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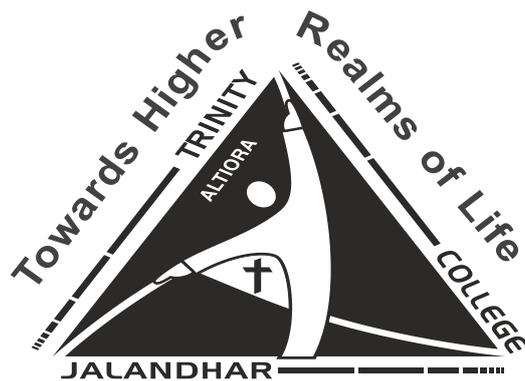
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# TRINITARIAN JOURNAL

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With immense pleasure and gratitude, we present the Sixth Volume, First Issue of the *Trinitarian Journal*, a biannual multidisciplinary research journal dedicated to fostering innovative thought and advancing academic discourse. This milestone reflects our steadfast commitment to providing a platform for diverse voices, cutting-edge research, and transformative ideas that span a wide array of disciplines.

The *Trinitarian Journal* stands as a testament to the power of collaboration among disciplines, uniting fields as diverse as humanities, sciences, social sciences, and beyond. In an era where complex global challenges demand integrated approaches, the importance of such cross-disciplinary engagements cannot be overstated. Each article published in this issue underscores the dynamic interplay of knowledge systems, illustrating how diverse perspectives can blend to generate transformative insights.

In this issue, readers will encounter a wide array of topics that reflect the journal's multidisciplinary ethos. From ground breaking research in environmental sustainability to thought-provoking analyses in cultural studies, this volume is a treasure trove of academic diversity. We are confident that these contributions will inspire both reflection and action among our readers.

As we release this issue, we are reminded of the journal's enduring mission to serve as a beacon of intellectual curiosity and scholarly integrity. We invite our readers to engage deeply with the content, to challenge their perspectives, and to contribute to the ongoing dialogue that defines the *Trinitarian Journal*. Moreover, we encourage scholars from all disciplines to consider submitting their work for future issues, helping us expand the horizons of multidisciplinary research.

In conclusion, we present this volume as a celebration of collective scholarship and a reaffirmation of our commitment to advancing knowledge. May the articles within spark new ideas, foster interdisciplinary collaborations, and inspire solutions to the pressing issues of our time.

We look forward to your continued support and engagement with the *Trinitarian Journal*. Together, let us continue to push the boundaries of knowledge and create a brighter, more interconnected academic future.

Warm regards,

**Fr. Peter Kavumpuram**

# RECTANGULAR SHAPE SPLIT RING RESONATOR (RSRR) LOADED DUAL BAND NOTCHED ANTENNA FOR WIRELESS APPLICATIONS

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## **Abstract**

In this paper, an ultra-wideband antenna with band notched properties inspired by metamaterials is presented. The suggested antenna is of small size of 20 X 16 X 1.6 mm<sup>3</sup> and a broad frequency range of 3.4 to 10.8 GHz. A single rectangular shaped split ring resonator (RSRR) metamaterial slot embedded the radiating patch and an S-shaped slot etched on the microstrip feed line were used to generate the notched bands. WiMAX band frequencies (3.51-3.7 GHz), C-band applications frequencies (3.7-4.2 GHz), WLAN band frequencies (5.15-5.62 GHz), X-band satellite communication system frequencies (7-8 GHz), and uplink X-band (8.89-10.38 GHz) frequencies have all been successfully rejected. Adjusting the dimensions of the metamaterial inspired slot and S-shaped slot can change frequency of the rejected band. At frequency 7.73 GHz, the proposed prototyped has a high gain of 14.3 dB, and simulated radiation pattern of the recommended antenna is seen at various frequencies.

**Keywords:** Metamaterials, SRR, radiation pattern, band notching, gain.

## **Introduction**

UWB communication systems are becoming increasingly attractive to academic and industrial researchers due to high data rate transmission, low power operation etc. Since the allocation of ultra-wide band frequency of range from 3.1 to 10.6 GHz by the Federal Communication Commission (FCC), its demand in communication system has been increased at large extent [1]. A planar antenna is an excellent contender for UWB communication applications. However, there are numerous challenges that must be overcome when designing a UWB system, as there are several other existing technologies that can interfere with the UWB system, such as the WiMAX frequency band (3.3-3.6 GHz), C-band downlink (3.8-4.2 GHz), WLAN frequency band (5.15-5.825 GHz), downlink of satellite communication system (7.25-7.75 GHz), and ITU X-band satellite



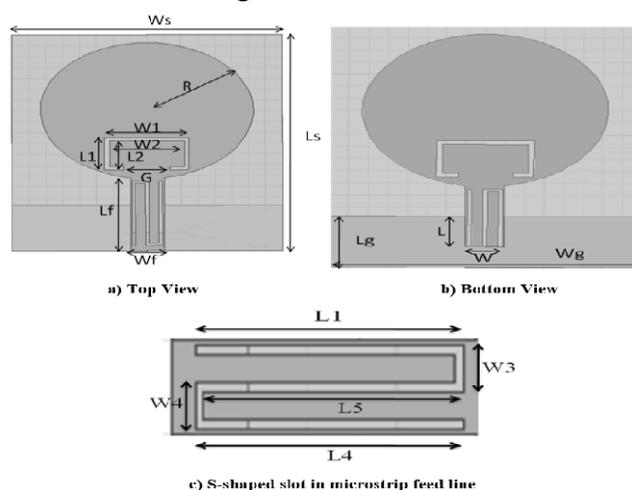
communication (8.025-8.4 As a result, it is critical to design antennas with band notched properties in order to avoid the previously mentioned intervention.

Various strategies have been used in recent years to generate a single rejected frequency band [2-5]. Recently, there have been reports of UWB antennas with multiple band notches [6–13]. In various designs, two frequencies bands are rejected by etching slots on the radiating patch as well as on the ground plane [6], CPW-fed having three rejected frequency band [7], by use of EBG structure [8], open rectangular parasitic elements [9], and with the help of U-shaped split ring embedded on patch [10]. Furthermore, on radiating patch, employing a quarter wavelength open ended slot and half wavelength slots leads in tri-frequency rejection [11], incorporating the band stop elements [12], and using slots of uneven widths [13]. Due to its high quality factor, the split ring resonator (SRR) can be utilised to create a filter with a band stop at a given frequency. SRR can also be used as a slot type structure to get rid of undesirable frequencies [4–16].

The present article proposes a compact ultra-wideband (UWB) antenna with band notch features. By utilising a SRR structure having metamaterial properties and an S-shaped slot on microstrip feed line, existing frequencies of WiMAX band, C-band, WLAN band, down-link satellite communication system, ITU band & X-band application are abolished. Controlling the rejected bands requires tweaking the dimensions of the RSRR slot & S-shaped slot. The suggested antenna is constructed from cost effective FR4-Epoxy substrate & employs a single rectangular split-ring resonator (RSRR) as well as an S-shaped slot for frequency rejection, thereby minimising system complication.

### Design of Antenna

The schematic detail of proposed antenna with frequency rejection characteristics is illustrated in Figure 1.



**Fig 1: Geometry of suggested antenna**



Ansoft HFSS 15 is used to simulate the outcomes of the suggested antenna. The suggested antenna is made of a  $20 \times 16$  mm<sup>2</sup> layer of FR4-Epoxy dielectric substrate tangent loss  $\tan\delta=0.02$  and a relative permittivity of 4.4. To achieve  $50\Omega$  impedance, the antenna height is 1.6mm and the feed line diameter is 2mm. Table 1 depicts the detail geometry of the proposed antenna.

<b>Parameters</b>	<b>Ls</b>	<b>Ws</b>	<b>Lf</b>
<b>Unit</b>	20	16	7
<b>Parameters</b>	<b>Wf</b>	<b>R</b>	<b>L1</b>
<b>Unit</b>	2	6.3	3
<b>Parameters</b>	<b>W1</b>	<b>L2</b>	<b>W2</b>
<b>Unit</b>	5	2.4	4.4
<b>Parameters</b>	<b>L3</b>	<b>L4</b>	<b>L5</b>
<b>Unit</b>	6	6	6
<b>Parameters</b>	<b>W3</b>	<b>W4</b>	<b>G</b>
<b>Unit</b>	0.6	0.6	2.8
<b>Parameters</b>	<b>Lg</b>	<b>Wg</b>	<b>L</b>
<b>Unit</b>	0.6	0.6	4.2
<b>Parameters</b>	<b>W</b>		
<b>Unit</b>	16		

One of the most important aspects of band notched antenna design [17-19] is determining the position and proportions of the injected SRR metamaterial. At the band's notch frequency, the length of the slot is usually half the guided wavelength [17]. Figures 2 and 3 depict the primary antenna's reflection coefficient curve and VSWR due to a single rectangular SRR slot on the radiator and an S-shaped slot in the feed line. By integrating a single rectangular split ring resonator (RSRR) slit on upper plane & an S-shaped slit on the microstrip feed line, frequencies rejection for WiMAX, C-band, WLAN & X-band satellite communication has been effectively realised, as shown in Fig.3.

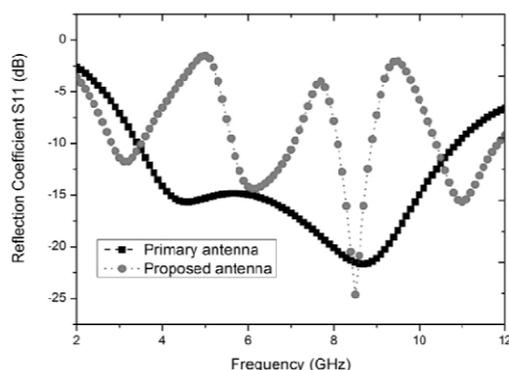
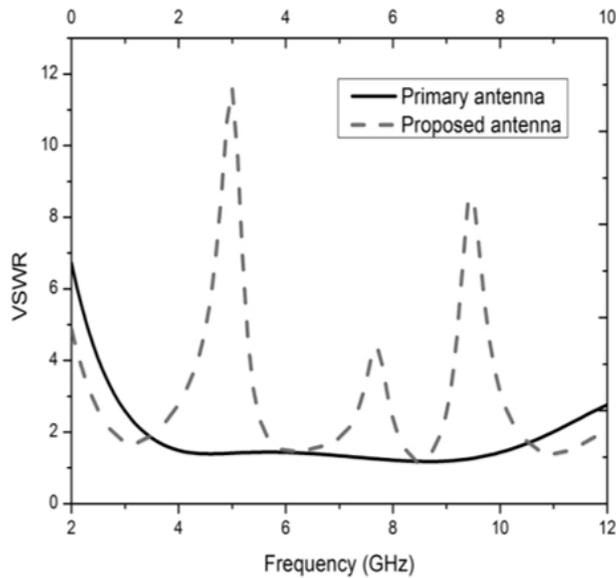


Fig 2: Reflection co-efficient curve for conventional and proposed antenna

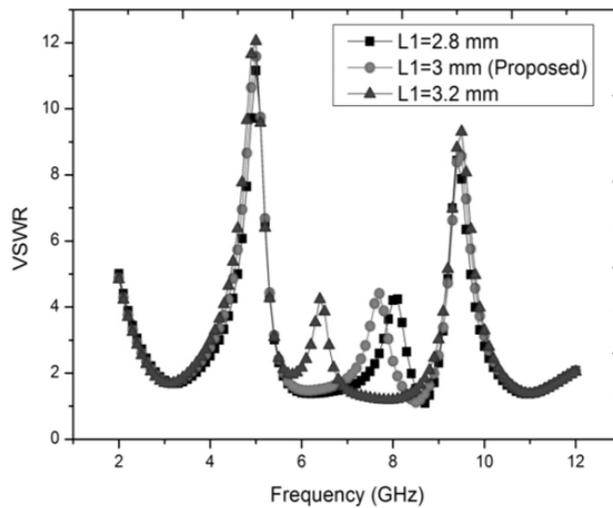




**Fig 3 VSWR variation curve for primary and proposed antenna**

**Parametric Study of Proposed antenna**

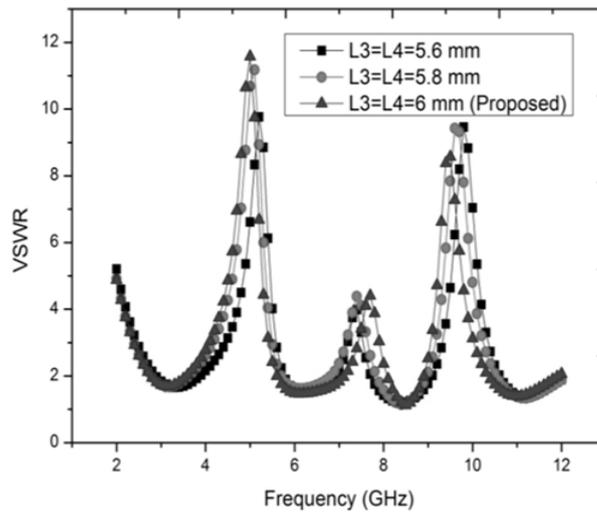
High frequency simulation software (HFSS) is used to assess the proposed antenna's performance. The parametric investigation is being carried out to see how variations in the dimensions of the SRR metamaterial slot and the S-shaped slot affect the results. Antenna optimization is performed using these parametric analyses. The length of the SRR metamaterial slot was optimised as shown in Figure 4.



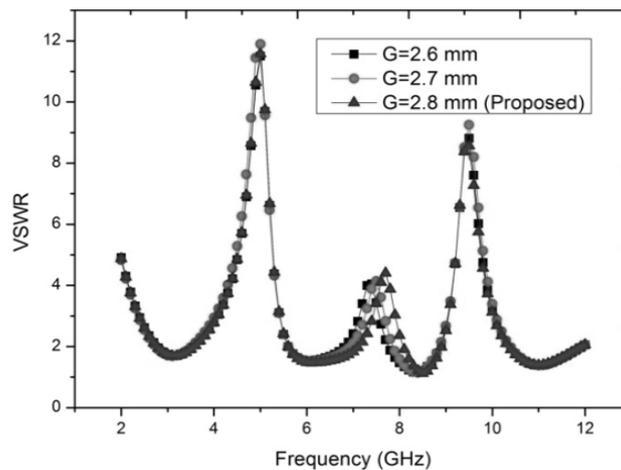
**Fig 4: VSWR curve for different dimensions of L1**



Figure 4 shows that as the value of L1 of the single rectangular shaped splitting resonator (RSRR) slot is increased from 2.8 m to 3.2 mm, the frequency of the rejected band shifts from 8.1 GHz to 6.4 Ghz.



**Fig 5: VSWR curve for different dimensions of S-shaped slot**



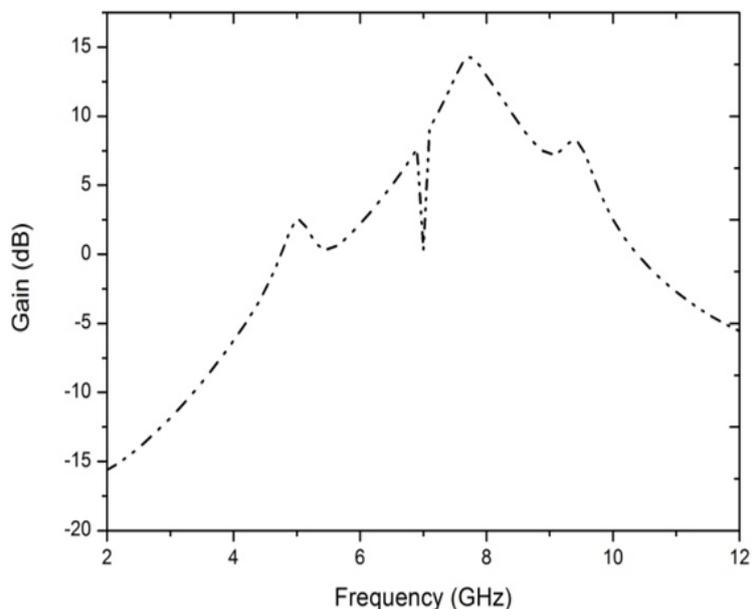
**Fig 6: VSWR curve for different dimensions of G**

The fluctuation in VSWR with different dimensions of the length of the S-shaped slot in the feed line is illustrated in Figure 5. With increment in the length of the DMS slot (L3 & L4) as illustrated in figure 5, the rejected frequency of the band shrinks. Due to the defective microstrip structure (DMS), the feed line's effective inductance & capacitance rise. Increases in slot length result in an increase in effective inductance, resulting in a smaller rejected band.

Fig.6 illustrates the fluctuation in gap G VSWR effects for a single rectangular SRR metamaterial slot on patch. As illustrated in Fig.4, a single rectangular SRR



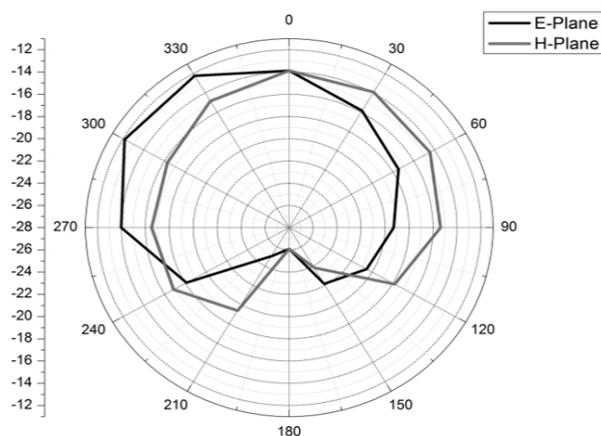
is capable of generating strong band rejection characteristics. When the length of the metamaterial-inspired rectangular SRR is increased, the effective inductance drops proportionately, which leads to frequency of high resonance.



**Fig 7: The simulated result of gain of presented antenna**

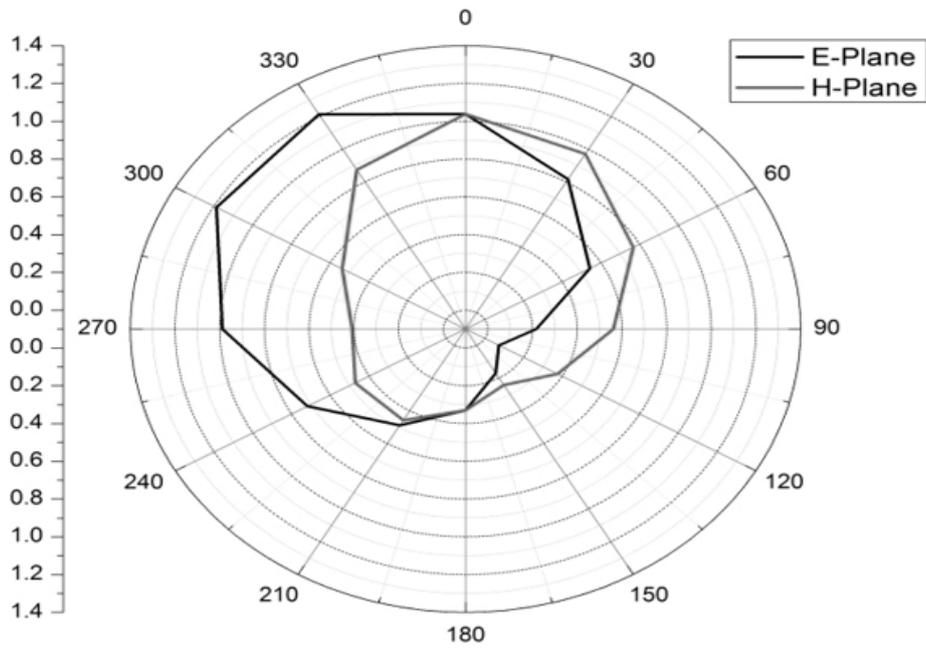
Figure 7 illustrates the simulated gain of the proposed band rejected antenna over the UWB frequency range (3-12 GHz). The obtained result indicates a 14.3 dB gain with a low value at rejected bands.

Figure 8 illustrates the proposed antenna's predicted radiation patterns. As seen in Figure 8, the proposed UWB antenna radiates in a bidirectional pattern in E-Plane and an omnidirectional pattern in H-Plane.

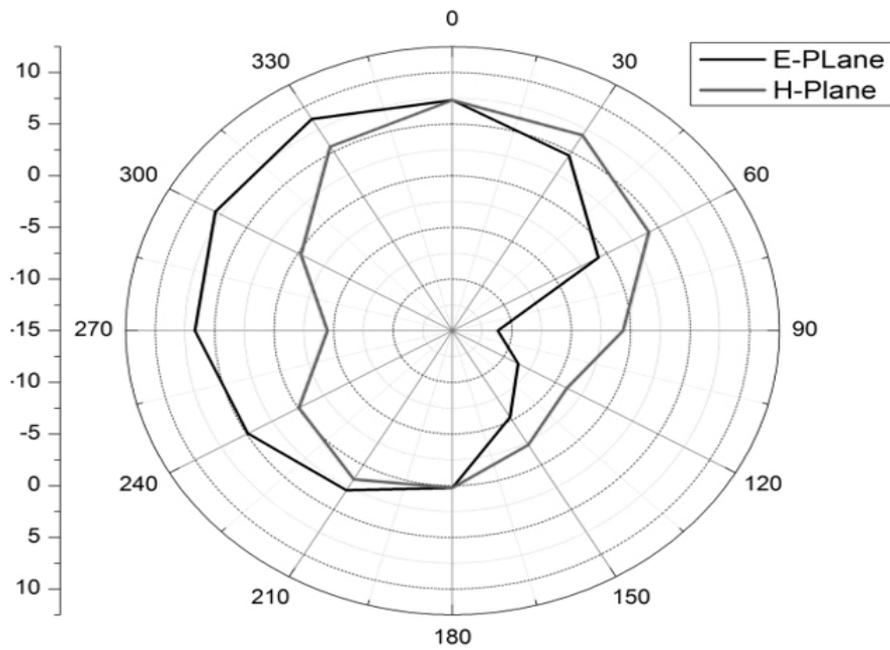


**(a) At 3.1 Ghz**





(b). 6.1 Ghz

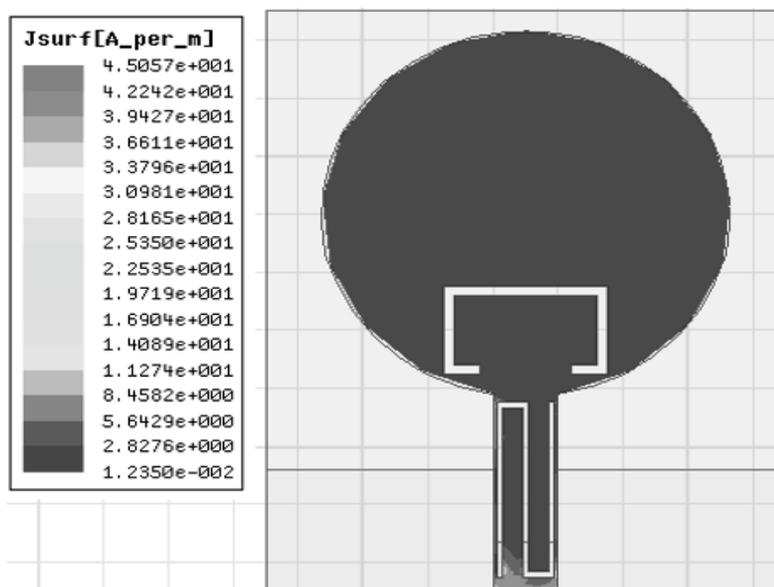


(c) 8.1 Ghz

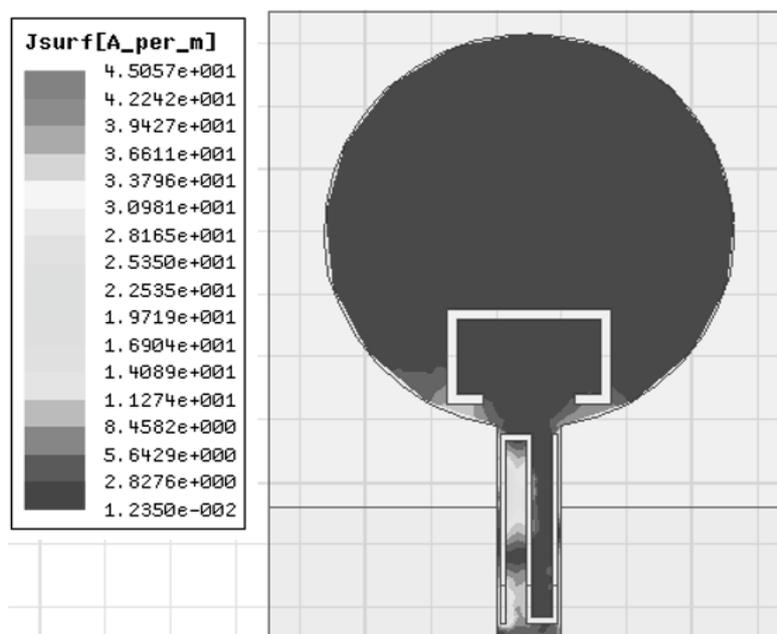
**Fig 8: Simulated result of radiation pattern at different frequencies**



Figure 9 illustrates the simulated surface current distribution at different frequencies. As illustrated in Figure 9, current is primarily spread across the rectangular shaped split-ring resonator (RSRR) metamaterial slot & the S-shaped rejected band slot.

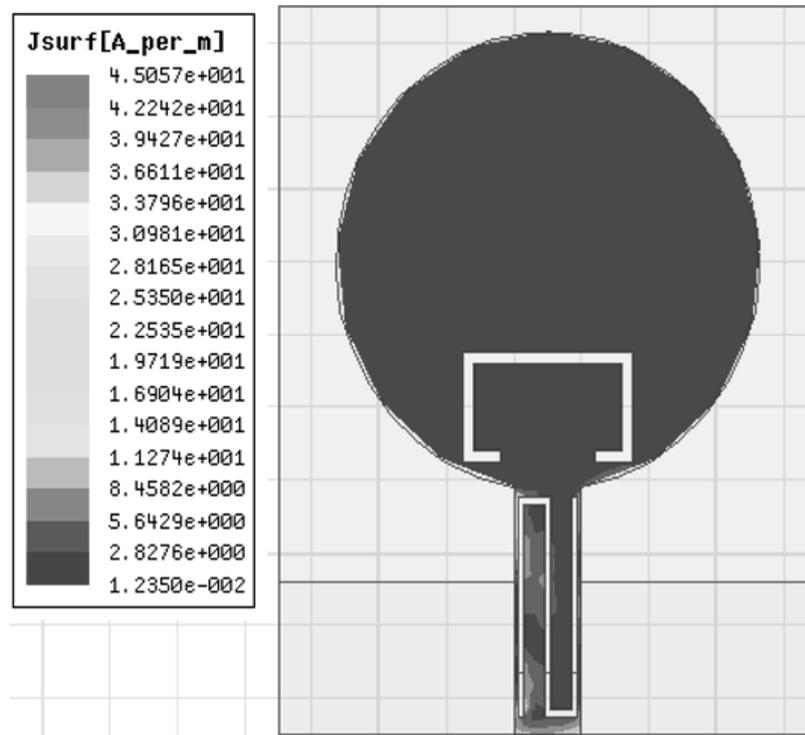


(a) At 5 Ghz



(b) At 7.7 GHz





(c) 9.5 Ghz

**Fig 9: Surface Current distribution different frequencies**

### Conclusion

This paper describes a miniaturised ultra-wide band antenna having band stop characteristics by using metamaterial inspired split-ring resonator (SRR) slot & S-shaped slot. They do not require additional space because they are introduced on the patch and on the feeding line of the rudimentary antenna. The notch frequencies are simply adjustable by making variation in the dimensions of the inserted slots. The device achieves a broad bandwidth of 3.4 to 10.8 GHz while providing a high gain of 14.3 dB at 7.73 GHz. Over UWB frequency, the suggested structure produces bi-directional radiation patterns in the E-Plane and omni-directional radiation patterns in the H-Plane.

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## EMOTIONAL FINANCE: A NEW RESEARCH DIRECTION

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### Abstract

The impact of psychological biases, heuristics, and emotions on the performance and decision-making of investors and managers is examined by behavioural finance and behavioural corporate finance. A significant paradigm change has been brought about by Taffler and Tuckett (2005) with the introduction of a brand-new area of study called emotional finance. This innovative method uses Freud's notion of phantastic objects to examine how unconscious, childlike emotions affect investors' choices. The dominant views that suggest that markets are guided by investors' conscious processes are challenged by the emotional finance hypothesis. It investigates the influence of both conscious and unconscious processes in investment decisions and is based on psychoanalysis. It provides fresh justifications for the origins and foretelling of the numerous crises and bubbles that have occurred, particularly since the 2000s. It uses ideas like narrative, collective feel, states of mind, and phantastic object in this framework that haven't been used in finance studies before. The literature review conducted in the area of emotional finance up until this point has not been as thorough as this study. It examines and models the core ideas of the theory in relation to their causes and effects. It presents findings to aid market regulators, fund managers, and investors in comprehending market bubbles.

**Keywords:** Emotional Finance, Narrative, Collective Feel, State of Mind, Phantastic Object, Psychoanalysis

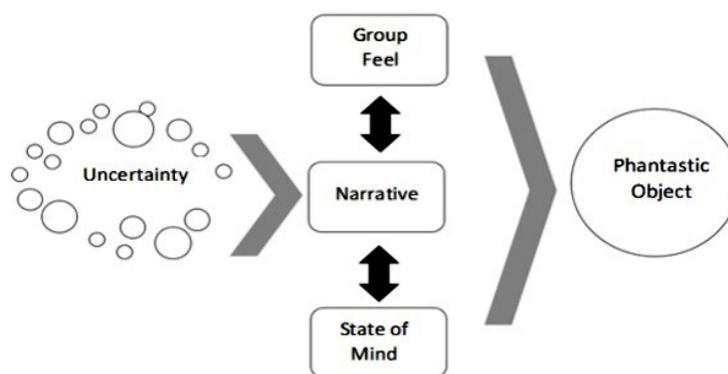
### 1. Introduction

Taffler and Tuckett (2011) believe that accepting the idea that investment activities have much deeper meaning in unconscious reality than is typically



acknowledged and go beyond simply maximising financial return is the first step in understanding investment behaviour. The emotional finance theory contends that unconscious mechanisms significantly influence how people make financial decisions. Emotional finance is the study of the function of unconscious mental processes in financial decision-making, and it is based on psychoanalysis. However, according to emotional finance, uncertainty rules the markets. Traditional financial theories analyse people's behaviour along the risk-return axis. The ideas of risk and uncertainty are fundamentally distinct from one another. According to Knight (1921), the key distinction between risk and uncertainty is that, whereas in the situation of risk, both the potential outcomes and the likelihood that an incident will occur are known, in the case of uncertainty, the potential outcomes are known but not the probabilities. Investors undoubtedly deal with "extreme uncertainty" and informational convergence, according to Tuckett (2012).

Figure 01. Basic concepts of emotional finance and its relationship with each other



Source: Dumanlı & Aren (2019), "Role of Narratives in Financial Decision Making from Perspective of Emotional Finance

Emotional finance makes use of ideas like story, collective feel, states of mind, and phantasmagorical objects to explain the unintentional actions of investors operating in an uncertain market. These principles will first be thoroughly presented in the article, after which the studies and research in the area will be discussed.

## 2. Basic Concepts Of Emotional Finance

### 2.1 Narratives

A story is a description of an event told orally or in writing. With the emotional



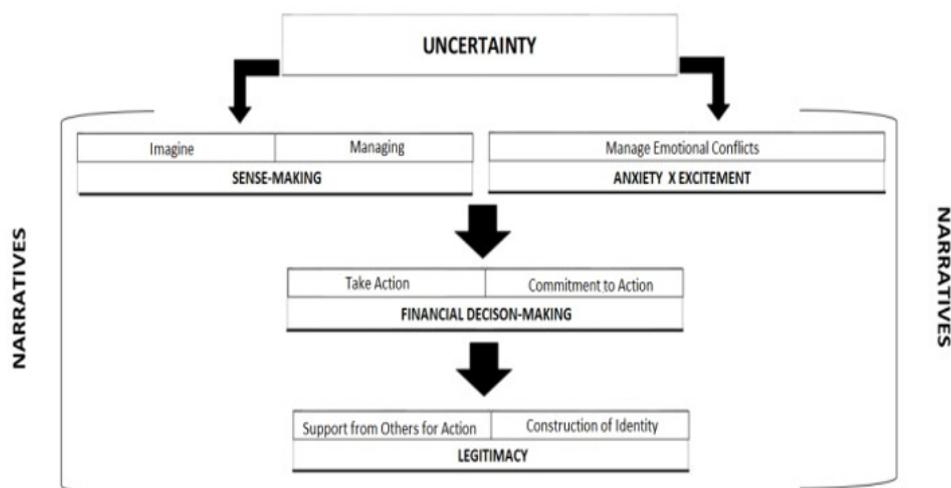
finance approach, narratives have begun to establish a presence in the literature of finance. Shiller (2017) asserts that despite the increased use of narratives across all disciplines, particularly since 2010, the study of narratives in the economics and finance fields only accounts for 5% of all research.

According to emotional finance, people who have to make decisions in the face of uncertainty construct stories to represent that uncertainty. In this situation, narratives serve as a kind of explanation for ambiguity (Dumanl & Aren, 2019). Making sense of one's life and moulding one's experiences is a natural human activity that is aided by narratives (Bruner, 1991). They give us the ability to create events, their significance in daily life, and their causal implications (Tuckett & Nikolic, 2017).

Contrarily, Chong and Tuckett (2015) contend that when people encounter circumstances with unexpected results, feelings of exhilaration and worry over loss are bound to develop. They also contend that people deal with these emotional conflicts by creating narratives. According to Nyman (2015), people make judgements by forming adequate opinions about prospective rewards while suppressing worry and their suspicions of probable loss, and then they act accordingly. In addition to helping, one make sense of the current state of uncertainty, narratives put an end to the struggle between the opposing sensations of excitement and worry.

When uncertainty is made sense of to make it manageable, Dumanl and Aren (2019), who summarise the function narratives play in emotional financial tales, claim that emotional conflicts are also eliminated. They make it possible for people to act and stick with that activity. Investors turn to narratives to support their investment choice both internally and within the social setting.

Figure 02. The role of narratives in emotional finance



Source: Dumanlı & Aren (2019), "Role of Narratives in Financial Decision Making from Perspective of Emotional Finance

Studies studying the impact of narratives on financial decision-making gave birth to the Conviction Narrative Theory (CNT), which aims to explain how people, through narratives, make judgements under ambiguity and how they remain committed to such decisions. The CNT is a theory, according to Nyman (2015), that seeks to comprehend and explain how people choose in situations where doing so would not be optimal. Belief and sentiment are represented by conviction. The hypothesis holds that people have a deep conviction in narratives and are fascinated by them.

## 2.2 Group Feel

The idea of "group feel" is distinct from the idea of "groupthink," which attempts to explain the reasons for group behaviour in social sciences, and the idea of "herding behaviour," which is used in behavioural finance. All these theories make an effort to explain the origins and consequences of group behaviour, but they fall short in explaining the psychological and emotional factors that underlie such behaviour. It will be helpful to clarify groupthink and herd behaviour before introducing the concept of group feel.

According to research on both herding behaviour and groupthink (Griffin, 2012, Hart, 1991, McCauley, 1998, Fenzl & Pelzman, 2012, Blasco et al., 2012), these approaches show that people interact with their social surroundings when making decisions. While both methods provide different justifications for how people's collective decision-making processes work, they neglect to emphasise the importance of emotions in group activities. Emotional finance takes a psychoanalytical perspective to group processes and tries to understand the group's collective mood and how it affects the market in addition to taking into account why people join groups. Group feel is the phrase used in emotional finance in place of groupthink. A condition known as "group feel" occurs when a group of people, based on a deep and unconscious basis, focus their thoughts and behaviour toward one another in an effort to blend in and feel the same as the other members of the group (Tuckett, 2011). This definition's interesting aspect is that the people's unconsciousness is what causes them to act in such a way. Both the herding behaviour model and the groupthink model view an individual's decisions and desire to join the herd as conscious behaviours.

According to conventional financial theory, markets are made up of individuals operating independently from one another. This is what the work group is known for. But financial markets frequently resemble sizable fundamental assumption groups that abandon individuality in their behaviour



(Tuckett & Taffler, 2008). The market transforms into a fundamental assumption group, according to the emotional finance theory, particularly in situations where there are asset price bubbles or financial crises. According to the collective feel concept, people should make decisions based on themselves, their deliberate actions reveal an underlying attitude that they all share in an effort to blend in and to foster positive emotions. The necessary point It's important to note that the market here "unconsciously" transforms into a basic assumption group (Tuckett, 2011). This point introduces "states of thought," another crucial a component of emotional finance.

### **2.3 States of Mind**

Making an investment decision can cause both exhilaration and fear. Regarding the asset's price rising, there is enthusiasm and hope. However, the possibility that the price will decrease makes people anxious. Due to the simultaneous generation of the emotions that cause excitement and fear, this causes an uncomfortable emotional conflict or ambivalence.

In the emotional finance approach, the behaviours of splitting (mentally separating good and bad feelings, repressing bad feelings and making them unconscious), projection (unintentionally attributing undesirable emotions to others), and denial (the individual's denial of the aspects of reality they do not wish to know in order to reduce or prevent the painful effects related to the reality) are very prominent in people who are in a DS (Auchincloss & Samberg, 2012, quoted by Taffler, 2014)

Understanding investor behaviour and the genesis of asset pricing bubbles requires a thorough understanding of the mental states that influence investment decisions.

### **2.4. Phantastic Object**

The investment process means that an investor engages in an ambivalent emotional relationship with something that can easily let them down (Taffler & Tuckett, 2011). In other words, investors are required to establish an “object relation” with their investments.

The definition of an object given by Freud serves as the foundation for this idea. This approach is used to pinpoint the "representations" of people, concepts, or objects that exist in our imagination and unconscious mind (Auchincloss & Samberg, 2012; cited by Taffler, 2018). Image is what is intended by representation. Eshraghi and Taffler (2012) assert that if an object points at a picture, different people may experience various versions of the same object in their thoughts.



From a psychoanalytic perspective, buying and selling assets necessitates the creation of fictitious object relations. In such a scenario, judgements regarding whether to buy, hold, or sell an investment must take into account hypothetical relationships aimed at forging or severing emotional bonds with it (Tuckett & Taffler, 2008).

Emotional finance uses the term "phantasy" to describe this process. According to Freud (1908, cited by Spillius, 2001), phantasy is the unconscious activity that satisfies a person's unfulfilled instinctual needs or wishes. The primary reason for the creation of a phantasy, according to Freud (1908, cited by Spillius, 2001), is a desire whose fulfilment was hindered. A covert manifestation and partial fulfilment of such a yearning is fantasy.

Investment instruments are referred to be "phantastic objects" when investors form an object relation with them that is dominated by phantasy. A phantastic object is the object, or its image or equivalent in the person's mind, that fully satisfies the person's deepest wishes at the time and in the manner desired by the person (Tuckett & Taffler, 2008).

The notions of narratives, group feel, and states of mind are directly tied to the creation of phantastic objects and their dominance of the market. Narratives alleviate emotional tensions in markets where phantasmagorical objects are present in addition to giving ambiguity purpose and making it controllable. In this manner, people take action and commit to their actions.

### **3. Studies In Emotional Finance**

Studies addressing fundamental principles and empirical studies are two categories under which research in the subject of emotional finance can be categorised. Conversely, in-depth interviews, relative sentiment shift analyses, and questionnaire methods can all be used to conduct empirical studies.

Conceptual studies tackle the four building stones of emotional finance which we had discussed in detail previously, and their correlation with one another. These studies are significant in order to enable understanding of the basic arguments in emotional finance.

Taffler et.al. (2017) have conducted 51 in-depth interviews with fund managers and revealed what kind of anxiety was caused by the uncertainty in the investment process among the fund managers. According to the findings obtained from the research, fund managers work under significant pressure and, although they are aware of the fact that they cannot beat the market, they repress or ignore this situation in order to be able to continue with their works. This information accords with the defense mechanisms approach. They demonstrated the existence of splitting, projection, and denial mechanisms.



There is only one study conducted by questionnaire method in the field of emotional finance. As a result of this study, a measure for emotional finance has been developed for the first time. Measures for phantasy and the determinants of phantasy were developed in the study performed by Aren and Nayman (2020). Measures were developed for narrative, divided state of mind, group feel, informed herding, uninformed herding, and phantasy, and furthermore, the capability of these determinants to describe phantasy was researched. It was demonstrated that divided state of mind affects phantasy directly, while group feel and narrative are indirectly affected by the informed herding. It was found out that the variables that direct the investment choices of individuals in the periods when asset pricing bubbles are formed are phantasy, group feel, uninformed herding, and divided state of mind. When the studies conducted in the field are evaluated, it is observed that there is no detailed literature review on conceptual studies. The studies conducted by way of in-depth interview have been performed only with fund managers who are professional investors. The studies carried out with RSS methodology have focused generally on periods of crises or asset pricing bubble, leaving the studies aimed at normal market conditions limited. The study performed by way of questionnaire methodology is significant for introducing a measure to the literature.

#### **4. Conclusion And Discussion**

Particularly during the 2008 financial crisis, studies in the subject of emotional finance received more traction. The basic ideas of emotional finance were attempted to explain the rise and subsequent bust of asset pricing bubbles, which the traditional finance theory had difficulties explaining.

The studies that have been done primarily concentrate on the times when asset pricing crises and bubbles have happened, which is a significant criticism that can be made here. The literature on emotional finance may be criticised as being "crisis literature" in a way similar to how Fama marginalised behavioural finance as "anomaly literature."

A further objection could be made in light of the difficulties in applying the phantastic object method recommended by emotional finance. Financial crises and asset price bubbles are hard to spot as they develop, and it can be difficult to tell when assets or investment instruments turn into phantoms in a healthy market. According to Tuckett et al. (2014), narratives can be used to follow the emergence and growth of phantastic things.

It is anticipated that as more policymakers become interested in monitoring financial stability in the wake of the most recent crisis and as the analysis of market participants' emotions toward assets or the market becomes more crucial, the number of studies on emotional finance will rise in the coming years. If



supported by machine learning-based approaches, it is thought that particularly new approaches, like monitoring the stories created by market participants in unstructured data sources and RSS aiming to use emotional changes as precursors, etc., may allow the early detection of potential phantastic objects and enable measures to be taken against bubbles or crises that may emerge.

On the other hand, in addition to the generic RSS, the prospect of forecasting fundamental macroeconomic indicators is enhanced by the development of new series based on more precise rules particular to the subject under study. The description capability and dependability of the indices calculated to measure financial stability will be improved by the inclusion of RSS for general and specialised purposes.

While the measure that is created can be enhanced by the addition of variables such as personality traits, it will also be feasible to show the differences between professional investors and individual investors by using the same measure on professionals. Additionally, it will be feasible to clearly show the cause-and-effect relationship between the recently introduced factors and fundamental ideas.

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# THE EMERGENCE OF AYURVEDA: A REVIEW OF ITS HISTORICAL SIGNIFICANCE, MODERN RELEVANCE, AND GLOBAL ACCEPTANCE

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## Abstract

Ayurveda, an ancient Indian system of natural medicine that has been practiced for over 5000 years, has recently experienced a newfound global interest due to its comprehensive approach to health and wellness. Ayurveda, which is profoundly rooted in the principles of equilibrium between the mind, body, and spirit, emphasises the use of natural remedies, personalised treatment, and preventive care. This review traces the historical development of Ayurveda, from its Vedic origins to its decline during colonial rule and its revival in the modern era. It examines the process by which Ayurveda has integrated with conventional medicine to address contemporary health challenges, such as chronic maladies and mental health disorders. The global acceptability and integration of Ayurvedic traditional therapeutic systems in contemporary healthcare systems are impeded by the necessity for scientific validation, regulatory frameworks, and the standardisation of practices. As this review paper underscores, Ayurveda has the potential to make a substantial contribution to sustainable and integrative healthcare solutions and to develop into a global therapeutic science while preserving its traditional wisdom.

**Keywords:** Ayurveda, holistic medicine, Tridosha, herbal medicine, AYUSH, alternative medicine.

## Introduction

The term Ayurveda, which is derived from the Sanskrit words Ayur (life) and Veda (knowledge), translates to the "science of life." It is a comprehensive medical system that aims to maintain a harmonious equilibrium between the mind, body, and spirit in conjunction with the environment in order to prevent disease and promote health. Ayurveda, widely regarded as one of the oldest healthcare systems in the world, has its roots in ancient Indian Vedic literature, such as the Rigveda and Atharvaveda, which date back to approximately 1500 BCE (Sharma & Dash, 1988). These ancient texts not only delineate the philosophical foundations of Ayurveda but also provide a comprehensive overview of its diagnostic and therapeutic methodologies, which have been refined and expanded over the course of millennia. The concept of balance is central to Ayurveda, and it is depicted by the three Doshas—Vata (air and space), Pitta (fire and water), and Kapha (water and



earth)—which represent the fundamental physiological and psychological energies in the body. Health is characterised by the equilibrium of these Doshas, whereas disease is believed to be the consequence of imbalance. In addition, Ayurveda prioritises personalised treatment, recognising that each individual possesses a distinctive constitution (Prakriti) that affects their health, susceptibility to disease, and response to treatment.

Ayurveda's historical importance transcends the realm of medicine. It has had a profound impact on Indian culture, affecting everything from dietary practices and yoga to spirituality and ethics. Its holistic wellness strategy encompasses recommendations for mental well-being, seasonal regimens (Ritucharya), and daily routines (Dinacharya), which are indicative of a profound comprehension of the interconnectedness of life. Nevertheless, Ayurveda encountered substantial obstacles during the colonial era in India, despite its strong foundation (Frawley, 2012; Tiwari, 2007). The practice and teaching of Ayurveda experienced a decline as a result of the marginalisation of traditional knowledge systems and the introduction of Western medicine. Practitioners were relegated to informal duties, and numerous traditional texts were either lost or neglected. However, Ayurveda endured due to the dedication of academicians and practitioners who meticulously maintained its essence (Mukherjee et al., 2017).

Ayurveda has experienced resurgence in popularity in the contemporary era, as a result of the growing recognition of the constraints of conventional medicine in treating chronic diseases and lifestyle disorders. The necessity of preventive and comprehensive healthcare systems has been underscored by the increasing prevalence of conditions such as diabetes, hypertension, and stress-related ailments on a global scale (Patwardhan et al., 2015). Ayurveda provides a sustainable solution to these challenges by emphasising the establishment of fundamental causes rather than the treatment of symptoms.

Scientific advancements and globalisation have also contributed to this resurgence. Many of the claims made by Ayurvedic botanicals and practices have been validated by research, which has lent credibility to its therapeutic potential. For instance, turmeric (*Curcuma longa*), which was historically employed for its anti-inflammatory properties, is now acknowledged globally for its health benefits, which have been validated by a wealth of scientific research (Hewlings & Kalman, 2017). Ashwagandha (*Withania somnifera*) and Triphala are also experiencing an increase in popularity as adaptogens and digestive aides, respectively (Baliga et al., 2012). Ayurveda has gained global recognition as a complementary and alternative medicine system. The number of Ayurvedic clinics, wellness centres, and educational programs has increased in countries such as the United States, Germany, and Australia (Joshi, 2010). The prevalence of yoga and Ayurveda has been further bolstered by their integration in the promotion of mental and physical health. Ayurveda's principles are in alignment with contemporary health and wellness trends, such as preventive healthcare, natural therapies, and personalised



medicine (Mukherjee et al., 2017).

Ayurveda is constantly improving its acceptance with emphasizes on holistic approach to health, addressing not just physical ailments but also mental and emotional well-being. Ayurveda's emphasis on plant-based medicines, herbal treatments, and dietary adjustments resonates with this shift. As more evidence emerges supporting its efficacy, it has gained credibility in the eyes of the global scientific community. There are a growing number of international organizations and certification bodies working to regulate and standardize Ayurvedic practices (Patwardhan et al., 2015) to ensure safety and quality. Many Ayurvedic practices, such as yoga, meditation, and dietary recommendations, are seen as effective tools for managing these conditions.

### **Ayurveda's Historical Foundations**

Ayurveda's philosophical and practical underpinnings can be traced back to ancient Indian texts. These foundational scriptures consist of

1. Charaka Samhita (c. 1000 BCE): This seminal treatise on internal medicine, which is attributed to the physician Charaka, concentrates on the diagnosis, prevention, and treatment of maladies. It emphasises the significance of preventive care and individualised treatment, providing exhaustive guidance on pharmacology, pathology, and physiology (Meulenbeld, 1999).
2. Sushruta Samhita (c. 600 BCE): This text, authored by the surgeon Sushruta, is renowned for its comprehensive descriptions of surgical techniques, anatomical studies, and the treatment of injuries. It emphasizes the sophisticated medical and surgical expertise of ancient India, with Sushruta frequently being referred to as the "Father of Surgery" (Rao, 2005).
3. AshtangaHridaya (c. 7<sup>th</sup> century CE): Vagbhata is the author of this text, which is a succinct compilation of the principles and practices of earlier Ayurveda. It provides a comprehensive overview of the eight branches of Ayurveda (Ashtanga Ayurveda) by incorporating knowledge from the Charaka and SushrutaSamhitas (Sharma, 1992).

The framework of Ayurveda is collectively established by these texts, which underscore the interconnectedness of the human body, mind, and environment. The three bio-energies or doshas—Vata (air and space), Pitta (fire and water), and Kapha (water and earth)—which regulate physiological and psychological processes are at the core of this system. The maintenance of health is contingent upon the equilibrium of these doshas, while disease results from an imbalance (Lad, 2002). It emphasis on preventive care serves as an illustration of its comprehensive methodology. Dinacharya, or daily routines, is a concept that outlines activities that are designed to align the body with natural rhythms. These activities include waking up early, maintaining hygiene, dining at appropriate times, and engaging in yoga and meditation (Frawley, 2012). Similarly, Ritucharya (seasonal regimens) provides recommendations for adjusting to seasonal fluctuations, with a focus on



detoxification, diet, and lifestyle in order to preserve equilibrium (Tiwari, 2007). Its principles are indicative of a profound comprehension of the interconnections between human health and the natural world inclinations towards sustainability and integrative medicine, providing a timeless perspective on the pursuit of well-being (Mukherjee et al., 2017). The foundational texts of Ayurveda have not only influenced traditional Indian medicine but also served as a source of inspiration for contemporary research on preventive care and holistic health over the course of centuries. As the global interest in Ayurveda continues to expand, these ancient treatises remain indispensable resources for the integration of traditional knowledge with modern healthcare systems.

### **A historical perspective on the decline of Ayurveda**

The colonial period presented significant challenges to the annals of Ayurveda, since the advent of European colonial powers in the 18th and 19th siècles. This change was partially influenced by allopathic medicine, which prioritised evidence-based practices, pharmacology, and surgical advancements. Indigenous knowledge systems, such as Ayurveda, were frequently disregarded as dubious and relegated to the periphery of formal healthcare systems (Mukherjee & Wahile, 2006).

### **The Impact of Colonialism on Ayurvedic Practice**

Ayurveda was largely restricted to rural regions, while western education and healthcare systems gained prominence, particularly in urban areas due to established medical colleges and hospitals by the British colonial government that exclusively focused on Western medicine, disregarding traditional practices. However, the professional and social status gradually eroded of traditional Ayurvedic practitioners. Additionally, the cultivation and commerce of medicinal plants, which were essential to Ayurvedic practices, were restricted by colonial policies.

### **Resilience in Rural Communities**

Ayurveda persevered in rural India in spite of these obstacles. Traditional physicians continued to depend on their understanding of herbal therapies, which was frequently transmitted orally through generations.

### **Post-Independence Revival**

Ayurveda's decline began to reverse after independence, as the Indian government acknowledged its cultural and medicinal significance. Key milestones in its resurgence included the establishment of the Central Council for Research in Ayurvedic Sciences (CCRAS) and the Ministry of AYUSH (Ayurveda, Yoga & Naturopathy, Unani, Siddha, and Homoeopathy). These institutions have been instrumental in the advancement of Ayurveda's integration into the national healthcare framework, as well as its standardisation and research (Kumar et al., 2021).

### **Revival and Modern-Day Relevance of Ayurveda**



In recent decades, Ayurveda has witnessed a resurgence, driven by global trends favoring holistic and preventive healthcare approaches, scientific validation, and supportive government policies.

#### 1. Shift towards Holistic and Preventive Healthcare

Modern medicine's challenges in addressing lifestyle disorders, such as diabetes, stress, and cardiovascular diseases, have amplified interest in Ayurveda. Ayurveda emphasizes prevention through lifestyle modifications, dietary interventions, and natural remedies, which align with contemporary health trends (Patwardhan et al., 2005).

#### 2. Scientific Validation and Global Research

Ongoing research has demonstrated the pharmacological potential of Ayurvedic herbs and formulations, contributing to its credibility:

**Curcumin (Curcuma longa):** Found to possess significant anti-inflammatory and antioxidant properties, making it effective for managing chronic inflammation and oxidative stress (Gupta et al., 2013).

**Ashwagandha (Withania somnifera):** Proven to enhance stress resilience, improve sleep quality, and boost physical performance in clinical studies (Chandrasekhar et al., 2012).

Collaborations between Ayurvedic researchers and modern medical institutions have facilitated clinical trials, further validating Ayurveda's efficacy and enabling its integration into global healthcare practices (Kumar & Dhiman, 2019).

#### 3. Government Policies and AYUSH

The Indian government's Ministry of AYUSH has played a pivotal role in Ayurveda's revival. Key initiatives include:

- Establishing research institutions and universities dedicated to Ayurveda.
- Promoting wellness tourism and events like International Yoga Day.
- Collaborations with the World Health Organization (WHO) to develop benchmarks for Ayurvedic practices and training standards (Ministry of AYUSH, 2020).

#### 4. Consumer Demand for Natural Products

The growing preference for natural and organic products has driven the demand for Ayurvedic wellness products, such as herbal cosmetics, immunity boosters, and nutraceuticals. Companies like Patanjali, Dabur, and Himalaya have leveraged this demand, propelling Ayurveda into global markets (Khan et al., 2021).

### **Global acceptance**

Ayurveda has been recognized as a complementary and alternative medicine (CAM) system in several countries. The global wellness industry, valued at \$4.4 trillion in 2020, has provided a platform for Ayurveda to gain traction as a natural healthcare solution (Global Wellness Institute, 2021). Countries like the United States, Germany, and Australia have incorporated Ayurvedic therapies into wellness



centres, spas, and CAM practices. Collaborative research between Indian and international universities has bolstered Ayurveda's credibility, facilitating its acceptance worldwide.

#### Holistic Approach to Health

Ayurveda emphasizes balancing physical, mental, and spiritual health, resonating with the global focus on preventive wellness. It is particularly effective for chronic conditions like stress and anxiety, as highlighted by Patel et al. (2020).

#### Scientific Validation

Research supports Ayurveda's efficacy, with studies showcasing turmeric's anti-inflammatory benefits for arthritis (Chandran & Goel, 2012) and ashwagandha's stress-reducing properties (Cooley et al., 2009).

#### Government and WHO Support

The Indian Ministry of AYUSH promotes Ayurveda through initiatives like the National AYUSH Mission, with WHO recognizing it as a legitimate traditional medicine system, enhancing global acceptance (WHO, 2013).

#### Integration with Modern Medicine

Combining Ayurveda with conventional treatments, such as panchakarma for lifestyle diseases, has improved outcomes, as noted by The Lancet (2018).

#### Demand for Natural Remedies

The global shift toward natural health solutions has boosted Ayurveda's appeal due to its plant-based, sustainable treatments (Agarwal, 2021).

#### Ayurvedic Tourism

The spread of Indian culture has popularized Ayurvedic wellness tourism globally, with an increasing number of centres offering treatments for mindfulness and wellness (Brown & Srinivasan, 2022).

### Conclusion

Ayurveda is a science that transcends time, seamlessly integrating primordial wisdom with contemporary relevance. It provides profound insights into health and well-being by emphasising the interconnectedness of life and harmony inherent in its holistic approach. The historical origins, core principles, and evolution of Ayurveda into the contemporary era have been the subject of this review, which has illuminated the factors that have contributed to its global acceptance and the obstacles that lay ahead. The vulnerability of indigenous knowledge systems to external forces is underscored by the decline of Ayurveda during the colonial period. Nevertheless, the enduring relevance of traditional medicine in addressing contemporary healthcare challenges is emphasised by its resilience in rural communities and subsequent revival.

In the present day, Ayurveda is not only a fundamental component of India's healthcare system, but it is also a topic of global interest, distinguished by its natural remedies and holistic approach. The significance of preserving the essence of



traditional knowledge while adapting it to contemporary requirements is underscored by the legacy of Ayurveda. As the world struggles with environmental sustainability and chronic maladies, Ayurveda provides a means to achieve a more harmonious and balanced lifestyle. Its potential to address contemporary health challenges through natural, preventive, and personalised care is indicated by its global resurgence. The integration of Ayurveda with modern technologies and its increasing global recognition present transformative opportunities, despite ongoing challenges such as scientific validation and regulatory standardisation. The future of sustainable and integrative global healthcare systems is on the brink of being significantly influenced by Ayurveda's ability to connect its ancient wisdom with contemporary rese.

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# "SLASH2CHAR: AN INCREDIBLE ORGANIC FARMING STRATEGY WITH BIOCHAR"- A REVIEW

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## **Abstract**

Crop residue burning is a major problem in Punjab and has emerged as a major environmental concern, leading to health problems. In order to curtail crop residue burning, biochar production aids an effective measure that replaces traditional "slash and burn" ethos with "slash and char" practices. It is an innovative farming technique that integrates the principles of traditional slash-and-burn agriculture with biochar production, offers a sustainable solution for enhancing soil fertility, reducing carbon emissions, and promoting organic farming. It is an effective approach for carbon sequestration in soil. Its applications encompass waste management, bolstering crop resilience, reducing reliance on chemicals, and promoting organic farming. This review explores the methodology, benefits, and challenges of char production while discussing its implications for sustainable agriculture and climate change mitigation in Punjab.

**Key words:** Biochar, Pyrolysis, carbon sequestration and waste management.

## **Introduction**

India, as the world's second-largest agricultural based economy, annually witnesses the burning of substantial amounts of agricultural waste, particularly crop residue. This practice causes an excessive amount of particulate matter to be released, which severely pollutes the air. Crop residue burning has emerged as a significant environmental concern, leading to health problems and contributing to global warming. In order to curtail these problem and rising need for sustainable agricultural practices has catalyzed biochar production as an effective technique which replaced traditional "slash and burn" ethos with "slash and char" practises.

Biochar, a carbon-rich product derived from the pyrolysis of organic materials (agricultural waste, wood chips and organic waste) by heating in the absence of



oxygen and has ability to improve soil health, sequester carbon, and enhance crop yields (Ghodake et al., 2021). Slash to Char transforms the traditional, slash-and-burn farming method into a carbon-negative approach by converting biomass into biochar instead of ash. Through this technique approximately 12% of the total anthropogenic carbon emissions by land-use changed in to biochar and can be stored in the soil (Layek et al., 2022). Compared to the original biomass, biochar has a high carbon concentration which is resistant to degradation, which increases its long-term stability in soil. (Yaashikaa et al., 2020). Pyrolysis at low temperatures in an oxygen-free environment yields this fine-grained, carbon-rich, porous product. When amended to soil, biochar improves water retention, increases soil surface area, and interacts with soil matrix, microbes, and plant roots. It also aids in nutrient retention and biogeochemical processes by increasing pH, increasing the earthworm population, and reducing fertilizer usage. Production of biochar can help in carbon Sequestration that has the immediate potential to turn into carbon dioxide gas and permanently storing the carbon dioxide in a stable form (Siegelman et al., 2019).

It helps in nutrient retention, reforms of soil profile, pH Regulation, carbon sequestration, contaminant remediation, livestock waste management etc. It also helps in reduction of greenhouse gas emissions, can be used as a valuable tool in sustainable agriculture and environmental management. However, its effectiveness can depend on factors such as feedstock selection, production methods, and application rates, which should be carefully considered for optimal. Significant variations seen in biochar characteristics were attributed to feedstock variation since pyrolysis conditions were constant. The yields of biochar ranged from 28% to 39% and average carbon content was 51%.

### **Background and Rationale**

Slash-and-burn is a farming method where vegetation is cut and burned to clear land for cultivation. While this technique temporarily increases soil fertility, it has several drawbacks, including:

- Release of greenhouse gases (GHGs).
- Loss of organic carbon in the soil.
- Long-term soil degradation and deforestation.

Punjab is an intensive agriculture predominates state and stubble burning surges 63% rise since 2022 creates a major environmental Concern. The Government has, banned the burning of crop residue “Under the Air (Prevention and Control of Pollution) Act, 1981. There has been an increase in interest in environmentally friendly and sustainable agricultural methods in Punjab. A potential remedy for these issues in agriculture is biochar (Lehmann, J., & Joseph, S. 2015). According to Vancouver, 2023, research's analysis of the Global Biochar



Market value around 160.9 Million USD in 2021 and expected to reach around 454.3 Million USD in 2030 (Global Market Insights 2021–2030.)

### **Methodology**

Pyrolysis at 300–700°C under low oxygen circumstances produces biochar. This controlled atmosphere preserves biomass carbon and inhibits total burning. The feedstock for biochar manufacturing is varied:

- Common agricultural leftovers include maize stalks, rice husks, and sugarcane bagasse. Many agricultural locations have ample but underutilised these minerals.
- Biochar production from forest trash reduces wildfire risks and enhances forest management methods.
- Animal manure provides nutrients and serves as a fuel for biochar production.
- Pyrolysis can be done in tiny kilns for farmers or huge industrial systems for businesses. Innovative mobile pyrolysis units have made the technique accessible to rural farming communities. Pyrolysis can be economically viable by capturing gases and oils and using them as bioenergy.

### **Diversified material used to create Biochar**

Biochar production involves pyrolysis, a process carried out at temperatures ranging from 300–700°C under low oxygen conditions. This controlled environment prevents complete combustion and retains a significant portion of carbon in the biomass.

The feedstock for biochar production is diverse and includes:

- Agricultural residues: Common examples are corn stalks, rice husks, and sugarcane bagasse. These materials are often abundant and underutilized in many agricultural regions.
- Forest debris: Fallen branches, leaves, and other forest residues can be collected and processed into biochar, reducing wildfire risks and adding value to forest management practices.
- Animal manure: Manure from cattle, poultry, and other livestock not only serves as a feedstock but also contributes essential nutrients to the resulting biochar.

The pyrolysis process can be carried out using small-scale kilns for individual farmers or larger industrial systems for commercial operations. Innovations such as mobile pyrolysis units have made the technology accessible to remote farming communities. During pyrolysis, gases and oils released can be captured and used as bioenergy, enhancing the economic viability of the process.



### Processes of formation of Biochar

1. **Pyrolysis:** It includes heating biomass in absence of oxygen- to prevent burning and as a result biochar is produced. It can be done at lower temperature for longer time and yields a higher-quality biochar with more stable carbon is called slow pyrolysis. Whereas in fast pyrolysis biomass rapidly heating biomass at high temperatures, resulting in the production of bio-oil, syngas, and biochar.
2. **Hydrothermal Carbonization (HTC):** HTC involves subjecting wet biomass to high temperatures and pressures in an aqueous environment. It produces hydrocarbon, which is similar to biochar but has different properties.
3. **In-situ Carbonization:** This method involves burying or incorporating biomass into the soil, where it slowly undergoes carbonization over time. It can improve soil quality and sequester carbon

### Benefits of using of Biochar

**Soil Health Improvement:** The use of biochar improves Punjabi soil's capacity to store water and retain nutrients, as well as its overall fertility. This soil has suffered from chronic overuse, nutrient depletion, soil compaction, and a decline in the amount of organic matter.

**Water Pollution Mitigation:** The excessive use of pesticides and fertilisers in agriculture has had a negative influence on Punjab's groundwater. Biochar may be used to minimise nutrient runoff and pesticide leaching in order to enhance water quality and protect water resources. Ground water in Punjab has been significantly impacted by excessive fertiliser and pesticide use in agriculture. In order to improve water quality and safeguard water resources, biochar may be used to lessen nutrient runoff and pesticide leaching.

**Climate Change Mitigation:** Punjab's agricultural practices contribute to greenhouse gas emissions, particularly through the release of nitrous oxide from fertilizers. Incorporating biochar into soil can sequester carbon and reduce emissions of nitrous oxide, contributing to climate change mitigation.

**Crop Resilience:** Biochar-amended soils have the potential to improve the resilience of crops to drought and water stress. Given Punjab's water scarcity issues, using biochar could help crops withstand periods of low water availability.

**Waste Management:** Punjab generates substantial agricultural and organic waste, which can contribute to pollution and health problems if not managed properly. Converting this waste into biochar could provide a sustainable waste management solution while also producing a valuable soil amendment.

**Livestock Farming:** Punjab has a significant livestock industry, and biochar



could be used to manage livestock waste, reducing odors and pathogens while also creating a useful product for soil amendment.

**Reduced Chemical Dependency:** The use of biochar could potentially reduce the need for synthetic fertilizers and chemicals, promoting more sustainable and environmentally friendly agricultural practices.

**Agroforestry and Land Rehabilitation:** Biochar could aid in reforestation efforts, improving soil conditions for tree growth and helping to restore degraded lands.

**Carbon Sequestration:** Biochar locks carbon in a stable form, reducing atmospheric CO<sub>2</sub>. Each ton of biochar can sequester approximately 3 tons of CO<sub>2</sub> equivalent.

**Reduction in Greenhouse Gas Emissions:** Slash to Char significantly reduces methane (CH<sub>4</sub>) and nitrous oxide (N<sub>2</sub>O) emissions compared to slash-and-burn.

### **Punjab scenario of stubble burning**

**Air Quality Improvement:** Open burning of crop residues in Punjab is a major contributor to air pollution and smog. Instead of burning these residues, they could be converted into biochar, reducing air pollution and generating a useful product. However, it's important to consider the specific conditions in Punjab, including the types of crops grown, soil characteristics, climate, and the socio-economic context. Successful implementation of biochar practices would require research, education, awareness campaigns, and collaboration among government agencies, farmers, researchers, and environmental organizations. Additionally, factors such as biochar production methods, feedstock selection, and proper application rates would need careful consideration to ensure effective and sustainable outcome. **Educational and Research Opportunities:** Introducing biochar usage could provide educational and research opportunities for agricultural institutions in Punjab, fostering innovation and sustainable practices.

### **The Barriers and Challenges using biochar in Punjab**

The Barriers of using biochar, not widely known, may lack awareness of its benefits and proper usage. Education and outreach efforts are needed to inform farmers about the potential advantages of using biochar.

**Crop Diversity:** Punjab is known for its major crops such as wheat and rice. The feasibility and benefits of using biochar might vary depending on the specific crops grown in the region. Research and pilot projects could have focused on assessing the impact of biochar on these staple crops.

**Technical Expertise:** Producing high-quality biochar requires understanding the pyrolysis process, feedstock selection, and optimal application methods. Farmers



might lack the technical expertise needed to produce and use biochar effectively.

**Limited Infrastructure:** The production of biochar requires specific equipment and facilities for pyrolysis. In areas with limited infrastructure or access to suitable technology, setting up the necessary equipment can be a significant challenge.

**Resource Constraints:** Establishing a biochar production system and applying biochar to fields can require financial resources for equipment, feedstock procurement, and training. Limited financial resources might hinder adoption.

**Feedstock Availability:** The availability of suitable feedstock for biochar production can be a challenge. Identifying and sourcing appropriate biomass materials might require additional efforts. **Scalability:** Scaling up biochar production to a level that can have a significant impact on agricultural practices can be challenging. Ensuring consistent quality and quantity of biochar at a larger scale requires careful planning.

**Integration with Local Practices:** Introducing a new agricultural practice like biochar needs to align with existing farming practices. Farmers might be hesitant to adopt something that seems unfamiliar or disrupts their traditional methods.

**Perceived Risks:** Farmers might perceive risks associated with using biochar, such as negative effects on crops, soil, or even human health. Demonstrating the safety and benefits of biochar is crucial to overcoming these concerns.

**Time Investment:** Incorporating biochar into farming practices might require additional time for learning, production, and application. Farmers with busy schedules might be reluctant to invest time in a new practice.

**Regulatory and Policy Issues:** Lack of clear regulations or policies regarding biochar production, use, and its potential impacts can create uncertainty and hinder adoption.

**Market Development:** Creating a market for biochar products can be challenging. Finding buyers for biochar and developing value chains for its distribution and application can be complex.

**Socioeconomic Factors:** Socioeconomic factors, including access to resources, land tenure systems, and cultural beliefs, can influence the adoption of new agricultural practices.

**Long-Term Commitment:** Biochar's benefits often take time to become evident. Some farmers might be reluctant to commit to a practice that might not yield immediate results.

### **How to mitigate the problem of stubborn burning**

**Awareness and Research:** Researchers, agricultural institutions, and environmental organizations in Punjab have likely conducted studies to assess the



feasibility and effectiveness of using biochar in various agricultural contexts. These studies would aim to evaluate its impact on soil health, crop productivity, and environmental sustainability.

**Government Initiatives:** Depending on the state of awareness and the recognition of biochar's potential benefits, the government of Punjab might have launched initiatives or programs to promote the adoption of biochar in agriculture. These could include subsidies, training, and awareness campaigns.

**Collaboration and Partnerships:** Collaboration between agricultural research institutions, government bodies, non-governmental organizations (NGOs), and farming communities would be crucial for the successful implementation of biochar practices. Partnerships could help disseminate information, provide technical support, and address challenges.

**Environmental Concerns:** While biochar offers several benefits, its production could also raise environmental concerns if not properly managed. Proper sourcing of feedstock, efficient production processes, and responsible land application would be important considerations to avoid unintended negative impacts.

**Local Innovation:** Farmers and communities might have experimented with biochar production and application on a smaller scale. Local innovations and knowledge sharing could have played a role in the gradual adoption of this practice

## Conclusion

Slash2Char represents a transformative approach to sustainable agriculture, blending traditional practices with modern ecological science. By enhancing soil health, reducing carbon footprints, and mitigating climate change impacts, this strategy can pave the way for resilient farming systems worldwide. However, its success hinges on addressing economic, educational, and logistical barriers to widespread adoption.

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# ENGLISH: THE INTERNATIONAL LINGUA FRANCA

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## **Abstract**

This paper examines the function of English as a lingua franca, serving both as a medium of communication and a means of identity. The designation of English as a lingua franca reflects its global role in facilitating interaction. The English language has achieved the status of a universal communication tool, representing a unique phenomenon in the history of world languages. It serves as a comprehensive and effective means of communication for a diverse range of individuals, including professionals, scholars, researchers, and educators. As the global lingua franca, English facilitates communication not only among native English speakers and those who speak English as a second language but also among individuals from various linguistic backgrounds. English continues to be taught globally as a key national standard, establishing itself as the predominant medium for international communication and an active area of scholarly research.

**Keywords:** English, Language, Lingua Franca, Communication, Global and Universal.

## **INTRODUCTION**

English is the most widely spoken language in the world and serves as a bridge to bridge linguistic divides, it is both a sui generis lingua franca and the dominating medium of international communication. A lingua franca is a language that is systematically employed to facilitate communication between individuals who do not share a first language, especially when that language is a third language that differs from both first language speakers.

The term lingua franca was first emerged during the middle Ages and described a language created as a combination of French and Italians that was developed by the crusaders and tradesmen in the Mediterranean. Today, English is a common lingua franca across the globe. According to survey, almost 80 percent of English speakers in the world are non-native speakers. UNESCO defined lingua franca in 1953 as "a language which is used habitually by people whose mother tongues are different in order to facilitate communication between



them"[1] .So English as a lingua franca is a name given to the language in its universal function and it has become a vibrant area of research.

## **English in the World**

### **1. Globalization**

English has long been an influential and dominant tool of communication and has gained the status of a language of global communication, and as such it presents a unique phenomenon that has no equivalent in the history of the world languages. Globalization may be thought as the widening, deepening and speeding up of worldwide interconnectedness in all aspects of contemporary social life. [2]

“English is the largest of human tongues, with several times the vocabulary of the second largest language this alone made it inevitable that English would eventually become, as it did, the lingua franca of the planet, for it is thereby the richest and the most flexible ,English swallows up anything that comes its way, makes English out of it.” [3]

English has come to us as a connecting link among various countries .U.N. has recognized five languages as its official languages and of them English takes the first position because of its background, international acclaim of easy access to the people. English serves as a window to the world. It is known to all that the legacy of English language has left an indelible imprint on the Indian psyche. Hence we can't deal with English just as foreign language. Secondly, the entire spectrum of education and philosophy, science and technology can be better understood through this language. English is now used exclusively as the language of Science. English has emerged as the most important global language and the de facto global language of science. English is the primary language of not only countries actively touched by British imperialism, but also many business and cultural spheres dominated by those countries. It is the language of Hollywood and the language of international banking and business. As such, it is a useful and even necessary language to know.

English is like no other language in its current role stands towering high internationally, indeed like no other at any moment in history. English with its wide open arms is serving the world more interconnected, making our networks extending further and bringing the different cultures and boundaries under one roof. Over the years English inarguably has reached a status of an international language and commonly is characterized as a lingua franca. It has become the language that is spoken by millions of groups and people all over the world; as the mother tongue, as the language used for international communication and as the language learned in the millions of schools.



“The status of English is such that it has been adopted as the world's lingua franca for communication... Unlike any language past or present, English has spread to all five continents and has become a truly global language. [4]

## **2. New Tags**

English being queen of all the languages and means of international communication has been awarded with variety of names. Labels include English as an International Language (EIL), World English, English as a global language, World Standard (Spoken) English, Euro-English, English as the Global Lingua Franca (EGLF), Globish, Lingua Franca English and English as a Lingua Franca (ELF).

## **3. Travel and Business**

The most optimum route to the zenith of success revolves across the English language. It is the firm foundation to become successful and has been considered as an asset to find better job. English is the language which connects people from different regions, cultures and nations. It has helped the world in sharing any kind of information swiftly and clearly without any translation. It has become a need for students, employers and professionals to perform efficiently in international job settings. It has become the official language in most of the companies these days. Fluency in English has become important in business world and knowledge of English is one of the most vital employability skills. It includes presentation skills, convincing and negotiation skills and interpersonal skills. When you advertise your business, greet your customer, implement transactions, and follow ups to make sure customer satisfaction, English comes handy unlocking opportunities that bring profit and success.

English skills will also help you in any business venture you choose to follow. If you visit some offices, companies, governmental organizations, or even math or engineering companies, you will see the importance of English. Any big company will hire their professional staff after getting to know whether the people they are hiring are good at English or not. Companies who want to function at an international level only consider their staff well educated if they are good English speakers, writers, and readers.

“Team work for better success” is the mantra followed by most of the companies. So there is less space for individual fame. Employees are expected to be interactive and communicative with others in the teams and outside.

## **4. The Internet and Press**

Today's android based generation is addicted to Internet which is the popular source of gaining information. Majority of websites are written and created in



English. Even sites in other languages often give you the option to translate the site. It's the primary language of the press: more newspapers and books are written in English than in any other language, and no matter where in the world you are, you will find some of these books and newspapers available. It is so dominant and influential in international communication, you will find more information regarding nearly every subject if you can speak this language. Most of the content produced on the internet is in English. Online, on tablets, smart phones, and e-readers, we read constantly. So only English allow access to an incredible amount of information which may not be otherwise available.

These days the world's top books, films, magazines and music are published and produced in English. Therefore English is the key to a great wealth of entertainment and greater cultural understanding. It has evolved be a language of science and technology. Majority of all important books for higher studies are written in English. English is also essential to the field of education. In many countries, children are taught and encouraged to learn English as a second language. Even in countries where it is not an official language, we will find many syllabi in science and engineering are written in English. Because it is the most dominant language in the sciences, most of the research and studies you find in any given scientific field will be written in it as well. At the university level, students in many countries study almost all their subjects in English in order to make the material more accessible to international students.

English is a language that is frequently used to exchange knowledge and stimulate global trade. English is the dominant language in many European and international institutions and has already established itself as the unofficial language in a number of industries, including computer technology, aviation, and tourism. Shakespeare's language also opens doors to the world and provides people with a global and universal perspective. Travelling is necessary. English will be the language of communication for any visitor to a foreign country. Additionally, consumers may access a multitude of English-language culture, including music, literature, and films, due to the popularity and widespread usage of English around the globe. Socially speaking, people are also influenced by the idea that English has a lingua franca would set people on an equal footing to clear up the differences of origin.

English exists in the world today as a mode of international communication as a way for people from different social groups to communicate with each other and to fulfill this function it would seem that disparity in the language needs to be condensed to a certain extent. That is to say, if the language becomes too diverse it will not remain mutually comprehensible across different social groups. So we have two impulses at work that are seemingly incompatible, or perhaps even in conflict, and the question we are faced with is how to render them as consistent, as



both being part of the existence of a single entity we call 'English'. This is one of the central issues in English language studies today – and it's a very modern issue because it has come about as a direct result of the unprecedented position that English now occupies in the world: as a language with global scope which is implicated in the history and present-day existence of societies all around the world.

People in the world have huge interest in learning English which is considered as one of the top desired languages. Learning English can be described as English mania. Almost two billions of people try to learn the language; it is more than one quarter of overall world population. This could be perfectly encapsulated by the words of Jay Walker: “The world has new obsession. Obsession of learning English.

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# “IMPACT OF COVID-19 ON EDUCATION, WITH A FOCUS ON PUNJAB, INDIA”

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## Abstract

The current corona virus pandemic had a major impact upon the health, economy and education worldwide. In India, the government as a part of the nationwide lockdown closed all educational institutions, as a consequence of which, the teaching-learning, examination and placement scenario of students were affected. UNESCO estimated that about 32 crore students have been affected in India. Covid-19 pandemic has become an international emergency in a short period and will have long-lasting effects. Within a short span of the COVID-19 pandemic, many researchers have shared their works on teaching and learning in different ways. Several schools, colleges and universities have discontinued face-to-face teachings. There is a fear of losing 2020 academic year or even more in the coming future. The need of the hour is to innovate and implement alternative educational system and assessment strategies. The COVID-19 pandemic has provided us with an opportunity to pave the way for introducing digital learning. This paper aims to highlight the impact of the COVID-19 pandemic on Education system in Punjab State. This present article helps to portray the advantages and disadvantages of online learning and how students, teachers and society are trying to accept the new education platforms. Online learning is just come into limelight after COVID-19 Pandemic.

**Keywords:** COVID-19 pandemic, online learning, technology, cross-sectional study, student's perception, factor analysis.

## Introduction

The World Health Organization (WHO) announced on February 11, 2020 the emergence of unidentified Virus, named COVID-19 from Wuhan, China in late December 2019. Many countries around the Globe faced unique challenges because of this pandemic (WHO, 2020). The first case of this novel corona virus was reported on January 30, 2020. One of the major impacts that affected the student's lifestyle was the closure of schools, colleges, and other educational institutions. This study we conducted focuses on the various positives and negatives faced by graduate students from various universities based in India and



their opinion on online-based learning. Initially, most governments have decided to temporarily close the schools to reduce the impact of Covid-19. Many students struggled to obtain the gadgets required for online classes. Teachers who are all experts Blackboard, Chalk, books, and classroom teaching were new to this digital teaching, but they adopted the new methods and handled it like a pro to aid the students in the current position. But on the negative side, many teachers were looking for an alternative job to support their families. The shutting down of colleges and the selection of shifting traditional classrooms to digital systems is not simplest developing gaining knowledge of inequality among children, but moreover pushing a massive sort of children out of school/college due to the digital divide. Other than gaining knowledge of the absence of education would possibly moreover have an extended lasting effect on the health and vitamins of children. However, while online learning can offer many benefits, distance education isn't necessarily the right choice for everyone. Some students may achieve better educational outcomes in a traditional, on-campus setting, which come with advantages of its own. To get the most out of your degree, it's important to determine which style of learning works best for you. Further, we've compared the pros and cons of online college vs. traditional college. The key differences while students are choosing between online or in-person learning are scheduling flexibility, course structure, learning environment, the role of technology, the need for self-motivation, and exposure to networking opportunities.

### **Literature Review**

Prava (2020) found that the educational institutions get closed and created many challenges for students and professors. Along these lines, the exercises like assessments, entrance tests, serious assessments, and confirmations led by numerous universities, schools, and colleges are dropped. Pravat (2020 b) reveal that the students and teachers expanded the utilization of web for sharing data by utilizing Google drive, WhatsApp, Twitter, Telegram etc. The Pandemic has made it hard for scientists to travel and cooperate with others. Some project is made complicated to do because of joint research and also scientific laboratory research work would not be conducted. E-conferences and Webinars became normal for sharing their academic ideas. They increased their skills for publishing their books and articles in their free time (Petrie, 2020). As schools have been closed to cope with the global pandemic, students, parents and educators around the globe have felt the unexpected ripple effect of the COVID-19 pandemic. While governments, frontline workers and health officials are doing their best slowing down the outbreak, education systems are trying to continue imparting quality education for all during these difficult times (Doucet et al., 2020). The flipped classroom is a simple strategy for providing learning resources such as articles,



pre-recorded videos and YouTube links before the class. The online classroom time is then used to deepen understanding through discussion with faculty and peers. This is a very effective way of encouraging skills such as problem-solving, critical thinking and self-directed learning. According to Maurin & McNally, (2008) it is also possible that some students careers might benefit from the interruptions. For example, in Norway, it has been decided that all 10th grade students will be awarded a high-school degree (Subedi et al., 2020). E-learning tools have played a crucial role during this pandemic, helping schools and universities facilitate student learning during the closure of universities and schools. While adapting to the new changes, staff and student readiness needs to be gauged and supported accordingly. The learners with a fixed mindset find it difficult to adapt and adjust, whereas the learners with agrowth mindset quickly adapt to a new learning environment.

### **Objectives**

1. To find out how COVID-19 pandemic affected the educationamong college students
2. To identify the student's preference between online
3. To study the effect of online classes on students'health and financial stability of their parents.
4. To examine the difficulties faced by students for learning during COVID-19 pandemic.

### **Database and Methodology**

#### **Study design**

The study is an attempt to seek online feedback of the students regarding this transition. For this purpose, data were collected with the aid of structured questionnaires (in Google Forms) drawn online from 200 students of various higher educational institutions of Punjab from October, 2020. The questionnaire was also circulated among other students by using the technique of snowball sampling.

#### **Sample size**

Study has been conducted on 150 teachers working in engineering colleges of border area of Gurdaspur, Punjab, India.

#### **Designing of questionnaire**

The questionnaire was designed with open-ended, close-ended and Likert-scale questions. The questionnaire consisted of three sections. The first section included the details regarding the socio-demographic details of the respondents.



The second section explored the information regarding online classes attended by the respondents, duration of classes, types of devices, applications and platforms used by students. The third section examined the students' perception toward online classes. A five-point Likert scale was employed to determine the perception of students regarding quality of audio and video lectures, instructors' content, preparation, instructiveness, discussion regarding doubts and assessing likes and dislikes of students. The responses were categorized such as strongly disagree, disagree, neutral, agree and strongly agree. A Likert scale was used to rate various statements by respondents to elicit a degree of agreement or disagreement about stimulus objects

## Results

This section explains the results of the present study on the basis of details obtained from the 200 questionnaires surveyed. The data were encoded-decoded first, and then it was analysed using SPSS version 21. The questionnaire was formulated in three sections, as already stated in the previous section. The results related to each section are explained below separately. Socio-demographic details in the first section the socio-demographic details of the students such as age, gender, class and nature of educational institutions have been analyzed. Table 1 presents the distribution of students according to the age. A major share of students, i.e. 115 (57.5%) students, was from the age group of 15-20 years. It has been found that 81 (40.5%) students belong to the age group of 20-25 years and 4 (2%) students come under the category of 25 and above. Table 2 exhibits the statistics regarding the sex composition of the students. Out of 100% data, 60% students were female and 40% were male. Table 3 shows the educational level of the students. The majority of the sampled respondents enrolled were in bachelor's degree category, i.e. 155 (77.5%), followed by 37 (18.5%) students from masters and above and 8 (4%) students were in diploma courses. It is evident from Table 4 that 128 (64%) students belong to aided educational institutions and 72 (36%) belong to government educational institutions.

Table 1. Age wise classification of student information regarding online classes

Age-group	Frequency.	Percent
15-20	115.0	57.5
20-25.	81.0	40.5
25 and above	2.0	4.0
Total	200	100

The second section examined the information regarding usage of online teaching-learning tools, duration of the classes, devices used and online application used for teaching by teachers. Figure 1 presents the online teaching-



learning tool employed by educational institutions. As shown in diagram, majority of educational institutions in Punjab preferred live videoconferencing tool (37%), online teaching applications (31%) followed by using the social media without streaming (10%), through video recording, e-learning platform (7%), audio recordings (5%) and social media via live streaming (3%). The next question asked to the students was about the duration of classes. Figure 2 highlights that students attended classes, in order of importance; that is more than 4 hr/day (47%), 2–4 hr/day (22%), 1–2 hr/day (10%) and less than 1 hr/day (21%). Figure 3 highlights that the majority of students (94%) used smart phones to attend their online classes and the remaining 6% of students used laptops/personal computers for the classes.

**Table 2. Distribution of sampled students according to the gender**

Gender	Frequency	Percent
Male	80	40
Female	120	60
Total	200	100

**Table 3. Distribution of students as educational level.**

Classes enrolled	Frequency.	Percent
Diploma.	8	4.0
Bachelor's degree	155	77.5
Masters and above.	37	18.5
Total	200	100

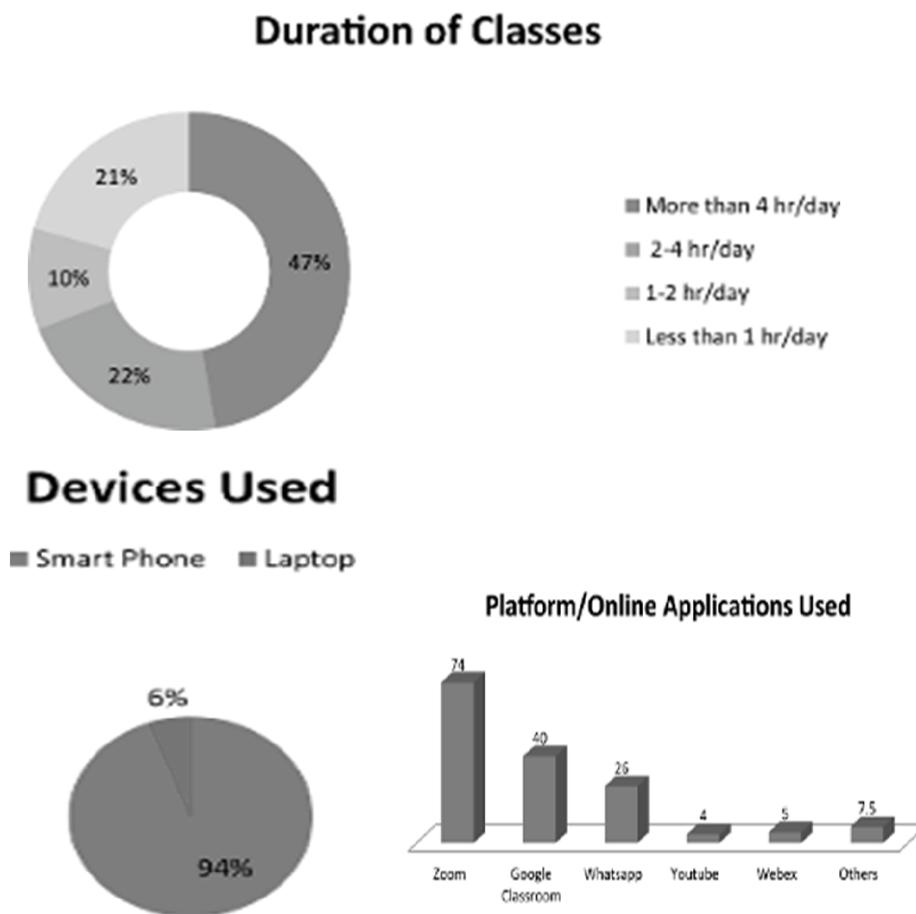
**Table 4. Category of educational institution**

Type of educational institution	Frequency	Percent
Government	72	36
Aided.	128	64
Total	200	100



The next section of this segment explains the platform/application used for attending online classes. The majority of students, i.e. 74% attended online classes by using Zoom application, followed by 40% using Google Classroom, 26% via WhatsApp, 5% used Webex, 4% used YouTube and 7.5% used other platforms like Cisco, Teams etc (see Figure 4).

4.3 Students perception the main objective of the present study was to know the opinion of the students about their knowledge, perception and preference toward e-learning. This section revealed the perception of students toward online classes. Table 5 shows that 101 (50.5%) students liked the online/virtual classes and 99 (49.5%) students did not like the online mode of classes and instead preferred face to face interactive classes. The first step was to check the reliability of the items by applying Cronbach's alpha method. Cronbach's alpha is scale reliability test, used to check the internal consistency. The values hover between zero and one, and closer the value nearing one, better it is.



**Figure 3 Devices used to attend online classes**



## Conclusion

The Government made all efforts to prevent the spread of the corona virus pandemic. Among other steps, the government suspended classroom teaching and started promoting e-learning platforms. This online teaching-learning approach becomes the constructive and advantageous method to achieve academic excellence. The educational institutes universities have adopted this e-learning platform to impart the education. Through the adoption of online teaching, an attempt has been made to minimize the loss of students and stress among students. Approximately 90% of the teachers and students had converted their class rooms to online mode during the present time. Remaining 10% students were nonmeeting online classes because of poor Internet connectivity and absence of smart phones as they belonged to poor families. Moreover, this sudden transition from regular mode to virtual classes was not easy for students as well as teachers. The present paper observed the perception of students of higher education in Punjab on the sudden online transition amid the pandemic. The survey was conducted on 200 students from different regions of Punjab, through a comprehensive and well-trained questionnaire. This questionnaire covered 30 statements related to online education. The study adopted factor analysis method to identify the various factors. The positive factors of preferring online education is instructors competence, accessibility, instructiveness, effectiveness; expanding expediency; and the factors like personal problems, technical problems and lack of motivation hinder the priorities of students toward online education. The training of instructors by school administrations must be sufficient to provide a seamless online environment. From a pragmatic view, online classes can help our country's educational development. In order to provide our pupils, the brightest future, we must encourage our administration to accept online education. As, students are exploring more opportunities by increasing their knowledge. Everyone takes their time to adapt this new platform of learning and deal with the situation effectively.

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# CO<sub>2</sub> CAPTURE FROM BIOMASS EMISSION SOURCES: A SHORT REVIEW

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## **Abstract**

Greenhouse gas (GHG) mitigation is essential to combat climate change, with carbon dioxide (CO<sub>2</sub>) capture and storage (CCS) emerging as a transformative strategy. This review explores the potential of CCS to mitigate CO<sub>2</sub> emissions from biomass energy systems, emphasizing its ability to achieve net-negative emissions. CCS involves capturing CO<sub>2</sub> from industrial and energy sources, transporting it, and securely storing it in geological formations or through mineral carbonation. Biomass energy systems integrated with CCS, known as Bioenergy with Carbon Capture and Storage (BECCS), offer a sustainable solution by addressing GHG emissions, managing bio-waste, and supporting rural development. While current CCS technology captures 85–95% of CO<sub>2</sub> emissions, challenges such as high energy requirements, economic feasibility, and long-term storage risks hinder large-scale deployment. In India, integrating CCS into bioenergy systems aligns with the nation's goals of energy security, waste management, and climate commitments. This review highlights the need for advancements in technology, regulatory frameworks, and public acceptance to scale CCS adoption. By leveraging its vast biomass resources and promoting international collaborations, India can lead in sustainable climate solutions. CCS, particularly in bioenergy applications, is a critical pathway toward achieving a low-carbon and sustainable future.

## **1. Introduction**

Mitigating atmospheric greenhouse gas (GHG) concentrations is critical to slowing the progression of global climate change. Various strategies have been proposed and implemented to achieve this goal, including the transition to



renewable energy, improvements in energy efficiency, and the deployment of advanced carbon capture and storage (CCS) technologies (IPCC, 2022). CCS has emerged as a transformative solution, particularly for hard-to-abate industries and energy sectors. By capturing carbon dioxide (CO<sub>2</sub>) at its source, transporting it, and securely storing it in geological formations or stabilizing it through mineral carbonation, CCS provides a pathway to significantly reduce atmospheric CO<sub>2</sub> levels (IEA, 2021).

When integrated with biomass energy systems, CCS has the potential to achieve net-negative emissions. This synergy, known as Bioenergy with Carbon Capture and Storage (BECCS), combines the natural carbon absorption of biomass with advanced CO<sub>2</sub> capture technologies, enabling the removal of more CO<sub>2</sub> from the atmosphere than is emitted. BECCS offers a sustainable approach to addressing climate change, with benefits such as reducing GHG emissions, managing bio-waste, and supporting rural economic development (Smith et al., 2016).

India, with its abundant agricultural residues and organic waste, holds significant potential to leverage BECCS for achieving its climate and energy goals. Integrating CCS into biomass energy systems aligns with India's objectives of enhancing energy security, promoting sustainable waste management, and meeting its international climate commitments (TERI, 2023). However, the deployment of CCS faces considerable challenges, including high energy requirements, economic constraints, and uncertainties related to long-term storage integrity (Global CCS Institute, 2022). Addressing these barriers necessitates advancements in technology, the establishment of robust regulatory frameworks, and greater public acceptance.

This explores the potential of CCS in mitigating CO<sub>2</sub> emissions, with a focus on its application in biomass energy systems. It highlights the current state of CCS technology, its role in achieving net-negative emissions, and the opportunities for India to lead in this domain through international collaboration and policy innovation. By advancing CCS within bioenergy applications, India can significantly contribute to global climate goals and foster a sustainable, low-carbon future.

## **2. Various methods have been proposed and implemented to achieve this goal, including:**

### **Improving energy efficiency.**

- Transitioning to less carbon-intensive fuels.
- Utilizing nuclear power.
- Promoting renewable energy sources.
- Enhancing biological carbon sinks.



- Reducing emissions of non-CO<sub>2</sub> greenhouse gases.
- Carbon dioxide (CO<sub>2</sub>) capture and storage (CCS).

Among these approaches, renewable energy adoption, biological sink enhancement, and CCS are especially crucial for bioenergy promotion in India. These strategies align with the nation's priorities to:

**Ensure energy security for all citizens.**

- Reduce GHG emissions.
- Manage the substantial bio-waste generated across the country.
- Additionally, bioenergy initiatives address ancillary objectives such as:
- Generating large-scale employment opportunities.
- Driving rural development.
- Carbon Dioxide Capture and Storage (CCS)

**However, the widespread adoption of CCS in India depends on several factors, including:**

- Effective technology transfer and diffusion.
- Economic viability and cost-efficiency.
- Technical feasibility and potential of the CCS system.
- Regulatory frameworks, environmental considerations, and public perception.
- Characteristics of CCS

**3. Key features of CCS technology include:**

- **Applicability to Large Point Sources:** CCS can be implemented at large-scale industrial facilities, including biomass energy plants.
- **CO<sub>2</sub> Transportation and Storage:** Captured CO<sub>2</sub> is compressed and transported for storage in geological formations, oceans, or through mineral carbonation.
- **Net Emission Reduction:** The overall emissions reduction depends on several factors, such as:
  - ✓ The fraction of CO<sub>2</sub> captured.
  - ✓ Additional CO<sub>2</sub> production due to efficiency losses in power plants using CCS.
  - ✓ Potential leakages during transport.
  - ✓ Long-term retention capacity of the storage site.
- **Capture Efficiency:** Current technologies can capture approximately 85–95% of CO<sub>2</sub> processed in a CCS plant.
- **Energy Requirements:** Power plants equipped with CCS systems require 10–40% more energy than equivalent plants without CCS, primarily for CO<sub>2</sub> capture and compression.



#### 4. A TYPICAL ILLUSTRATION OF ALGAL BIO-REFINERY INTEGRATED TO A CARBON CAPTURE & STORAGE SYSTEM

A typical illustration of an algal bio-refinery integrated with a Carbon Capture and Storage (CCS) system would feature several key components working together to capture CO<sub>2</sub> and convert it into valuable bio-products. Here's a breakdown of how such an integrated system might look:

- **CO<sub>2</sub> Capture and Utilization:**

- Industrial CO<sub>2</sub> emissions are captured using CCS technologies from sources like power plants or factories.
- The captured CO<sub>2</sub> is directed to the algae cultivation system for utilization.

**Algae Cultivation:**

- Algae are grown in **open ponds** or **photobioreactors (PBRs)**.
- During the day, algae perform photosynthesis, using sunlight, CO<sub>2</sub>, and nutrients to grow and accumulate biomass.

**Biomass Harvesting and Processing:**

- The algae, after absorbing CO<sub>2</sub>, are harvested for their biomass.
- The biomass is processed into various bio-based products such as biofuels, bioplastics, and animal feed.

**Conversion or Storage of CO<sub>2</sub>:**

- CO<sub>2</sub> can be converted into renewable energy sources like biodiesel or bioethanol.
- Alternatively, it can be stored underground or converted into stable forms like mineral carbonation.

**Integration with Renewable Energy:**

- The system can be powered by renewable energy sources such as solar or wind power to improve sustainability and reduce the carbon footprint.

**Wastewater Utilization:**

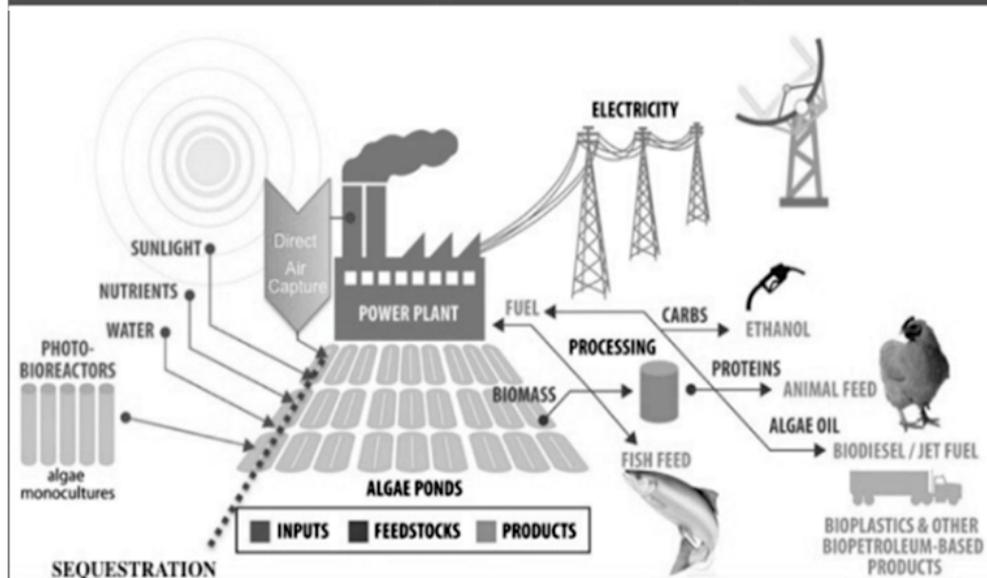
- Wastewater from industrial processes is used to provide essential nutrients (e.g., nitrogen, phosphorus) to the algae, reducing the environmental impact of the system.

**Sustainability and Environmental Benefits:**

- The integrated system offers a sustainable solution by recycling CO<sub>2</sub> and producing valuable products, while contributing to carbon reduction and resource optimization.



## Algal Bioenergy and Co-Products combined with Carbon Capture and Storage



<https://www.eesi.org/articles/view/marine-microalgae-the-future-of-sustainable-biofuel>

In India, where substantial amounts of agricultural and organic waste are generated annually, integrating biomass energy systems with CCS presents a sustainable and multifaceted solution (Verma et al., 2021). Such systems can significantly reduce waste by converting it into renewable energy while simultaneously achieving net-negative emissions (Chaudhary & Gupta, 2020). This approach aligns with India's goals of enhancing energy security, managing bio-waste sustainably, and meeting its international climate commitments (Sharma, 2022). By leveraging this potential, India can transform biomass into a strategic asset, addressing waste management challenges, reducing greenhouse gas emissions, and advancing its renewable energy portfolio (Patel et al., 2023).

### 5. Types of CO<sub>2</sub> Capture Systems

Several methods exist for CO<sub>2</sub> capture, each with specific applications based on the characteristics of the emission source:

- Post-Combustion Capture: CO<sub>2</sub> is separated from the flue gas after fuel combustion.
- Pre-Combustion Capture: CO<sub>2</sub> is captured from fuel gasification products before combustion.



- **Oxyfuel Combustion:** Combustion occurs in an oxygen-rich environment, resulting in a highly concentrated CO<sub>2</sub> stream.

## 6. Factors Influencing Capture System Selection:

The choice of capture system depends on:

- The concentration and pressure of CO<sub>2</sub> in the gas stream.
- The type of fuel being utilized (solid, liquid, or gas).
- Current Status of CCS Technology

## 7. Challenges in implementation:

**Lack of Integration:** There is limited experience in combining CO<sub>2</sub> capture, transport, and storage into a fully operational CCS system.

**Scale-Up Issues:** Large-scale deployment of CCS in power plants remains untested in most regions, including India.

**Economic Constraints:** High costs associated with CCS infrastructure and operation hinder widespread adoption.

## 8. Limitations of CCS Technology

Several challenges must be addressed to enable the effective deployment of CCS:

**Energy Penalty:** The additional energy required for CO<sub>2</sub> capture and compression reduces the overall efficiency of power plants.

**Storage Risks:** Long-term CO<sub>2</sub> storage poses risks of leakage, which could undermine its effectiveness as a mitigation strategy.

**Economic Viability:** High initial capital and operational costs make CCS less competitive compared to other GHG reduction methods.

**Regulatory and Public Acceptance:** The lack of comprehensive regulatory frameworks and concerns regarding environmental impacts and public safety hinder acceptance.

The Role of CCS in Biomass Energy

## 9. Biomass as a CO<sub>2</sub> Source and Sink:

Biomass energy systems hold a unique advantage in addressing climate change as they can function both as a source of CO<sub>2</sub> emissions and a carbon sink when integrated with Carbon Capture and Storage (CCS) (Smith et al., 2020). This dual functionality stems from the natural carbon cycle: biomass absorbs CO<sub>2</sub> from the atmosphere during growth, and when it is used for energy production, capturing and storing the resulting CO<sub>2</sub> creates a net-negative emissions system (Johnson & Williams, 2019). This capability makes biomass energy with CCS



(BECCS) an effective tool for reducing atmospheric carbon levels (Brown, 2018).

## 10. Conclusion

CO<sub>2</sub> capture and storage represent a critical component of global climate change mitigation strategies. When integrated with biomass energy systems, CCS offers unique advantages by enabling net-negative emissions. However, the success of CCS in India depends on overcoming challenges related to cost, technological integration, and public acceptance.

By addressing these challenges and leveraging its vast biomass resources, India can position itself as a leader in sustainable and innovative climate solutions. The adoption of CCS, particularly in combination with bioenergy systems, aligns with the nation's goals of energy security, rural development, and environmental sustainability.

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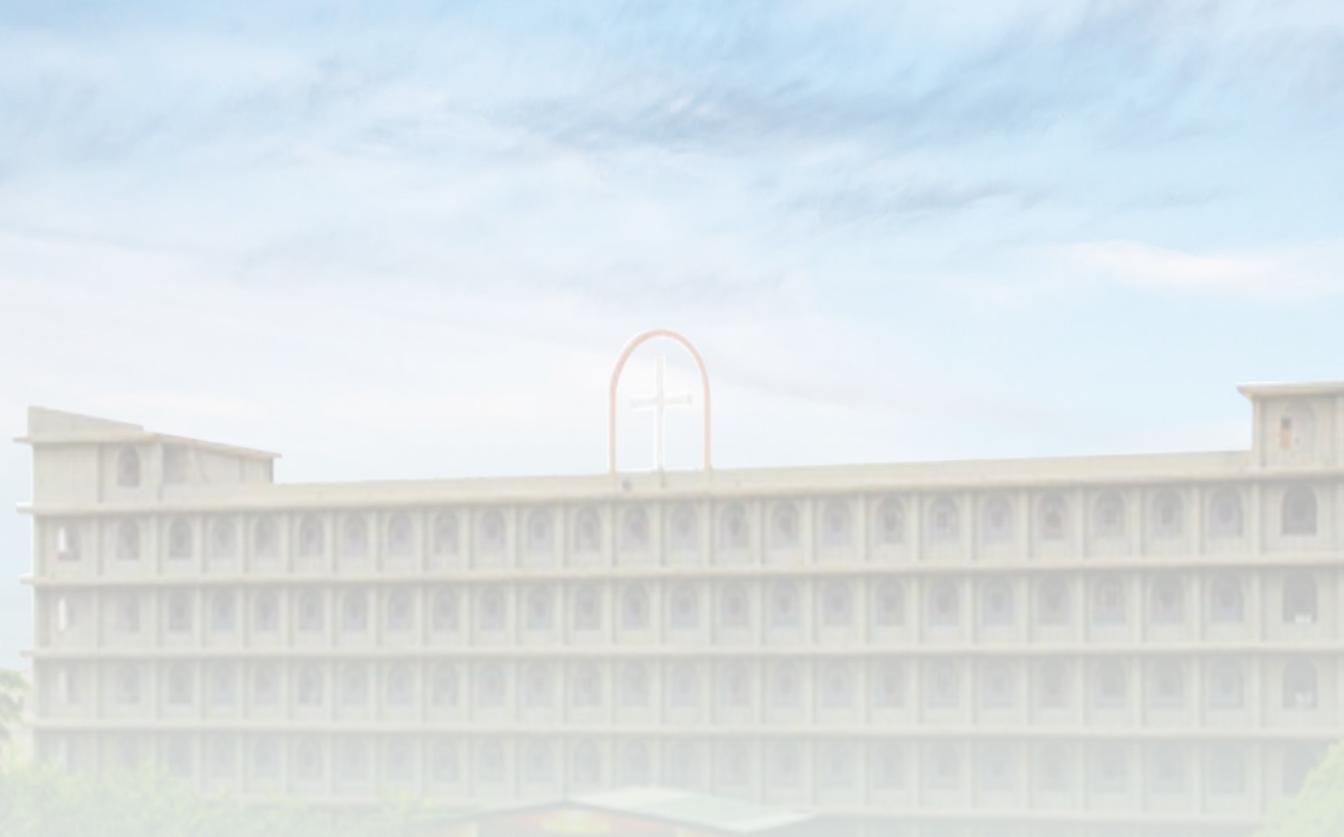
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