveness of biochar [93].

Biochar is produced via pyrolysis of biomass at temperatures ranging from 300 to 800 °C with a restricted oxygen supply. Pyrolysis is divided as rapid and slow pyrolysis based on the retention time. Carbonization using conventional methods, i.e., slow pyrolysis, needs a prolonged residence time (>1 h) and a low heating rate (5–7 °C/min), yielding mostly biochar and a trace quantity of syngas containing CO, CH₄, H₂, and condensed bio-oil. The rapid pyrolysis of biomass for the creation of biochar is carried out at a rate of 200 °C/min with a residence period of less than 10s [94]. The inadequate pyrolysis of biomass and the entrapment of tar-like particles within the pores results in the biochar's tiny surface area [95]. Hydrothermal carbonization of biomass occurs at low temperature 180–250 °C produces hydro-biochar under pressure in water thus, does not require energy-intensive drying of feedstocks [96, 97], consequently, it is a cost-effective method of generating biochar for catalytic applications.

Biochar catalytic efficacy can be tailored using suitable techniques before or after the synthesis process such as i) metal impregnation to immobilize metal on biochar as an active site; ii) phosphoric acid treatment to alter the physical characteristics of biochar, such as surface area or pore volume, is one of the pre-synthesis treatments used to prepare biomass for biochar production [95,98]. Biochar can be used as an alternative to commercial activated carbon for pollutants removal from the soil, water, and air. Studies have indicated that carbon in biochar remains stable, therefore, making it sustainable for removing contaminants such as organic pollutants, heavy metals, and their immobilization, etc. as shown in Fig. 6. Biochar efficacy as catalyst can be altered by tailoring its catalytic properties using appropriate techniques before or after the synthesis process such as i) metal impregnation to attach metal as active site on biochar; ii) phosphoric acid treatment to modify physical properties of biochar like increase surface area or pore are some of the pre-synthesis treatments of biomass for producing biochar.

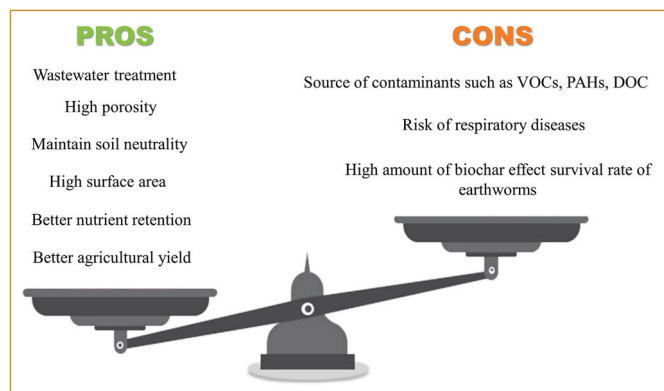


Fig. 6. Flowchart shows physical properties, chemical properties, and application of biochar.

Biochar used in livestock feed acts as a binding agent and possess multiple benefits to animal health and in improving weight gain. Additionally, biochar reduces the odors related to manure as well as help in reducing methane emission related to cattle, but it still requires more research to make it fully functional [135]. However, apart from these potential advantages Biochar has several disadvantages such as:

- The process causes damage of biodiversity.
- It has high contents of moisture, water-soluble fraction, Cl, K, Na, O and some trace elements (Ag, Br, Cd, Co, Cr, Cu, Hg, Mn, Ni, Pb, Se, Tl, Zn, others).
- It produces shoot which causes inhalation risk.
- Technological problems during processing include agglomeration, deposit formation, slagging, fouling, corrosion, erosion, etc.
- It needs excess water, fertilizers, and pesticides.
- The practical implementation of the biofuel has not yet fully clear.
- It requires heavy investment.

6. Policies and reforms implemented in India

Lignocellulose aims towards sustainable bioenergy feedstock with enormous amount of reserves, in contrast to fossil fuels. The annual global lignocellulose yield is estimated to be around 200 billion metric tons, with agricultural crop wastes and land residues accounting for the majority of this. In accordance with new reforms discussed in, 9th meeting of China's Central Committee for Financial and Economic Affairs [112] and 16th International Conference on the European Energy Market [113], conversion of lignocellulosic waste into clean energy, like biohydrogen, bioethanol, biogas, and other biofuels [114], can potentially fulfil the energy demand of upcoming era.

India, like other countries, is particularly interested in developing biofuel technology since rising oil prices and GHG emissions which become a major threat to nations. There is urgent need of renewable feedstock of fuels to replace petrol-based fuels and secure energy demands of world second populated country like India. India is one of several countries that have a special ministry dedicated to the development of renewable energy resources. The Government of India's Ministry of Petroleum & Natural Gas (MoPNG) imposed a 5% ethanol blend in gasoline by oil marketing corporations (OMCs). After engaging with key stakeholders at the state and federal levels, including the Society for Indian Automobiles and major sugar manufacturers [120] the 5% blending was implemented.

The 'Ethanol Blending Program' was implemented in several Indian pockets since January 2003. The planning commission committee fixed for India to develop and progressively transition of biofuels utilization [121]. The sufficient biomass accessibility (approximately 80% of all biomass residues created, mainly through crops) is reported by authenticate Indian agencies [122]. Several organizations such as Biochemical Engineering Research Centre, IIT, Delhi, India etc. engaged in ethanol research, where Rice straw was employed as the feedstock for this process and yielding 230 L/ton of ethanol [123]. In April 2003, the Planning Commission issued a report on bio-fuels [124] such as production of biohydrogen [125] and bioethanol [126], in which India strengthened its bioethanol Programme [115,116]. The description examined various blending targets, price and feedstock availability and issued recommendations to enlarge the industry to meet 5–10% bio-ethanol blends. After E5 blends were installed across the country, the 11th five-year plan (2007–2012) recommended increasing the obligatory bioethanol blending to 10% [117]. The National Policy on Biofuels proposes E20 blending target by 2017 [118,119].

7. Status of lignocellulose biomass industries

Whenever the interaction stages are incorporated effectively, a cycle can be streamlined furthest degree conceivable. Forward-in reverse mix has been demonstrated to be very powerful in bringing down costs. The

lignocellulose ethanol plant and sugarcane bagasse bioconversion workplace can be shut down for better efficiency, fundamentally diminishes conveyance budgets. The CO₂ delivered during the aging system has business esteem and can be utilized. The CO₂ created during ethanolic aging can likewise be chemically hydrogenated to yield methanol [113]. The cellulose piece of hydro-thermally pre-treated wheat straw was changed over to ethanol (0.41 g ethanol/g sugar), the hemicellulose-rich hydrolysate was changed over to biohydrogen (78 ml-H₂/g sugar), and effluents from the two cycles were changed over to biomethane (0.324 and 0.381 m³ methane/kg unpredictable solids, separately) utilizing this idea [114]. The xylose arrangement acquired after pre-treatment of lignocellulosic biomass can be used in an assortment of coproduct creation techniques. Xylitol, 2,3-butanediol, acidic corrosive, furfural, and animal feed are instances of these [11].

The present scenario of the lignocellulosic ethanol industry precludes business fabricating. Making cellulosic ethanol innovation from the lab to a business biorefinery costs a large chunk of change. Feedstock crushing, pretreatment, SSF, and ethanol refining are immeasurably powerful handling frameworks (www.ott.doe.gov/biofuels). A few cellulosic ethanol creation innovations tried in limited scope offices are drawing nearer to business creation. Be that as it may, increasing the innovation, bringing down creation expenses, and financing huge scope plants remain obstacles. Iogen Corporation in Canada has developed an exhibit unit that can cycle 20–30 tons of feedstock each day and produce 5000–6000 L of cellulosic ethanol each day. Wheat, oat, and grain straw are utilized as unrefined substances in the processing plant. Denmark's Inbicon has constructed a biomass processing plant showing office for biomass-to-ethanol transformation and energy combination that can create 1.4 million gallons of ethanol. Praj Industries in India has as of late started an exhibition plant equipped for handling 2 tons each day of lignocellulosic feedstock, here methodology depends on restrictive energy and water-saving innovation and a creative reactant pretreatment process that productively isolates lignin from sugars (www.praj.net/).

Lignocellulosic biomass-based compounds and their related applications in today's energy field reveal the scope of commercial. Recent development of advanced materials field and energy related research frame the importance of these compounds extensively. Understanding of energy-saving technologies, energy storage technologies, innovating materials, polymer science and their pathways to future development of state-of-the-art non-conventional energy system [135]. Further, management of the lignocellulosic biomass derived chemicals and polymers for sustainability frame is one of another aspects which should be included for climate neutral and Sustainable Development Goals [136, 137].

Techno-economic research on lignocellulosic biorefineries suggest important aspects for the commercial development such as process complexity, biomass valorization and other global drivers playing role in the scale-up [138]. Another study examines the operating expenditures, irregularities in biomass supply chain, technical process immaturity for the scale up challenges and discuss the bottlenecks solutions and perspective on commercialization [139]. Intelligent nanomaterials and polymeric interface research upgraded the biosensor and bioelectronics field to new heights where, understanding the constituents, production and quality control might be easy in biomass conversion monitoring [140–142]. Currently, management and logistics in industrial energy sector refer to climate neutral and net zero technologies [136,137,143].

8. Challenges and perspective

Bioenergy creation from LB through anaerobic bioprocesses is essential for society's drawn-out improvement. In any case, pretreatment of the headstrong design of LCB is a critical bottleneck in its bioprocessing. A few examinations have evaluated a few organic and non-natural ways for fruitful LCB pretreatment; yet, regular cycles have a few disadvantages.

- The various components of lignocellulose pretreatment, like lignin expulsion, natural impact, and reagent recuperation, and the significant expense of pretreatment remains unsettled.
- Due to its low lignin content, lignocellulosic feedstock might be a metabolically adaptable objective.
- Integrated biorefinery is a fundamental lignocellulose use innovation that essentially lessens inhibitor and feedstock squander.
- Utilization of lignocellulosic waste to generate renewable energy entails a vast economy, but research lacks the overall logistics for a full-scale system.

Even though lignocellulosic substrates have a high potential for biomethane blend, their inborn stubbornness keeps them from being utilized in anaerobic assimilation processes. Subsequently, pretreatment is a crucial stage in the effective use of biomass, and different medicines can change the design of the biomass by killing lignin, expanding surface region, diminishing translucent nature, and length of the polymer chain. While inspecting the general financial matters of interaction combination, every procedure offers benefits and detriments. More review is required in the future to foster financially savvy and economic pretreatment methodologies for effective biogas creation from different lignocellulose substrates.

9. Conclusions

This article provides an intangible information and systematic review that enable a sustainable ecosphere for renewable energy. Lignocellulosic biomass processing and conversion were summarized at single contest to understand bio-handling and roadmap of sustainable energy production. Finally, economic, and climate neutral energy system require the orientation in terms of large-scale production. The utility of lignin-based biomass in terms of physio-chemical understanding, processing, and utilization. With sustained research, we expect that bio-resource techniques will provides important lead in net-zero energy generation.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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November 01, 2023

TO WHOM IT MAY CONCERN

Certified that Dr. Deepa Sharma, Assistant Professor of Physics, Department of Higher Education, Government of Haryana currently posted at SUS Government College, Matak-Majri has been collaborating with me in our joint research work on Thermoelectric properties of Single-walled Carbon Nanotubes and Graphene since Aug 2017. Her contribution as a computational expert has always been quite significant and fruitful to our research.

I think very highly of the continued collaboration and look forward to undertaking many concurrent research projects with her in the future as well.

Sincerely,

Santanu K. Maiti

Santanu K. Maiti
Associate Professor of Physics
Indian Statistical Institute
Kolkata, India



VCU College of Engineering

May 3, 2019

Indo-U.S. Fellowship for Women in STEMM
(Science, Technology, Engineering, Mathematics and Medicine)
(WISTEMM)
Indo-U.S. Science & Technology Forum
Fulbright House, 12 Hailey Road
New Delhi-110001, India

Reference: Host letter for WISTEMM application of Dr. Deepa Sharma

Dear Dr. Chaitali Bhattacharya,

I certify that I am collaborating with Dr. Deepa Sharma in research on the use of Carbon nanostructures as electrodes in batteries. I see immense potential in her and have already provided her remote access to my lab facilities that she may utilize for as long as she desires. If given Women Overseas Fellowship Award under the Indo-U.S. Fellowship for Women in STEMM, she will be provided office and laboratory space, access to equipment and library facilities etc. alongwith guest accommodation at the Virginia Commonwealth University for implementing the research project proposal submitted by her under this fellowship.

Sincerely,

Ram B. Gupta, Ph.D.

Professor, Associate Dean for Faculty Research Development
College of Engineering, Virginia Commonwealth University
601 West Main Street, Suite 331, Richmond, VA 23284-3068, USA
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URL: <https://sites.google.com/view/swastikabanerjee-iitroorkee>

November 8, 2023

Subject: Certificate of participation in a research project

To whomever it may concern,

I am writing to confirm that Dr. Deepa Sharma, Assistant Professor of Physics, Department of Higher Education Government of Haryana (India), has made commendable contributions to our collaborative research project titled "Effect of conjugation on the vibrational modes of a carbon nanotube dimer". Dr. Sharma has been an integral part of the project team from January 1st, 2020, and her involvement is ongoing.

Please feel free to contact me through email (sbanerjee@cy.iitr.ac.in) or phone (+91-1332-284993) for any further information regarding Dr. Sharma's credibility.

Sincerely,

Swastika Banerjee, Ph.D.
Assistant Professor
Department of Chemistry
Indian Institute of Technology
Roorkee
India



INF Secretariat
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19 Albion Street
Manchester
M1 5LN
England

E-mail: inf@netball.org
Tel: 44 (0) 161 234 6515

30th July 2022

CERTIFICATE OF APPRECIATION

Certified that Dr. Deepa Sharma, Chairperson, International Executive Committee, Netball Federation of India was inducted in the Draft Committee of Junior Netball Policy of New Zealand as INF nominee. The draft was submitted to International Netball Federation on 23rd May, 2022 and approved and accepted in the special meeting of World Netball Congress held on 29th July, 2022 online through Microsoft Teams. Her contribution to the policy draft is highly commendable. INF expresses deepest appreciation and thanks to her for sharing her valuable time and expertise.

A handwritten signature in black ink, appearing to read 'Liz Nicholl', is written in a cursive style.

Liz Nicholl CBE
President INF

www.netball.sport

INF is the trading name of International Netball Federation Limited.
Incorporated in The Isle of Man. Registered Number 008607V
Registered Office: 1st Floor, Millennium House, Victoria Road, Douglas, Isle of Man, IM2 4RW
Directors: Liz Nicholl CBE, Sue Taylor AM, Ann Tod, Shirley Hooper, Cecilia Molokwane, Gaby Hochbaum, Marva Bernard OD, Lyn Carpenter, Wainikiti Bogidrau

From: **Prof., Dr. Sergey Y. Yurish, IFSA President** <syurish@sensorsportal.com>

Date: Thu, Apr 20, 2017 at 5:34 PM

Subject: Invitation to join the Conference Program Committee

To: <bhargava.dp@gmail.com>

20.04.2017, 14:04:44

Delivered to: bhargava.dp@gmail.com

Dear Dr. Deepa Sharma,

We are in the process of inviting the program committee members for the annual OPAL series of conferences sponsored by the United Nations. The First International Conference on Optics, Photonics, and Lasers is scheduled to be 10-12 May 2018 – in Barcelona, Spain. I would greatly appreciate you to accept our invitation to join the conference committee.

We count on program committee members to submit papers (hopefully to attend), help review 2-3 papers, recommend new program committee members, suggest topic improvements, special sessions, keynote speakers, and tutorials, and disseminate the Call for Papers.

Please reply to the invitation as soon as possible with your CV attached. We would like to post committees as soon as possible and start distributing the Call for Papers. Make sure to include 7 keywords from your topics of interest so as to facilitate the reviewing assignments.

Thank you beforehand.

Waiting for your reply.

Prof., Dr. Sergey Y. Yurish,
IFSA President

Parc UPC-PMT, Edifici RDIT-K2M
c/ Esteve Terradas, 1
08860 Castelldefels, Barcelona, Spain

Tight binding simulation study on zigzag single-walled carbon nanotubes

Deepa Sharma ✉, Neena Jaggi, and Vishu Gupta

<https://doi.org/10.1142/S021797921850020>

Shizuoka University, Shizuoka, Japan

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Abstract

Tight binding simulation studies using the density functional tight binding (DFTB) model have been performed on various zigzag single-walled carbon-nanotubes (SWCNTs) to investigate their electronic properties using DFTB module of the Material Studio Software version 7.0. Various combinations of different eigen-solvers and charge mixing schemes available in the DFTB Module have been tried to chalk out the electronic structure. The analytically deduced values of the bandgap of (9, 0) SWCNT were compared with the experimentally determined value reported in the literature. On comparison, it was found that the tight binding approximations tend to drastically underestimate the bandgap values. However, the combination of Anderson charge mixing method with standard eigensolver when implemented using the smart algorithm was found to produce fairly close results. These optimized model parameters were then used to determine the band structures of various zigzag SWCNTs. (9, 0) Single-walled Nanotube which is extensively being used for sensing NH_3 , CH_4 and NO_2 has been picked up as a reference material since its experimental bandgap value has been reported in the literature. It has been found to exhibit a finite energy bandgap in contrast to its expected metallic nature. The study is of utmost significance as it not only probes and validates the simulation route for predicting suitable properties of