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# Biomass Energy: A Clean and Sustainable Energy for the Future

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## ABSTRACT

*Biomass has been a primary source of energy for the world's inhabitants since the dawn of human civilisation. Biomass energy or Bioenergy both are same and are the energies derived from organic matter that has been used by humans for thousands of years, since people began burning wood to prepare food or keep warm. Our primary biomass resources are still non-wood, forest residue, and agricultural biomass.*

*Biomass is one of the world's most ubiquitous and widely distributed resources. As a result, biomass has the potential to provide a renewable energy source that is both allowable and available in wide portions of the world. From 2008 to 2021, overall investment in the Biomass sector is expected to reach up to $104 billion. Bioenergy is currently the most important renewable energy option and will remain so in the near and medium term. Several countries have already attempted to investigate the use of biomass in the bio energy and polymer composite sectors. India provides an enabling environment for the rapid adoption and internalisation of bioenergy technologies (BETs).*

*Nearly a quarter of its primary energy is derived from biomass resources, and nearly 70% of the rural population relies on biomass to meet their daily energy needs. India has demonstrated bioenergy packages for over two decades. This potential is recognised by the Ministry of New and Renewable Energy (MNRE). To support bioenergy development, the MNRE, state governments, and central and state regulatory commissions have developed a number of policy instruments (tariff support) and financial incentives (capital subsidy, interest subsidy, etc.). Plant residues from agriculture and forestry are examples of biomass. As a result, proper biomass usage can be environmentally favourable because it can not only alleviate the throwaway problem but also create value added products from this biomass. It is also a renewable resource because plants produce biomass, which can be cultivated repeatedly, and it can undoubtedly be used as an alternative source of energy. Agricultural applications of biomass are continuously expanding and will most likely continue to expand in the future.*

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## I. INTRODUCTION

Humans have relied almost exclusively on bioenergy for their energy needs for hundreds of thousands of years. Very little water, wind, sun, and geothermal energy have also been utilised over the past two millennia.[2] Fossil fuels (FFs) were also burned in small amounts prior to the explosive expansion of coal after 1800, followed by oil and gas in the 20th century, which caused FFs to overtake bioenergy as the main source of energy. Wood continued to supply more than 90% of all primary energy even in 1850. Today's total production of bioenergy is likely at its highest level ever, despite the fact that the proportion of all forms of bioenergy has decreased to about 10%. It is estimated that using biomass can help lessen global warming when compared to using fossil fuels. Biomass feed stocks are energy crops such as fast-growing trees and grasses. The usage of biomass feed stocks can also assist agricultural-based enterprises to enhance revenues. Biomass derived from agricultural forest use can be used to manufacture various commodities and bioenergy required in modern life, in comparison to other available resources. Nonetheless, empirical evidence indicates that the rate of spread of BETs is rather low due to institutional, technical, informational, market, and financial barriers.[3]This this thesis examines the obstacles and makes recommendations to overcome them. These policy instruments, if carefully crafted, will not only demonstrate the effectiveness of BETs in a developing country like India but will also assist the government in meeting its renewable energy targets. Biomass has been a key player in energy generation even in the past. Biomass defined as all land and water-based vegetation as well as organic wastes, fulfilled almost all of human kind's energy needs prior to the industrial revolution. In present day scenario, once again its utilization for generation of energy has gained momentum because of the limited availability of conventional energy resources as well as environmental concern due to greenhouse gas emissions. Even in the past, biomass played a significant role in the production of energy. Prior to the industrial revolution, biomass—defined as all land- and water-based flora as well as organic wastes—met practically all of humankind's energy needs. Due to the scarcity of traditional energy resources today as well as growing environmental concern over greenhouse gas emissions, its usage for energy generation has once more gained pace. The desire to use biomass as an energy source has grown in recent years, and it now accounts for around 14% of global final energy consumption.[4] By 2050, estimates suggest that biomass might provide 15–

[2] Smil, V. *Energy Transitions: History, Requirements, Prospects*; Praeger: Santa Barbara, CA, USA, 2010. Encyclopedia 2022, 2, 1357–1369. https://doi.org/10.3390/encyclopedia2030091,

[3] Bioenergy in India: Barriers and policy options, An *Article by Darshini Ravindranath and Srinivas Shroff Nagesha Rao United Nations Development Programme, India*

[4] India (2009) Energy publication Division. Ministry of Information and Broadcasting. Government of India, A Comprehensive Overview of Renewable Energy Status in India, Atul Sharma et al, pages 96-97.

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50% of the world's primary energy needs. These are the main causes, in order: First, technological advancements in conversion, crop production, and other areas hold out the prospect of using biomass at a lower cost and with greater conversion efficiency than was previously achievable. Second, biomass is a source of renewable energy, and when it is produced sustainably, it theoretically releases nearly the same amount of carbon during conversion as is absorbed by plant growth. Hence, using biomass does not cause CO2 to increase in the atmosphere. In tropical Africa, as well as some Asian and Latin American countries, bioenergy is consumed in the form of fuelwood or animal dung, and is combusted at very low energy efficiencies. This traditional use of bioenergy still appears to account for a significant share of bioenergy use today (Table 1).[5] Other forms of bioenergy include conversion into liquid fuels for transport (chiefly bioethanol and biodiesel), as a fuel for electric power production and modern boilers, and as an input into the production of biogas. Table 1 gives the breakdown for bioenergy in year 2020.

| Bioenergy Type | 2020 EJ |
|---|---|
| Modern solids | 31.8 |
| Modern liquids | 3.8 |
| Modern biogas | 2.2 |
| Traditional fuelwood | 24.1 |
| All biomass | 61.9 |

Agency (IEA). Table.No.1: Global bioenergy (EJ), as per the estimations of IEA in (2020) [6]

Bioenergy is more adaptable than other RE[7] sources since it can be employed in solid, liquid, or gaseous form, as shown in Table 1. Moreover, biomass is the sole RE source that may be burned like FFs; in fact, biomass is the source of all FFs. It can be used as a fuel in thermal power plants when combined with FFs. Other RE sources (hydro, wind, sun, tidal, and wave energy) can create primary electricity or heat that can be used directly or fed into a thermal power plant (geothermal)[8] Bioenergy does not need to be transformed into other energy forms

[5] Supra 9
[6] International Energy Agency IEA. *World Energy Outlook 2021*; IEA/OECD: Paris, France, 2021. Available online: https://www.iea.org/topics/world-energy-outlook (accessed on 24 June 2022). *Encyclopedia* **2022**, *2*, 1358 https://doi.org/10.3390/encyclopedia2030091https://www.mdpi.com/journal/encyclopedia
[7] Renewable Energies
[8] Moriarty, P.; Honnery, D. *Switching off: Meeting Our Energy Needs in a Constrained Future*; Springer:

for storage, unlike the majority of other RE sources[9] as it already exists in material form. Hydropower is an exception since the energy is stored as gravitational energy. Moreover, bioenergy can be kept as living plant mass and used as needed.

The term "biomass resources" refers to a broad range of materials that can be used to produce energy, from firewood gathered from forests and farmlands to crops developed expressly for this purpose to agricultural and forestry products. Based on the sustainability of bioresources, environmental preservation, and economic consideration, energy production from food wastes or food processing waste, particularly from waste edible oils, appears to be appealing.

With a potential of 16,881 MW (Agro-residues and plantations), 5000 MW (Baggase cogeneration), and 2700 MW, India is particularly rich in biomass (energy recovery from waste). In India, the biomass energy sector attracts investments of more than INR 600 crores annually, producing more than 5,000 million kilowatt-hours of electricity and providing more than ten million man-days of employment annually in rural regions.[10]

## II. BIOENERGY CONTRIBUTIONS IN ACHIEVING THE SUSTAINABLE DEVELOPMENT GOALS (SDGS)

It has always been difficult to achieve the sustainable development goals (SDGs) that were outlined in the 2030 Agenda for Sustainable Development, the Paris Agreement, and their linked Sustainable Development Goals (SDGs). Yet, the issue has been made worse by the advent and quick global dissemination of COVID-19.

While the effects of the global pandemic are still being fully assessed, it is important to remember that despite what seemed to be insurmountable obstacles, unprecedented rapid, collective, transboundary, and cross-sectoral action in the development and rollout of a vaccine has been witnessed. It has given rise to hope that the deadly virus could be eradicated, but perhaps also that the world could come together to actively and decisively combat it as mentioned in the table below.

| **Sustainable Development Goals** | **Bioenergy Development and Its Contribution for achieving SDGs.** |
|---|---|

Singapore, 2022; 90p, ISSN 2191-5520.

[9] Moriarty, P.; Honnery, D. Energy accounting for a renewable energy future. *Energies* **2019**, *12*, 4280. [CrossRef]

[10] Singh and Gu S, (2010) Biomass conversion to energy in India- a Critique. Renew Sustain Energy Rev 14:1367-1378. Ibid 5

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| | |
|---|---|
| SDGs.No.1 - No Poverty. | Bioenergy offers small farmers the possibility to increase and diversify their crop production and generate additional revenues: |
| SDGs.Goals no. 1- No Poverty, No.2- Zero Hunger, No.3- Good Health and Well Being. | Through bioenergy projects and revenues, small farming communities can have access to food, a better diet and im-proved health conditions, and thus enjoy better standards of living |
| SDG.No.3- Good Health and Well Being | The use of biofuels such as bioethanol can reduce indoor air pollution thanks to cleaner cooking. |
| SDGs. No. 4- Quality Education and No.8- Decent work and Economic Growth. | Vocational training and education in bioenergy raises the level of knowledge and understanding of these technologies and paves the way to new jobs, especially in areas with increased bioenergy potential, such as rural areas. Sustainable Development Goals |
| SDG. No.5- Gender Equality | Improved practices have a positive impact on gender equality, as women could improve their income and status. |
| SDG.No.6 Clean Water and Sanitation. | Some bioenergy technologies, like biogas production, specifically address the treatment of wastewater and help reduce water pollution. |
| SDG.No7- Affordable and Clean Energy. | Biomass, biogas and bioethanol technologies help to provide access to affordable, reliable, sustainable, and modern energy, particularly in LDCs(Least Developing Countries) |
| SDGs.No No.8- Decent work and Economic Growth. No.9- Industry Infra-Structure and Innovation. | Bioenergy helps add value to biomass and allows the development of new activities and related jobs through the improvement of existing practices; the introduction of innovative technologies and the enhancement of infrastructure along the value chain. |

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| | |
|---|---|
| SDG. No.10- Required Inequalities | The development of bioenergy projects in rural areas, close to biomass feedstock production, can contribute to the reduction of inequalities in less developed areas |
| SDG. No 11- Sustainable Cities and Communities | The management of organic waste via bioenergy conversion is key to making cities and communities more accommodating and sustainable |
| SDG.No.12- Responsible Consumption and Production | Production, promotion and consumption of biofuels con-tribute to the improvement of the environment through the reduction of fossil fuel consumption and the reuse of waste material generated by bioeconomy activities. |
| SDG.No.13- Climate action | Within the bioeconomy, the development of bioenergy is one of the highest contributors to the mitigation of GHG emissions and carbon sequestration. |
| SDG No.14- Life Below Water. | Bioenergy conversion of waste that would otherwise be discharged into rivers, canals and oceans can strongly contribute to the preservation of aquatic life. |
| SDGs. No 15- Life on Land and No.12- Responsible Consumption and Production | The sustainable management of biological resources and the production and supply of biomass feedstock to bioenergy processes can help prevent land degradation. |
| SDG.No.16- Peace, Justice and Strong Institutions. | Bioenergy also supports rural communities through the creation of more equitable societies, which should generate more sustainable institutions. |
| SDG.No.17- Partnerships for the Goals. | Many Countries face bioenergy implementation challenges. The exchange of experience and creation of global partnerships can help bioenergy to keep growing steadily throughout the world. |

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So, in this context, we must keep working diligently as a group to advance, promote, and activate climate technologies. It is evident that knowledge sharing through platforms like this paper will give others the power they need to discover, organise, and carry out their own bioenergy projects. This will ultimately support our joint efforts to achieve energy self-sufficiency and the SDGs. Sustainable Development provides an overview of global bioenergy projects, the majority of which were carried out by UNIDO[11] and funded by the GEF[12]. The goal of achieving dependable, safe, and affordable clean energy for people in low-income countries—providing clean energy to some of the most vulnerable and underserved people in the world while also aiding in the reduction of dependence on fossil fuels and the associated greenhouse gas (GHG) emissions—is shared by all of the studies, regardless of their scope, technologies, applications, descriptions, or results. Which can be excited to receive a glimpse inside the comparatively small but incredibly promising bioenergy industry.

## III. THE IMPORTANCE OF BIOENERGY IN PROMOTING THE BIOECONOMY IN LEAST DEVELOPED AND DEVELOPING NATIONS

### (A) Bioeconomy in sustainable mode:

The Food and Agricultural Organization of the United Nations (FAO)[13] published recommendations for the establishment of a sustainable bioeconomy in 2016 and founded the International Sustainable Bioeconomy Working Group (ISBWG)[14] with the support of the German government. These guidelines address the following sustainability concerns for the

[11] Established by the General Assembly in 1966, the United Nations Industrial Development Organization (UNIDO) became a UN specialised organization in 1985 whose mandate is to promote industrial development and cooperation. UNIDO offers tailor-made solutions for the sustainable industrial development of developing countries. It cooperates with governments, business associations and the private industrial sector to build industrial capabilities for meeting the challenges and spreading the benefits of globalisation of industry. https://www.undp.org/jposc/unido doi: 19/20/2023. The **United Nations Industrial Development Organization** (**UNIDO**) (French: Organisation des Nations unies pour le development industrial; French/Spanish acronym: **ONUDI**) is a specialized agency of the United Nations that assists countries in economic and industrial development. It is headquartered at the UN Office in Vienna, Austria, with a permanent presence in over 60 countries. As of April 2019, UNIDO comprises 170 member states, which together set the organization's policies, programs, and principles through the biannual General Conference. *United Nations Industrial Development Organization - Wikipedia*

[12] The **Global Environment Facility** (**GEF**) is a multilateral environmental fund that provides grants and blended finance for projects related to biodiversity, climate change, international waters, land degradation, persistent organic pollutants (POPs), mercury, sustainable forest management, food security, and sustainable cities in developing countries. It is the largest source of multilateral funding for biodiversity globally, and distributes more than $1 billion a year on average to address inter-related environmental challenges. *Global Environment Facility - Wikipedia*

[13] The **Food and Agriculture Organization of the United Nations** (**FAO**) is an international organization that leads international efforts to defeat hunger and improve nutrition and food security. Its Latin motto, *fiat panis*, translates to "let there be bread." It was founded on 16 October 1945.
Food and Agriculture Organization - Wikipedia

[14] https://my.southsouth-galaxy.org/en/solutions/detail/fao-led-international-sustainable-bioeconomy-working-group. Doi:19/2/2023

bioeconomy through ten major points:

1. Promoting nutrition and food security at all levels
2. The preservation, enhancement, and protection of natural resources.
3. Promoting inclusive and competitive economic growth.
4. Improving the sustainability, health, and social resilience of communities and ecosystems.
5. Focusing on increased resource and biomass use efficiency.
6. Making use of ethical and practical governance techniques.
7. Using current information that is relevant, dependable technology, and ethical behaviours, as well as, where necessary, encouraging research and innovation.
8. Making use of and encouraging ethical trade and market behaviours.
9. Meeting social requirements and promoting sustainably produced goods and services.
10. Encouraging interest and concern among interested and concerned stakeholders in all pertinent sectors and at all pertinent levels.

These guidelines are consistent with the SDGs of the UN and are relevant to all bioeconomy sectors.[15]

**(B) Biomass Energy and its sustainability objectives under Clean Development Mechanism:**

Worldwide studies predict that by 2050, the demand for bioenergy will have greatly increased. The International Energy Agency has recommended that bioenergy use triple by 2050, to about 135 exajoule[16] (EJ) per year, in order to reduce energy-related CO2 emissions to half of current levels by that time,[17] bioenergy potential estimations range from 100 to 300 EJ by that time.[18]

Yet, it is uncertain how much bioenergy will contribute to broader sustainability objectives.

[15] The Role of Bioenergy in The Clean Energy Transition and Sustainable Development- Lessons from Developing Countries. Role of Bioenergy in Stimulating the Bioeconomy in DCs and LDCs Page no.10

[16] It is equal to 1.00E+18 times joules. Symbol : EJSo 1 exajoule = 1.00E+18 joules. Example Conversion: 539 exajoule = 1.00E+18 X 539 joules. Web search.

[17] International Energy Agency (2010) Energy Technology Perspectives 2010: Scenarios & Strategies to 2050. OECD Publishing, Paris, France. http://www.iea.org/publications/free_new_Desc.asp?PUBS_ID=2100 Bioenergy Projects and Sustainable Development: Which Project Types Offer the Greatest Benefits? Carrie Lee and Michael Lazarus,*Stockholm Environment Institute , working paper -2011ent*

[18] Chum, H., Faaij, A., Moreira, J., Berndes, G., Dhamija, P., Dong, H., Gabrielle, B., Goss Eng, A., Lucht, W., Mapako, M., Masera Cerutti, O., McIntryre, T., Minowa, T. and Pingoud, K. (2011) 'Bioenergy.' IPCC Special Report on Renewable Energy Sources and Climate Change Mitigation, O. Edenhofer, R. Pichs-Madruga, Y. Sokona, K. Seyboth, P. Matschoss, S. Kadner, T. Zwickel, P. Eichemeier, G. Hansen, S. Schlomer, and C. von Stechow (eds.). Cambridge University Press, United Kingdon and New York, NY, USA.

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Rural and lower-income people still use a lot of bioenergy today, and the materials are frequently gathered in an unsustainable manner.[19] Food, feed, and fibre production may be harmed in areas where new bioenergy crops are grown, and the use of agricultural and forestry residues may have a negative impact on soil fertility.[20] According to the Special Report on Renewable Energy Sources and Climate Change Mitigation by the Intergovernmental Panel on Climate Change[21], emerging nations will likely account for a large portion of the growth in demand for biofuels as well as any possible supply. Both the use of biomass for energy and the production of biofuels for transportation have increased significantly in a number of developing countries, where small-scale power and heat production from agricultural wastes (like rice husks and coconut husks) and bagasse power, which is made from sugar cane after it has been extracted, is becoming more common.[22]

Researchers think with a greater knowledge of how diverse bioenergy project types might promote sustainable development[23] (SD) in poor countries is necessary given this diversity and the large range of possible results. The goal of this analysis is to shed light on how these benefits differ between bioenergy projects so that the types of projects with the most potential for sustainable development can be found.

Various international programmes, including those aimed at the carbon market, like the Clean Development Mechanism (CDM), Verified Carbon Standard, or World Bank Bio-Carbon Fund[24], and those aiming at a wider range of sustainability and development benefits, support

[19] Ibid 14

[20] Fargione, J., Hill, J., Tilman, D., Polasky, S. and Hawthorne, P. (2008) 'Land Clearing and the Biofuel Carbon Debt.' *Science*, 319. 1235–38. doi:10.1126/science.1152747. Bioenergy Projects and Sustainable Development: Which Project Types Offer the Greatest Benefits? Carrie Lee and Michael Lazarus,*Stockholm Environment Institute , working paper -2011ent*

[21] Ibid 11

[22] Alexeew, J., Bergest, L., Meyer, K., Petersen, J., Schneider, L. and Unger, C. (2010) 'An analysis of the relationship between the additionality of CDM projects and their contribution to sustainable development.' *International Environmental Agreements: Politics, Law and Economics*, 10. 233–48. doi: 10.1007/s10784-010-9121-y. Bioenergy Projects and Sustainable Development: Which Project Types Offer the Greatest Benefits? Carrie Lee and Michael Lazarus,*Stockholm Environment Institute , working paper -2011-*

[23] **Sustainable development** is an organizing principle that aims to meet human development goals while also enabling natural systems to provide necessary natural resources and ecosystem services to humans. The desired result is a society where living conditions and resources meet human needs without undermining the planetary integrity and stability of the natural system. The Brundtland Report in 1987 defined sustainable development as "development that meets the needs of the present generation without compromising the ability of future generations to meet their own needs". The concept of sustainable development nowadays has a focus on economic development, social development and environmental protection for future generations.
Sustainable development – Wikipedia

[24] The Bio Carbon Fund is a public-private sector initiative managed by the World Bank and supports projects that generate multiple revenue streams. It combines financial returns from the sale of emission reductions (i.e., carbon credits) which increase local incomes and provide other indirect benefits from sustainable land management practices. Generating multiple revenue streams is crucial to rural communities that otherwise have limited sources of income. The Bio Carbon Fund has tapped the carbon market both by working extensively within the UNFCCC's Clean Development Mechanism (CDM) and the voluntary carbon market such as Verified Carbon Standard (VCS).

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bioenergy projects (Global Environment Facility[25], Global Village Energy Partnership[26], and EUEI—Intelligent Energy COOPENER).[27] And the comparison is limited to CDM biomass energy installations.

With its standardised project documentation and sizable project volume, the CDM offers a singular testing ground for investigating the SD aspects of bioenergy initiatives. In accordance with the Kyoto Protocol, the CDM is a flexible compliance method that enables industrialised countries to invest in low-carbon projects in developing nations to fulfil a portion of their emission reduction commitment. The CDM has two goals, as stated in **Article 12** of the Protocol: to generate greenhouse gas emission reductions and to advance sustainable development in developing nations.[28]

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The payments made by the BioCarbon Fund are results-based, thus providing strong incentives for good project management, performance, and impact. An equally important component of BioCarbon Fund operations is the delivery of additional benefits, so called 'co-benefits', that accrue to the communities in addition to the payments for the emission reductions. These co-benefits often take the form of biodiversity conservation, improved water services, and social/institutional benefits (e.g., improved land tenure and stronger community organizations). https://www.biocarbonfund.org/about-us. Assessed on 19/2/2023

[25] Ibid 9

[26] The Partnership Platform is United Nations' global registry of voluntary commitments and multi-stakeholder partnerships made in support of sustainable development and the 17 Sustainable Development Goals. The platform is open to all stakeholders, including Member States, civil society, local authorities, private sector, scientific and technological community, academia, and others, to register a voluntary commitment or multi-stakeholder partnership which aims to drive the implementation of the 2030 Agenda and the SDGs. Managed by the Division for Sustainable Development Goals, UN Department of Economic and Social Affairs (DSDG/DESA), the platform also brings together different registries launched in support of various UN conferences and processes dealing with sustainable development over the years, including the 2017 & 2022 UN Ocean Conference, the 2014 SIDS Conference, and the 2012 Rio+20 Conference. It also provides access to thematic multi-stakeholder action networks that are maintained by other UN entities and actors o galvanize partnerships and commitments in support of the SDGs. https://sdgs.un.org/partnerships/about. Assessed on 19/2/2023

[27] COOPENER is the external component of the European Union "Intelligent Energy - Europe II 2007 - 2013". COOPENER addresses the role of sustainable energy for poverty alleviation in developing countries in the context of the EU Energy Initiative (EUEI). https://www.globalbioenergy.org/toolkit/financing-options-for-bioenergy/fin-det/en/c/42848/. Assessed on 19/2/2023

**COOPENER resources address:**

*• Sustainable energy services as a cross-cutting issue, providing power to supply the most urgent development needs such as access to food, clean water, health services, and education through new and more appropriate approaches.• Priority will be given to projects which are associated with the Partnerships that are being formed between the EU and developing countries through the "EU Energy Initiative for Poverty Reduction and Sustainable Development" and through the JREC.• Energy policies, legislation and market conditions for enabling poverty alleviation in developing countries*

***Activities should:***

*• be complementary and upstream to the support which may later be provided in the frame of other community development co-operation programmes,• be in line with the EU's global strategy for sustainable development, in particular the EU contribution to sustainable development in the developing world, • give priority to the role of energy in enabling poverty eradication and sustainable development, • increase the share of renewable energies in global energy supplies (Johannesburg Renewable Energy Declaration – JREC-).• ensure close co-ordination and linkage with any relevant initiatives implemented through other European Community policies and instruments*

[28] United Nations (1997) *Kyoto Protocol to the United Nations Framework Convention on Climate Change*. http://unfccc.int/resource/docs/convkp/kpeng.pdf. Bioenergy Projects and Sustainable Development: Which Project Types Offer the Greatest Benefits? Carrie Lee and Michael Lazarus,*Stockholm Environment Institute , working paper -2011ent Institute, Working Paper* - 2011

## IV. BIOENERGY CARBON CAPTURE STORAGE- NEGATIVE EMISSION

Bioenergy with carbon capture and storage (BECCS)[29], a promising technique for lowering greenhouse gas emissions, combines the use of bioenergy (energy from biomass) with geologic carbon capture and storage to produce negative carbon dioxide emissions. BECCS is based on the integration of trees and crops that take in carbon dioxide (CO2) from the atmosphere as they develop, the use of biomass in processing industries or power plants, and the utilisation of carbon capture and storage through the injection of CO2 into geological formations. The use of biochar, enhanced weathering, carbon dioxide air capture, and biomass burial are additional ways to remove and store carbon dioxide besides BECCS. Three different facilities currently have a combined BECCS capacity of 550 000 metric tonnes of CO2 per year, according to recent Biorecro research[30] as of January 2012.

In its Fourth Assessment Report, the Intergovernmental Panel on Climate Change (IPCC)[31] recognised BECCS as a key technology for achieving low carbon dioxide atmospheric concentration goals. By the year 2050, BECCS is anticipated to produce more than 2 gigatonnes of negative CO2 emissions annually, which is equivalent to a reduction in global atmospheric carbon dioxide concentrations of 50 to 150 ppm, in accordance with the International Energy Agency's "BLUE Map" climate change mitigation scenario. The most mature technology is BECCS, and there aren't many significant practical obstacles to its adoption in the current energy system. Early deployment will be supported if a primary product is present. According to the OECD, the deployment of BECCS is crucial for reaching lower concentration targets (450 ppm).

The capacity of BECCS to produce negative CO2 emissions is its key selling point. CO2 is successfully removed from the atmosphere by the capture of carbon dioxide from bioenergy sources.[32] Biomass, a sustainable energy source that also acts as a carbon sink while it grows,

[29] The idea behind this method of geoengineering involves capturing carbon dioxide from industries, power plants and other sources, then storing them deep underground as a way to reduce carbon in the atmosphere. This is called "BECCS" which stands for Bioenergy with Carbon Capture and Storage. It could be used to curb climate change in the future. https://www.esgthereport.com/what-is-beccs/. Assessed on 20/2/23

[30] Bioenergy with Carbon Capture and Storage (BECCS) captures carbon emissions from biomass like, pulp and paper, rather than from fossil fuels as is done with CCS. At Biorecro they look at where CO2 is already being collected and use those findings to process biomass that's from existing waste streams. That way no virgin biomass is used. By drawing carbon dioxide from biomass and permanently storing it thousands of meters below the Earth's surface, our BECCS technology goes beyond net zero to produce net negative emissions. https://www.biorecro.com/beccs-technology/. Assessed on 19/2/2022

[31] https://www.ipcc.ch/2005/09/22/intergovernmental-panel-on-climate-change-ipcc-to-launch-report-on-carbon-dioxide-capture-and-storage/. Assessed on 19/2/2023

[32] Read, Peter; Lermit, Jonathan (2005). "Bio-energy with carbon storage (BECS): A sequential decision approach to the threat of abrupt climate change". Energy 30 (14): 2654. doi: 10.1016/j.energy.2004.07.003. https://dx.doi.org/10.1016%2Fj.energy.2004.07.003

is the source of bioenergy. The CO2 is released back into the atmosphere when biomass is burned or processed for industrial purposes. So, there is a net zero emission of CO2 as a result of the process. Nevertheless, depending on the carbon emissions linked to biomass cultivation, transportation, and processing (see below under environmental considerations), this may be favourably or adversely affected.[33] The technology known as carbon capture and storage (CCS) is used to stop the emission of CO2 into the atmosphere and direct it to geological storage areas.[34] In addition to being emitted from power plants using biomass fuel, CO2 with a biomass origin is also produced during the manufacturing of paper pulp and biofuels like biogas and ethanol. Many industrial operations can likewise make use of the BECCS technology.[35]

It is suggested that the BECCS[36] technique allows for the long-term storage of carbon dioxide in geologic formations, as opposed to a tree, which can only store carbon for as long as it is alive. In its report on CCS technology, the IPCC[37] estimates that more than 99% of the carbon dioxide stored through geologic sequestration is likely to remain there for more than 1000 years it is alive. In its report on CCS[38] technology, the IPCC estimates that more than 99% of the carbon dioxide stored through geologic sequestration is likely to remain there for more than 1000 years.

BECCS technology is believed to offer superior permanence by storing CO2 in geological formations, but other types of carbon sinks, such as the ocean, plants, and soil, may involve the risk of negative feedback loops at rising temperatures.[39]

In order to meet low emission limits, it is thought that the amount of CO2 that has been released so far is too large to be able to be absorbed by typical sinks like soil and trees. Even in the most ambitious low-emission scenarios, there will be significant new emissions this century in

[33] G. Cassman, Kenneth; Liska, Adam J. (2007). "Food and fuel for all: Realistic or foolish?". Biofuels, Bioproducts and Biorefining 1: 18. doi:10.1002/bbb.3. https://dx.doi.org/10.1002%2Fbbb.3

[34] Möllersten, Kenneth; Yan, Jinyue; r. Moreira, Jose (2003). "Potential market niches for biomass energy with CO2 capture and storage—Opportunities for energy supply with negative CO2 emissions". Biomass and Bioenergy 25 (3): 273. doi:10.1016/S0961-9534(03)00013-8. https://dx.doi.org/10.1016%2FS0961-9534%2803%2900013-8

[35] Möllersten, K.; Yan, J.; Westermark, M. (2003). "Potential and cost-effectiveness of CO2 reductions through energy measures in Swedish pulp and paper mills". Energy 28 (7): 691. doi:10.1016/S0360-5442(03)00002-1. https://dx.doi.org/10.1016%2FS0360-5442%2803%2900002-1.

[36] Ibid 32

[37] The Intergovernmental Panel on Climate Change (IPCC) is an intergovernmental body of the United Nations. Its job is to advance scientific knowledge about climate change caused by human activities. The World Meteorological Organization (WMO) and the United Nations Environment Programme (UNEP) established the IPCC in 1988. (Wikipedia)

[38] Carbon capture and storage (CCS) is the capture and storing of carbon dioxide (CO2) before it is released into the atmosphere. The technology is able to capture up to 90% of CO2 emissions that are released by burning fossil fuels during electricity generation and industrial processes such as steel or cement production. https://www.twi-global.com/technical-knowledge/faqs/what-is-carbon-capture-and-storage. Assessed on 20/2/2023

[39] "Global Status of BECCS Projects 2010". Biorecro AB, Global CCS Institute. 2010. http://www.globalccsinstitute.com/publications/global-status-beccs-projects-2010/online/27026. Retrieved 2011-12-09.

addition to the ones already generated. Hence, BECCS has been proposed as a technology to buck the emission trend and establish a global net-negative emissions system.

This suggests that the emissions would not only be zero but also negative, resulting in a decrease in both the emissions and the atmospheric concentration of CO2.

The costs[40] expected to be incurred in order to achieve the 350 ppm and 450 ppm target scenarios by 2100. The pre-industrial atmospheric CO2 level was 265 ppm. [41]

## V. CLIMATE CHANGE AND BIOENERGY

The merits of biofuels for combating climate change are being questioned more and more, despite the possibility that the issue may eventually become irrelevant—at least for road transportation. There is debate in the US regarding whether corn ethanol actually lowers CO2 emissions when compared to gasoline.[42] And if looked at the effects of the US Renewable Fuel Standard (RFS) on the environment and found that "the RFS caused enough domestic land use change emissions such that the carbon intensity of corn ethanol produced under the RFS is no less than gasoline and probably at least 24% higher.[43] "This assertion is, of course, vigorously disputed; Scully and colleagues[44] claim that the best estimate of maize ethanol's carbon intensity in the US is 46% lower than that of pure gasoline. Given the age of the debate—it has been going on for several decades—and the fact that climate change is not the only factor in sustainability, it is unlikely that these significant discrepancies in carbon intensity will be resolved anytime soon. "Irrigation of biomass plants may globally exacerbate water stress more than climate change,".[45] Another factor for big energy plantation monocultures is biodiversity loss.

### (A) The future potential of Biomass in India:

India is self-assured to become the leader of the world in power generation for Biomass in near future. Indian has potential to generate an additional 20 GW of electricity from Biomass residues. In order to realize the potential effectively various fiscal incentives are being provided by government. Like Captial subsidy, Clean Development Mechanism, which can be utilized

[40] Obersteiner, M. (2001). "Managing Climate Risk". Science 294 (5543): 786–7. doi:10.1126/science.294.5543.786b. PMID 11681318. https://dx.doi.org/10.1126%2Fscience.294.5543.786b/

[41] https://handwiki.org/wiki/index.php?curid=1095203/

[42] Lark, T.J.; Hendricks, N.P.; Smith, A.; Gibbs, H.K. Environmental outcomes of the US Renewable Fuel Standard. *Proc. Natl. Acad. Sci. USA* **2022**, *119*, e2101084119.

[43] Moriarty, P.; Honnery, D. Feasibility of a 100% global renewable energy system. *Energies* **2020**, *13*, 5543

[44] Scully, M.J.; Norris, G.A.; Falconi, T.M.A.; MacIntosh, D.L. Carbon intensity of corn ethanol in the United States: State of the science. *Environ. Res. Lett.* **2021**, *16*, 043001.

[45] Stenzel, F.; Greve, P.; Lucht, W.; Tramberend, S.; Wada, Y.; Gerten, D. Irrigation of biomass plantations may globally increase water stress more than climate change. *Nat. Commun.* **2021**, *12*, 512.

effectively to make the project economically attractive. [46]

To reduce the risk of technological advancement, clean developed mechanisms give additional cash in the form of CER[47] (certified emission reductions) revenues. The project's ability to make money. As of December 31, 2023, 185 biomass-based projects from India[48], had been registered under the clean development mechanism. The use of efficient cookstoves in homes and the substitution of non-renewable biomass with renewable biomass projects are just a few examples of the numerous projects that qualify for carbon credits. A (PoA)[49] for a biomass-based project from India has previously been registered under the green development mechanism, "Promotion of biomass-based heat generation in India," and new CDM methods like programme of activity (PoA) have also been effective.[50]

**1. Biofuels**

Ethanol and biodiesel, two liquid biofuels, are utilised to replace petroleum-based transportation fuels. India's biofuel initiatives are centered on employing non-food sources, such as sugar molasses and non-edible oil seeds, as well as second generation biofuels in the near future, for the manufacture of biofuels. Improved convention technologies are being developed for ethanol that will enable it to combine with agricultural and forestry waste. As it becomes technologically and economically feasible, using one third of the surplus biomass could produce nearly 19 billion litres of ethanol, which could eventually replace all of the nation's gasoline usage. Microalgae is an advanced feedstock for biodiesel production that is now being studied and has very promising potential in India.[51] It can give a land unit twice as much of the highest-yielding crop (oil palm).[52] India produces very little commercial biodiesel, and what it does produce is

[46] Future Potential of Biomass energy in India , Bioenergy India Issue 7- January -March 2011, page no.7

[47] **Certified Emission Reductions** (**CERs**) are a type of emissions unit (or carbon credits) issued by the Clean Development Mechanism (CDM) Executive Board for emission reductions achieved by CDM projects and verified by a DOE (Designated Operational Entity) under the rules of the Kyoto Protocol. CERs can be used by Annex 1 countries in order to comply with their emission limitation targets or by operators of installations covered by the European Union Emission Trading Scheme (EU ETS) in order to comply with their obligations to surrender EU Allowances, CERs or Emission Reduction Units (ERUs) for the $CO_2$ emissions of their installations. CERs can be held by governmental and private entities on electronic accounts with the UN. Certified Emission Reduction - Wikipedia

[48] https://cdm.unfccc.int/Projects/projsearch.html 19/2/2023

[49] https://www.southpolecarbon.com/_downloads/PoA_Guidebook_Southpole.pdf. Referred in Future Potential of Biomass energy in India , Bioenergy India Issue 7- January -March 2011, page no.8 in information column. The aim of PoAs was to allow replicable projects with low and physically spread greenhouse gas reductions into the CDM. This type of project is often linked to higher sustainability benefits, but are too small to pay back the transaction cost involved in the CDM process. It was expected to allow African countries a higher participation in the CDM in particular. *Program of Activities - Wikipedia*

[50] Future Potential of Biomass energy in India , Bioenergy India Issue 7- January -March 2011, page no.8-9

[51] A Comprehensive Overview of Renewable Energy Status in India, Atul Sharma et al, pages 101

[52] Indian Renewable status report(2010) Background report for DIREC 2010, pp 94, A Comprehensive Overview of Renewable Energy Status in India, Atul Sharma et al, pages 101-102.

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generally sold as food stocks, including non-edible oil seeds, non-edible oil waste, animal fat, and spent cooking oil. shows the growth in global liquid biofuels production from the 1990s to present. The two leading countries for production are the US, where corn is the main input feedstock, and Brazil, where cane sugar is the preferred feedstock. In 2020, these two countries accounted for almost 60% of global liquid biofuel production.[53]

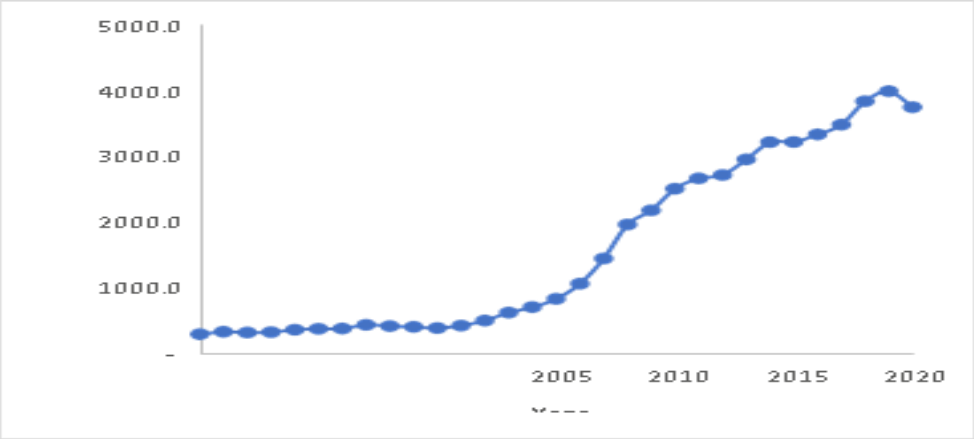


**Figure 1.** Global liquid biofuels production (in EJ) from 1990 to 2020. Source: BP.

In India, attempts to produce biodiesel are concentrated on using non-edible oils because the country's supply of edible oil is insufficient to meet domestic demand. After determining that Jatropa Curcas is the best regenerated oil seed for biodiesel production, the Indian government established "The National Biodiesel Mission." As jatropa oil may be used directly in diesel generators and engines after extraction without processing, it has been used for many years in India as biodiesel to meet the diesel fuel needs of isolated and rural Forest populations. An increase in jatropha oil production benefits India's economy on a macroeconomic or national scale because it lowers the cost of the country's fossil fuel imports for the production of diesel, which minimises the use of India's foreign exchange reserves for fuel and allows India to increase its expanding foreign exchange reserves. A large-scale production of jatropa oil will also reduce the nation's carbon emission profile because it is carbon neutral. The last point is that this alternative is considered the most politically and morally acceptable among India's current biofuel options; nonetheless, it has a negative influence on the production of vast quantities of grains and other essential agricultural products. India produces to supply its enormous population's needs for food. Alternative biofuels, like corn ethanol or palm biodiesel, that employ food crops grown on productive agricultural land have sharply increased the cost

[53] *BP Statistical Review of World Energy 2021*; BP: London, UK, 2021. Available online: https://www.bp.com/en/global/corporate/energy-economics/statistical-review-of-world-energy.html. Can Bioenergy Once again Become a Major Global Energy Source? Patrick Moriarty. Page No. 1359. Encyclopaedia 2022, 2, 1357–1369.https://www.mdpi.com/journal/encyclopedia

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of staple foods like grains and edible oils in other nations. The potential annual availability of non-edible oils in India is also estimated to be around 1 million tonnes. Sal oil (180,000 tonnes), mahua oil (180,000 tonnes), neem oil (100,000 tonnes), and Karanja oil (55,000 tonnes) are the resources that are most readily seen.

Nonetheless, the government has identified Jatropa curcas oilseeds as a significant food source for biodiesel in India[54] based on substantial study conducted by numerous institutes in the nation. Molasses, a waste product of the sugar industry, is fermented to create ethanol in India. In addition to 1.5 billion litres of gasoline ethanol, India has 330 distilleries that can generate more than 4 billion litres of rectified spirit (alcohol) annually. About 140 of them can produce roughly 2 billion litres[55] of conventional ethanol annually, which is enough to satisfy the demand for gasoline with a 5% ethanol blend.

The nation's biofuel initiative is still in its infancy. India makes ethanol from sugarcane molasses to mix with gasoline. India's ambitious "ethanol blending scheme" required a 5% ethanol blend in gasoline starting in January 2003." India's ability to produce ethanol and alcohol is heavily dependent on the availability of sugar molasses (are by product of sugar production). Due to India's cyclical sugar cane production, the production of ethanol similarly varies with sugar and sugar cane production and cannot guarantee the Optimal Supply levels required to satisfy demand at any given moment.[56]

From early 2001, various state governments and the ministry of rural development have run initiatives to promote the widespread planting of jatropha. Madhya Pradesh, Chattisgarh, Rajasthan, Maharashtra, Andhra Pradesh, and Gujarat are the states having the most potential in terms of wastelands. By 2012, the Planning Commission established an ambitious goal of planting 11 million hectares of jatropha, which would produce enough biodiesel to blend 20% with gasoline and diesel. But, the country's total area of Jatropha plantations is currently estimated to be over 450,000 hectares, of which 60 to 70 percent are New Plantations that have not yet reached full output. In the upcoming three to four years[57], the New Jatropha Plantation is anticipated to reach maturity.

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[54] Gonslaves J (2006) An assessment of biofuels industry in India. United Nations Conference on trade and development, Geneva, 18th October 2006. A Comprehensive Overview of Renewable Energy Status in India, Atul Sharma et al, pages 101-102.

[55] United States Department of Agriculture- Foreign Agriculture Service (2009) Global Agricultural Information Network. " India Biofuels Annual 2012"., A Comprehensive Overview of Renewable Energy Status in India, Atul Sharma et al, pages 100-101.

[56] A Comprehensive Overview of Renewable Energy Status in India, Atul Sharma et al, pages 100-101.

[57] United States Department of Agriculture- Foreign Agriculture Service (2009) Global Agricultural Information Network. " India Biofuels Annual 2009"., A Comprehensive Overview of Renewable Energy Status in India, Atul Sharma et al, pages 101-102.

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Recently, on World Environment Day's " Hon'ble Prime Minister Modiji, in the "Report of the Expert Committee on Road Plan for Ethanol Blending in India, 2020–2025" India has pledged to comply with the 2015 Paris Agreement by reducing its carbon emissions by 33–35% (from 2005 levels) by 2030. India had set a goal of mixing 10% ethanol into gasoline by 2022 and 10% into diesel by 2030 in the year 2020. Presently, 8.5% percent ethanol is added to gasoline throughout the nation. As a result, 320 crore litres of ethanol were purchased. The government asserts that the purchase of ethanol generated Rs 21,000 crores, providing farmers with additional revenue. The main sources of ethanol utilised for blending are sugarcane (87%), rice leftovers, and wheat byproducts. Vehicle pollution and agricultural waste pollution are both decreased by mixing ethanol. As the third-largest oil importer in the world, it can also reduce India's oil imports.

However, it costs Rs 62.65 per litre and needs roughly 2,860 litres of water to make one litre of ethanol from sugar. Nitin Gadkari, a minister in the Union, requested that automakers create flex-engine vehicles in March 2021. These engines can operate with ethanol blends in any percentage between 20% and 100%.[58]

**2. Biogas**

In order to decrease operating costs, increase biogas yields, and reduce greenhouse gas emissions, biogas production technology has advanced in recent years. There are a number of design factors and operating aspects that must be taken into account in order to achieve steady and effective biogas production. Also, by properly monitoring a variety of operational characteristics, it is possible to adapt the process to unexpected circumstances.[59] An alternative energy source made primarily from organic waste is biogas. For the past three decades, India has promoted the usage of biogas made from cow dung. A clean, low-carbon technique called biogas production allows for the effective management of organic wastes and their conversion to clean, renewable biogas and an organic fertiliser source. It has the potential to aid in the establishment of sustainable livelihoods and combat both local (land, air, and water pollution) and global pollution. Cooking, lighting, and other uses including refrigeration, electricity generation, and transportation can all be powered by biogas, which is produced by anaerobic digestion of loose or leafy organic wastes like cattle dung.

Since biogas plans help reduce greenhouse gas emissions, they can be implemented to receive

[58] https://www.downtoearth.org.in/video/environment/india-s-20-ethanol-petrol-blending-target-advanced-to-2025-77334. Doi 19/2/2023

[59] Operational Parameters of Biogas Plants: A Review and Evaluation Study, Abdullah Nsair et al. abstract. file:///C:/Users/krusa/OneDrive/Desktop/DR.%20MONY%20MATERIALS/bio%202022%20dec%20new/energies-13-03761.pdf. Doi: 19/12/2022

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benefits from the clean development mechanism (CDM)[60], which will increase revenue for greater coverage and lower the cost of biogas plans for the government and beneficiaries. Based on the availability of cattle manure, it is estimated that there are roughly 12 million family-type biogas plants in the nation with the potential to produce about 15,000 million cubic metres of biogas yearly on average. Moreover, biogas plants deliver high-quality organic manure containing nutrients to the soil, enhancing its fertility for long-term growth and productivity.

Since 1981–1982, the National Biogas and Manure Management Program (NBMMP)[61] has been in place in the nation to promote biogas programmes based on animal manure and other organic wastes. The NBMMP primarily focuses on building family-style biogas plants to address the country's cooking energy demands while also making enriched biofertilizer available to farmers. Clean energy's accessibility lessens the toilsomeness of rural women, eases pressure on the forest, and highlights social advantages. Biogas Development and Training Centers (BDTCs) have been established in universities, Indian Institutes of Technology (IITs), and other technical Institutes in order to provide technical help and training support. According to the Ministry of New and Renewable Energy's (MNRE)[62] report[63], over 35% of the predicted potential has already been reached with the installation of 4.31 million family-type biogas systems by January 2011.[64]

Hydrogen has enormous promise as a clean energy source for a variety of uses, such as transportation and power generation. Both power generation and transportation use can use hydrogen. Hydrogen can be used directly as a fuel in fuel cells to generate electricity or

[60] The **Clean Development Mechanism** (**CDM**) is a United Nations-run carbon offset scheme allowing countries to fund greenhouse gas emissions-reducing projects in other countries and claim the saved emissions as part of their own efforts to meet international emissions targets. It is one of the three Flexible Mechanisms defined in the Kyoto Protocol. The CDM, defined in Article 12 of the Protocol, was intended to meet two objectives: (1) to assist non-Annex I countries (predominantly developing nations) achieve sustainable development and reduce their carbon footprints; and (2) to assist Annex I countries (predominantly industrialized nations) in achieving compliance with their emissions reduction commitments (greenhouse gas emission caps). Clean Development Mechanism - Wikipedia

[61] The National Biogas and Manure Management programme is a Central Sector Scheme primarily set up for rural and semi-urban households. Categories are designated accordingly: cattle-dung, and other bio-degradeable materials such biomass from farms, gardens, kitchens, and night soil. They delineate the benefits of biogas as well:(i) It provides clean gaseous fuel for cooking and lighting.(ii) Digested slurry from biogas plants is used as enriched bio-manure to supplement the use of chemical fertilizers.(iii) It improves sanitation in villages and semi -urban areas by linking sanitary toilets with biogas plants.(iv) Biogas Plants help in reducing the causes of climate change. https://www.iea.org/policies/4308-national-biogas-and-manure-management-programme. Visited on 19/2/2023

[62] The **Ministry of New and Renewable Energy** (**MNRE**) is a ministry of the Government of India, headed by current Union Cabinet Minister Raj Kumar Singh, that is mainly responsible for research and development, intellectual property protection, and international cooperation, promotion, and coordination in renewable energy sources such as wind power, small hydro, biogas, and solar power. Ministry of New and Renewable Energy - Wikipedia

[63] MNRE achievements as of December 31st 2012, A Comprehensive Overview of Renewable Energy Status in India, Atul Sharma et al, pages 101-102.

[64] A Comprehensive Overview of Renewable Energy Status in India, Atul Sharma et al, pages 101-102.

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combined with diesel and compressed natural gas in internal combustion engines. Several problems that the global energy system is facing have been linked to hydrogen energy as potential solutions. The usage of hydrogen has the advantages of producing almost no emissions at the point of consumption and allowing for decentralised generation using a variety of fuels.

In order to close technological gaps in a variety of hydrogen energy-related fields, including its production, storage, transportation, and delivery, applications, safety codes and standards, and capacity building for the years up to 2020[65], the National Hydrogen Energy Road Map (NHERM) is a programme in India that was started by the National Hydrogen Program in India by the National Hydrogen Energy Board (NHEB) in 2003 and approved in 2006. The Murugappa Chettiar Research Centre (MCRC), Chennai, the Banaras Hindu University (BHU), Varanasi, and the Indian Institute of Technology (IIT), Kharagpur, are some of the leading research institutions specializing in biological, biomass, and other renewable energy generation technologies for hydrogen.

The MCRC Murugappa Chettiar Research Center has demonstrated batch-scale hydrogen synthesis from distillery waste, and the Ministry of New and Renewable Energy has financed research and development in this area. The pilot plant has the capacity to produce up to 18,000 pounds of hydrogen per hour.[66]

Biomass-derived hydrogen Vehicles, fuel cells, and specialised internal combustion engines can all run on hydrogen. Since hydrogen can be produced from a variety of renewable sources, such as biomass and water, many believe it will eventually play a significant role in the decarbonization of the transportation industry.

The process by which biomass is transformed into hydrogen can take a number of distinct forms. They include:

- biological routes, such as the direct synthesis of hydrogen by photosynthetic organisms;
- thermal routes, such as gasification followed by upgrading and reforming of syngas;
- aqueous phase reforming of biomass-derived solutions; and
- bio-oil reforming.

The commercial maturity and quantity of the necessary conversion processes vary between

[65] WHEC (2008) 17th world hydrogen energy conference, http://www.whec2008.com/abstract/499.asp. Doi 18/2/2023
[66] EAI(2013) http://www.eai.in/ref/ae/geo/geo.html. Doi 18/2/2023

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these approaches. But they all share one thing in common: none of them are currently or even very soon economically viable. Also, the use of hydrogen as a transportation fuel will require the introduction of hydrogen-powered cars and a corresponding infrastructure for refuelling them.

Alternately, biomethane and bioethanol, for which fuelling stations have already been installed, might be used as hydrogen carriers and converted to hydrogen aboard the vehicle using reformers, although this would add significantly to the complexity and cost of the vehicle.[67]

## VI. CONCLUSION

Any nation's national energy policy is driven by three factors: environmental protection, economic growth, and energy security. Due to the high price of crude oil, there is a need to intensify efforts for the development and promotion of renewable energy sources. To lessen reliance on the depleting effects of fossil fuels and to slow down climate change, it is vital to switch from energy systems based on petroleum to ones based on renewable sources. Also, Shell has created numerous employment prospects at all levels, particularly in rural regions, thanks to renewable energy. Hence it is necessary to connect isolated systems with rural industries as their cost is dependent on load factor. A prerequisite is also creative financing. The National Action Plan on Climate Change calls for the promotion of additional renewable energy sources.

Promoting climate innovation and fundamental research in renewable energy technologies, resolving issues with development and commercialization, and improving the regulatory/tariff framework are some of the specific action points that have been mentioned. These will help mainstream renewable energy sources into the country's electrical grid. As a result, there is more attention being paid to the use of renewable energy, which is predicted to make up 05% of all electricity by 2032. The production of energy from biomass has a huge potential to help India meet its rising energy demands. Significant advances in technology are being made available.

However, a monetary incentive, and policy changes are all being used to speed up investment in the area. The supply of biomass at affordable costs and the competitiveness between various marketplaces, however, remain concerns.[68] Predicting where our world will go in the future is getting harder and harder. The present pandemic, which had significant effects on the world economy, energy use, transportation, global inequity, and, of course, human health and suffering, was not widely predicted. A lot of variables will affect how bioenergy is used in the

[67] Bioenergy – a Sustainable and Reliable Energy Source, MAIN REPORT, page No.37
[68] Future Potential of Biomass energy in India , Bioenergy India Issue 7- January -March 2011, page no.10-11

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future. First, how much energy will be consumed globally in, say, 2050? Some estimations are significantly greater than they are right now due to the current worldwide discrepancy in energy use per person. Second, would using fewer fossil fuels or CDR[69] strategies like negative emissions technology be used to combat climate change? Although CDR would allow for the continued use of fossil fuels, none of the various techniques have been tested on the scale that is necessary, and their implementation would take decades.[70] Solar geoengineering, which involves using sulphate aerosols in the high atmosphere to reflect insolation and increase Earth's albedo[71] is an even more ambitious endeavour. Instead, would there be lip service paid to reducing climate change while high levels of fossil fuel use are maintained, as they are now?

These uncertainties may be greater than for other energy sources, whether fossil or renewable. The future use of conventional fuels is another significant uncertainty. Its global consumption is not precisely known, as was already indicated. Fuel wood demand in low-income nations may increase in the future if global inequality is not curbed. Unfortunately, most of this consumption may not be sustainable because forests and woodlands are being cut down faster than they can regenerate. Both biodiversity and carbon emissions may be impacted by this condition, which is currently present in some locations.[72]

Moreover, bioenergy must compete with other types of renewable energy, including wind and solar energy. They are subjected to competition for arable land or water to a much lesser extent than biofuels. Additionally, their theoretical potential is far greater than that of bioenergy.[73] According to the IEA[74] all of their scenarios call for an increase in the combined growth of these two RE sources from their 2020 level of roughly a factor of seven in their "business as usual" "stated policy scenario" to a factor of nearly 20 in their NZE[75] scenario.

These two RE sources, however, have their own concerns about the enormous amounts of rare minerals they require and the values of their EROI[76]

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[69] Carbon-di-oxide Removal

[70] Moriarty, P.; Honnery, D. New approaches for ecological and social sustainability in a post-pandemic world. *World* **2020**, *1*,191–204.

[71] Robock, A. Benefits and risks of stratospheric solar radiation management for climate intervention (geoengineering). *Bridge* **2020**,*50*, 59–67. Available online: http://climate.envsci.rutgers.edu/pdf/RobockBridge.pdf

[72] Specht, M.J.; Pinto, S.R.R.; Albuquerque, U.P.; Tabarelli, M.; Melo, F.P.L. Burning biodiversity: Fuelwood harvesting causes forest degradation in human-dominated tropical landscapes. *Glob. Ecol. Conserv.* **2015**, *3*, 200–209.

[73] Moriarty, P.; Honnery, D. Can renewable energy power the future? *Energy Pol.* **2016**, *93*, 3–7.

[74] International Energy Agency IEA. *World Energy Outlook 2021*; IEA/OECD: Paris, France, 2021. Available online: https://www.iea.org/topics/world-energy-outlook.

[75] Net Zero Emission

[76] In energy economics and ecological energetics, **energy return on investment** (**EROI**), also sometimes called **energy returned on energy invested** (**ERoEI**), is the ratio of the amount of usable energy (the *exergy*) delivered from a particular energy resource to the amount of exergy used to obtain that energy resource. Energy return on

In addition to lowering methane emissions into the atmosphere, using landfill and sewage plant gas (biomethane) can also help replace FF consumption, which has a twofold positive impact on reducing climate change. Municipal organic waste may and is being burned for electricity or district heating programmes, which reduces the need for landfill space and produces green energy. Although a significant portion of forest and crop waste must be left in place to maintain soil fertility and prevent wind and soil erosion, the sustainably used residual can be a useful addition to clean energy. Biomass materials can first be used for construction, packaging, or newsprint, and then, at the end of their useful lives, be burned for energy. The exact amount of bioenergy's contribution to future energy production is undetermined, but it will be significant.

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investment - Wikipedia

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