

Renewable Energy Sources in India and its significance in Climate Mitigation: an Overview

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Abstract

This paper analyzes the major energy sources in India and significance of renewable energy sources in climate mitigation. The aim of this paper is to provide renewable energy sources with the future of the energy industry, and it is through supportive and extensive legislation covering all possible aspects of the energy sector that these revolutions should be regulated. In this paper, the existing renewable energy legislation and regulations mechanism in India is analyzed and the barriers and challenges to the renewable energy industry are examined. Policies were developed to support the growth of specific technologies in the field of renewable energy.

India is undergoing significant economic progress while the changing economy is thrusting on surplus electrical power. Every year, the grid could further slowdown population growth, economic growth and the demand for electricity. Consequently, it is vital to intensify the installed power. India currently faces enormous challenges to meet its energy requirements, and current energy arrangements are inherently unsustainable. Meeting the energy sector challenges is essential for the financial development of India and ensuring the country's energy security. The significant growth in the deployment of renewable energy has been apparent in the past decade and renewable power generation has been rapidly increasing, current figures are not sufficient to address energy security problems, energy reliance on fossil fuels, environmental protection issues and social equity. Measures shall be taken to enhance efficiency, transmission and distribution of electricity. A supportive policy and regulatory environment is necessary in order to encourage green growth, because a competent legislative framework has always been the main promoter of technological change in a country.

It is striking that India has not yet produced a Renewable Energy Law which has proven to be high in energy requirements with the goal of increasing renewable energy deployment. In the 20th century, Government initiatives in the form of mandatory laws and policies have always been the main catalyst for technological transitions. In order to expand the green energy sector in the country, certain countries like Austria and Portugal have already adopted renewable energy laws. China is a global leader in the deployment of clean energy and a maximum part of the world's installed total capacity. For overall growth of the nation, it is essential for a compulsory act, specifically regulating the renewable energy sector.

Keywords: Renewable Energy, Climate, Energy Sources.

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I. Introduction

Energy is the golden thread that links economic growth, greater social equity and a world-building environment. Compatible, cost-effective, and consistent power systems are vital to global prosperity, as power sector growth is linked to a nation's overall growth, economic stability, and environmental sustainability. The energies sector is one of the most fundamental components of economic advancement since the availability of adequate energy resources depends on the economic activities from production to transport goods. Non-renewable energies, such as oil, coal, petroleum and so on, have, although a significant contribution to the growth of economy and national development, also become the main cause of serious environmental and health concerns. Present energy generation and use are not sustainable and at both national and global level are intimidating the environment.

India ranks third in terms of global carbon contributors. Around 32.5 gigatons of carbon dioxide were released world-wide in 2017, of which China is responsible for 9 gigatons, 5 gigatons in the United States and India about 2 gigatons in carbon dioxide. There are limited additional conventional sources and insufficient to meet current global energy requirements. The International Energy Agency estimated that modern and efficient

energy services should be provided to an additional 700 million persons by 2015 if the MDG poverty reduction objective is to be achieved. An efficient energy arrangement is therefore needed, which can expand access and strengthen the conditions for the deprived billions in this field to modern energy services.

In order to sustain economic development, developing countries must in particular achieve energy security and expand access to clean and green energy agreements. It is the well-established theory that the nation that generates clean and renewable energy will guide the 21st century. Renewables are the key drivers of renewable energy distribution throughout the world in terms of potential for dealing with energy inefficiency, energy insecurity, dependence on fossil fuels and carbon emissions. It is also beneficial to the environment to maximize the utilization of renewable resources and increase its share in the total energy mix. Renewables are regarded as a clean energy source because their use does not produce greenhouse gas emissions and also promotes the retention of fossil resources for generations to come. This development in India is the result of the international platform initiatives in which India became part of and made international obligations such as domestic duties through local laws and policies.

Worldwide, the use of renewable energy is growing at a significant rate. Roughly 8% of growth and renewable capacity were reported in 2018. Around 61% of all new renewable energy facilities originated in Asia, compared to 8.4% in Africa. One-third of the world's power capacity now includes the renewable energy sector. The total capacity to generate renewable energy worldwide was more than 2300 Giga Watt in 2018, when more than 1100 Gigawatt in overall capacity came from Hydropower. The next major renewable resources with over 1000 Giga Watt RE power were Wind and Solar Power. In 2018, approximately 170 Giga watts were added to renewable capacity.

The renewable energy capacity that has been newly installed set new records in 2016 and a further 160 Giga Watt, including large hydropower plants, was worldwide added. The added capacity has grown to almost 9 percent worldwide, thus bringing the total RE installed capacity to almost 2.017 GW by 2016, including large hydro mass. The increase in capacity is considered to be the highest growth in a year to date. The Solar PV held its major stake of 47% in newly installed renewable energy, while the wind stood at 34% and the hydropower stood at 15.5%. It is therefore obvious that in 2016, renewables represented approximately 62 per cent of net energy supplies worldwide.

Objectives

The main objectives of the study are as follows:

1. To critically analyze the major energy sources in India and significance of renewable energy sources, its potential and role in climate mitigation.

II. Review Of Literature

Karl Mallon (2006): The book discourses the legislations of renewable energy and explains the inter relation between government, business and civilization. The book also highlights the international case laws supplemented with essentials required to complete the legislations on renewables. In nut shell, the above-mentioned book is relevant in shaping the Renewable Energy Act for India. Eric Martinot and Kilian Reiche, Working Paper, World Bank, June (2000): The book explores different governing methods to motivate the aspects of power services in rural areas in developing nations. It also describes the discounts are provided to rural off-grid electricity using both conservative and non-conventional resources. Fred Beck and Eric Martinot, In Cutler J. Cleveland (ed.), *Encyclopedia of Energy*, Elsevier, (2004): This publication commences with explosion of changes in power policies which happened during 1990 worldwide. Such changes are result of commercial, environment, security and societal factors and in turn impact the renewables. Janet Sawin, International Conference for Renewable Energies, January (2004): This paper describes the National Energy regulations with an aim to discover as to which policies were effective in promoting renewables. The main stress was mainly upon "grid connected electricity and vehicle fuels, but also looks briefly at the remote uses of photovoltaic (PVs) and heat systems." Miguel Mendonca Earthscan, (2007): The book provides a summary of the application of methods and policies around the globe and explains as to the reason behind their success in promotion of renewable energy. It provides an introduction to the obstacles and supporting system to renewable energy and describes as how in Germany, the institution of feed-in tariff regulations were called as gentle and benevolent, actually considered as essential after their primary achievement as civil assurance against the stress of some of the well-known actors of the non- renewable energy sources. Fonte et al. (2005) developed a wind speed prediction method using back propagation network in order to predict the average hourly wind speed. The correlation coefficient between previous wind speed observations is utilized for the input selection. The result shows a mean square error of 1.012. Limitation include accuracy is very poor. Torres et al. (2005) suggested ARMA based hourly average wind speed forecasting model.

III. Research Methodology

Research methodology is a way to systematically solve the research problem. A research design is the set of strategies used to accumulate and study all methods of the variables detailed in the research problem. It includes information about the attitude of research art, the evaluation tool, access to different data, perceptions, testing, testing, etc. The procedure for deciding the sample of the analysis is research work Policies have been issued as and when necessary to assist the growth of specific Renewable Energy technologies.

Data is collected from both primary and secondary levels. Data collection is the systematic way to collect and measure data from sources to get complete and precise data for research activities. Primary statistics are obtained from the first-hand point of view by means of surveys, remarks, interviews, questionnaires and tests, special findings, collected through direct study. Secondary data are the data collected from Government department's journals, Organizational records, Magazines, journals, books, Newspapers etc. The statistical tools are used in study are Percentage analysis, T-test, Chi-square

IV. Result & Discussion

The use of renewable resources for the development of eco-friendly, resource-friendly, polymeric products as an alternative to petrochemical feedstock during production of polymer. Vegetable oils are a good viable option for polymer production as a renewable feeding stock. It offers numerous benefits for easy availability, economic viability, structural flexibility and property versatility, environmental safety and biodegradability most importantly. These ideal characteristics make them a precursor for polymers synthesis based on renewable resources. The careful customization of their building blocks' structure and composition offers ample scope for tuning PU's attributes. This includes HPU development with unique 3D architectural features that are less enclosed, globular, and highly-functional with desired qualities such as high solubility, low solution and sludge viscosity, good compatibility to others, etc. The conception of such a unique HPU complements their material aspects considerably. In this context it offers a good opportunity to develop eco-friendly polymeric materials by using vegetable oils as renewable resources in HPU's synthesis. It is further learned that further modifying or operating vegetable oil with appropriate monomeric units offset its moderate reactivity and creates an interesting tactic to obtain an HPU in addition to urethane with additional chemical functions. In many cases it often appears desirable to improve various material properties by incorporating additional bindings and chemical features. In terms of academic interest and applicability, aliphatic PUs are later less explored. With a luminous stability and excellent optical clarity, Aliphatic PU with its structure consisting of saturated long chain moieties.

In addition, the long aliphatic chains in the polymer can also enhance flexibility and hydrophobic character. An interesting strategy to develop aliphatic HPUs can be used under those circumstances by the vegetable oil modified or functionalized precursor with its inherent aliphatic nature. In this regard, a simple strategy for the synthesis of pure aliphatic HPU was reported to use a ricin oil-modified polyol as a multifunctional branching precursor along with other conventional reactants. During the characterization of the synthesized HPU several sophisticated spectroscopic and analytical techniques were employed. Various HPU characteristics were assessed, including mechanical and thermal. The study also examined and discussed the chemical resistance, biodegradability, UV aging and form-specific memory behavior of HPU to highlight its potential as environmentally-friendly multifaceted material.

1. Synthesis of COMP

CO, which primarily comprises of triricinolein, a triglyceride of ricinoleic acid was modified to a comparatively more reactive polyol by a single pot, one-step reaction with DEA, as illustrated in the figure. In this reaction, CO undergoes transamidation reaction with DEA at a high temperature of 120°C to yield diethanol fatty amide of CO (1) as the primary product with some residual amounts of glycerol (2) and unreacted diethanolamine (3), collectively regarded as COMP.

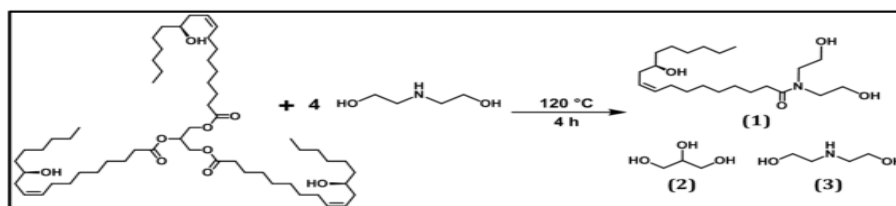


Figure 1. Synthesis of COMP

COMP was found to be soluble in most of the common polar organic solvents like methanol, ethanol, acetone, xylene, ethyl acetate, THF, DMF, DMac, DMSO, etc. due to the presence of diverse functional moieties like hydroxyl groups and amide carbonyl groups. Moreover, its solubility in hydrocarbon solvents like xylene and toluene validates the presence of long fatty acid chain in the structure.

2. Characterization of COMP

2.1. FT-IR analysis

A comparative study of COMP and CO FT-IR spectra showing prominent changes in vibrational frequencies, as shown in Figure 2, supports COMP formation. Especially in disappearing the ester C=O, which stretched to 1732 cm^{-1} of CO and the carbonyl amide, which developed at 1620 cm^{-1} , 1 was affirmed. An expansion of the O-H peak at 3408 cm^{-1} because O-H and N-H are overlapped with stretch frequencies 1 with 2 and 3. In addition, there is additional evidence of COMP collective structure with the C-N stretch frequency 1 and 3 appearance at 1053 cm^{-1} and N-H (out of plane) 3 bending frequency at 731 cm^{-1} .

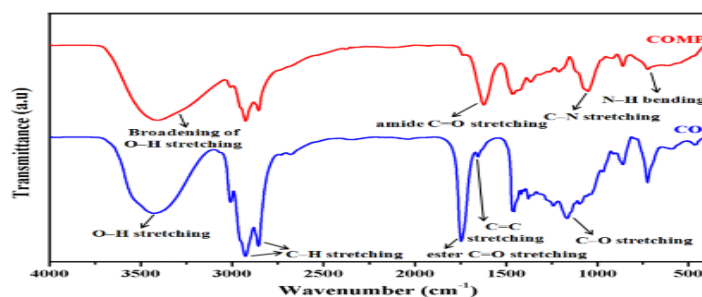


Figure 2. FT-IR spectra of CO and COMP

2.2. NMR analysis

NMR COMP study discloses additional details of COMP as a highly functional and complex compound structural composition featuring 1, 2 and 3 (Scheme 4.1). The ^1H NMR spectrum shown in Figure 3 shows the kinds of protons in the COMP structure. The 0.88 ppm singlet peak is the fatty amide chain of 1 terminal methyl (-CH₃) and, because of the inner methylene (-CH₂) [12, 32], the large singlet peak is about 1.30 ppm. The 1.60 ppm signal can be assigned to the C=O of the fatty amide chain by beta methylene (β -CH₂). The allylic methylene (-C=C-CH₂) protons of 1 [20] may be assigned to the peaks around 2.03 ppm and 2.20 ppm. The singlet at 3.60 ppm is connected to the methine proton (-CH) of the -OH group 1. 1 vinyl (=C-H) protons emerge on a 5.55-5.49 ppm multiple while 1, 2 and 3 free hydroxy (-OH) protons appear on 5.42-5.36 ppm multiples [12-23].

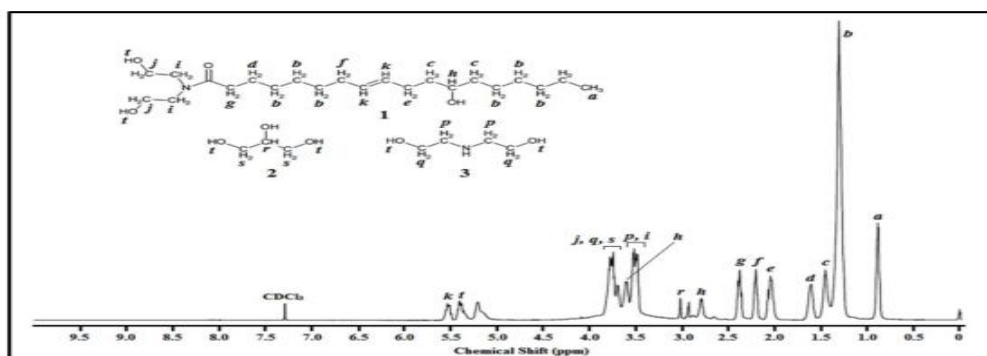


Figure 3. ^1H NMR spectrum of COMP

Figure shows the relevant chemical shifts in the structure of COMP for the type of carbon nuclei. The chemical shifts of the methyl (-CH₃) group (-CH₂) and the fatty acid chains of methyl (-CH₂) groups of 1, respectively, correspond to the chemical shifts (δC) of 14, 16 and 22, 69- 36, 83 ppm ([12, 20]). The N substituted methylene carbons 1 and 3 are composed of the signals 50, 49 ppm and 50, 97 ppm. Mono-substituted alcoholic coal of 3, 1 and 2 respectively are assigned the peaks of 52.28 ppm, 60.64 ppm, 61.12 ppm and 63.06 ppm [20-23]. The alcohol di-substitutes of 1 and 2 are attributed at about 71.61 ppm and 72.55 ppm. The 125, 38 and 133, 09 ppm signal is due to the unsaturated fatty acid chain carbons of 1. At 175.63 ppm the peak is accredited to 1 [20, 22, 23] carbon amide.

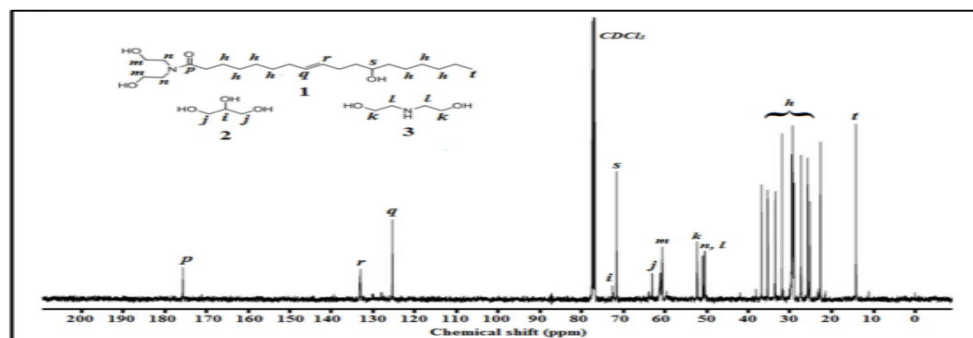


Figure 4. C NMR spectrum of COMP

3. Synthesis of HPU

HPU was synthesized using the COMP as multi-functional plugging movement by means of two-step, one-pot polymerization reaction using the "Ax+By" approach ($x, y \geq 2$). The synthesis for HPU is described in figure. Macro glycol PCL reacted in the first step to form a pre-polymer -NCO ended by maintaining the 1,5 NCO/OH ratio with diisocyanate IPDI. In these steps the macro glycol is added to the diisocyanate by the nucleophilic process to produce linear urethane connections. The first step in dilution of 15% (xylene as solvent) was only done because the reactors were di-functional. In the second step of delivery of HPU both the -NCO terminated prepolymer were simultaneously reacted to both COMP and MGE multi-branch units. In this step, urethane connections to MGE and highly branching chain extension to COMP undergo further linear chain enlargement. In order to avoid gel formation, the addition of the multi-branch unit was carefully processed. This was done with a 40 percent dilution reaction (xylene as solvent). Due to the presence of aliphatic moieties, the reaction was well preserved even at a high temperature, with no signs of gel formation. At 2270 cm^{-1} , lack of free NCO belt in the FT-IR mix spectrum took directly without purification indicated the completion of the reaction. The reaction was not completed. Similarly, the content of the multi-functional COMP Company was modified by different compositions of HPU. The reactions of polymerisation in PU mainly correspond to the polymerisation of stepped growths. Contrary to the addition of polymerisation, small molecules are not removed. It is also frequently called polymerization rearrangement [9].

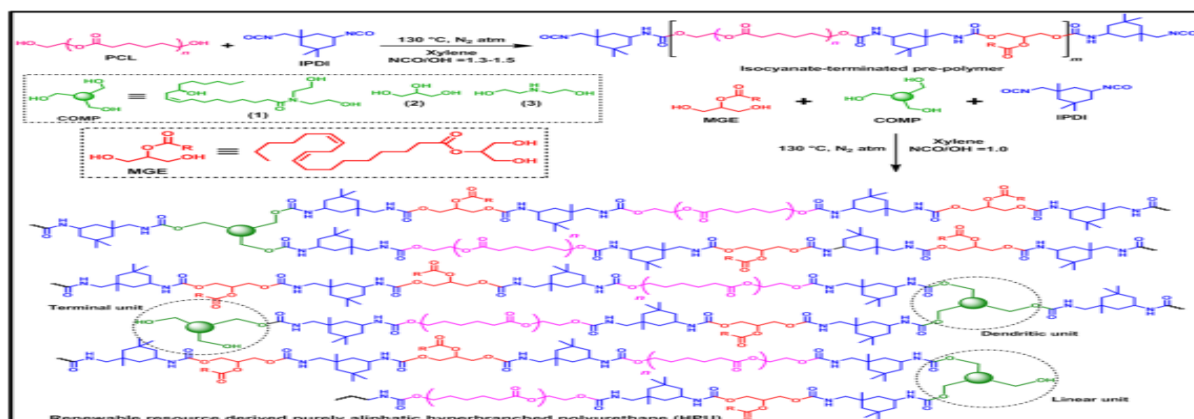


Figure 5. Synthesis of HPU.

4. Characterization of HPU

4.1. FT-IR study

The chemical linkages of structures of the synthesized PUs were detected by FT-IR spectroscopy. The initially synthesized spectrum of the pre-polymer FT-IR, in Figure 7.a, showed the presence of an isocyanate-finished prepolymer (PF) sharp free -NCO band at 2270 cm^{-1} . The lack of a free band -NCO at $2270\text{--}2250\text{ cm}^{-1}$ indicates that, as previously stated, the reaction is over. The band of $3441\text{--}3450\text{ cm}^{-1}$ is caused by the overlaps of vibration -NH and OH. For the ester -C=O stretching a small band appears at 1735 cm^{-1} , and the sharp band appears at 1637 cm^{-1} , which is because of the amide -C=O stretching vibrations. While the band is 1031 cm^{-1} with vibration of -O-C=O stretching. All these belts indicate that the urethane connection of the macromolecule is characteristic.

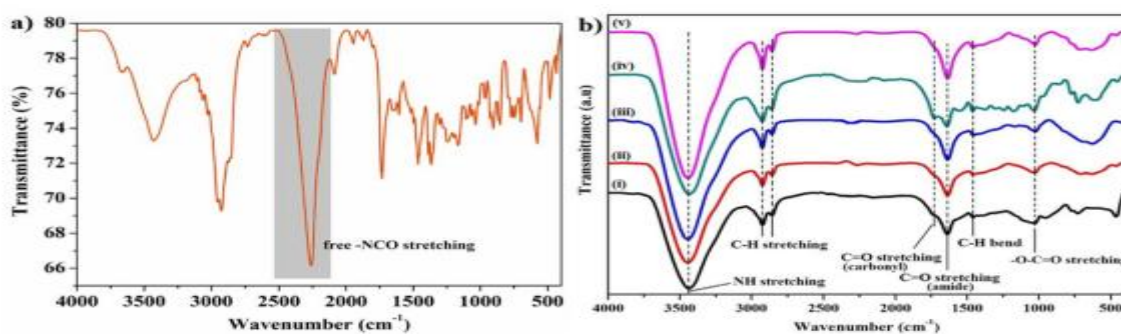


Figure 6. FT-IR spectrum of isocyanate-terminated pre-polymer, and b) FT-IR spectra of (i) HPU1, (ii) HPU2, (iii) HPU3, (iv) BLPU and (v) LPU

4.2. NMR study

Due to the existence of IPDI in 2 isomeric forms (E and Z), together with 2 types of isocyanates (primary -NCO and secondary -NCO), it is not easy to fully interpret the ^1H NMR spectrum of HPU. As a result, in different conditions, IPDI displays varying urethane selectivity. Nonetheless, data from ^1H NMR provide imperative evidence of urethane binding, MGE, COMP and PCL fatty acid chain. The proposed hyperbranched HPU structure was therefore proposed. Figure 4.5 shows the ^1H NMR HPU spectrum.

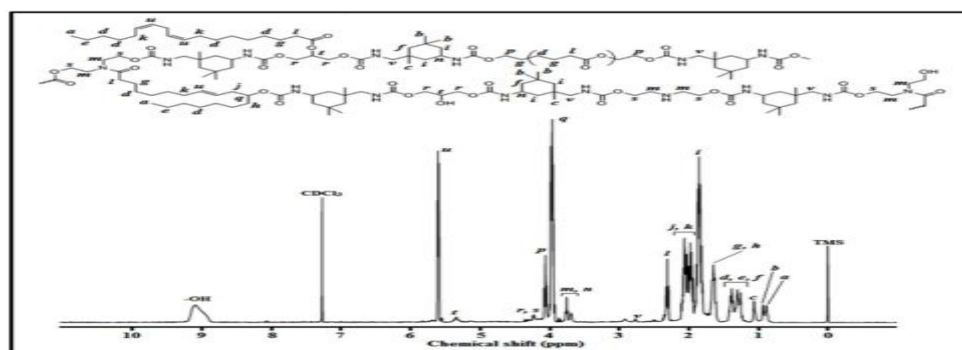


Figure 7. ^1H NMR spectrum of HPU

The fatty acid moieties in MGE and COMP and IPDI methyl groups are respectively [7, 20 and 25] due to the signals from 0,89 ppm, 0,93 ppm and 1,06 ppm. The peaks at 1,26 ppm and 1,30 ppm are in the internal fatty acid filets of MGE, COMP and PCL moieties of Methylene (-CH₂). At 1,40 ppm and 1,85 ppm, IPDI methylene protons appear [25]. The allylic (=C-CH) and alpha methylene (α -CH₂) protons are the C=O of the COMP and MGE fatty acid chains respectively [7, 20] at 1,98 ppm, 2,08 ppm, and 1,31 ppm. [7, 20]. The protons of methylene (-CH₂) next to the urethane bond are 2,91 ppm. The protons of methylenes and methine (-CH) with COMP amide and urethane binding are peaks with 3,70 ppm and 3,76 ppm. The ^1H NMR HPU spectrum is however no longer quantitative, since peaks of interest appear to be complex aggregates. However, the degree of branching is not information. However, the whole process is viable for hyperbranched architectural building using a branching template.

4.3. XRD study

The presence of PU crystallinities, as illustrated by strong diffraction patterns in Figure 4.6, was confirmed by XRD analysis. Two strong diffractions of 2 pounds = $21,1^\circ$ and 2 pounds = $23,5^\circ$, corresponding to macromolecular crystalline movement (1 1 0) and crystalline PCL planes (2 0 0) [6] were revealed in the analysis. Due to PCL presence, all PUs had the same diffraction patterns. There is, however, a minute shift in HPU and BLPU diffraction peaks compared to only LPU, which in addition to PCL is due to the presence of components based on renewable resources. Furthermore, with the increase in the percentage content of COMP, decreased diffraction intensity of the HPUs is observed. The result is a relatively less effective packing of crystalline PCL motor, as against regular structured LPUs (6, 7). This is attributable to the hyperbranched architecture of HPUs.

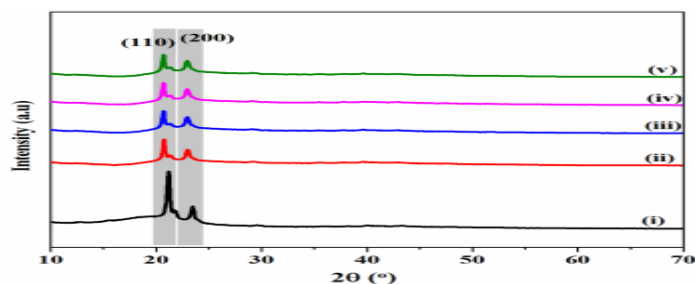


Figure 8. XRD patterns of (i) LPU, (ii) BLP, (iii) HPU1, (iv) HPU2 and (v) HPU3.

5. Physical properties

In order to improve understanding of the structure of the polymer, the physical properties of HPU have been examined. HPU was soluble in THF, DMF, DMAc, DMSO, Acetone etc. polar-optic solvents as well as in chloroform, DCM, etc. HPU was soluble. The global structure of HPUs and the presence of polar surface and terminal groups on the polymer backbone can be accredited to better dissolve various solvents [27]. In protic solvents, like water and alcohol, HPU was nonetheless insoluble. As in order of 10⁴, HPU molecular weights were found to be high. HPU1 was found to be approximately 2.59 x 10⁴ g mol⁻¹ and 3.75 x 10⁴ g mol⁻¹, with a polydispersity (PDI) of 1.54 respectively, for a mean number (M_n) and average weight (M_w) molecular weight. The increase of the hard segment ratio, thus enhancing the density by means of various polar interactions in the polymer chains, can justify this slight variation and lead to the structural compactness [6, 11]. HPU was yellow, mainly due to the color of the precursors of renewable vegetable oil. The presence of purely aliphatic precursors meant that HPU films showed modest transparency mostly.

6. Mechanical properties

The mechanical efficiency of PU depends on different factors like the presence of polar bonds (e.g. urethylene, ester) in the polymer matrix, degree of urethane binding, physical/chemical cross-linking, physical state, molecular weight, distribution of the polymer, and different physico-chemical interactions, such as hydrogen bonding, polar polar interactions.

Table 1. Mechanical properties of Pus

Composition	LPU	BLPU	HPU1	HPU2	HPU3
Tensile strength (MPa)	3.6±0.4	4.1±0.1	4.3±0.2	4.6±0.1	5.3±0.1
Elongation at break (%)	361±20	625±10	668±20	625±5	632±10
Toughness ^a (MJ m ⁻³)	12.00±0.5	26.18±0.2	27.06±0.5	27.97±0.1	32.16±0.2
Scratch hardness ^b (kg)	4.5±0.5	5.0±0.5	6.0±0.5	7.2±0.5	10.0±0.5
Impact resistance ^c (kJ m ⁻¹)	13.68	15.06	16.56	18.45	19.02

HPUs demonstrate higher than their linear counterpart's mechanical properties. Compared to LPUs, HPUs showed increased tensile strength, following an increasing trend with the increase in COMP's percentage content. The unique 3D structure of HPUs, with large numbers of polar functional moieties in the polymeric chains, can be attributed this improvement. These numerous polar functional moieties have produced stronger interactions between physical and chemical components in the polymer network, thus giving the HPU structure rigidity [11]. At the same time, HPUs were highly elongated during a break compared to LPUs, although the values showed a decreased pattern when the content of the COMP was increased. The flexibility of the polymer chains because of the presence of long chain aliphatic moieties supports this view, although the inherent rigidity of the structure caused by several secondary interactions in the polymer chains affects flexibility [6]. The impact resistance of the HPUs over linear analogs, which could be due to the high toughness angle of the HPUs, i.e. the ability to absorb applied external power and to reimburse it to its molecular network, was also found [6]. The development of the hyper-branched architecture helps absorb and distribute impact energy, thus enhancing the durability of HPUs.

7. Thermal properties

TGA and DSC were used to assess the thermal properties of the synthesized PU. The thermal stability of PU is dependent on the composition of the hard and soft segments, the level of the urethane interconnection, the extent and distribution of physical/chemical cross-connection, crystal and molecular weight [6, 7]. Figures

show that HPUs and BLPU are subject to a two-step degradation pattern, while synthetic LPU are subjected to single step degradation. The urethane bonds and ester groups of hydrocarbons are the cause of the second step degradation [6, 28]. In the event of synthetic LPU, the thermal decomposition of urethane connections is the only step degradation.

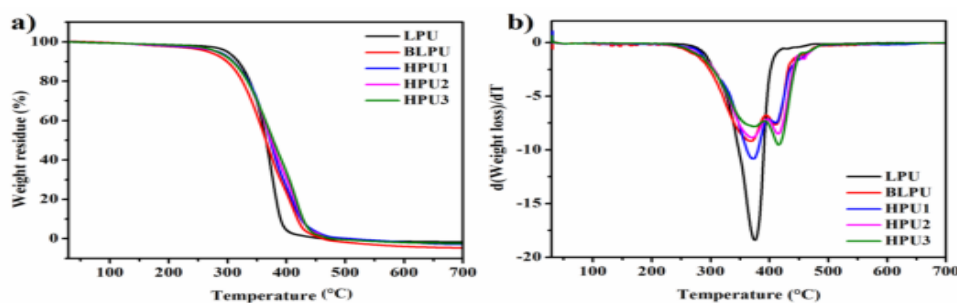


Figure 9. TG curves, and b) TG curves of PUs.

The thermal degradation temperature of HPUs was higher than that of their linear analogs, showing their higher thermal stability. Furthermore, the temperatures of degradation of HPUs increased as the content of the COMP was increased. A hyperbranched architecture, which prevents the polymer matrix decomposition by cross-linking and secondary interactions [6, 7], can be attributable to the good thermal stability in HPU.

8. Chemical resistance study

In different chemical contexts PU chemical resistance was tested: 10% aqueous NaCl (w/v), 20% aquatic ethanol (v/v), 5% aqueous HCl (v/v), 3% NaOH (w/v) and normal tap water (v/v). Table 4.4 shows the results of these tests of chemical resistance. In comparison to their linear analogs, HPUs exhibited superior chemical resistance in all chemical environments tested. Interestingly enough, hydrolysable ester connections in the macromolecule's moieties are shown to have better chemical resistance to alkali. The hyperbranched architecture, which leads to greater interaction from the field and different secondary interactions, such as hydrogenic bonding, polar-polar interacting, etc., can mainly be attributed to this good chemical resistance of HPUs within the PU matrix.

Table 2. Weight loss (%) of PUs in different chemical media

Polymer	10% NaCl	20% EtOH	5% HCl	3% NaOH	Tap Water
HPU1	0.020	0.033	0.042	0.481	0.0
HPU2	0.018	0.028	0.040	0.434	0.0
HPU3	0.013	0.011	0.039	0.375	0.0
BLPU	0.022	0.031	0.049	4.325	0.0
LPU	0.029	0.033	0.055	5.050	0.0

9. Biodegradation study

The PU's biodegradation was investigated by exposure to *P. aeruginosa* bacterial strain in a nutrient medium in the PU film. As shown in Figure OD measurement of the media of bacterial crop up to 7 weeks in succession indicated that HPU is more biodegradable than linear analogs. HPUs also undergo significant biodegradation compared to LPUs as demonstrated by the percentage weight loss recorded in HPUs in Figure after 7 weeks of bacterial strain exposure. The overall biodegradability of HPU may be attributable to the hyperbranched macromolecule structure and the presence of renewable precursors in the polymer's backbone with hydrolysable links. The biodegradability of HPU has also improved with an increase in the proportion of the COMP precursor of renewable resources. The highest biodegradation for HPU3 was found, as its contents were of COMP, while the lowest biodegradation was observed in LPU without a regeneration component and with a lower ester hydrolysable linkage. This observation, which showed significant bacterial adherence and surface erosion, was further justified by SEM micrograms of HPU in below Figure.

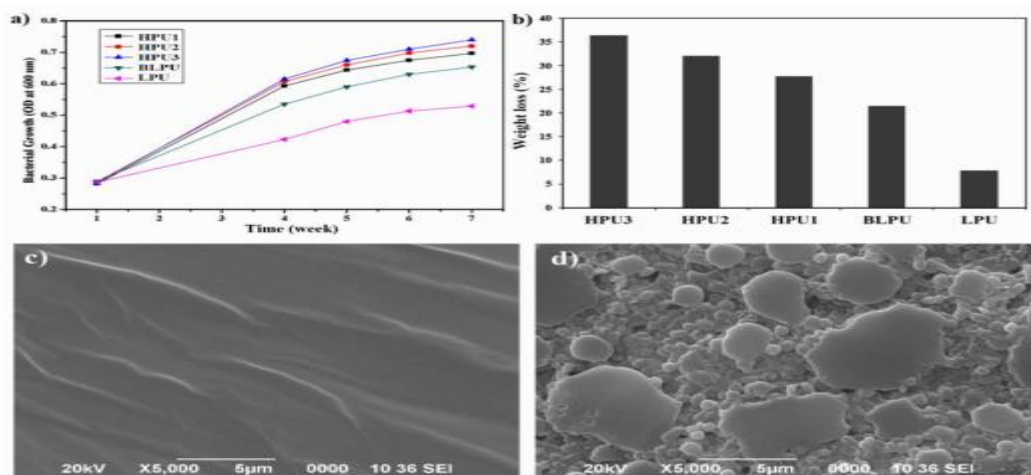


Figure 10. Optical density (OD) plots showing growth of *P. aeruginosa* bacterial strain against time for PUs during initial 7 weeks, b) Weight losses of PU films after 7 weeks of exposure to *P. aeruginosa* strain and SEM micrographs of HPU film c) before and d) after biodegradation.

10. UV-resistance study

The UV aging of PUs took place through the exposure of their films for the period of 2 weeks to UV wavelength 254 nm. Mechanical property evaluation for PU films showed minor variations compared to those for LPUs prior to and after UV-aging for HPUs. The increase in the crosslinking and break down of the polymer matrix caused simultaneously by UV irradiation can be attributed to this variability. This improved UV resistance of HPU was further illustrated in the retention percentage, as indicated in Table 5 Tensile strength (~98%), break elongation (~88%) and hardness were shown to be very high percentage retention by HPU (87 percent). The percentage of elongation retention at break and strength, in particular, was significantly higher than LPUs. This higher mechanical retention percentage reflects better UV resistance in HPUs. The hyperbranched architecture of HPU with more mechanical stability than the linear counterparts can be attributable to this superiority. The pure aliphatic nature of the HPU matrix, containing less UV light absorbing groups, complements this mechanical stability, thus providing greater stability to UV degradation

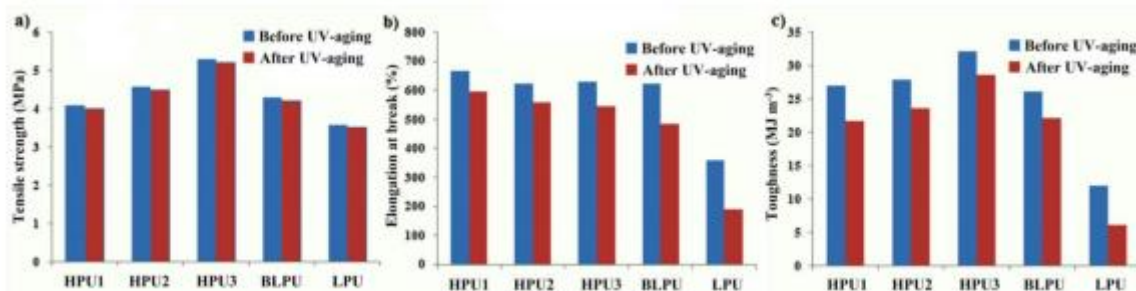


Figure 11. Histograms showing a) tensile strength, b) elongation at break, and c) toughness of PUs before, and after UV-aging.

Table 3. Retention (%) of mechanical properties of PUs after UV-aging

Parameter	LPU	BLPU	HPU1	HPU2	HPU3
Tensile strength	97.14	97.67	97.50	97.70	98.07
Elongation at break	10.99	71.13	88.10	88.59	84.03
Toughness	4.87	82.33	75.29	81.83	87.63

11. Shape memory study

PU shape memory behavior was investigated by temporarily changing the shape of the UP films and then by applying various external stimuli to recover the original shape. That PU form memory attribute shows macromolecular entropy [33, 34]. The PU films in their original forms are arranged in a high degree of entropy

in their molecular chains. The mobility of these chains becomes dynamic when films are heated at 65°C (>T_m), which leads to entropy and films are transformed into a temporary ring shape. Then, the temporary form is fixed at -5 °C (<T_g flavor) for 15 mins by freezing the sample in an ice water-salt bath. The polymer films lose their dynamics in this state because of freezing of the macromolecular chains and entropy reduction. Multi-stimulation reactionary memory behavior was demonstrated in HPUs under thermal heating, microwave and sunlight. Table shows the fixity of the forms, the form recovery and the time for recovery from thermal, microwave and sunlight. Due to the hyperbranched structure with enhanced physico-chemical cross linkage and secondary interactions in the temporary fixed direction of the polymer segments, HPUs had an excellent form fixity compared with LPUs. In comparison to LPUs, HPUs showed improved form recovery and less form recovery time. The hyperbranched structure with consistently distributed hard and soft segments and enhanced secondary interactions [13] can attribute to the better form of recovery for HPU the increasing amount of stored energy in the system.

Table 4. Shape memory behavior of Pus

Stimulus	Shape memory parameter	HPU1	HPU2	HPU3	BLPU	LPU
Thermal	Shape fixity (%)	95.7	96.1	96.3	87.8	72.4
	Shape recovery time (s)	21	20	20	25	42
	Shape recovery (%)	96.8	96.9	97.1	95.5	90.5
Microwave	Shape fixity (%)	95.5	96.1	96.7	85.1	70.8
	Shape recovery time (s)	95	91	91	130	156
	Shape recovery (%)	96.5	96.3	98.2	95.1	90
Sunlight	Shape fixity (%)	95.1	95.7	94.3	88.0	70.7
	Shape recovery time (min)	21	19.2	15.7	27	30
	Shape recovery (%)	96.1	96.7	96.4	88.2	72.5

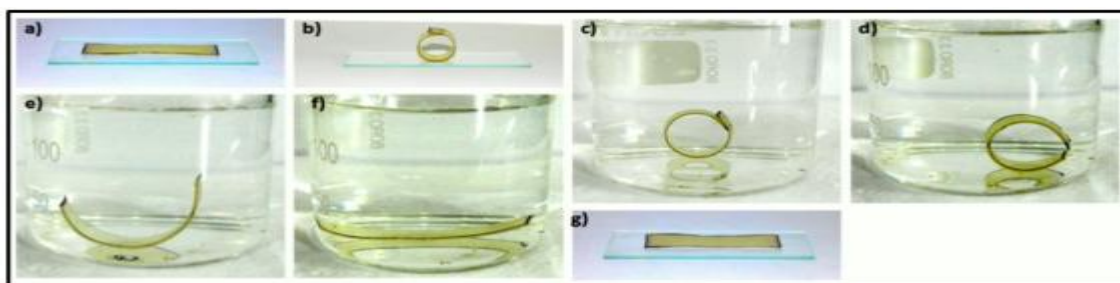


Figure 12. Digital images displaying the shape memory behavior of HPU2: a) Original shape, b) temporary fixed shape at room temperature, c)–f) shapes at 50 °C in 5s, 10s, 15s, 20s and g) regained original shape at room temperature

The usefulness of ricotor-oil polyol as a renewable precursor for HPU synthesis is described in the current study. Following the Ax+By (x, y alternative) approach, pure Aliphatic HPU is successfully synthesised by prepolymerization technique. There are various and optimized compositions in this study for the beaver oil-modified polyol. Different microscopic, analytical, and spectroscopic techniques contribute to the structural composition of the HPU. The HPU gained considerable benefits due to its unique hyperbranched architecture and its purely aliphatic nature. As a multiform material for advanced applications, the synthesized polymer has a remarkable potential. In addition, overall performances were determined in HPU for the production of different nanocomposites with the subsequent study with the general coding of the HPU, with the highest content for rizinous oil modified polyol, i.e. the HPU3, to be optimal.

5.1 Conclusion

Economic progress and the social welfare of the nations are mainly driven by the energy or energy sector. For the nation's economy to constantly grow, survival and growth of the power industry are essential. India is currently experiencing significant economic development while the evolving economy is at the same time thrilling with excess power installed. Every year the grid could be further strained by popular growth, economic growth and an increase in electricity demand. Increasing electrical capacity installed is therefore crucial. India has formidable challenges to meet its energy needs and to provide adequate, sustainable and competitively priced, energy of desired quality in various forms. Renewable energies, often called clean power, come from persistently regenerated natural sources or methods. Although we often believe that renewable resources are an important new energy source, we are surprised that we have long used the power of nature. There has been considerable global expansion in the recent past of the renewable energy sector. Two main

drivers of worldwide renewable energy use have been energy efficiency, energy insecurity, dependence on fossil fuels, and carbon emissions. The transition to sustainable non-conventional and renewable sources, such as the winds, solar, hydroelectric power, bioenergy and nuclear, is evident from conventional sources such as coal, oil, natural gas and lignite. Similarly, the challenges of increasing domestic energy consumption, increasing coal demand, significant import dependence have made renewable energy, an important element of India's energy scheme.

Renewable energy becomes more and more important internationally. A global energy revolution supporting green and renewable energy resources is critical in order to achieve energy security and avoid climate change problems. Compulsory rules and regulations concerning renewable energies may play an important role in the establishment at national level of compulsory regulation, since international accountability for the Nation's casual conduct in relation to renewables is possible. The growth of the Indian Renewable Energy Sector is also a result of the international community initiatives on which India was interested.

The deployment of renewable energy sources in India is heavily dependent on the achievement of NAPCC Renewable Purchasing Obligation Objectives. However, it was not encouraging overall compliance with RPO. It is vital that the SERC's and state agencies are effectively implementing the renewable purchasing obligation. In order to achieve this, SERC rules must be based on strict legislation, which provides for an efficient monitoring, penalty and compliance mechanism. Renewable resources constitute future energy resources and, consequently, these resources are regulated under separate legislation or by the extension of the 'Electricity Act 2003' by amendments which promote renewable energy sector growth specifically. China (the world leader in the clean energy transition China) analyzed its legislative and institutional framework. The goal is to draw on and adopt best regulatory strategies in India in order to remove the existing barriers in the energy regulation of India. Because of the growing population, India and China are both the world's major energy consumers. Both countries are struggling with issues such as access to energy, energy-related climate issues that cannot afford energy services and increased domestic poverty. Both countries also have prominent policies and regulations that focus on enhancing the use of renewable sources of energy.

The Centre has power over energy resources and fewer taxes in India, whereas States have competence over 'water and land rights, natural gas infrastructure and mineral rights taxation and electricity consumption and sales.' Whereas countries have power to determine tariffs for energy, to formulate and enforce policies on renewable energy, are prerogative states where the Govt Center only acts as a guiding force for the States. There is no entity with supreme authority over state policy integration. Many ministries and agencies are establishing policies, regulations, energy deployment strategies that ultimately result in ineffective decisions.

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