Template/Pro forma for Submission

NMHS-Himalayan Institutional Project Grant

# NMHS-FINAL TECHNICAL REPORT (FTR)

Demand-Driven Action Research and Demonstrations

| NMHS Reference No.: | NMHS/2017-18/SG39/20 |
|---|---|

| Date of Submission: | 2 | 0 | 1 | 2 | 2 | 0 | 2 | 2 |
|---|---|---|---|---|---|---|---|---|
| | **d** | **d** | **m** | **m** | **y** | **y** | **y** | **y** |

# DEVELOPMENT OF SUSTAINABLE TECHNOLOGY FOR PRODUCTION OF BIOMASS PELLET BASED FUEL AND HERBAL BY-PRODUCT FROM RESIDUE OF PRUNED TEA PLANT: AUGMENTING RURAL DEVELOPMENT

**Project Duration:** *from* (**01.04.2018**) *to* (**30.09.2021**).

***Submitted to*:**
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**GENERAL INSTRUCTIONS:**

1. The Final Technical Report (FTR) has to commence from the date of start of the Project (as per the Sanction Order issued at the start of the project) till its completion. Each detail has to comply with the NMHS Sanction Order.
2. The FTR should be neatly typed (in Arial with font size 11 with 1.5 spacing between the lines) with all details as per the enclosed format for direct reproduction by photo-offset process. Colored Photographs (4-5 good action photographs), tables and graphs should be accommodated within the report or should be annexed with captions. Sketches and diagrammatic illustrations may also be given giving step-by-step details about the methodology followed in technology development/modulation, transfer and training. Any correction or rewriting should be avoided. Please give information under each head in serial order.
3. Training/ Capacity Building Manuals (with details contents of training programme technical details and techniques involved) or any such display material related to project activities along with slides, charts, photographs should be brought at the venue of the Annual Monitoring & Evaluation (M&E) Workshop and sent at the NMHS-PMU, GBP NIHE HQs, Kosi-Katarmal, Almora 263643, Uttarakhand. In all Knowledge Products, the Grant/ Fund support of the NMHS should be duly acknowledged.
4. The FTR Format is in sync with many other essential requirements and norms desired by the Govt. of India time to time, so each section of the NMHS-FTR needs to duly filled by the proponent and verified by the Head of the Lead Implementing Organization/ Institution/ University.
5. Five (5) bound hard copies of the Project Final Technical Report (FTR) and a soft copy should be submitted to the **Nodal Officer, NMHS-PMU, GBP NIHE HQs, Kosi-Katarmal, Almora, Uttarakhand**.

The FTR is to be submitted into following two parts:

**Part A – Project Summary Report**

**Part B – Project Detailed Report**

Following Financial and other necessary documents/certificates need to be submitted along with Final Technical Report (FTR):

| | |
|---|---|
| **Annexure I** | **Consolidated and Audited Utilization Certificate (UC) & Statement of Expenditure (SE)**, including interest earned for the last Fiscal year including the duly filled GFR-19A (with year-wise break-up) |
| **Annexure II** | **Consolidated Interest Earned Certificate** |
| **Annexure III** | **Consolidated Assets Certificate** showing the cost of the equipment in Foreign and Indian currency, Date of Purchase, etc. (with break-up as per the NMHS Sanction Order and year wise). |
| **Annexure IV** | **List of all the equipment, assets and peripherals** purchased through the NMHS grant with current status of use including location of deployment. |
| **Annexure V** | Letter of Head of Institution/Department confirming Transfer of Equipment Purchased under the Project to the Institution/Department |
| **Annexure VI** | **Details, Declaration and Refund of any Unspent Balance transferred through Real-Time Gross System (RTGS) in favor of NMHS GIA General** |

**NMHS-Final Technical Report (FTR)** *template*

Demand-Driven Action Research Project

*DSL: Date of Sanction Letter*

| 2 | 8 | 0 | 3 | 2 | 0 | 1 | 8 |
|---|---|---|---|---|---|---|---|
| d | d | m | m | y | y | y | y |

*DPC: Date of Project Completion*

| 3 | 0 | 0 | 9 | 2 | 0 | 2 | 1 |
|---|---|---|---|---|---|---|---|
| d | d | m | m | y | y | y | y |

## Part A: Project Summary Report

### 1. Project Description

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| i. | Project Reference No. | NMHS/2017-18/SG39/20 | | | | | | | |
| ii. | Type of Project | Small Grant | | Medium Grant | ✓ | Large Grant | | | |
| iii. | Project Title | Development of sustainable technology for production of biomass pellet-based fuel and herbal by- product from residue of pruned tea plant: Augmenting rural development | | | | | | | |
| iv. | State under which Project is Sanctioned | Livelihood Options and Employment Generation | | | | | | | |
| v. | Project Sites (IHR States covered)<br>(Maps to be attached) | NIT Arunachal Pradesh<br><br>Arunachal Pradesh, Assam | | | | | | | |
| vi. | Scale of Project Operation | Local | | Regional | | Pan-Himalayan | ✓ | | |
| vii. | Total Budget/ Outlay of the Project | **0.4890880** (in Cr) | | | | | | | |
| viii. | Lead Agency | NIT Arunachal Pradesh | | | | | | | |
| | Principal Investigator (PI) | Dr. Saikat Kumar Jana<br>National Institute of Technology, Arunachal Pradesh | | | | | | | |
| | Co-Principal Investigator (Co-PI) | NA | | | | | | | |
| ix. | Project Implementing Partners | NA | | | | | | | |
| | Key Persons / Point of Contacts with Contact Details, Ph. No, E-mail | NA | | | | | | | |

### 2. Project Outcomes:

**Abstract** (not more than 500 words) [it should include background of the study, aim, objectives, methodology, approach, results, conclusion and recommendations).

***Background*:** Even after 70 years of Independence, the rural India still has a sparse access to clean energy. The dependence on agro biomass and cow dung-based fuels is the major source of energy in these places. The health hazards associated with the use of such fuels are well known. The primary victims of such poor-quality fuel are the women as they are exposed to the toxic emissions of the frugal ovens. The need of the hour is to provide clean fuel to rural parts. Moreover, if the fuel is made from local resources, then it can be produced economically. In doing so, if any further product is also generated then revenue generation can make the overall process economically viable.

***Objectives/ Aim:*** The aim of our innovation was to develop concomitant technology that would produce clean fuel and also some value-added product. In tea estates, the tea plants were cultivated and regularly pruned to maintain proper shape of tea bush. In doing so, a lot of biowaste is generated in terms of old leaves, stems etc. these agro-wastes could be a lucrative source of polyphenol and the residues can be converted in biomass pellet. These biomass pellets can be used as clean fuel and the poly phenols can be used as value added products such as preparation of hand sanitizer.

***Methodology:***

- Phenolic content was measured by spectrophotometric method using Folin Ciocalteau reagent (FCR). Antioxidant property was measured by DPPH assay.
- The base of each cosmetic was prepared while maintaining proportions of raw materials (basically chemicals), and physicals parameters were set to achieve a consistent and usable form of phase where herbal extracts (primarily tea extracts) are incorporated to produce the desired herbal cosmetics.
- Pruned tea plant was collected from local tea garden and dry in sun for approximately 7-8 days for completely dried. The dried tea plant is cut into small pieces by knife and then pulverized in domestic blender PAS-180 220V/380V., to produce powder (CPP Guar gum binders were used for better strength and durability. After mixed with binder the samples were kept for dry, moisture contents reduce to 16-23%. Moisture content was measured by digital moisture meter EMT01. Accuracy 0.5%, 9V Temp. Range 0-40 degree.
- TGA (Thermo gravimetric analysis) was done to determine the proximate analysis (Moisture, volatile, fixed carbon and ash contents) of the biomass pellets. Using TGA model: Hitachi STA7200

***Approach:*** Villagers and the beneficiaries needed to understand that this is a solution to their long-standing issues with affordable fuel and sustained livelihood, where they can view the project initially as a complementary business and eventually as an alternative once the market development was ensured.

***Results*:**

- The extract of newly shade dried leaves treated with 50 % ethanol at 70 oC for 2 hours showed the highest phenolic content and it was evaluated to check its antioxidant property. 100 µg of extract depicted the % inhibition of 72.69 % implying significant antioxidant property and thus potential therapeutic activity.
- The cosmetics prepared are namely antiseptic cream, cold cream, lip balm, shampoo, hair oil, body oil, face wash, hand sanitizer, cool body powder and tooth paste.
- Bio pellets are made from tea plantation waste produce negligible emissions while providing fuel that has a calorific value.

**Conclusion:** These value-added herbal products were made by mixing correct proportion of base materials with the tea extract. The cosmetics prepared are namely antiseptic cream, cold cream, lip balm, shampoo, hair oil, body oil, face wash, hand sanitizer, cool body powder and tooth paste. The pruned tea waste has great potential to produce biomass pellet that are extensively used in the IHR especially in the remote regions.

**Recommendation:** We can use Gasifier with this technique to generate electricity & also we can make Biomass briquettes.

### 2.2. Objective-wise Major Achievements

| S. No. | Objectives | Major achievements (in bullets points) |
|---|---|---|
| 1 | Optimization of phenolic and antioxidants from pruned Tea plant residues | • Herbal by-product with the bioactive compounds extracted from tea residues. |
| 2 | Development of value-added products such as soaps, sanitizer etc. using extracted phenolic and antioxidants | • One demonstrative model in the form of workshop<br>• Technology Transfer Manual to the students for preparing cosmetics using herbal extracts |
| 3 | Optimization of process parameters for bio-pellet production from extracted waste residues | • Biomass pellets produced from pruned tea waste and the parameters are optimization<br>• Around 40 KG biomass pellet prepared |
| 4 | Investigation of suitability of bio-pellet as clean alternative fuel or as alternative to coal | • Promotion and demonstration of Tea waste-based biomass pellets, stoves at different rural part of Arunachal Pradesh as domestic energy sources.<br>• Technology has been demonstrated to rural people of Arunachal Pradesh. |

### 2.3. Outputs in terms of Quantifiable Deliverables*

| S. No. | Quantifiable Deliverables* | Monitoring Indicators* | Quantified Output/ Outcome achieved | Deviations made, if any, & Reason thereof: |
|---|---|---|---|---|
| 1 | Development of a prototype/pilot scale production model for Bio-pellet | No. of New Datasets generated (Nos.) | 10 | |
| | | No of demonstrative models/ Pilot project (Nos.) | 10 | |
| | | Quantity of residue processed (Kg) | 40 | |
| 2 | Development of commercially viable value-added products such as shampoos, sanitizers, etc. | No. of Stakeholders benefitted (No. of Rural Youth, No. of Women, and Total No. of Beneficiaries); | 60 | |
| 3 | Establishment of market linkages for value added | Technology Transfer Manual for Rural | A complete process manual distributed in print to the | |

| | | | | |
|---|---|---|---|---|
| | projects | Entrepreneurs etc (Nos.) | participants. Unfortunately, still it is not distributed with Rural Entrepreneurs | |
| 4 | Manual for technology transfer to rural entrepreneurs | Other Publications and Knowledge Products (Nos.) | Manuscript is communicated to journal | |

(*) As stated in the Sanction Letter issued by the NMHS-PMU.

### 2.4. Strategic Steps with respect to Outcomes (in bullets)

| S. No. | Particulars | Number/ Brief Details | Remarks/ Attachment |
|---|---|---|---|
| 1. | New Methodology developed | 2 | 1.Value added products development from pruned tea leave extract 2.Methodology for converting pruned tea waste in to a productive source of fuel |
| 2. | New Models/ Process/ Strategy developed | 2 | 1.Different types of instruments developed to make biomass pellet 2.value added products made out of other forms |
| 3. | New Species identified | NA | NA |
| 4. | New Database established | | |
| 5. | New Patent, if any | NA | NA |
| | I. Filed (Indian/ International) | | |
| | II. Granted (Indian/ International) | | |
| | III. Technology Transfer(if any) | | |
| 6. | Others (if any) | NA | NA |

### 3. Technological Intervention

| S. No. | Type of Intervention | Brief Narration on the interventions | Unit Details (No. of villagers benefited / Area Developed) |
|---|---|---|---|

| | | | |
|---|---|---|---|
| 1. | Development and deployment of indigenous technology | 1.Manually operated all the instruments for biomass pellet production developed in the project site.<br>2. Biomass pellet-based stove is designed based on solar power. This stove offers negligible smoke when compared to traditional stoves.<br>. | More than 100 villagers benefitted. |
| 2. | Diffusion of High-end Technology in the region | The instruments and their related set of operations have been kept as simple as possible to allow for basic training, minimal technical knowledge requirements, and use by both men and women as well as by elders and younger people. | Inderjuli, kampu, Sangopota villages of Papum Pare district, Arunachal Pradesh. |
| 3. | Induction of New Technology in the region | Biomass pellet based stove development | Distributed in three schools under Unnat Bharat Abhiyan |
| 4. | Publication of Technological / Process Manuals | Under Process | NA |
| | Others (if any) | NA | NA |

## 4. New Data Generated over the Baseline Data

| S. No. | New Data Details | Status of Existing Baseline | Additionality and Utilisation New data |
|---|---|---|---|
| **1.** | **Energy usage** | Pruned tea residue has never been used as a source of Energy for Household or Commercial purposes. | Pruned tea waste have become the source of Cooking and Heating Energy at household. |

| | | | |
|---|---|---|---|
| **2.** | **Livelihood options** | People are getting involved to make biomass pellet for economic activities interestingly. | The direct beneficiaries who have been involved and the others who have received training are beginning to engage in a work-from-home alternative with a plentiful free resource for the first time. |

## 5. Demonstrative Skill Development and Capacity Building/ Manpower Trained

| S. No. | Type of Activities | Details with number | Activity Intended for | Participants/Trained | | | |
|---|---|---|---|---|---|---|---|
| | | | | **SC** | **ST** | **Woman** | **Total** |
| 1. | Workshops | **4** | Activities for demonstration of operation and maintenance related to the fabricated machines and stoves were planned. | **10** | **50** | **60** | **105** |
| 2. | On Field Trainings | **2** | Beneficiaries received practical instruction through stove demonstrations. The proper and improper use of the equipment was covered. | **5** | **45** | **32** | **60** |
| 3. | Skill Development | **2** | Research team engaged beneficiaries with project related activities ranging from collection of raw materials and development of value added products, biomass pellet and stove designing. | **10** | **50** | **60** | **105** |
| 4. | Academic Supports | **1** | One hard copy of manual was distributed among all participants. | **10** | **50** | **60** | **105** |
| | Others (if any) | | | | | | |

## 6. Linkages with Regional & National Priorities (SDGs, INDC, etc)/ Collaborations

| S. No. | Linkages /collaborations | Details | No. of Publications/ Events Held | Beneficiaries |
|---|---|---|---|---|
| 1. | Sustainable Development Goal (SDG) | 1.The primary objective of the initiative has been to give residents with viable economic opportunities by expanding their access to local resources.<br>2. Most of the people in rural areas still depend on fuel wood/coal to satiate their daily energy needs. Women are the primary victims of the drudgery of using poor-quality fuel and associated health hazards from the toxic emissions of the frugal ovens. The current research aims to develop biomass pellet made from pruned tea leaves that has a calorific value comparable to that of wood and lower-grade coal and is somewhat cleaner in terms of emissions than the other two.<br>3. Especially, women in the rural setting were ensured through the Project. | Total 4 workshops and training organized for the beneficiaries. | More than 100 |

| | | | | |
|---|---|---|---|---|
| 2. | Climate Change/INDC targets | Climate change is a worldwide concern, and 'emissions everywhere affect people everywhere,' so it's crucial to find inexpensive, scalable solutions that lead to a cleaner environment. The current project showed how to use pruned tea waste that is burnt by locals in IHRs, reducing carbon emissions in the region. The team tried to convert the local economy to a cleaner one by discovering and developing market prospects. | | |
| 3. | International Commitments | N/A | N/A | N/A |
| 4. | Bilateral engagements | N/A | N/A | N/A |
| 5. | National Policies | N/A | N/A | N/A |
| 6. | Others collaborations | N/A | N/A | N/A |

## 7. Project Stakeholders/ Beneficiaries and Impacts

| S. No. | Stakeholders | Support Activities | Impacts |
|---|---|---|---|
| 1. | Gram Panchayats | N/A | N/A |
| 2. | Govt Departments (Agriculture/ Forest ) | N/A | N/A |
| 3. | Villagers | More than 100 villagers took part in trainings and benefitted. | New skillset has been developed among the villagers. |
| 4. | SC Community | The field team paid extra attention to the women from the most marginalised groups, making sure they were included in all meetings, workshops, and trainings. | It is estimated that 3 low-income families benefited from the project. |
| 5. | ST Community | We have taken extensive efforts to involve underrepresented groups in the project. Without regard to their social or religious backgrounds, all villagers were | More than 50 people were able to get themselves skilled and trained on the biomass pellet production and value-added products |

| | | | |
|---|---|---|---|
| | | regarded as equals and included in the success of the village as a whole. | development. |
| 6. | Women Group | Special focus was given to the participation of the women. | Total of 60 women from the were benefited from the project. They were the backbone of the project. |
| | Others (if any) | | |

## 8. Financial Summary (Cumulative)

| S. No. | Financial Position/Budget Head | Funds Received | Expenditure/ Utilized | % of Total cost |
|---|---|---|---|---|
| I. | Salaries/Manpower cost | 1474452 | 1447923 | 98.2 |
| II. | Travel | 369923 | 315104 | 85.18 |
| III. | Expendables &Consumables | 569808 | 548696 | 96.29 |
| IV. | Contingencies | 139998 | 124659 | 89.04 |
| V. | Activities & Other Project cost | 370427 | 369729 | 99.81 |
| VI. | Institutional Charges | 469161 | 469161 | 100 |
| VII. | Equipments | 1470000 | 1461600 | 99.43 |
| | Total | 4863776 | 4736872 | 97.39 |
| | Interest earned | **5537*** | | |
| | Grand Total | **4869313** | | |

*** Interest amount Rs. 58577.00 is adjusted to consumables & Rs. 9014.00 is adjusted with institutional charges. Hence total interest amount is Rs. 73128.00**

* Please attach the consolidated and audited Utilization Certificate (UC) and Year wise Statement of Expenditure (SE) separately, *ref*. **Annexure I.**

## 9. Major Equipment/ Peripherals Procured under the Project** (if any)

| S. No. | Name of Equipments | Cost (INR) | Utilisation of the Equipment after project |
|---|---|---|---|
| 1. | Rotary vacuum Evaporator | 7.3 lakhs | Weaker section people are constantly invited to our campus for the production of value-added products as well as to promote in various remote regions of Arunachal Pradesh. |
| 2. | Pellet machine + Hammer Mill (pulverizer) +Mixer | 5.32 lakhs | Weaker section people are constantly invited to our campus for the production of biomass pellets as well as to promote the stove and biomass pellets in various remote regions of Arunachal Pradesh. |

| | | | |
|---|---|---|---|
| 3. | Autoclave reactor (High temperature vessel) | 1.3 lakhs | Weaker section people are constantly invited to our campus for the production of value-added products as well as to promote in various remote regions of Arunachal Pradesh. |
| 4. | Stoves | 3000.00 each | Can be used for household purpose for cooking. |

**Details should be provided in details **(***ref* **Annexure III &IV).**

**10. Quantification of Overall Project Progress**

| S. No. | Parameters | Total (Numeric) | Remarks/ Attachments/ Soft copies of documents |
|---|---|---|---|
| 1. | IHR States Covered | 2 | Arunachal Pradesh and Assam |
| 2. | Project Site/ Field Stations Developed | 1 | Laboratory set up for the accomplishment of the project |
| 3. | New Methods/ Modeling Developed | 2 | One for value added products development and another for production of biomass pellet |
| 4. | No. of Trainings arranged | 4 | Above 100 beneficiaries attended trainings. |
| 5. | No of beneficiaries attended trainings | 105 | A model is distributed with all participants in hardcopy form |
| 6. | Scientific Manpower Developed (Phd/M.Sc./JRF/SRF/ RA): | 2 | 1 JRF, 1 RA |
| 7. | SC stakeholders benefited | 10 | Throughout the project 3 families of backward section benefitted. |
| 8. | ST stakeholders benefited | 50 | Total of 50 beneficiaries from the weaker sections of the society were given a chance to develop a skill and participate in the project and generate livelihood options for themselves. |
| 9. | Women Empowered | 60 | Took activities in different workshop programme related to this project. |
| 10. | No of Workshops Arranged along with level of participation | 4 | 4 major workshops held. Around 60 people directly benefited from those workshops. |
| 11. | On field Demonstration Models initiated | 3 | • Kampu Primary School<br>• Inderjuli Primary School<br>• Sangopota Primary School |
| 12. | Livelihood Options promoted | 3 | • Kampu Primary School<br>• Inderjuli Primary School<br>• Sangopota Primary School |
| 13. | Technical/ Training Manuals prepared | 1 | One training manual was Provided in the kit received by the students & villagers who |

| | | | |
|---|---|---|---|
| | | | registered in the workshop. |
| 14. | Processing Units established | One full set of instrum | Photos are attached in detailed report. |
| 15. | No of Species Collected | 1 | Species of tea from Godrick tea estate |
| 16. | New Species identified | Nil | NA |
| 17. | New Database generated (Types): | | |
| | Others (if any) | | |

## 11. Knowledge Products and Publications:

| S. No. | Publication/ Knowledge Products | *Number* | | *Total Impact Factor* | *Remarks/* Enclosures |
|---|---|---|---|---|---|
| | | National | International | | |
| 1. | Journal Research Articles/ Special Issue: | | | | |
| 2. | Book Chapter(s)/ Books: | | | | |
| 3. | Technical Reports | | | | |
| 4. | Training Manual (Skill Development/ Capacity Building) | | | | |
| 5. | Papers presented in Conferences/Seminars | | | | |
| 6. | Policy Drafts/Papers | | | | |
| 7. | Others: | | | | |

* Please append the list of KPs/ publications (with impact factor and further details) with due Acknowledgement to NMHS.

## 12. Recommendation on Utility of Project Findings, Replicability and Exit Strategy

| Particulars | Recommendations |
|---|---|
| Utility of the Project Findings | • The use of crude tea extracts from pruned tea leaved as an ingredient in cosmetics was justified by the in vitro assays. The cosmetics prepared are namely antiseptic cream, cold cream, lip balm, shampoo, hair oil, body oil, face wash, hand sanitizer, cool body powder and tooth paste. The base of these formulations was made and tea extract was incorporated in them to make herbal value-added products from waste pruned tea residues.<br>• Biomass pellets are made from tea plantation waste produce negligible emissions while providing fuel that has a calorific value as high as Grade 10 coking coal.<br>• The cost of biomass pellet is about Rs 8 per Kg which will sustain 45-60 minutes of cooking on a full flame. |
| Replicability of Project | • The instruments do not require bulky setup or electricity, it can be easily transported to the remote locations, these are gender friendly and can be operated easily with basic training of few hours.<br>• Thus, the locals could easily operate these instruments at their homes and can achieve economic gains and energy security from the same. |

| | |
|---|---|
| Exit Strategy | • After discontinuation of funding the proposed work could be sustain by encouraging a PPP (Public Private Partnership) model. In this district administration can engage unemployed youth for production of final outcome of the proposed project which could be potentially commercialize by involving a private institution. This would help in uplifting the financial status of both the human resource involved in public and private partnership. The proposed project thereby can be ideal model for sustainable growth and promoting entrepreneur skills. |


(**PROJECT PROPONENT/ COORDINATOR**)

**(Signed and stamped)**

(**HEAD OF THE INSTITUTION**)

**(Signed and Stamped)**

**Place:** Jote, Papum Pare, Arunachal Pradesh
**Date:** 20/12/2022

# PART B: PROJECT DETAILED REPORT

## 1. EXECUTIVE SUMMARY

### Purpose

Even after 70 years of Independence, the rural India still has a sparse access to clean energy. The dependence on agro biomass and cow dung-based fuels is the major source of energy in these places. The health hazards associated with the use of such fuels are well known. The primary victims of such poor-quality fuel are the women as they are exposed to the toxic emissions of the frugal ovens. The need of the hour is to provide clean fuel to rural parts. Moreover, if the fuel is made from local resources, then it can be produced economically. In doing so, if any further product is also generated then revenue generation can make the overall process economically viable**.** The aim of our innovation was to develop concomitant technology that would produce clean fuel and also some value-added product. In tea estates, the tea plants were cultivated and regularly pruned to maintain proper shape of tea bush. In doing so, a lot of biowaste is generated in terms of old leaves, stems etc. these agro-wastes could be a lucrative source of polyphenol and the residues can be converted in biomass pellet. These biomass pellets can be used as clean fuel and the poly phenols can be used as value added products such as preparation of hand sanitizer. The availability of tea based agro residues are in abundance in states like Assam, Arunachal Pradesh and west Bengal. The suitability of such residues as clean fuel can have great impact on the health of the population involved in its cultivation and processing. Moreover, revenue generation opportunity can be created using the by-products extracted from these agro-residues and further help in social upliftment of them. Development of such innovative biorefinery based technology where many products can be produced from single feedstock can be helpful for rural development and prosperity. The aim of our innovation will be to develop concomitant technology that would produce clean fuel and also some value-added product.

### Problem

The Indian Himalayan Region presents a number of difficulties and is very susceptible to socio-economic risks. These vulnerabilities are a result of the topographical constraints, which on the one hand include a scarcity in terms of local socioeconomic resources, opportunities, and support and are driving the loss of livelihood, unbalanced development of women and children, migration

of youth, and an improper and uncertain future for subsequent generations. On the other hand, it also results in pushing the locals to get engaged in unproductive modes of livelihood, which are most of the time destructive.

**Result and Recommendation**

The project has developed a model-based value chain that is self-sustainable, which will not only provide the rural youth with the opportunity to become an entrepreneur but will also provide the community with skills, various options for livelihood, and a source of energy that is low cost, clean, and efficient.

The extract of freshly shade-dried leaves that had been treated with 50 percent ethanol at 70 degrees Celsius for two hours showed the highest phenolic content when it was put through an evaluation for its antioxidant capacity. The percentage of inhibition represented by 100 g of extract was 72.69%, indicating substantial antioxidant capability and, as a result, potential therapeutic action. The cosmetics prepared are namely antiseptic cream, cold cream, lip balm, shampoo, hair oil, body oil, face wash, hand sanitizer, cool body powder and tooth paste. Bio pellets are made from tea plantation waste produce negligible emissions while providing fuel that has a calorific value.

We can use Gasifier with this technique to generate electricity & also we can make Biomass briquettes. With the help of this a new revenue will be generated.

## 2.INTRODUCTION

### 2.1 Background:

Our country has a vivid topography with a vast variety of flora and fauna. The semi-temperate, tropical, and hilly regions of our country are known for their exotic plant species. In this region, significant human resources are employed in the field of horticulture. Tea, coffee, spices, etc. are popular crops. The Himalayas' alluvial plains and hilly peninsula are ideal for growing such plants. Lack of access to clean fuel, water, and jobs is a key development barrier in such locations. Sustainable development projects can boost regional growth.

Rural residents in these regions rely on wood logs and plant wastes for fuel. The health dangers of burning such fuels are well known, and rural women are the main victims. Burning such fuels produces serious household pollution and respiratory illnesses in women and children. According to the WHO, inhaling dirty fuel smoke by women is equivalent to smoking 400 cigarettes every hour. In addition, women and children have to go through the drudgery of collecting firewood. Unfortunately, only 2-3% of people in the North East region have LPG gas connections, and the current government intends to increase the number of domestic LPG gas connections by 2030.The need of the hour is to find a suitable technology that would help mitigate these problems. The use of biomass-based pellets as fuel has gained importance in recent times. Commercial smokeless ovens are also being developed to utilise these fuels. Biomass pellets made from Himalayan farm waste can meet local energy needs.

High-value crops are economically important and can provide year-round employment for Himalayan women. North-eastern India's subtropical climate is ideal for growing plantations. Tea, coffee, and rubber are key crops. Assam and Tripura introduced tea as an industrial crop in the mid-19th century; it has since expanded to other non-traditional states in the region. Suitable land and climatic conditions provide a favorable environment for tea, coffee, and rubber plantations in Arunachal Pradesh, Manipur, Meghalaya, Mizoram, and Nagaland. Mature bushes are pruned at intervals in tea and coffee plantations to renovate the branch system and keep the bush in the vegetative phase. Pruning is required to promote lateral growth of the plant with higher foliar growth. It stimulates the production of new sets of vigorously growing branches to replace the old ones. In general, after punning and skiffing tea plants, all agricultural residues are burned. These clipped wastes could be biomass pellet feedstock. In addition, trimmed tea plant stem and leaf residues contain a large number of secondary metabolites (polyphenols, tannins, antioxidants, etc.). In this proposal, we want to explore the possibility of extracting secondary metabolites (polyphenol, tannin, antioxidants, etc.) from pruned residues to manufacture value-added goods and bio-pellets for clean fuel. If such technology is built using local resources, it can be manufactured economically and generate cash for the local population. If more products are made, the total process can become profitable.

## 2.2 Overview of the Major Issues

There is a massive amount of untapped potential for the creation of next-generation agricultural goods in the Himalayan region. The potential for economic growth in the area has been hampered by the absence of scientific information regarding the utilisation of natural resources.

These places have an abundance of readily available forest and agricultural leftovers, which potentially have the potential to serve as a source of fuel that is pure. However, at the moment, both the technology and the knowledge are in their infant stages. Utilizing ovens that are fueled by biomass pellets presents an opportunity to reduce the risk to one's health that is connected to the release of hazardous emissions by low-cost cooking appliances. Agricultural wastes that would have been thrown away otherwise can be used to make biomass pellets, which can then be manufactured in an efficient and cost-effective manner. Because of this, economically disadvantaged societies may have easier access to environmentally friendly fuels, which may have a positive impact on their general health.

Our goal is to produce new goods out of waste residues from pruned tea plants, such as soaps, shampoos, biomass pellets, and other products, with the intention of turning those waste residues into a source of revenue.

## 2.3 Baseline Data and Project Scope

The suitability of pruned tea residues as clean fuel can have great impact on the health of the population involved in its cultivation and processing. Moreover, revenue generation opportunity can be created using the byproducts extracted from these agro-residues and further help in social upliftment of them. Development of such innovative biorefinery based technology where many products can be produced from single feedstock can be helpful for rural development and prosperity. The resources required for successful implementation of the proposed project are locally available and to some extents are renewable in nature.

## 2.4 Project Objectives and Target Deliverables

**Objective 1.** Optimization of phenolic and antioxidants from pruned Tea plant residues.

**Objective 2.** Development of value-added products such as soaps, sanitizer etc. using extracted phenolic and antioxidants.

**Objective 3.** Optimization of process parameters for bio-pellet production from extracted waste residues.

**Objective 4.** Investigation of suitability of bio-pellet as clean alternative fuel or as alternative to coal.

**Target Deliverables**

- Development of a prototype/pilot scale production model for Bio- pellet.
- Development of commercially viable value-added products such as shampoos, sanitizers, etc.
- Establishment of market linkages for value added projects
- Manual for technology transfer to rural entrepreneurs

## 3. METHODOLOGIES, STARTEGY AND APPROACH

### 3.1 Methodologies used for the study

**Objective 1:** Optimization of phenolic and antioxidants from pruned Tea plant residues

Prior to extraction, samples were pre-treated by autoclaving and shade drying. Extraction parameters like temperature and solvent were varied to optimize the process. Total phenolic content and antioxidant property of each sample (i.e., crude extracts) were performed to claim the best extraction process. Phenolic content was measured by spectrophotometric method using Folin Ciocalteau reagent (FCR). Antioxidant property was measured by DPPH assay.

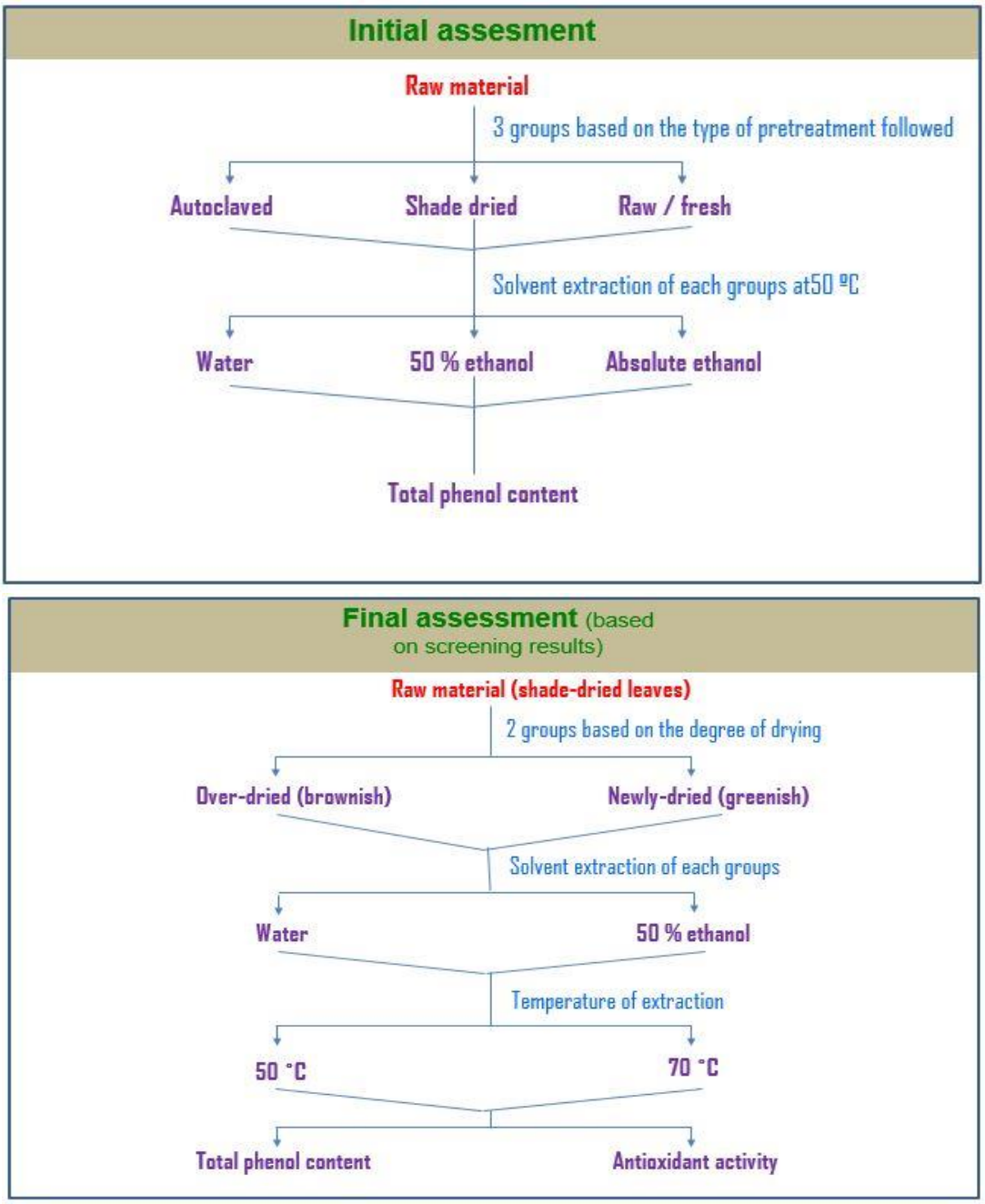



**Figure 1: Schematic diagram portraying the methodology briefly**

**Objective 2:** Development of value-added products such as soaps, sanitizer etc. using extracted phenolic and antioxidants

The base of each cosmetic was prepared while maintaining proportions of raw materials (basically chemicals), and physicals parameters were set to achieve a consistent and usable form of phase

where herbal extracts (primarily tea extracts) are incorporated to produce the desired herbal cosmetics.

**Objective 3:** Optimization of process parameters for bio-pellet production from extracted waste residues

Pruned tea plant was collected from local tea garden and dry in sun for approximately 7-8 days for completely dried. The dried tea plant is cut into small pieces by knife and then pulverized in domestic blender PAS-180 220V/380V., to produce powder (CPP)., which act as raw material for the subsequent extraction processes. Guar gum binders were used for better strength and durability. For binder two different concentrations of 20% and 40% were made separately, mixed thoroughly with CPP. After mixed with binder the samples were kept for dry, moisture contents reduce to 16-23%. Moisture content was measured by digital moisture meter EMT01. Accuracy 0.5%, 9V Temp. Range 0-40 degree.

**Objective 4:** Investigation of suitability of bio-pellet as clean alternative fuel or as alternative to coal

TGA (Thermogravimetric analysis) was done to determine the proximate analysis (Moisture, volatile, fixed carbon and ash contents) of the biomass pellets. Using TGA model: Hitachi STA7200 following the procedure given by Garcia, R., Pizarro, C., Lavín, A.G. and Bueno, J.L., 2013.

### 3.2 Preparatory Actions and Agencies Involved

**Not Applicable**

### 3.3 Scientific data collected and Equipment Used

The study conducted is amongst the first researches that identifies, collects and prioritizes all the factors that are acting as barriers & pose a hindrance to any energy generation initiative using pruned tea leaves in the state of Arunachal Pradesh. An extensive literature review was done to

identify and collect major barriers to energy generation & development of value-added products using pruned tea leaves.

**Equipment used**

- Rotary vacuum Evaporator
- Pellet machine
- Hammer Mill (pulverizer)
- Mixer
- Autoclave reactor (High temperature vessel)
- Hot air oven
- Moisture metre
- Desiccator

### 3.4 Primary Data Collected

Data was collected on the recipients' household energy usage patterns as well as the livelihood alternatives, particularly for women, in the local area. The villagers' reliance on the local fuelwood is evident from the data. The outcome was anticipated because both of the villages are close to areas of forest and tea gardens, making it easier for them to get fuelwood. As a result, there is a partial or complete reliance on fuelwood in the area to meet daily household energy needs. While interacting with the locals on a daily basis, I learned another intriguing fact: on average, women in the village spend 4 hours collecting fodder, grass, and fuel wood. In one of the settlements, this average rises to 5 hours at the start of the winter season. Since it is extremely difficult to venture outside during the winter due to terrible weather conditions, this increase in average time is the result of the ladies gathering extra feed, grass, and fuelwood.

### 3.5 Details of Field Survey arranged

## Professor and team from NIT Arunachal Pradesh create a clean, affordable alternative to toxic solid fuels used in rural India

**Yupia, Dist AP, December, 13th, 2019:** In 2019 more than two-thirds of households in rural India still use firewood and chips for cooking, indicating a higher use of traditional biomass among low-income households. Women are the primary victims of the drudgery of using poor-quality fuel and associated health hazards from the toxic emissions of the frugal ovens.

LPG is becoming popular in rural India as a convenient and clean cooking fuel where a survey conducted from 2015 to 2018 by Council for Energy, Environment and Water (CEEW) concluded that the share of households (in six major energy access deprived states) using LPG as their primary cooking fuel increased from 14 to 37% (CEEW, May 2019). However, the cost of stove and cylinders still remains the major barrier towards the adoption of LPG (Goulda&Urpelainen, 2018). Refueling of LPG cylinders in rural areas and transportation of heavy cylinders in difficult Indian terrains like mountains and remote areas is still challenging. A study conducted by Research Institute for Compassionate Economics, mentions that 90% of Ujjwala beneficiaries (a scheme launched in 2016 that provides subsidized LPG connections to women of the poor households) still use solid fuels for cooking. Affordability and availability of solid fuels compared to LPG makes them the primary choice of fuel in large areas of India. As a result, the rate of increase in uptake of LPG as primary cooking fuel has been slow in spite of introducing schemes like Deepam, Rajiv Gandhi Gramin LPG VitrakYojna& Pradhan Mantri UjjwalaYojna.

If fuel is made from local resources, it can be produced economically. This could create a whole economy around agriculture waste where rural residents engaged in agriculture could sell their waste to be converted to bio-fuel instead of burning it or discarding it. This can open up another revenue stream for them, mitigate pollution caused by burning of Agro waste and encourage them to switch to fuel made by their own raw material that is sustainable, clean and affordable. Dr. Saikat Kumar Jana, Assistant Professor Biotechnology at NIT Arunachal Pradesh is leading one such initiative. His project titled “Development of sustainable technology for production of biomass pellet-based fuel and herbal by-product from residue of pruned tea plant: Augmenting rural development” recently got funded by the Ministry of Environment, Forest and Climate Change (MoEF&CC). “More than 350 million tonnes of

agro-waste is generated annually, which has the potential to be turned into affordable and sustainable biofuel. Our bio pellets are made from tea plantation waste and produce negligible emissions while providing fuel that has a calorific value as high as Grade 10 coking coal", said Dr. Jana. He also added that the cost of biomass pellet is about Rs 5 per Kg which will sustain 45-60 minutes of cooking on a full flame. Dr. Jana's group is also preparing a new biomass pellet-based stove keeping the needs of the rural population in mind, as a result, will be very user-friendly and extremely affordable compared to the existing stoves present in the market. The fuel is made using the residue of the pruned tea plants. The leaves and branches that are produced as waste during the pruning process each year go through a crushing and threshing process which converts them into a powder-like texture. A proprietary natural binder is then added to this mixture to hold it together. This bound mixture is then cut into pellets.

On 22nd November, Dr. Jana and his team of students conducted a promotional campaign to test the usability of the bio-pellets, made in their lab at NIT, at different schools (KAMPU, INDERJULI, and SANGOPOTA) in Jote district of Arunachal Pradesh. The biomass pellets were distributed with a stove in three schools as an alternative fuel for cooking meals under the Unnat Bharat Abhiyan scheme. "The teachers and students were very enthusiastic about the stove and pellets and asked several questions. I think we piqued the curiosity of the students and hopefully encouraged them to come up with their own solutions to address the energy gaps in our country".

**Fig 2. Introducing agricultural waste-based biomass pellets and stove in different rural parts of Arunachal Pradesh**

**Fig 3. Discussing with teacher to replace LPG gas by pellet-based energy for mid-day meal preparation**

**Fig 4. Sharing our knowledge for preparation of clean biomass fuel**

### 3.6 Strategic Planning for each Activities

**Optimization of phenolic and antioxidants from pruned Tea plant residues**.

- Investigation of different extraction processes viz. Ethanol extraction, Steam extraction, etc.
- Optimization of particle size for improved extraction of phenolics.
- Estimation of product yield and stability.

**Development of value-added products such as soaps, sanitizer etc. using extracted phenolic and antioxidants.**

- Study of anti-microbial activity, anti-fungal activity, toxicity evaluation of the extracted phenolic.
- Supplementation study with defined liquid soaps for commercial application.

**Optimization of process parameters for bio-pellet production from extracted waste residues.**

- Investigating the role of different binders suitable for tea residue-based bio-pellets.
- Study of the packaging density, moisture content, porosity and structural strength of pellets.

**Investigation of suitability of bio-pellet as clean alternative fuel or as alternative to coal.**

- Study of emission profile, calorific value, combustion efficiency using biomass pellet-based ovens.
- Study of Life cycle analysis and Environmental impact assessment.

### 3.7 Activity wise Time frame

| Activities | April 2018-September 2018 | October 2018-March 2019 | April 2019-September 2019 | October 2019-March 2020 | April 2020-December 2020 | January 2021-March 2021 | April 2021-September 2021 |
|---|---|---|---|---|---|---|---|
| Literature Review | | | | | Lockdown | | |
| WP1 | | | | | | | |
| WP2 | | | | | | | |
| WP3 | | | | | | | |
| WP4 | | | | | | | |
| Workshop, Training | | | | | | | |
| Manuscript | | | | | | | |

## 4. KEY FINDINGS AND RESULTS

### 4.1 Major Research Findings

- Initial investigation of raw materials proved shade dried leaves to be the best one.
- Temperature of 70 $^{o}$C and 50 % aq. ethanol are the best extraction parameters.
- The use of crude tea extracts from pruned tea leaved as an ingredient in cosmetics was justified by the in vitro assays. The cosmetics prepared are namely antiseptic cream, cold cream, lip balm, shampoo, hair oil, body oil, face wash, hand sanitizer, cool body powder and tooth paste. The base of these formulations was made and tea extract was incorporated in them to make herbal value-added products from waste pruned tea residues.
- Biomass pellets are made from tea plantation waste produce negligible emissions while providing fuel that has a calorific value as high as Grade 10 coking coal.
- The cost of biomass pellet is about Rs 8 per Kg which will sustain 45-60 minutes of cooking on a full flame.

## 4.2 Key Results
## Objective 1

**TPC of extracts:** The standard curve of GA is used to quantify the amount of total phenolics in an individual extract.

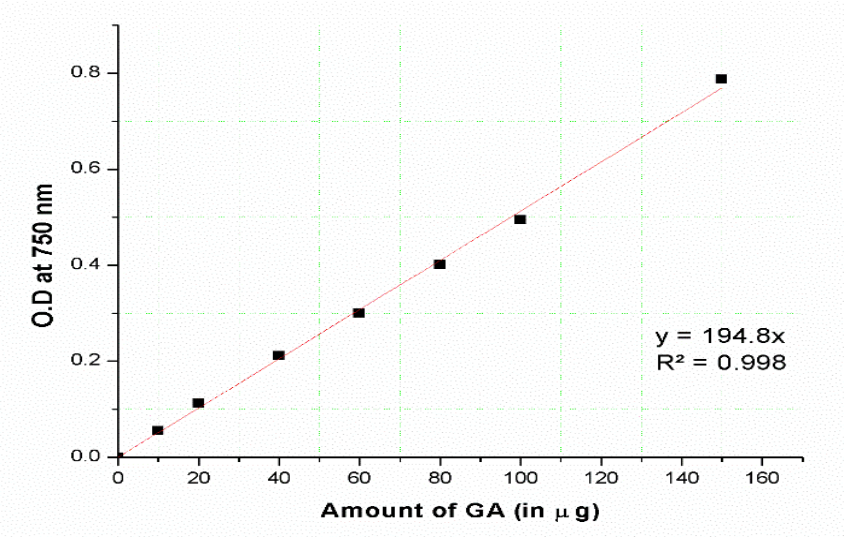



**Figure 5: Standard curve of Gallic acid**

TPC of samples is represented in milligram of Gallic acid equivalent (GAE) per gram of raw materials. A comparison of the phenolic content between autoclaved, shade dried and raw leaves is established in the initial study.

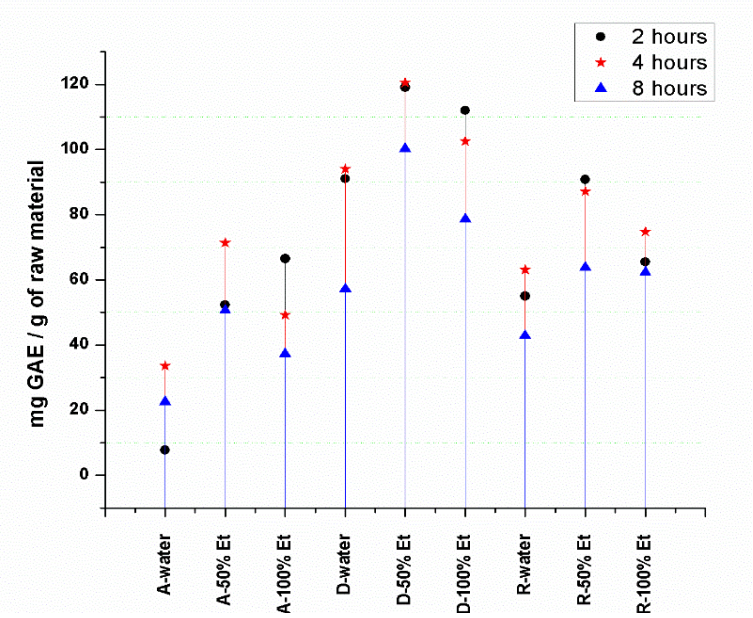


**Figure 6: TPC of different samples at 2, 4 and 8 hours (temperature maintained at 50 ºC). A, D and R are autoclaved, dried and raw leaves whereas water, 50 % Et, and 100 % Et indicates water, 50 % ethanol and 100 % ethanol respectively.**

**From figure 6** it can be depicted that extracts from shade dried leaves witnessed highest extraction of phenols. The idea of autoclaving the leaves before storage was to deactivate the enzyme polyphenol oxidase which eventually oxidizes the phenolic compounds. But the application of high temperature for a period of more than 30 minutes seemed to degrade some polyphenols also. Among the solvents used, 50 % ethanol is the most efficient solvent for phenolic extraction. The highest yield of phenols is 12.05 %. A trend is observed which revealed that prolonged extraction (more than 4 hours) exhibited a significant decrease in TPC. Based on the initial screening results, autoclaved and raw leaves were discontinued due to poor phenolic content. Also, absolute ethanol was not used henceforth as it proved to be a less efficient solvent that 50 % aq. ethanol and the extraction time was restricted to 4 hours.

Browning of leaves during drying is caused by the oxidation reactions catalyzed by polyphenol oxidase. The two groups of dried leaves, one brown and one green, classify the raw material on basis of the extent of activity exhibited by polyphenol oxidase. Further optimization of extraction procedure was done by performing the same extraction procedure discussed earlier at 30 ºC and 70 ºC.

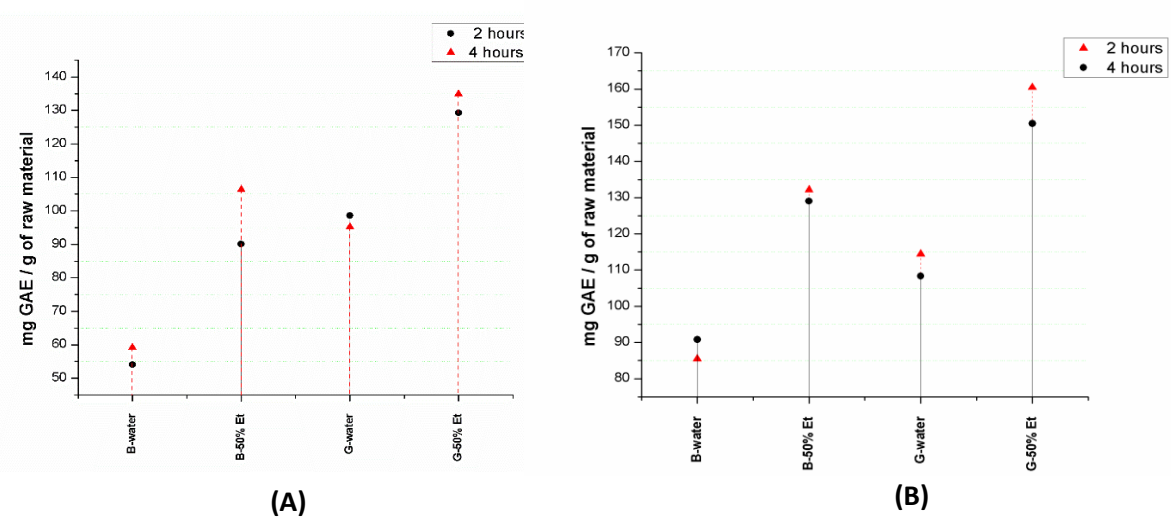



**Figure 7: TPC of different samples at 2 and 4 hours. B and G indicate groups with brown and green dried leaves whereas 50 % Et indicates 50 % ethanol. (A) and (B) corresponds to the samples extracted at 30 ºC and 70 ºC respectively.**

**Figure 7** portrays that among shade dried leaves, green leaves act as a better source of polyphenols than brown ones. This can be supported by the fact that over drying causes prolonged activity of the enzyme polyphenol oxidase to which is responsible to lower the TPC values. When extracted at 30 $^{o}$C with 50 % ethanol, the highest TPC achieved is 134.89 mg GAE / g of green dried leaves while at 70 $^{o}$C the value reached 160.46. Moreover, at 70 $^{o}$C, maximum extraction of polyphenols occurred during the first 2 hours and prolonged extraction time lowered the phenolic content.

**Antioxidant activity (using DPPH) of extracts:**

The standard curve of AA is used to estimate the antioxidant activity of an individual extract.

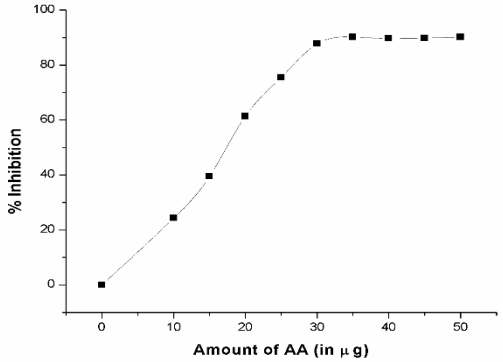



**Figure 8: Standard curve of antioxidant activity**

The extract of newly shade dried leaves (green in color) treated with 50 % ethanol at 70 $^{o}$C for 2 hours showed the highest phenolic content and it was evaluated to check its antioxidant property. 100 µg of extract depicted the % inhibition of 72.69 % implying significant antioxidant property and thus potential therapeutic activity.

**Objective 2**

- ✓ The cosmetics prepared are namely antiseptic cream, cold cream, lip balm, shampoo, hair oil, body oil, face wash, hand sanitizer, cool body powder and tooth paste.
- ✓ Incorporation of herbal extracts in cosmetics for achieving addition benefits/increasing efficacy of products.
- ✓ One demonstrative model in the form of workshop.
- ✓ Technology Transfer Manual to the students for preparing cosmetics using herbal extracts

**Objective 3**

From the various combination with different concentration. Nine pellet samples (figure 9) are obtained. The obtained pellets were in cylindrical shape with the size of 20 mm in length and 8 mm in diameter. The outer surface was smooth with no cracks on the surface, shiny appearance for the guar gum pellets. For starch, combination of starch and guar gum pellets, a dull appearance with no cracks. The three parameters were kept in optimum conditions (temperature-100°C, moisture content- 10%, pressure- 200Mpa). When the parameters have some changes then the obtained pellets have some deformities for example when the moisture content was less than 10% then the pellets were easily breakable and turned in to powder. When the moisture content was more than 10% obtained pellets were bended and also cracks were found. The temperature and the pressure are also equally important as they have the capacity to trigger the natural binders present in biomass. These natural binders along with added binders promotes the cohesion of the of the particles (particle density increases with increase in temperature). The pressure increases with the molecular contact of the particles. Therefore, the obtained pellets quality is good.


**Figure 9**. Biomass samples of different binder concentrations (1) 5% of guar gum, (2) 10% of guar gum, (3) 15% of guar gum, (4) 5% of starch, (5) 10% of starch, (6) 15% of starch, (7) 5% of starch and guar gum (1:1 ratio), (8) 10% starch and guar gum (3:1 ratio), and (9)15% of starch and guar gum (5:1 ratio).

**Table 1**. Proximate Study of tea pruned biomass pellets

| Analysis | Samples | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **Proximate Analysis (%)** | **1** | **2** | **3** | **4** | **5** | **6** | **7** | **8** | **9** |
| Moisture before drying | 9.29 | 11.06 | 11.12 | 10.13 | 10.58 | 10.42 | 11.25 | 9.28 | 10.61 |
| Moisture after drying | 2.3 | 2.6 | 2.1 | 2.7 | 2.8 | 3.0 | 3.2 | 3.5 | 2.5 |
| Volatile matter | 63.9 | 66.71 | 63.26 | 62.38 | 63.66 | 63.26 | 68.97 | 65.35 | 63.96 |
| Fixed carbon | 14.09 | 15.04 | 16.24 | 17.15 | 17.42 | 17.92 | 18.66 | 16.54 | 14.21 |
| Ash content | 12.72 | 7.19 | 9.38 | 10.16 | 8.35 | 8.4 | 5.72 | 8.82 | 7.22 |

In proximate analysis (Table 1) contains four major parameters such as moisture content, ash content, volatile matter and fixed carbon. The pellets which are commercially available contains 10-12% of moisture content. The obtained moisture content before drying is between 9-11% and after drying is between 2-3.5%. So, this shows the moisture content is less than 5% and similarly low moisture content is obtained due to the length of drying process. The moisture content of the pellet determined the quality of the pellet as well as heating value. The moisture content present in the vapors during the combustion process, decreases the heating efficiency and performance of the pellet. Higher moisture content decreases the burning carbon rate. This action leads to incomplete combustion of volatile matter and deposits unburned carbon which smokes. Ask content in a fuel represents the mineral content left after the combustion process. The compounds that are commonly present in the ash are silica oxides, aluminum oxides, potassium oxides, sodium oxides and iron oxides. These are the solids residues which are responsible for the formation of slags and fouling layers inner parts of boilers, and also influence the combustion rate during pyrolysis and gasification process. Ash is non-flammable material but high ash content results affect the high heating value (HHV) scene, the pellets are made out of biomass pellets (agrowaste), they can also be reused as an organic fertilizer for the agriculture fields. For the guar gum (sample

no 1-3) 10% concentration sample shows a moderate level of ash content compared to 5% and 15%. For starch (sample no 4-6) 5% shows the high ash content, 10% and 15% shows moderate level. For the combination of binders- 5% shows the least ash content and other two concentrations have a moderate level of ash content. Therefore, according to the ash content sample 7 (5% 1:1 ratio) has the best out of all other samples. The reason for the high ash content for other samples are due to insufficient and excess amount of binder added to biomass. Volatile matter is the organic compounds (hydrocarbon, methane, carbon monoxide, nitrogen and unburned gases) present in the pellets which results in good HHV by releasing vapours during combustion process. The present of high volatile matter content also makes ignition process much easier. For the samples, the volatile matter content various from 63% to 68%. The highest value of volatile matter was obtained at sample 7 (5% with 1:1 ratio). Fixed carbon (FC) is also known as solid carbon. These FC and carbon content from the ultimate analysis is not the same. FC is a carbon which remains after volatile matter during combustion process. FC has a greater influence on the HHV as because the higher FC content, higher combustion value. For the sample the value of FC ranges from 14 to 18% in that the highest value obtained for the sample 7 (5% with 1:1 ratio).

**Table 2**. Ultimate Study of tea pruned biomass pellets

| **Analysis** | **Samples** | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **Ultimate Analysis (%)** | **1** | **2** | **3** | **4** | **5** | **6** | **7** | **8** | **9** |
| Nitrogen | 1.78 | 2.96 | 2.42 | 2.46 | 2.5 | 2.25 | 1.99 | 1.85 | 1.97 |
| Carbon | 44.44 | 43.35 | 43.48 | 43.4 | 43.17 | 43.52 | 43.54 | 44.22 | 44.05 |
| Hydrogen | 6.6 | 6.3 | 6.57 | 6.45 | 6.27 | 6.4 | 6.19 | 6.28 | 6.56 |
| Oxygen | 36.24 | 40 | 38.15 | 37.53 | 39.73 | 39.43 | 42.56 | 38.83 | 40.2 |
| Sulfur | Trace | Trace | Trace | Trace | Trace | Trace | Trace | Trace | Trace |

Ultimate analysis (Table 2) mainly focuses on C, N, H and O content. The sulfur content is less than the detectable limit or in a trace amount. C, H, N and O are the major compounds that are present in the biomass carbon is the most essential element present in carbonaceous fuels. Nitrogen is also present but the proportion is varying from plant to plant. C and H content has some influence on ash content and HHV. When the C and H content is high then, the HHV and ash content is also high. The main purpose of the ultimate analysis is to measure the pollutant which are going to be released in the environment after combustion process. The results obtained or the samples does

not have much difference the nitrogen content was around 2%, the carbon content was 43-44%, the hydrogen was 6%, oxygen was 36-40%. Sulfur was found to be in trace amount. During combustion process very less or negatable amount of $NO_x$ and $SO_x$ will be released in the environment which is harmless.

**Table 3**. Compression and HHV study of tea pruned biomass pellets.

| Analysis | Samples | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
| **Compression force (N)** | 1800 | 1500 | 1600 | 1900 | 1800 | 1800 | 1800 | 2200 | 1200 |
| **Tensile strength (TS) (MPa)** | 7.16 | 5.97 | 6.36 | 7.56 | 7.16 | 7.16 | 7.16 | 8.75 | 4.77 |
| **HHV (according to proximate analysis) (MJ/Kg)** | 14.19 | 14.92 | 14.77 | 14.91 | 15.2 | 15.29 | 15.15 | 15.18 | 15.49 |

Compression analysis (Table 3) was done to check the deformation property of the pellet. An external force is applied, so that the strength of the pellet can be measured. Form this analysis the reason for the deformation of the pellets can be identified. For sample 9 (15% with ratio 1:5) shows the least force 1200N and tensile strength of the sample was found to be 4.77Mpa. The highest force was resisted by the sample 8 (10% with the 1:3 ratio) the force was recorded at 2200N and the tensile strength was found to be 8.75Mpa. For starch samples alone the maximum force was recorded for the sample 4 (5%) and tensile strength was 7.56Mpa. For guar gum, sample 1 (5%) the force was recorded as 1800N and tensile strength was found to be 7.16Mpa. So, according to the analysis reports the highest force was recorded for the sample 8, which has a good strength and will not deform during rough transportation and storage.

High heating value (HHV) (Table 3) is a measurement of heat measured during the combustion of biomass pellet in which the pellet is completely burned. Usually, the HHV is measured in bomb calorimeter but the HHV can also be calculated by the elemental composition and the value will be mentioned in MJ/Kg. HHV mainly consider two main element C and H combined in a biomass with low ash content will have a HHV and verse versa. Therefore, for this work the obtained value

was between 14-15.5 MJ/Kg. The values were calculated by using FC and VM values from proximate analysis. There was not much difference in the obtained HHV. Therefore, the results of sample 7 was better as compared to all the samples as because the results are moderate in strength analysis and HHV along with the ash content was also less than 5%.

Smoke emission was done for sample 7 as because from the obtained results sample7 was found to be best. The results obtained from the smoke emission was HC (hydrocarbon)-5ppm, CO (carbon monoxide)-0.05%, $CO_2$ (carbon dioxide)-0.32%, and $NO_x$ (nitrogen oxides)-7ppm. The pollutant that will be released in to the environment was measured in trace amount which will not be harmful for the environment and human kind.

### 4.3 Conclusion

The in vitro assays established the potency of our crude extract to be an ingredient in the formulation of cosmetics. These value-added herbal products were made by mixing correct proportion of base materials with the tea extract. Conducting workshop cum hands on training with students helped us to verify its usability with their feedbacks. The cosmetics prepared are namely antiseptic cream, cold cream, lip balm, shampoo, hair oil, body oil, face wash, hand sanitizer, cool body powder and tooth paste. These 10 products are widely used in our daily life and a cost-effective approach to manufacture skin friendly cosmetics can prove to be promising industrially. The use of tea leaves extract makes use of less synthetic antioxidants and thus certainly restricts their side effects in the long run.

This work reports about a raw material available in North-East India for future biomass pellet production. The feedstock such as pruned tea waste has a high content of cellulose, and they may be potential candidates for biomass pellet production. These lignocellulosic biomasses are indigenous to North-East India and similar exploration can add to the database of biomass for pellet production. The pruned tea waste has great potential to produce biomass pellet that are extensively used in the IHR especially in the remote regions. Bio pellets are made from tea plantation waste produce negligible emissions while providing fuel that has a calorific value as high as Grade 10 coking coal. The cost of biomass pellet is about Rs 8 per Kg which will sustain 45-60 minutes of cooking on a full flame.

## 5. Overall Achievements

### 5.1 Achievement on Project Objectives

- Herbal by-product with the bioactive compounds extracted from tea residues.
- One demonstrative model in the form of workshop
- Technology Transfer Manual to the students for preparing cosmetics using herbal extracts
- Biomass pellets produced from pruned tea waste and the parameters are optimized

- More than 40 KG biomass pellet prepared.
- Promotion and demonstration of Tea waste-based biomass pellets, stoves at different rural part of Arunachal Pradesh as domestic energy sources.
- Technology has been demonstrated to rural people of Arunachal Pradesh.
- Biomass pellet-based stove is designed based on solar power. This stove offers negligible smoke when compared to traditional stoves.
- More than 100 peoples are directly and indirectly benefitted from this project.

### 5.2 Establishing new database

**Not applicable**

### 5.3 Generating Model Predictions for different variables

**Not Applicable**

### 5.4 Technological intervention

As part of the training programme, all equipment were installed at NIT Arunachal Pradesh. This helped in providing hands-on training to participants and provided them a real time experience of assembling, installation and commissioning of instruments related to biomass pellet production. Exposure about the development of value-added products from tea waste, production of biomass pellet, improved biomass cookstove, etc were done.

Main objective to provide students detail hands-on practical knowledge on value-added products from tea waste, production of biomass pellet and biomass improved cook stove during the course.

## 5.5 On field Demonstration and Value-addition of Products


**Fig 10. Workshop on Formulation of Cosmetic Products using Tea extract**

**Fig 11. With students and beneficiaries**


**Fig 12. Value added products using Tea extract**

Sanitizer developed from tea plant extract oil

YUPIA, Mar 23: A faculty from the National Institute of Technology, Dept. Of Biotechnology, Dr. Saikat Kumar Jana and his research group produced hand sanitizer with tea plant extract oil under the project of MOEF, Govt. of India.

Sanitizers have been considered indispensable in the past few days to fight against COVID-19. Unfortunately, the inadequate supply of hand sanitizers is jeopardizing the crusade against the deadly virus. Signs of "No mask and sanitizer available" in pharmacies have made the scenario much worse resulting in panicked common people.

In this situation, institutes like National Institute of Technology, set an example to fight against it innovatively with a touch of humanity.

Jana while talking to this daily informed that "the sanitizer is not for commercial purposes but to protect the faculties and staff and for those who cannot afford the basic hygiene equipment."

He also said that in this hour of need, awareness and proper precautions can only save us.

**Fig 13. Sanitizer developed from tea plant extract oil**


**Fig 14. Certificate provided to participants**


**Fig 15. Workshop on biomass pellets production utilization for energy production**

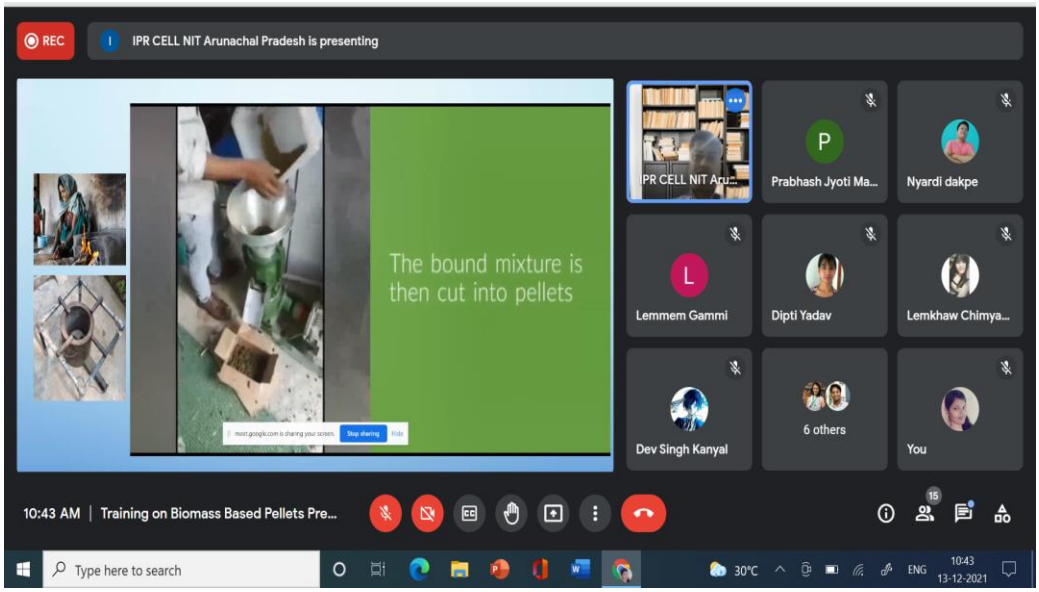



**Fig 16. Online workshop on biomass pellets production**

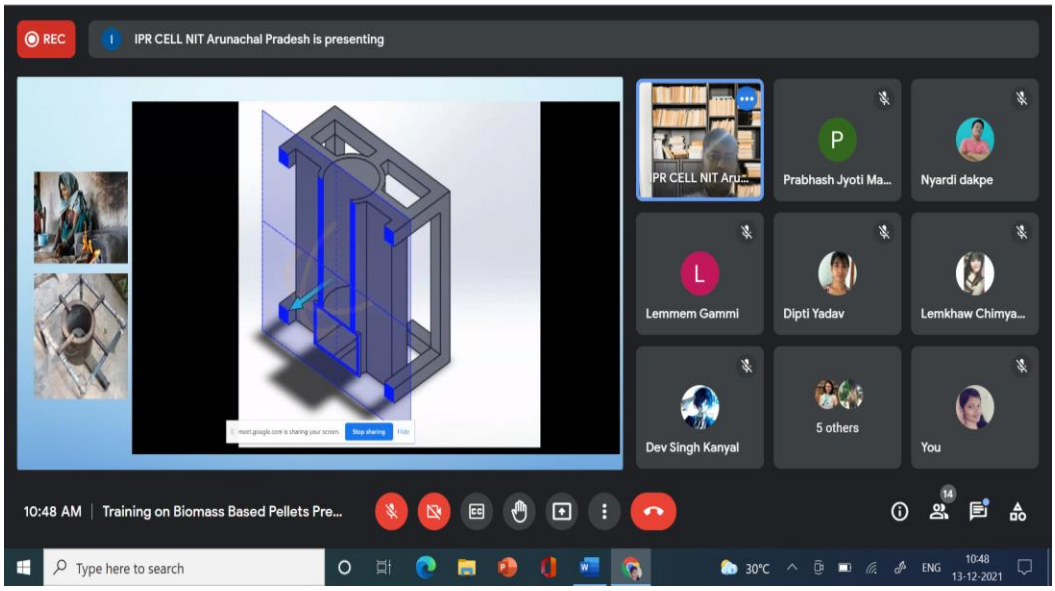
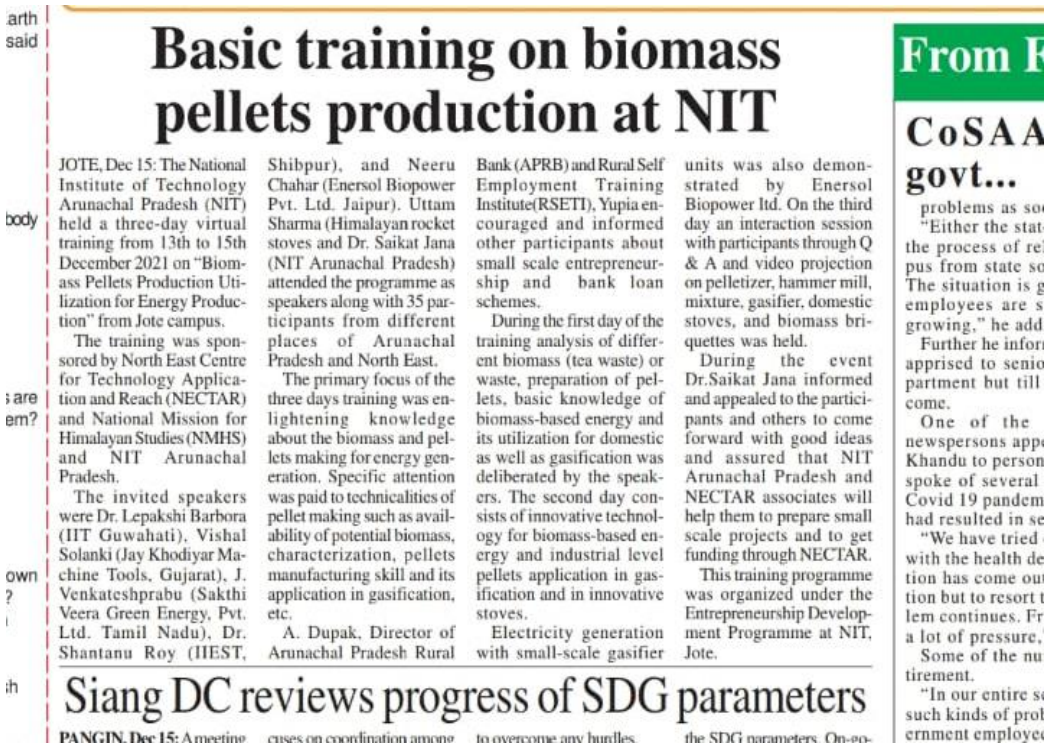



**Fig 17. Demonstration on Stove design**



# Basic training on biomass pellets production at NIT

JOTE, Dec 15: The National Institute of Technology Arunachal Pradesh (NIT) held a three-day virtual training from 13th to 15th December 2021 on "Biomass Pellets Production Utilization for Energy Production" from Jote campus.

The training was sponsored by North East Centre for Technology Application and Reach (NECTAR) and National Mission for Himalayan Studies (NMHS) and NIT Arunachal Pradesh.

The invited speakers were Dr. Lepakshi Barbora (IIT Guwahati), Vishal Solanki (Jay Khodiyar Machine Tools, Gujarat), J. Venkateshprabu (Sakthi Veera Green Energy, Pvt. Ltd. Tamil Nadu), Dr. Shantanu Roy (IIEST, Shibpur), and Neeru Chahar (Enersol Biopower Pvt. Ltd. Jaipur). Uttam Sharma (Himalayan rocket stoves and Dr. Saikat Jana (NIT Arunachal Pradesh) attended the programme as speakers along with 35 participants from different places of Arunachal Pradesh and North East.

The primary focus of the three days training was enlightening knowledge about the biomass and pellets making for energy generation. Specific attention was paid to technicalities of pellet making such as availability of potential biomass, characterization, pellets manufacturing skill and its application in gasification, etc.

A. Dupak, Director of Arunachal Pradesh Rural Bank (APRB) and Rural Self Employment Training Institute(RSETI), Yupia encouraged and informed other participants about small scale entrepreneurship and bank loan schemes.

During the first day of the training analysis of different biomass (tea waste) or waste, preparation of pellets, basic knowledge of biomass-based energy and its utilization for domestic as well as gasification was deliberated by the speakers. The second day consists of innovative technology for biomass-based energy and industrial level pellets application in gasification and in innovative stoves.

Electricity generation with small-scale gasifier units was also demonstrated by Enersol Biopower ltd. On the third day an interaction session with participants through Q & A and video projection on pelletizer, hammer mill, mixture, gasifier, domestic stoves, and biomass briquettes was held.

During the event Dr.Saikat Jana informed and appealed to the participants and others to come forward with good ideas and assured that NIT Arunachal Pradesh and NECTAR associates will help them to prepare small scale projects and to get funding through NECTAR.

This training programme was organized under the Entrepreneurship Development Programme at NIT, Jote.

## Siang DC reviews progress of SDG parameters

PANGIN, Dec 15: A meeting ... cuses on coordination among ... to overcome any hurdles ... the SDG parameters. On-go-

**Fig 18. Workshop details published in Arunachal Local News paper**

## CERTIFICATE OF PARTICIPATION

This is to certify that

.....

has participated in the three days Entrepreneurship Development Programme (EDP) on

"***Training on Biomass Based Pellets Preparation and Utilization for Energy Production***" held on 13th to 15th December 2021 organized by ***National Institute of Technology (NIT), Arunachal Pradesh*** sponsored by **National Mission on Himalayan (NMHS)** and ***North East Centre for Technology Application and Reach (NECTAR).***

NIT, Arunachal Pradesh

Saikat Kr. Jana.

Dr Saikat Kumar Jana
Department of Biotechnology,
NIT, Arunachal Pradesh

**Fig 19. Certificate of Participation**

### 5.6 Promoting Entrepreneurship

We have already given training to local villagers how to prepare biomass pellet and stove. Already we have arranged few trainings program to promote new entrepreneur. We have given our protocol to Naturum Technology Pvt. Ltd.(NTPL) to prepare biomass pellet in large scale. The program which we have arranged are mentioned below.

### 5.7 Developing Green Skills

The supply of sustainable or green energy is the main challenge that mankind will face over the coming decades, especially because of the need to address climatic changes. Biomass being abundantly available in nature can make a substantial contribution to cater future energy demands in a sustainable way. Currently, it is the largest universal contributor of green energy and has significant potential to expand in the production of electricity, heat and fuels. It was also shown low carbon emission as well as it can replace LPG gas for restaurant, catering, food processing company, tea processing units etc. Tea based biomass pellet is newly prepare by us and which can help to the farmer for extra income and to prepare a new start-up. Self-help group and women can make their new entrepreneurship. Beside that it will also reduce the pollution which is environmental hazardous.

### 5.8 Cross-cutting Issues

Women are the main stakeholders since they have historically served as the backbone of society and the primary knowledge-holders, particularly in the Himalayan region. In this training, opportunities were created for local youths require to train and equip community members with new skills.

<u>Climate Change:</u>

The project has also taken into account the potential effects of climate change and climate variability, including any localized climate-related issues that have already arisen or are likely to do so in the future.

Gender Equality:

Projects consider gender equality. Special attention has been devoted to gender variations in access to and use of resources (including revenue creation and use), participation in decision making, social attitudes and perceptions, and laws, policies, and institutions that may affect men and women's engagement in the project.

## 6. PROJECT'S IMPACTS IN IHR

### 6.1 Socio Economic Development

A process of social transformation known as "socioeconomic development" entails an improvement in people's lifestyles as a result of improvements in education, income generation, employment opportunities, skill development, better environmental quality, and better energy options in a way that increases the capacity of the society to realise its aspirations. By enhancing education, income creation, work prospects, and skill development, people's lifestyles can be improved.

It is a well-known fact that mountainous areas are more vulnerable to socioeconomic issues. Due to geographical limitations, these vulnerabilities include a lack of local socioeconomic resources, opportunities, and support, uneven development of women and children, youth migration, and challenges associated with farming and rural life.

The present work turns these weaknesses into strengths because it focuses both directly and indirectly on these factors. In this work, an attempt was made to capitalise on the wealth of the waste tea leaves in order to convert it into a productive source for generating livelihoods, mitigating climate change, and then bringing in the associated effects for the socio-economic development. In other words, the present work turns vulnerabilities into strengths.

Nearly 100 persons gained proficiency with the instruments through technology interventions and skill development, and they either directly or indirectly benefited from the study.

### 6.2 Scientific Management of Natural Resources

In this study we have not used any of natural resources whereas waste agriculture residues are used for value added products like biomass pellet and herbal cosmetic products.

We have collected agriculture waste of tea plant after the process of pruning and skiffing. Without using all waste materials cultivator will burn or throw it which causes environmental pollution.

### 6.3 Conservation of Biodiversity

Biodiversity conservation can be defined as the preservation, management, and protection of ecosystems with the purpose of achieving long-term benefits for present and future generations. Ecosystems are necessary for biodiversity. Healthy biodiversity is guaranteed by a healthy ecology. The environment suffers greatly as a result of factors including pollution, climate change, erosion, overexploitation of resources, rapid urbanisation, and industrialization, especially in eco-sensitive zones. Biodiversity also suffers as a result.

The current work focuses on precisely these aspects, with the overall goal of preserving the ecosystem and the harmony between it and development by putting an end to fires caused by waste in the area while simultaneously generating livelihood options from the underutilised forest resources through techniques and technological advancements that support sustainable development in the area.

### 6.4 Protection of Environment

As was indicated previously, the dependence on fuelwood for satisfying daily energy needs has led in the degradation of forest resources in the regions. Within the tea garden, workers generally burn pruned tea leaves and as a result the huge wastes are lost without using. In this context, this project focuses on this huge pruned tea leaves waste to make biomass pellet which is cleaner fuel than wood and low graded coal.

### 6.5 Developing Mountain Infrastructures

**Not Applicable**

### 6.6 Strengthening Networking in IHR

**Not applicable**

## 7. EXIT STRATEGY AND SUSTAINABILITY

### 7.1 How effectively the project findings could be utilized for the sustainable development of IHR

As we all know, sustainable development is the process of meeting the demands of the present generation without jeopardising the ability to satisfy the requirements of future generations. Therefore, finding better methods to do things while keeping in mind the welfare and needs of both the present generation and the future generation is essentially what sustainable development is all about. In order to create low cost, environmentally friendly sustainable energy for domestic and commercial uses, as well as value-added goods, the project is focused on developing biomass pellet technology. This will enable a significant socioeconomic transformation in the state of Arunachal Pradesh. Therefore, in a broader sense, the current project addresses the requirements and welfare of the current generation using a strategy that is in line with sustainable development because it targets the following SDG's:

- The primary objective of the initiative has been to give residents with viable economic opportunities by expanding their access to local resources.
- Most of the people in rural areas still depend on fuel wood/coal to satiate their daily energy needs. Women are the primary victims of the drudgery of using poor-quality fuel and associated health hazards from the toxic emissions of the frugal ovens. The current research aims to develop biomass pellet made from pruned tea leaves that has a calorific value comparable to that of wood and lower-grade coal and is somewhat cleaner in terms of emissions than the other two.
- Especially, women in the rural setting were ensured throughout the Project.

### 7.2 Efficient ways to replicate the outcomes of the project in other parts of IHR

The model created during this pilot phase, which incorporates technology, community involvement, value addition through product innovation, and the growth of the entire value chain, is solid and resilient from the need for adoption to the availability of raw materials to the market opportunity. The created structure must be accurately copied to the utmost scalability level. All that remains is to reach out and put the same into action.

### 7.3 Identify other important areas not covered under this study needs further attention

A comparable study should be conducted right now to determine how well the entire socioeconomic system of a small area and its inhabitants may be linked and connected to the waste trimmed tea leaves residue-based livelihood. This will make it possible to strengthen the model's centrality and move toward self-sufficiency in terms of energy production, consumption, and generating income. In addition to value-added items, household, small-business, and bakery electrical generation might also be a major cause for worry.

### 7.4 Major recommendations for sustaining the outcome of the projects in future

We can use Gasifier with this technique to generate electricity which might be used in household, small shop, bakery industry or any other small business. We can make Biomass briquettes which also be an alternative energy of coal or fuelwood.

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## 9. ACKNOWLEDGEMENT

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Also acknowledged are the Tea Boards of Assam and Arunachal Pradesh.

We would like to express our gratitude to all the villagers, community organisers, mentors, and other participants at all levels, both directly and indirectly.

**OTHERS**

**Fig 20. Rotary vacuum Evaporator**

**Fig 21. Pellet machine**

**Fig 22. Hammer Mill (pulverizer)**

**Fig 23. Mixture Machine**

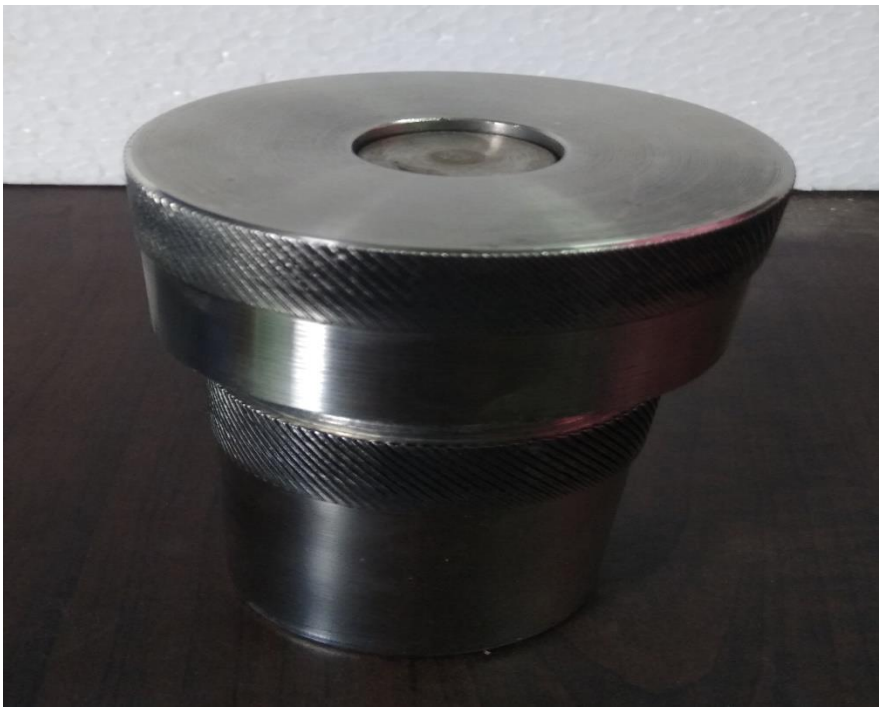

**Fig 24. Autoclave reactor (High temperature vessel)**