Final Report

Scoping study on Bio-waste and Non-ozone Depleting Substance- non-HFC alternatives in India

Report on Potential Interventions in State of Punjab and Haryana

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Abbreviations:

AQI	Air Quality Index
BMC	Bulk Milk Chiller
BPCL	Bharat Petroleum Corporation Ltd
CBG	Compressed Bio-Gas
CCAC	Climate & Clean Air Coalition
CCHP	Combined Cooling Heating and Power
CEA	Central Electricity Authority
CFC	Chloro-flouro Carobon
CNG	Compressed Natural Gas
CO_2	Carbon Di-oxide
CPCB	Central Pollution Control Board
GHG	Green House Gas
GWP	Global Warming Potential
HCFC/CFC	Hydro-chloro-flouro carbon
HFC	Hydroflouro carbons
HPCL	Hindustan Petroleum Corporation Ltd
HVAC-R	Heating Ventilation Air-conditioning Refrigertion
ICAP	Indian Cooling Action Plan
INR	Indian National Rupees
IOCL	Indian Oil Corporation Limited
KVK	Krishi Vigyan Kendra
MoEPI	Ministry of Food Processing Industry
MoU	Memorandum of Understanding
MT	Metric Tonne
NCR	National Capital Region
NIK	Not-in-kind
NRSA	National Remote Sensing Agency
NTPC Ltd	National Thermal Power Corporation Limited
O&M	Operation and Maintenance
ODS	Ozone Depleting Substances
OMCs	Oil Marketing Companies
PEDA	Punjab Energy Development Agency
PM	Particulate Matter
PRESPL	Punjab Energy Systems Pvt Ltd
SDG	Sustainable Development Goals
SLCP	Short-Lived Climate Pollutants
SMS	Straw Management System
Swedish EPA	Swedish Environment Protection Agency
TPD	Tonnes per day
TPD	Tonnes per day
USA	United States of America

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Study overview

1.1 Study background

India-Sweden Project aims to eliminate the use of Ozone Depleting Substances (ODS) and HFC through alternative technologies and practice and have a strategic approach to an integrated management of biomass burning in the state of Haryana and Punjab. The pathway addresses delivery of sustainable renewable energy; showcasing efficient logistics and valorisation of waste-biomass e.g. via a product, application of tri-generation solutions (applications for cooling, heating, electricity, bio-char production) that address mitigation of GHG, particulate matter (PM), SLCP, use of chemical fertilisers and other pollutants from uncontrolled biomass /waste burning.

The aim is to address the opportunity with an integrated strategy and actions, such as:

1. Improving logistics and activities which enable resource and efficiency measures, e.g. in the HVAC-R sector, that reduce air pollution, e.g. emissions of CO_2 and SLCP contributing to mitigation goals of climate change, protection of the ozone layer (Montreal Protocol/CCAC) and sustainable development goals (SDG)
2. Policies and investments supporting, energy-efficient dwellings, power generation, and better municipal waste management to reduce pollution;
3. Reducing emissions from agriculture and waste incineration. The activity is to reduce rural and peri-urban air pollution sources;
4. Reduction of indoor smoke that poses a health risk to many people who cook and heat their homes with biomass fuels.

The results are expected to contribute to an integrated management of biomass burning; and through that to health improvement, moving towards sustainable development goals (SDG), and helping reduce the use of ODS and HFC through alternative technologies. The outcome of the project would have the potential to raise awareness levels amongst the stakeholders to redress the issue of crop burning in a win-win mode for the farmers and the administrators. The project aims to take forward deliverables through a joint action plan between India and Sweden on environment protection and climate.

It is evident from the research literature that burning of crop residue is one of the major causes of atmospheric pollution, and consequently of the worsening public health impact in India. Around 35 million tonnes of biomass-crop are burned every year in Punjab and Haryana alone. It is therefore highly desired to redress this issue in a manner to convert the biomass crop residue into a superior resource which can either be used as energy alternative or for producing useful material with simultaneous reduction in GHG emissions. Besides, a lot of energy is consumed in air-condition and refrigeration sector, and it is growing exponentially in developing countries like India. This in turn contributes about 1-5 % of hydro fluorocarbon (HFC) related global greenhouse gas (GHG) emissions. Today, it is possible to use not-in-kind (NIK) alternative non HFC and non-ODS technologies for a variety of cooling and refrigeration applications. This project aims to capture these benefits along with possibilities to reduce crop residue burning. The main purpose of this scoping

study is to analyse current practices, alternate options, policies, factors which influence burning of crop residues and also identify gaps in technology, policies, skills and capacity for integrated and effective management of crop residues and to establish a sound basis to help Swedish EPA to develop a long-term intervention strategy in developing actions for bio-waste management, promoting non-HFC-ODS technologies and thereby improving the air quality and combating impacts of climate change in affected regions in the country.

1.2 Study objective

The scoping study was executed with the four specific objectives:

1. Map Government of India's policies and specific programmes/schemes on bio-waste management, cooling and refrigeration
2. Review of trends and extent of problem of crop residue burning with specific reference to the States of Haryana and Punjab,
3. Explore opportunities of alternative technologies and practices to minimize crop-residue burning through in-situ and ex-situ measures,
4. Identify cooling/co-generation/tri-generation applications in agricultural value chain – where not-in-kind (NIK) alternative technological solutions can be potentially applied, and
5. Identify specific areas of interventions for an integrated crop residue management.

The study focused on both national and state level issues. For detailed analysis, the study identified two districts on the basis of a multi-criteria analysis based on secondary level information.

The basic objective of this Scoping Study is to undertake detailed collection of data to the pathway envisioned assessment of volume, duration available, issues of storage, identification of efficient logistics for harvesting and collection, valorisation of waste-biomass in the form of crop residue, its potential applications in cold chain development and examining technology solutions available in the country as well as outsourced from other countries, including Sweden. Perceived solutions could be in the form of bio-char production, pallets making, and exploring use of these as fuel for decentralized applications, such as, cooling, heating and electricity generation in industrial, commercial and institutional establishments.

1.2.1 Study Methodology and Process

The methodology primarily consisted of desk based literature research, consultations with key stakeholders at National and State level, field visits to shortlisted districts and field data analysis. The activities were grouped in three distinct phases as presented in figure 1.

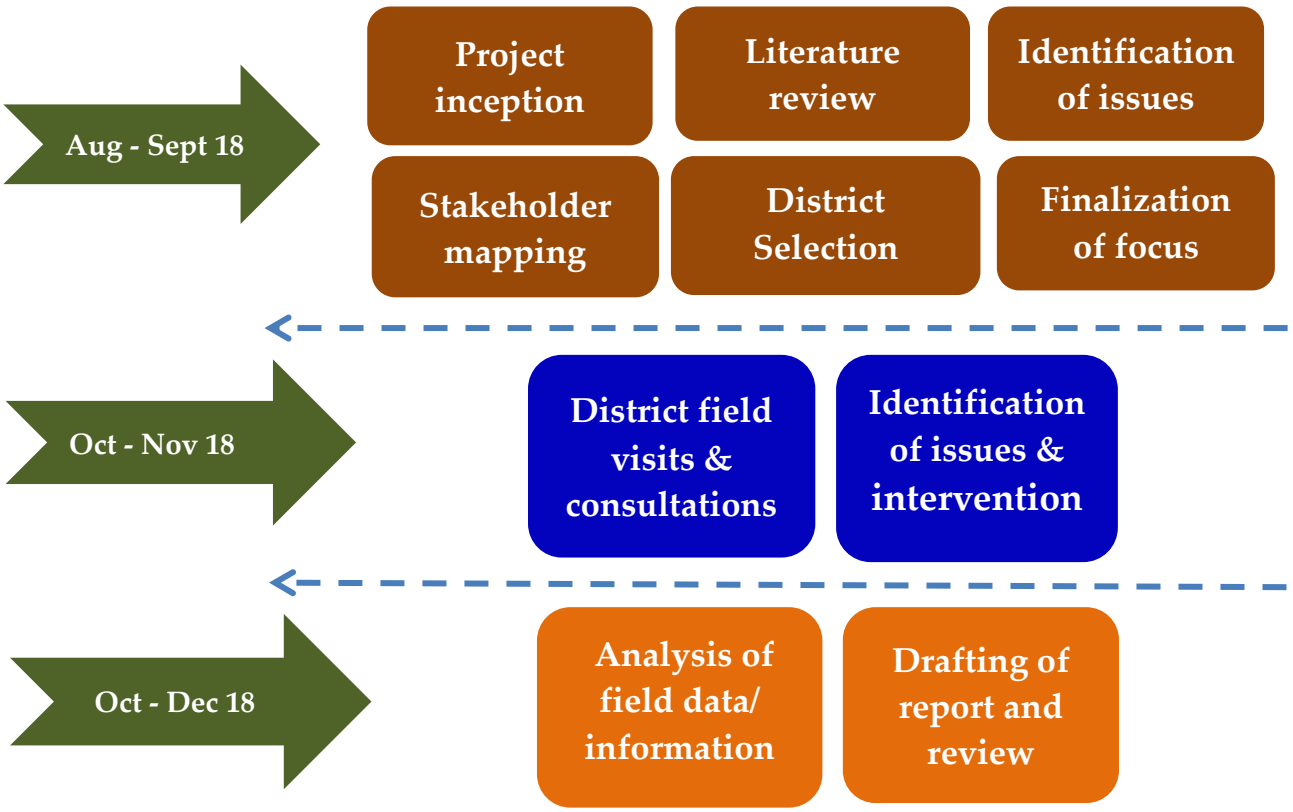

Figure 1: Methodology adopted to undertake study of the District

The overall approach include mapping and collection of various policies, programs and schemes in these states, following up it with identification of paddy straw value chain, prevalent fuel and energy applications with focus on agricultural value chains, adoption of energy efficient and renewable energy based cold chain for perishable foods, non-fuel applications, and stakeholders' identification. The work is supported with field surveys and stakeholder consultations at both state and district level agencies. Field visits were conducted to the shortlisted districts and interactions were held with farmers and relevant stakeholders and got direct feedback from the field. Based on the above methodology and activities, analysis was done to identify potential areas of intervention to mitigate the issues of bio-waste burning.

2. Bio-waste, non-HFC-ODS - policies and management practices in focus states

The current chapter provides overview of the current policies, programs and schemes of both National and State Government to address the challenges of bio-waste management and resultant air pollution problem.

2.1 National and State Government - current policies and initiatives

The important policies and initiatives were compiled and studied and given in the section below:

2.1.1 National Government/CPSU

National Policy for Management of Crop Residues (NPMCR)-2014 - Through the Ministry of Agriculture, Cooperation and Farmers Welfare, implementing national policy which envisages adoption of technical measures including diversified uses of crop residue, capacity building & training along with formulation of suitable law/legislation. The above policy also envisages to use satellite based remote sensing technologies to monitor crop residue management, with active involvement of National Remote Sensing Agency (NRSA) and Central Pollution Control Board (CPCB).

In March 2018, The Cabinet Committee on Economic Affairs approved Promotion of Agricultural Mechanization for in-situ management of Crop Residue in the States of Punjab, Haryana and Uttar Pradesh and NCT of Delhi. The total outgo from the Central funds would be Rs.1151.80 crores (~ 165 million USD) to establish Farm Machinery Banks for Custom Hiring Centre (CHC) of in-situ crop residue management machinery. Financial assistance @ 80% of the project cost will be provided to the cooperative societies of the farmers, FPOs, Self Help Groups, Registered Farmers Societies/ Farmers Groups, Private Entrepreneurs and Group of Women Farmers. A provision is also made for financial assistance to the farmers for Procurement of Agriculture Machinery and Equipment for in-situ crop residue management. Financial assistance @ 50% of the machinery/ equipment cost will be provided to individual farmer for crop residue management. During 2018-19, central financial assistance of Rs 332 crore and Rs 137 crore is provided to Punjab and Haryana respectively for awareness creation, establishment of CHC and subsidy on farm equipment to individual farmers. In the state of Haryana, out of total target of 5563 beneficiaries of individual implements, 4274 beneficiaries were provided with individual implements of farm machineries. In case of CHCs, total of 894 CHCs were established in the State. In the state of Punjab, 3500 CHCs were established and 1200 Happy Seeders were given to individual farmers and CHC.

National Biofuel Policy 2018 - This policy outlines development of biofuels to utilize waste. Thrust is given to advanced 2G biofuels technologies including conversion of agricultural

residues/waste which can be converted to ethanol and bio-CNG. In all 12 bio-ethanol pilot plants are being planned to be set up in the country with different feedstocks and technology. Out of 12 2G Ethanol plants, one plant is being up by IOCL at Panipat (Haryana) with output capacity of 100 KL per day production based on enzymatic hydrolysis technology developed by Praj Industries with an investment of Rs.900 Crore. It is estimated that about 2 lakhs tonne of agricultural biomass will be utilized annually by this plant. Another 2G ethanol plant is being set up by Hindustan Petroleum in Nasibpura, a village of Bathinda district in Punjab. This plant is being designed to utilize paddy straw as main feedstock with investment of about Rs.1000 Crore. The plant on full capacity will utilize about 500-600 tons of paddy straw per day to generate about 100 KL of ethanol. Both these plants are expected to be commissioned by end of 2019. IOCL had signed a MoU of Rs.5000 Crore with PEDA, Government of Punjab on January 15, 2018, under which it would set up bio-CNG plant in Punjab. IOCL has further signed MoUs with private investors such as Sampurn Agri Ventures Pvt. Ltd. In the first stage, IOCL will set up approximately 42 plants in Punjab, out of which they already have identified three sites at Sangrur, Bathinda and Nabha.

MNRE has launched a programme on Energy from Agricultural waste/ residue in the form of biogas-bio-CNG, enriched biogas/ power: Projects based on bio waste from urban and agricultural waste (paddy straw, agro-processing industry residue, green grasses etc.) are eligible for Central Finance Assistance (CFA) in the form of capital subsidy and grant-in-aid under the programme. The main objective of the programme is to create conducive conditions and environment, with fiscal and financial regime, to develop, demonstrate and disseminate utilisation of waste and residue for recovery of energy. There is a provision of CFA to the tune of Rs.3.00 crore per MW (maximum Rs.10 crore per project) has been made for power projects based on biomass and agricultural waste materials. Project with bio-CNG generation based on biogas generated from agricultural waste are eligible for Rs.4 crores CFA per 4800 kg of bio-CNG per day. The total CFA of Rs.78.0 crores with physical target of 57.0 MWe, for the period of 2017-20.

Sustainable Alternative Towards Affordable Transportation (SATAT) - On 1st October 2018, Minister of Petroleum and Natural Gas has announced an initiative with PSU Oil Marketing Companies (OMCs, i.e. IOC, BPCL and HPCL) inviting Expression of Interest (EoI) from potential entrepreneurs to set up Compressed Bio-Gas (CBG) production plants and make available CBG in the market for use in automotive fuels by better usage of agricultural residue, cattle dung and municipal solid waste.. The policy aims to roll out 5,000 Compressed Bio-Gas plants across India in a phased manner. It is planned to roll out 250 plants by the year 2020, 1,000 plants by 2022 and 5,000 plants by 2025). It is expected that the proposed plants will be set up mainly through independent entrepreneurs. CBG produced at these plants will be transported through cascades of cylinders to the fuel station networks of OMCs for marketing as a green transport fuel alternative. The entrepreneurs would be able to separately market the other by-products from these plants, including bio-manure, carbon-dioxide, etc., to enhance returns on investment. This initiative is expected to produce 50 million tonnes of bio-manure for crops.

Ministry of Power, Government of India, has issued a policy advisory for biomass utilization for power generation through co-firing in pulverized coal fired boilers. The document highlights successful demonstration of the co-firing of 7% blend of biomass

pellets with coal. Approximately, 2.5 to 3.0 lakh tonnes of biomass pellets are required for 7% blending in a thermal power plant of 1000 MW capacity. In order to promote the biomass pellets, all power plants/utilities are advised that all fluidized bed and pulverised coal units shall endeavour to use 5-10% blend of biomass pellets made from agro residues.

NTPC Ltd, India's largest power generator, plans to start biomass co-firing across all its coal-based thermal power stations in a bid to reduce greenhouse gas emissions and cut pollution, official sources said. Co-firing is the use of two different types of fuel for generation of electricity.

NTPC plans to burn biomass crop residues along with coal to generate electricity. Biomass can typically provide between 5-10 per cent of the input energy into the power plant. NTPC has floated EoI in the form of tender to procure biomass fuels in pellets and torrefied material for procuring 1,000 tonne per day (TPD) of agro-residue based fuel and has received interests from three companies. There are three parties which have come forward with quantity of around 250 tonne per day. It does not really define whether the agro-residue is going to be from rice or from wheat. The tender seeks supply for two years. A capping price of Rs.5, 500 per tonne has been kept for agro residue-based pellets and Rs.6, 600 per tonne for pellets or briquettes of torrefied agro residue. One of the selected vendor "Neway Engineers MSW Private Limited" will supply the paddy straw based torrified pellets from their facility, which is currently under construction in Bhatinda district of Punjab. It is expected that the company will start their commercial operations to produce and supply the pellets by end of December 2018. With coal based generation of 1,96,098 MW, about 100 million tonnes of agro residue can be absorbed in coal-based power plants with 10 per cent co-firing with non-torrefied pellets while reducing their carbon emission. Biomass co-firing has the potential to reduce emissions from coal-fuelled generation, without substantially increasing costs or infrastructure investments. The Central Electricity Authority (CEA) had issued an advisory to all public and private generating utilities to endeavour to use 5-10 per cent biomass pellets primarily made of agro residue along with coal.

Ministry of Environment, Forest and Climate Change has prepared India Cooling Action Plan (draft in consultation) in order to synergize actions for addressing the cooling demand across all sectors. India's aggregate cooling requirement will increase by eight times in the next 20 years and is in sync with India's commitment to the Monteral Protocol (reduction of ozone depleting substances) as well as the Paris Agreement (reduction of emission intensity) to meet the challenges of climate change. Major objectives of this action plan are to recognise the "cooling and related areas" as a thrust area of research under national science and technology program to support development of technological solutions and encourage innovation challenges. Moreover, it also promotes the use of energy-efficient refrigerant-based appliances as well as not-in-kind technologies, development of energy efficient and renewable energy based cold chain for perishable foods, R&D efforts to foster an innovative ecosystem to support development and deployment of low-GWP refrigerant alternatives. The highlighted sectors under this action plan are Space Cooling, Cold-chain, Refrigeration, Transport, air conditioning and RAC Servicing Sector.

The demand of cooling energy in agricultural value chain and storage of perishables are considered for use of crop residue and development of energy efficient and renewable energy based cold chain and its overall potential in the states of Punjab and Haryana.

Central Pollution Control Board (CPCB), in association with State Pollution Control Boards of Punjab, Haryana and Uttar Pradesh, has established ambient air monitoring stations in respective States so as to capture and build data base on stubble burning and crop residue burning under National Air Monitoring Programme (NAMP) (i.e. 20 in Punjab, 10 each in Haryana and Western U.P. on priority).Government of India through Ministry of Environment, Forest and Climate Change has drawn "National Clean Air Program" (NCAP) which envisages, Air pollution emission issues are associated with many sectors which inter alia include power, transport, industry, residential, construction, and agriculture. The impact of air pollution is not limited to health but it gets extended to agriculture and general well-being of human, flora and fauna population as well. In order to address this issue, Government has undertaken many significant steps which inter-alia include notification of National Ambient Air Quality Standards and sector specific emission and effluent standards for industries; setting up of monitoring network for assessment of ambient air quality; introduction of cleaner gaseous fuels like CNG, LPG etc. and ethanol blending; launching of **National Air Quality Index (AQI)**; universalization of BS-IV for vehicles by 2017; leapfrogging from BS-IV to BS-VI standards for vehicles by 1st April, 2020; banning of burning of biomass; promotion of public transport network; Pollution Under Control Certificate; issuance of directions under Air (Prevention and Control of Pollution) Act, 1981; installation of on-line continuous (24x7) monitoring devices by 17 highly polluting industrial sectors; ban on bursting of sound emitting crackers between 10 PM to 6 AM; notification of graded response action plan for Delhi and NCR identifying source wise actions for various levels of air pollution, etc.

A number of measures/directions have been proposed that include ensured strict enforcement of ban on burning of agricultural waste and crop residues in order to improve the air quality in Delhi and NCR.

Ministry of Food Processing Industries (MoFPI) has developed a scheme of cold chain. This scheme is under implementation since 2008. The objective of this scheme is to provide integrated cold chain and preservation infrastructure facilities, without any break, from the farm gate to the consumer. It covers creation of infrastructure facility along with the entire supply chain viz. pre-cooling, weighing, sorting, grading, waxing facilities at farm level, multi product/ multi temperature cold storage, CA storage, packing facility, blast freezing in the distribution hub and reefer vans, mobile cooling units for facilitating distribution of horticulture, organic produce, marine, dairy, meat and poultry etc. The scheme provides 50% project cost as grant and remaining 50% is raised through loan and equity component.

A total of 234 Cold Chain Projects has been approved as on 30.09.2018 under this scheme. Out of the total 234 projects, 9 and 17 cold chain projects are implemented in the State of Haryana and Punjab respectively.

2.1.2 State Governments

2.1.2.1 Government of Punjab

Punjab Government has announced its "New and renewable sources of energy policy" - in 2012 to promote RE power. Under this policy, a capacity target of 600 MW from biomass and 500 MW from Cogeneration (both bagasse and non-bagasse) has been set up by 2022 for the state of Punjab. But only 62.5 MW has been commissioned through seven power projects

so far in the districts of Muktsar, Ferozpur, Hoshiarpur, Jalandhar, Patiala, Mansa and another 44 MW through five projects in various stages of planning and implementation. Other than this, three similar projects of aggregated capacity of 14 MW are in process in the districts of Hoshiarpur, Jalandhar and Moga.

Table 1: Status of biomass power plants in the State[1]

Sr. No.	Taluka	District	Project Capacity (MW)	Status
1.	Mukatsar	Mukatsar	6	Commissioned
2.	Abohar	Ferozpur	8	Commissioned
3.	Malout	Mukatsar	14.5	Commissioned
4.	Garhshankar	Hoshiarpur	6	Commissioned
5	Nakodar	Jallandhar	6	Commissioned
6.	Rajpura	Patiala	12	Commissioned
7.	Mansa	Mansa	10	Commissioned
		Total	**62.5**	
8	Garhshankar	Hoshiarpur	4	In Process
9.	Nakodar	Jallandhar	4	In Process
10.	Nihalsinghwala	Moga	6	In Process

1. Seven currently operational biomass-based power projects of total capacity 62.5 MW consume 0.5 million tonnes per year of paddy straw. Five additional biomass-based power projects of total capacity of 44 MW are in various stages of planning, which will use an additional 0.72 million tonnes per year of paddy straw. However, the currently operational and planned projects in Punjab would cumulatively utilize just 1.22 million tonnes of paddy straw against estimated 17–18 million tonnes produced.
2. PEDA has invited expression of interest from the interested project developers for setting up of 150 MW capacity 100% rice straw based biomass power plants on Viability Gap Funding based competitive bidding.
3. There is a proposal to set up five bio refineries for the production of cellulosic ethanol, each of capacity 75,000 kilo litre/year, using paddy straw as feedstock. About 1.5 million tonnes per year of paddy straw shall be used in these bio refineries.
4. Currently, 0.62 million tonnes out of 17–18 million tonnes of paddy straw is utilized. There are proposals to utilize an additional 3.49 million tonnes of paddy straw through various usages.

2.1.3.2 The Government of Haryana

Haryana Bio-energy Policy 2018 –

Objective: To promote generation of energy from surplus biomass in the State.

Haryana has surplus biomass availability of 8416 thousand tons which has tremendous potential for utilization of the residues of these crops to generate electricity/biogas/ bio-

[1] http://peda.gov.in/main/Bio-massPower.html

CNG/bio-manure/bio-fuels etc. The State has potential to generate about 1000 MW of power or 11.5 lac tons of bio-CNG. The policy proposed was to achieve a target of minimum 150 MW biomass based power generation (or equivalent) by 2022.This Policy will strive to promote Biomass to bio energy projects based on the technologies using Rankine cycle, Bio-CNG/bio-gas cum organic manure projects using advanced anaerobic digestion and bio-fuels/ bio ethanol and other innovative technologies etc.

It is proposed to achieve a target of minimum 150 MW biomass based power generation (or equivalent) by 2022.

Table 2: List of paddy straw based proposed power projects in Haryana

Name of project	Location	Capacity	Status
Fatehabad Bio Energy	Fatehabad	10 MW	PPA not signed, approval pending with HERC
Hind Samachar Limited	Kurukshetra	15 MW	PPA not signed, approval pending with HERC
Jind Bio Energy	Jind	10 MW	PPA not signed, approval pending with HERC
Sukhbir Agro Energy Limited (SAEL)	Kaithal	15 MW	PPA not signed, approval pending with HERC

Source: Interaction with power plant owners

2.2 Existing technological options

The existing practices and interventions for crop residues management adopted by the farmers are classified in two broad category; (i) in-situ management and (ii) ex-situ management. The details are given in the sections below.

2.2.1 In-situ management practice

2.2.1.1 Spreading on field and use as manure

This process is made possible by using a farm implement called "Happy Seeder" that was developed by Punjab Agricultural University. In this process, the paddy straw is spread on the field itself using a separate machine called the Straw Management System (SMS) which spreads the straw evenly throughout the field. The SMS is an attachment to the harvester combine used for harvesting paddy crop. The Happy Seeder is then deployed which carries out sowing of wheat along with required fertilizer input directly into the field without resorting to any other/specific field preparation.

2.2.1.2 Incorporation into soil

While spreading the loose straw on the field is simpler and less costly, incorporation of the same into the soil is a costly affair. In this process, the paddy straw is put inside the soil of the agricultural field by digging and for a proper incorporation; it needs to be at least a foot deep into the soil. If done improperly, it leads to low productivity of the next crop and even an increase in the GHG emissions. Even with proper incorporation, the GHG emissions from such paddy fields is about 1.5 times higher than from the fields that had paddy straw removed (http://www.knowledgebank.irri.org/step-by-step-production/postharvest/rice-by-products/rice-straw/in-field-rice-straw-management).

2.2.2 Ex-situ management

2.2.2.1 Collection, compaction and baling

The option of removing paddy straw from fields using mechanized equipment is becoming more common following the ban on burning the same in the fields. The use of baling is an important process in removal and transportation of paddy straw from the agricultural fields. The volume of paddy straw in bales decreases by 1.5 to 2 times that of loose straw. The bales can then be sold to cardboard factories, power plants or briquetting units, etc.

2.2.3 Uses of paddy straw for energy and non-energy applications

Option A: Briquetting. Densification of crop-residues (biomass) is performed using briquetting presses, pellet mills and other extrusion processes, for increasing the density and to overcome feeding, storing, handling, and transporting problems. Though in principle a variety of biomass residues, such as bagasse, rice straw, cotton stalk, groundnut shells, etc., are available for briquetting/pelletizing; the economics and logistics of collection, transportation and storage of these residues can be a tricky affair. The briquettes can be used in various thermal applications such as industrial boilers, furnaces as well as in power plants.

Option B: Biomass Power plant. The biomass based power plant can be set up using paddy straw as the basic raw material with other agricultural residue being used when available. The technology option is well established in India and several biomass based power generation plants are operational in northern India.

Option C: Torrification/Bio-char and/or gasification. Converting waste biomass into bio-char is an age old practice that is used for soil enrichment. Bio-char is produced when crop residue (or any biomass) is burnt in the absence of oxygen (or in controlled conditions as in gasification process). It is similar to charcoal but is more porous and helps retain moisture and other nutrients in the soil. Biomass gasification is another process wherein solid biomass fuels (agriculture residues, briquettes, etc.) are converted into gaseous fuel (producer gas) by a series of thermo-chemical processes to generate thermal and/or electrical power on small-scale.

Option D: Crop residues can be effectively used in various applications such as heating; cooling etc. this would further help India to meet its global commitments with regard to low carbon pathway, GHG emissions and refrigerant phase-out. Some Not-in Kind Cooling strategies are:

Trigeneration: Trigeneration or combined cooling, heating and power (CCHP) offers an optimal solution for generating air conditioning and/or refrigeration. The trigeneration systems are suitable for industrial and commercial applications where there is a continuous demand for electricity and heating or cooling at the same time. They have multiple advantages such as onsite generation of electricity, heat and power, maximum total fuel efficiency, reduced fuel and energy costs, lower electrical demand during peak time, elimination of HCFC/CFC refrigerants and emission reduction. However, its use is limited to specific applications where there is a simultaneous demand for heat and power and uninterrupted availability of fuel.

Renewable and Alternate Energy Technologies - There are a number of renewable and alternate energy technologies that are promising especially for cold chain applications. In order to deliver on their potential for a sustained period of time, these technologies will require excellent engineering and installation, high quality components, and stringent commissioning and O&M services. Cooling options using available technology may include Biomass gasifier, Solar/Biomass Co-generation (Waste heat Recovery) specially using paddy straw and other agro residue as a primary fuel.

The Ministry of Agriculture & Farmers Welfare supports the deployment of such alternate energy technologies in cold-chain development.

Tri-generation or combined cooling, heating and power (CCHP) offers an optimal solution for generating air conditioning and/or refrigeration. The tri-generation systems are suitable for industrial and commercial applications where there is a continuous demand for electricity and heating or cooling at the same time. They have multiple advantages such as onsite generation of electricity, heat and power, maximum total fuel efficiency, reduced fuel and energy costs, lower electrical demand during peak time, elimination of HCFC/CFC refrigerants and emission reduction. However, its use is limited to specific applications where there is a simultaneous demand for heat and power and uninterrupted availability of fuel.

Option E: Paper/Board/Eco-panel making - There are paper and board making industries in the state of Punjab which are already using around 0.1 million tonnes of paddy straw per annum. In the process of converting paddy straw into paper production, paddy straw is initially cut to sizes followed by preparation of straw pulp by the soda pulping process in batch rotary digesters for delignification and cooking with sodium hydroxide. The straw after digestion is washed in a multi-stage washer with counter current system. Paddy straw pulps are blended with high strength material such as waste cloth and used gunny bag pulps for paper making. Kriya Labs (a start-up incubated at IIT-D's Technology Business Incubator) has developed a sustainable processing technology that can convert agro-waste like paddy straw into pulp. From one tonne of stubble, 500 kg of pulp can be produced. The pulp that is made from the paddy waste can be sold for Rs.45 per kg.

Another good option is to use paddy straw for making eco-panels which can be used as panels and partitions in place of wood/ply board. The technology has already been established abroad but its cost effectiveness in the country needs to be assessed.

Option F: Paddy straw use as hay-bedding: Paddy straw can also be used as hay-bed to some extent. But it is not very convenient and may also cause diseases among cattle if it remains there along with cattle dung and urine for prolonged periods.

3. Bio-waste and cooling energy status in Focus States

This current chapter provides overview of Agricultural activities, potential of paddy production and residues generation, existing practices for crop-residues management including burning incidents trends during last few years, and needs of cooling energy in agricultural value chains (horticulture and milk) in both the States. The key findings and observations such as socio- economic status, potential of paddy straw, cost factors, management practices, solid fuels demand in industries and brick making units, demand of cooling energy in horticulture produces and milk chilling applications was discussed. Various factors which can influence paddy straw burning by the farmers or its subsequent usage are also discussed in this chapter.

3.1 Punjab

The State of Punjab has total geographical area of about 53.381 lakh ha. Out of this total area about 41.168 lakh ha area is net sown area, 37.27 lakh ha area is sown twice comprising 78.43 lakh ha gross sown area. The total paddy straw generated in the state is around 23.07 million tons out of which, 16.78 million tonnes are surplus biomass.

In kharif season, major crops cultivated include paddy, sugarcane, maize, and in rabi season, crops like wheat, jau, chana, pea, are cultivated. The district wise geographical area, net sown area, gross cropped area, paddy area, quantity of paddy straw and surplus biomass in the state of Punjab is given in Table 3 below. The districts such as Sangrur, Ludhina, Patiala, Moga and Ferozpur has large amount of crop residues surplus in the State.

Table 3: District wise geographical area, net sown area, gross cropped area and paddy area, quantity of paddy straw and surplus biomass in Punjab

District	Geographical area (in Hectare)	Net sown area (In Hectare)	Gross Sown area	Paddy Area (In Hectare)	Paddy Straw (in Kilo Tonne)[2]	Surplus Biomass (in kilo tonne)[3]
Amritsar	264700	219202	414392	183800	1053.466	792.628
Barnala	141000	124361	248570	106200	999.389	494.697
Bathinda	338500	293870	558050	109000	963.475	858.456
Faridkot	146900	127025	248000	102800	875.962	754.466
Fatehgarh Sahib	118000	101910	191061	86200	759.139	413.351
Fazilka	311300	252750	475370	91333	606.128	420.047
Ferozepur	530500	218095	415567	213800	1695.782	1427.001
Gurdaspur	263500	209454	423579	185000	1178.544	583.379
Hoshiarpur	336500	199306	350446	71600	527.558	470.055
Jalandhar	263200	242916	412947	165400	1241.702	971.135
Kapurthala	163200	133779	267159	117400	919.718	646.47

[2] TIFAC report "Estimation of surplus crop residue in India for biofuel production", October 2018
[3] TIFAC report "Estimation of surplus crop residue in India for biofuel production", October 2018

Ludhiana	376700	298977	592502	257000	2333.146	2125.029
Mansa	217100	189430	359389	78600	643.555	159.28
Moga	221600	185595	381367	175000	1621.478	1444.737
Shri Muktsar Sahib (Muktsar)	261500	228186	447489	118400	939.533	465.069
Shaheed Bhagat Singh Nagar (Nawan Shahr)	126700	97279	187708	57000	462.749	274.873
Pathankot	92900	47815	93633	28333	155.488	76.967
Patiala	321800	260153	512156	232400	1882.781	1584.36
Rup Nagar (Ropar)	136900	80865	141978	37400	279.053	138.131
Sahibzada Ajit Singh Nagar (Mohali)	109300	77120	106201	31200	227.866	112.793
Sangrur	351452	311513	621990	273200	2577.11	2296.205
Tarn Taran	244900	217230	394413	175400	1124.054	278.203
Total	**5338152**	**4116831**	**7843967**	**2896466**	**23067.676**	**16787.332**

The data on crop-residues burning incidents (district wise) monitored using satellite remote sensing was compiled and given in Table 4. It can been seen that that a total of 59668 burning event in the current year, which is about 85% of the events detected in 2017 and about 59% of the events detected in 2016. Though the number of crop burning events are reducing over the years but still it is very high despite significant efforts were made by both National and State Governments to prevent open burning through regulations and law enforcement agencies.

Table 4: District wise crop burning instances in Punjab[4]

Districts	**01 Oct – 29 Nov**		
	2016	**2017**	**2018 (till November)**
Amritsar	2170	1362	1404
Barnala	5701	3426	3279
Bathinda	8846	5777	6346
Faridkot	4630	3472	3058
Fatehgarh Sahib	2461	1642	866
Fazilka	0	0	0
Firozpur	13643	9938	9989
Gurdaspur	2219	1594	1171
Hoshiarpur	905	497	199
Jalandhar	4662	2126	1393
Kapurthala	3136	1626	750
Ludhiana	9546	4753	3044
Mansa	5652	4501	4317
Moga	6393	2776	2730
Muktsar	7037	5441	5786
Nawashahar (SBS Nagar)	1366	686	303
Pathankot	0	0	0

[4] http://creams.iari.res.in/cms/index.php?option=com_content&view=article&id=49&Itemid=267

Patiala	6545	5034	4217
Rupnagar	719	328	87
Sangrur	11862	8429	7782
SAS Nagar	365	246	199
Tarn Taran	4513	3314	2748
Total	**102371**	**66968**	**59668**

Source: Consortium for Research on Agro ecosystem Monitoring and Modelling from Space (CREAMS) of Indian Agricultural Research Institute

3.1.2 Overview of cooling energy in agriculture sector

Punjab has high production of milk and horticulture produce, the processed agriculture and dairy products such as freezing/cooling of perishable agriculture products, Whole Milk Powder, Skimmed Milk Powder and Dairy Whitener etc. would cater to the growing demand for the products. During year (2012-13), the total annual horticulture production of the State is 3.5 million tonnes and total milk production is about 9678000 tonnes. The district wise details of horticulture production and milk production are given in Table 5. The districts namely; Hoshiarpur, Firozepur and Jalandhar has highest production of horticulture while districts; Ludhiana, Ferozepur and Sangrur has highest milk production in the State.

Table 5: District wise horticulture produce (2012-13)[5], bovine milk production (2012-13)[6] in Punjab

District	Horticulture production (in MT)(2012-13)	Bovine milk production (000 MT) (2012-13)
Firozepur	598350	791
Ludhiana	185597	1050
Sangrur	37692	775
Patiala	143509	601
Hoshiarpur	609508	508
Moga	157639	444
Gurdaspur	37468	723
Jalandhar	546361	521
Amitsar	205425	772
Bathinda	202265	444
Tarantaran	50090	555
Sri Muktsar Sahib	143211	310
Kapurthala	238744	329
Barnala	29487	261
Fatehgarh Sahib	111656	287
Mansa	22144	333
Faridkot	28433	245
Shaheed Bhagat Singh Nagar (Nawan Shahr)	84298	259
Sahibzada Ajit Singh Nagar	51728	258

[5] http://nhb.gov.in/Statistics.aspx?enc=K1SxiJnLqCTqPmc6tzC6mBuHmjyjK79Diz12BGKh5acu41PoHDv5hOakPtQZEaGJBUhkPLH24/5uwVKWN0rSKg==

[6] Integrated Sample Survey Reports (1993-94 to 2012-13), Animal Husbandry Department, Govt. of Punjab.

(Mohali)		
Ropar	50070	212
Fazilka		
Pathankot		
Total	**3533675**	**9678**

Based on a preliminary analysis district of Sangrur was selected for detailed analysis of status, stakeholder consultations, practices and potential interventions for paddy straw utilization and demand for cooling energy. The details of selection criteria of district are given in Annexure II.

3.1.3 Bio-waste and cooling energy Status – Sangrur

Sangrur is border with Ludhiana and Ferozpur districts in the north side, Bhatinda district in the west side, Patiala in the East side and Jind district (Haryana State) in the south side. The district has population 1655169 (Census – 2011) and ranks 2nd in area and 7th in population in the State. The district is sub-divided into 9 blocks and district glance is given in the Table 6. The map of district is shown in **Figure 2** below.

Table 6: District Sangrur at a glance

Total Area	**361000 Hectares**
Total Population	1655169 (Census – 2011)
Population density	457/km^2
Area under paddy straw cultivation	262000 hectares
Number of farm burning events	
2016	11862
2017	8429
2018 (Till Nov)	7782

Figure 2: District map of Sangrur

The blocks namely; Sunam and Sangrur have highest gross and net sown area in the district. Table 7 below shows the block wise geographical area, net sown area and gross cropped area of District Sangrur

Table 7: Block wise geographical, net sown and gross cropped area in the district (Area in ha)

Blocks	Geographical area	Net sown area	Gross cropped area
Sangrur	44589	37292	74795
Bhawanigarh	33790	29413	58512
Ahmedgarh	34120	28599	59143
Malerkotla	41748	34790	66842
Dhuri	26163	22338	45080
Sherpur	27439	24420	49399
Sunam	79582	69487	138696
Lehragaga	41861	36343	72008
Andana	32460	28831	57515
Total	**351452**	**311513**	**621990**

Source: District Agriculture Office, Sangrur

It can be seen from Table 8 the most of the framers are having land holding with less than 4 ha area. The district has mostly semi-medium and medium category farmers as per the classification based on their land holding pattern. Only 5% of the farmers in the district is having land area more than 10 hectares and can afford renting farm equipment for in-situ management.

Table 8 Agriculture Census of Sangrur District (2010-11)

Size Class (in ha)	No. of Farmers	Area operated (in ha)
Marginal (< 1)	13310	8532.54
Small (1.0 - 2.0)	16398	24100.76
Semi Medium (2.0 - 4.0)	29973	83007.76
Medium (4.0 - 10.0)	21691	124810.8
Large (10.0 & Above)	4025	55301
Total	**85397**	**295752.86**

Source: District Agriculture Office, Sangrur

As per the data collected from District Agriculture department, under the on-going in-situ management program, the department has a set-up 99 Common Hiring Centres (CHC) in the district. The details of farm machineries implemented during the year are given in the Table 9. Overall 1158 Happy Seeder machines were provided to the farmers in the district.

Table 9: Type of farm machineries available in Sangrur district (till 12th Dec, 2018)

Name of machineries	Purchased by CHCs/individual farmers
Happy Seeder	1158
Super SMS with combined harvester	446
Chopper	82
Mulcher	61
MB Plough	74
Zero till drill	166
Rotavator	74

Source: District Agriculture Office, Sangrur

Table 10: Capital and operational cost details of typical baler machine

Baler output	1 acre/hour
Cost of baling machine	11 lakh
Baling cost	Rs. 1200/- per acre
Diesel cost	Rs. 300/- per acre
Roping cost	Rs. 500/- per acre

Source: Interaction with biomass aggregator and district agriculture officer

Table 10 shows the capital and operational cost details of typical baler machine. High capital cost of baler machine and limited local demand of paddy straw are found to be the main factor which limits the use of baler by farmers in the district.

3.1.4 Paddy straw generation and its use

The total surplus paddy straw generation in the district is 2296.205 kilo tons during the year of 2018. Total area under paddy straw in the district is 273200 hectares out of which non-basmati paddy straw area is around 85%. Paddy straw is mainly used through the following modes;

3.1.4.1 In situ mode (through happy seeder)

As per the details provided by the agriculture department and farmers, happy seeder machine is capable of mulch straw into the soil about 8-10 acre land area on daily basis. It is estimated that total area of 74112 hectares (31.9%) is covered through the Happy seeder machines during the harvesting season, assuming all available machines are 100% utilized by the farmers.

3.1.4.2 Ex-situ mode (through baler)

There are eight balers in the district and estimated to cover 640 hectares (0.3%) of paddy area during the season. These bales are mainly purchased by a briquetting unit situated in the district.

It is estimated that almost 67.8% of the paddy area of the district is burnt by the farmers. Therefore, there is limited impact of in-situ management scheme is observed in the district which is also witnessed through the farm burning incidents (as per the Table 4) reported in the district.

3.1.5 Horticulture activities

The block wise details of fruits and vegetables production was obtained and given in tables 11 and 12. It can be seen from the table 11that the major fruit production in the district is Guava, Ber, banana and Kinnow. In case of vegetable crops, table 12 shows cauliflower, cabbage, chillies and vine crops are the major horticulture produce in the district apart from onion and potato. Generally these produce are sold by farmers in the mandi (market) immediately after their harvest due to limited storage facility.

Table 11: Block wise fruit production (in MT) in Sangrur District, 2017-18

Blocks in Sangrur Dist	Kinnow	Sweet orange	Lemon	Mango	Guava	Pear	Peach	Plum	Grapes	Ber	Banana	Others	Total
Sangrur	357	37	57	49	1622	57	507	30	151	531	-	134	3532
Bhawanigarh	324	-	61	61	831	42	42	10.6	44	564	64	148	2191.6
Ahmedgarh	146.71	11	195	362.3	1037	13.5	163.8	-	74.2	513	1961.8	81	4559.31
Sunam	719.94	-	76	-	1648	132	77	10	138	781	70	38	3689.94
Lehra Gaga	267	-	20	8.7	1125	92.7	38.4	-	30.7	426	-	22	2030.5
Anndana	302	-	25	-	121	-	-	-	2.1	-	-	-	450.1
Sherpur	49	-	348	46	1382	64	42	5	-	201	144	65	2346
Dhuri	199	33	440	36	1378	64	10	10	-	452	-	128	2750
Maler Kotla	196	-	388	346.2	3537	94.8	394.8	-	96.2	1114.5	676.5	128	7007
District Total	2595.65	81	1610	909.2	12681	560	1275	65.6	536.2	4582.5	2916.3	744	28556.45

Source: District Horticulture Office, Sangrur

Table 12: Block wise vegetable production (in MT) in Sangrur district, 2017-18

Blocks in Sangrur Dist	Potato	Onion	Garlic	Tomato	Brinjal	Cauli flower	Cabbage	Okra	Chillies	Peas	Vine crops	Root crops	Other crops	Total
Sangrur	2420	4205	210.6	572	252	1050	840	495	3417	1173	795.44	609	1483	17720.04
Bhawani garh	1380	294	128	420	144	2162	975	375	2400	287	612.11	72	70	9404.61
Ahmed garh	6384	2713.2	416	1157	825	3774	695.45	656.7	903.3	112	2892.5	747.5	180	21791.7
Sunam	1800	3696	56	392	432	2820	780	660	1600	246	658.94	276	175	13691.69
Lehra Gaga	720	2268	14	84	126	1316	702	180	600	69.7	142.5	168	168	6586.2
Anndana	560	1700	7	168	216	2720	760	270	500	64	750	870	154	9019
Sherpur	990	1628	100	44	219	464	384	65	1486	601	655	71	604	7353
Dhuri	2002	2835	170	44	204	844	350	130	1757	635	2081	325	1800	13419
Maler Kotla	6000	9280	600	1170	3000	14740	7600	1560	2240	1310	6402	1150	4896	60610.5
District Total	22256	28619.2	1701.8	4051	5418	29890	13086.45	4391.7	14903.3	4497.7	14989.49	4288.5	9530	159595.69

Source: District Horticulture Office, Sangrur

Table 13: Type and quantity of Fruits in Sangrur district

Name of Fruit	Area (in Hectares)
Kinnow	2595.65
Sweet orange	81.00
Lime/Lemon	1610.00
Mango	909.20
Guava	12681.00
Pear	560.00
Peach	1275.00
Plum	65.60
Grapes	536.20
Ber	4582.50
Banana	2916.30
Others	744.00
Total	**28556.45**

Source: District Horticulture Office, Sangrur

Table 14: Type and quantity of Vegetables in Sangrur district

Name of vegetable	Area (in Hectares)
Potato	22256.00
Onion	28619.20
Garlic	1701.80
Tomato	4051.00
Brinjal	5418.00
Cauliflower	29890.00
Cabbage	13086.45
Okra	4391.70
Chillies	14903.30
Peas	4497.70
Musk Melon	1535.25
Water Melon	437.50
Vine crops	14989.49
Root crops	4288.50
Other crops	9530.00
Total	159595.69

Source: District Horticulture Office, Sangrur

It can be seen from the table 13 above that the major fruits in the district are Guava (44%), Ber (16%), Banana (10%) and Kinnow (9%) while table 14 shows cauliflower (19%), Onion (18%) and Potato (14%) are the major vegetables in the district. Malerkotla block in the district has highest fruit production (7007 MT) as well as vegetable production (60610 MT). Based on the discussion with farmers, it was clear that due to limited cold storage facility and no price support mechanism the farmers are not interested to shift to these horticulture crops.

3.1.6 Milk production, collection and storage, cooling energy needs

The total estimated milk production in the district is about 775000 MT and out of the total milk production about 80% is assumed to be for commercial purpose and remaining is utilized for domestic consumption. It is estimated that an average of 800-1000 L of milk is collected daily in each village of the district. This milk is stored at the Bulk Milk Chiller (BMC) during morning and evening before it has been transported to milk collection and chilling facility. In the milk collection and chilling facility the surplus milk is collected from BMC plant from nearby villages. Total of 10000-12000 L of milk is stored in the Milk Collection and Chilling centre, which is then transported through milk van to milk processing units for production of milk products. The typical milk collection, storage and supply chain model is shown in Figure 3.

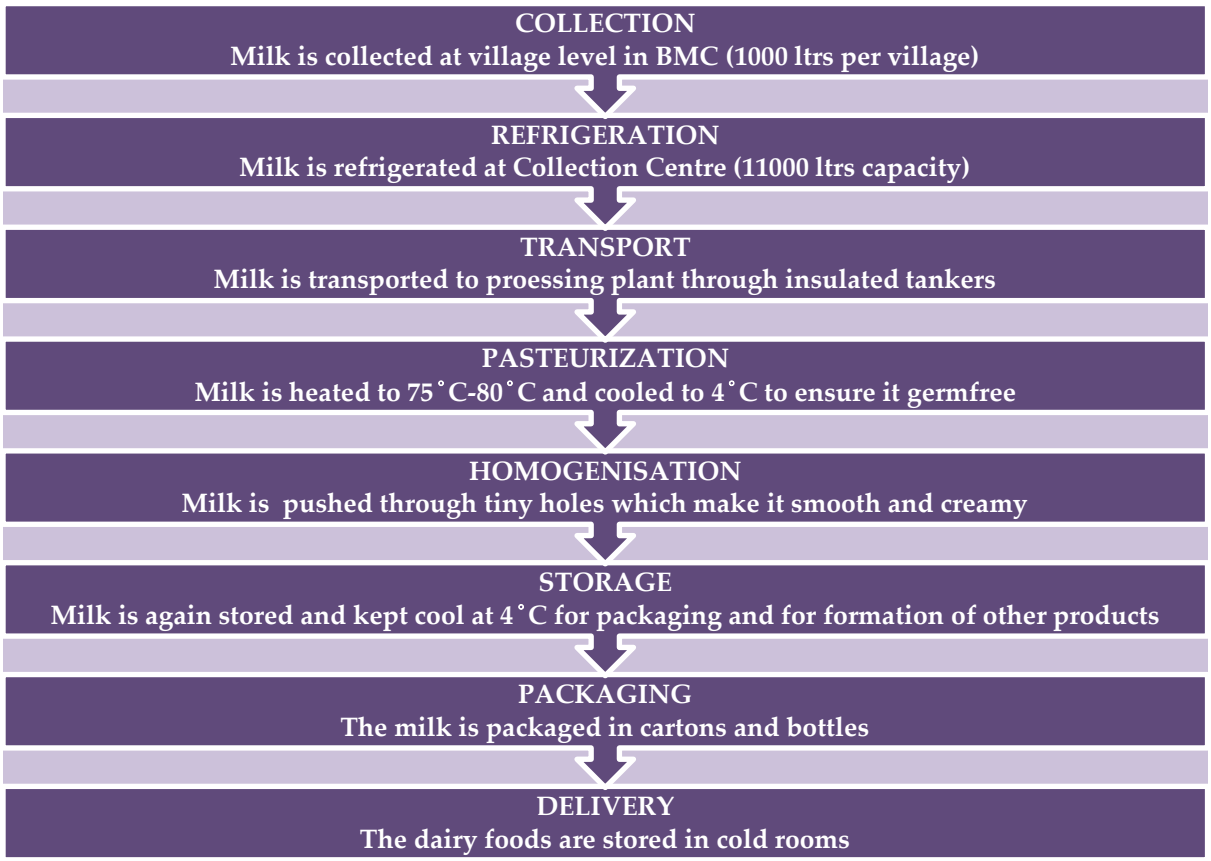

Figure 3: Milk collection, storage and supply chain mechanism in the district

The demand of cooling energy at the different stages of milk collection and storage is estimated. It is observed that a 2.5 ton vapour compressor based chiller is generally used at each BMC in the district to store 1000 L of milk. The electricity grid is used to run the plant and a back-up diesel generator set is used in case of grid failure. It is estimated that total of 32000 units of electricity is consumed annually in a BMC and it is assumed that around 500 BMC units exist in the district. Hence, estimated electricity demand of BMC units in the district is around 16 million units of electricity.

The milk from 10-15 BMCs is then transported to collection centre having refrigeration storage capacity of 11000 litres. Ammonia based vapour compression refrigeration system is used to run the chilling unit. The system is mainly operated on grid electricity and typical load demand of milk chilling centre is 48 HP including 40 HP compressor load. The chilling centre operated for 20-24 hours in summer and 4-6 hours in winter. The electricity consumption of this unit is 788 kWh during summer day and 179 kWh during winter day. It is estimated that total of 1.9 lakh units of electricity is consumed annually in milk collection centre and it is assumed that around 35 such units are there in the district. Hence, estimated electricity demand of milk collection centres in the district is around 6.7 million units of electricity.

3.1.5 Fuel demand in the industries, power generation

a) Coal demand in brick kilns in the district

There are almost 212 brick kilns in Sangrur District, out of which around 175 brick kilns are operational. About 50% of the brick kilns have installed "induced draft zigzag" firing technology, which is supposed to be more efficient and reducing coal consumption to about 20 per cent in comparison to conventional kilns. At present, all brick kilns in the district are using imported coal and the cost of this imported coal is found to be Rs. 10/- per kg. The typical consumption of coal in the brick kiln is ~ 5 TPD and ***estimated annual consumption of coal in the district is about 218759 tons.***

b) Paddy straw demand in proposed Bio-CNG plant in the district

Verbio India Private Limited (A Germany-based Company) is implementing a project based on their patented technology to convert paddy straw into biogas generation based on anaerobic digestion technology. The project is being set up at Bhutalkalan village of Sangrur district. The proposed project will produce Bio-CNG of 80,000 m^3/day capacity and expected to start commercial operation by end of 2019. ***Annual estimated demand of paddy straw for the proposed bio-CNG plant is 110960 Ton.***

c) Paddy straw demand in briquetting plant in the district

The district has one briquetting plant named as "Punjab Renewable Energy Systems Pvt. Ltd" (PRESPL). This unit consumes saw dust, paddy straw and cane trash as main raw materials for making briquettes. There are two machines with capacity of 1.2 tons per hour output. ***The briquetting plant utilize about 8410 tons/year of paddy straw***, which is generally collected from nearby villages in the vicinity. The unit supplies the briquettes as boiler fuel to "Pepsico India" bottling plant located at Village Channo in Sangrur district.

Key observations made during stakeholders interactions:

- Around 2 million tons of paddy straw is generated every year in Sangrur district (10% of Punjab)
- There are three villages in the district namely; Kanoi, Pupali and Tungan where 80% burning was reported last year and aiming for zero burning during this year. INR 1 lakh per village panchayat is proposed to incentivize such villages
- Mulching capacity of Happy Seeder is about 1 Acre/hour and generally used 8-10 hours daily for sowing of wheat crop.

- Happy seeder renting cost is about Rs 1200-1500 per acre (including tractor, driver and diesel)
- Krishi Vigyan Kendra (KVK) is creating awareness among farmers about adverse effects of crop residue burning and organizing workshops in villages to practically demonstrate the in-situ farm machineries
- KVK has acquired a land of 50 hectares each in 4 villages to demonstrate the uses of in-situ farm machineries. 25 farmers from each village is selected for the demonstration purpose. KVK conduct 5 days' workshop in each village for this purpose
- Baler average output is 2-3 ton/h. Due to limited demand of paddy straw in the district very few farmers in Sangrur district are converting their paddy straw into bales. These bales are mainly purchased by a briquetting industry in the district.

3.2 Haryana

The State of Haryana has total geographical area of about 44.212 lakh ha. Out of this total area about 35.21 lakh ha area is net sown area, 30.14 lakh ha area is sown twice comprising 65.35 lakh ha gross sown area. Total paddy straw generated in the state of Haryana is 7.73 million tonnes out of which 1.827 million tons is surplus. In kharif, major crops cultivated include Paddy, Sugarcane, groundnut and maize and in rabi, crops like wheat, gram, barley and oilseeds are cultivated. The district wise geographical area, net sown area, gross cropped area, paddy area, paddy straw generated and surplus paddy straw in the state of Haryana is given in Table 15 below.

Table 15: District wise geographical area, net sown area, gross cropped area, paddy area, paddy straw generated and surplus paddy straw in the state of Haryana

District	Geographical area (in Hectare)	Net Area Sown (in Hectare)	Gross Cropped Area (in Hectare)	Paddy Area (In Hectare)[7]	Paddy straw (in Kilo Tonne)[8]	Surplus Biomass (in kilo tonne)[9]
Ambala	157400	107894	207145	82524	643.968	159.382
Bhiwani	477800	399494	794131	18704	82.560	20.434
Faridabad	74100	28910	58993	10703	52.116	25.797
Fatehabad	253800	221343	428358	91071	728.592	360.653
Gurgaon	125800	78377	105563	4852	29.928	1.481
Hisar	398300	332700	653498	44431	238.392	59.002
Jhajjar	183400	140782	238622	30016	136.740	33.843
Jind	270200	243834	476110	116437	634.164	156.956
Kaithal	231700	202712	380856	160257	995.364	197.082

[7] TIFAC report "Estimation of surplus crop residue in India for biofuel production", October 2018382.511
[8] TIFAC report "Estimation of surplus crop residue in India for biofuel production", October 2018382.511
[9] TIFAC report "Estimation of surplus crop residue in India for biofuel production", October 2018382.511

Karnal	252000	193398	391727	170226	1079.988	32.076
Kurukshetra	**153000**	146860	287471	117932	898.872	213.572
Mahendragarh	189900	152571	288802	21	0.097	00
Mewat	150700	111625	172537	5824	36.120	00
Palwal	135900	107594	199639	32370	182.148	00
Panchkula	89800	22294	44263	9169	56.244	2.784
Panipat	126800	94085	162108	75905	396.804	39.284
Rewari	159400	125704	192492	2513	15.480	12.260
Rohtak	174500	137239	225789	39008	149.640	14.814
Sirsa	427700	398533	735247	67668	382.511	340.817
Sonipat	212200	151556	281606	91215	448.920	22.222
Yamunanagar	176800	124246	210697	71818	544.380	134.734
Haryana	**4421200**	**3521751**	**6535654**	**1242643**	**7733.028**	**1827.19**

The districts such as Fatehabad, Sirsa, Kurushetra and and Kaithal has large amount of crop residues surplus in the State.

The data on crop-residues burning incidents (district wise) monitored using satellite remote sensing was compiled and given in **Table 16.** It can been seen that that a total of 9196 burning event were reported in the current year, which is about 70% of the events detected in 2017 and about 58% of the events detected in 2016. Though the number of crop burning events are reducing over the years but still it is very high despite significant efforts were made by both National and State Governments to prevent open burning through regulations and law enforcement agencies.

The top 5 districts, which has reported maximum burning event during this year are Fatehabad (2549), Sirsa (1781), Kaithal (1292), Jind (886) and Karnal (856).

Table 16 District wise crop burning instances in Haryana

Districts	01 Oct – 29 Nov		
	2016	2017	2018
Ambala	537	502	332
Bhiwani	93	47	22
Faridabad	288	343	188
Fatehabad	4831	3734	2549
Gurugram	0	0	0
Hisar	414	192	211
Jhajjar	43	19	34

Jind	861	945	886
Kaithal	1748	1512	1292
Karnal	1640	1513	856
Kurukshetra	1079	1150	682
Mahendragarh	0	0	0
Mewat	0	0	0
Palwal	0	0	0
Panchkula	0	0	3
Panipat	102	110	64
Rewari	0	0	0
Rohtak	103	98	51
Sirsa	3580	2444	1781
Sonipat	100	86	43
Yamunanagar	253	323	202
Total	**15672**	**13018**	**9196**

Source: Consortium for Research on Agro ecosystem Monitoring and Modelling from Space (CREAMS) of Indian Agricultural Research Institute

3.2.1 Overview of cooling energy demand in agriculture sector

Haryana produces about 2.1 million ton of horticulture produce as per the data available for the year 2012-13. Table 5 shows district wise horticulture production (2012-13), milching cattle population (2012-13) in Haryana. The district wise details of horticulture production and mulching cattle population (2012-13) is given in Table 17. The districts namely; Sonipat (10%), Mahendragarh (10%), Sirsa (9%), Yamuna nagar (9%) and Kurukshetra (8%) has highest production of horticulture while based on number of mulching cattles in the districts, top 5 districts having highest estimated milk production are Bhiwani (8%), Kaithal (7%), Jind (7%), Hisar (7%) and Sirsa (7%).

Table 17: District wise horticulture production (2012-13), milching cattle population (2012-13) in Haryana

District	No. of Milching Cattles[10]		Horticulture (in MT)[11]
	Cows	Buffaloes	
Ambala	22581	79678	104892
Bhiwani	36635	165062	70749
Faridabad	14088	48316	58170
Fatehabad	20458	101327	76970
Gurgaon	20060	59503	105063

[10] http://esaharyana.gov.in/Portals/0/ABSTRACT%2016-17%28English%29.pdfzx

[11] http://nhb.gov.in/Statistics.aspx?enc=K1SxiJnLqCTqPmc6tzC6mBuHmjyjK79Diz12BGKh5acu41PoHDv5hOakPtQZEaGJBUhkPLH24/5uwVKWNorSKg==

Hissar	28994	157064	70795
Jhajjar	15322	85139	66226
Jind	20544	151498	84621
Kaithal	21450	142632	91695
Karnal	49568	112132	72865
Kurukshetra	31042	69263	161085
Mahendragarh	16438	87234	200396
Nuh	11265	75841	32834
Palwal	13025	102129	44865
Panchkula	7029	27910	44196
Panipat	17917	76158	95447
Rewari	16795	73810	29636
Rohtak	13826	85773	96645
Sirsa	62016	108723	197477
Sonipat	29700	117473	200963
Yamuna Nagar	45386	76223	194922
Total	**514139**	**2002888**	**2100512**

The district of Kurushestra has been shortlisted for primary research work. Field surveys and stakeholder consultations were conducted with the district level agencies and other stakeholders. The details of selection criteria of district are given in Annexure II. The interactions were held with district level departments, farmer groups and industries to get the field level information/data to achieve the overall objective of the scoping study. The section below gives details of various interactions and analysis of the information/data collected.

3.2.2 Status of Bio-waste and cooling energy - Kurukshetra

Kurukshetra lies on the main Delhi Ambala Railway line about 160 kilometers North of Delhi, 34 kms North of Karnal and 40 kms South of Ambala. Kurukshetra is a place known all over India for its great cultural heritage. It came into existence on 23 January 1973. It is situated in North-East part of Haryana. Its adjoining districts are Ambala, Yamuna Nagar, Karnal, Kaithal and Patiala (Punjab). The district has population 964231(Census – 2011) and ranks 15th in area and ranks 16th in population in the State. The district is sub-divided into 7 blocks` and comprises of 419 villages and district glance is given in the Table 18. The map of district is shown in Figure 4. The block wise geographical area and net and gross sown area is given in Table 20.

Table 18: Kurukshetra district at a glance

Total Area	**153000 Hectares**
Total Population	964231 (2011 census)
Population density	630/km^2
Area under paddy straw cultivation	121000 (2017-18)
Number of farm burning events	
2018	682
2017	1150
2016	1079

Figure 4: District map of Kurukshetra District

3.2.3 Agriculture profile of the district

It can be seen from the table 19 that 83 % of the farmers in Kurukshetra District hold below 4 acres of land. 13% of the farmers have land holding of 4 to 10 acres and only 4 % farmers have land holding of the area of 10 acres or above.

Table 19: Different category of farmers based on the their land size in Kurukshetra District

Type of farmers	No. of operational holdings	Area (in Hectare)
Marginal (below 1 acre)	24870	11063
Small (1 to 2 acre)	10477	14962
Semi-Medium (2 to 4 acre)	9411	26823
Medium (4 to 10 acre)	6821	42411
Large (10 acres and above)	2271	48880
Total	53850	144140

Source: District Agriculture Office, Kurukshetra

The number of different farm machineries/ equipment available in the CHC under "Central Sector Scheme of in-situ management" and under SMAM respectively is given in Table 20 and 21.

Table 20: Number of different farm machineries/equipment available in the CHC in Kurushestra District (80% Subsidy)

Name of Farm Machineries	Total count (Available at CHCs)
Super SMS	10
Straw Chopper	70

Reversible Plough	111
Rotary Slasher	16
Rotavator	100
Zero till drill	76
Happy seeder	124
Mulcher	41
Shrub master	47
Total	595

Source: District Agriculture Office, Kurukshetra

Table 21: Number of farm machineries under SMAM (40% subsidy)

Name of Farm Machineries	Total count
Tractors (50 HP to 70 HP)	131
Balers	8

Other than this, 20 balers are owned by "Sainsons Paper Industries" and they rent the other balers from Punjab as requirement.

Table 22 shows cost details of different farm machinery/ equipment available in the CHCs, Kurukshetra and Table 23 shows the cost break up of paddy straw baling, collection and transportation in Kurukshetra District.

Table 22: Cost details of different farm machinery/ equipment available in the CHCs, Kurukshetra

Name of equipment	Purchasing cost (INR lakhs)	Diesel consumption (litres/acre)	Renting cost (INR per acre) [including diesel, tractor and driver]
Baler (with rack)	15	12	2500/-
Reversible plough	2.8	12-13	2000/-
Land leveller	3	10	1200/-
Reaper + chopper	3.5	10	2000/-
Happy seeder	1.5	8-10	1500/-
Rotavator	0.9	7	1200/-
Shredder	0.3	2.5	500/-

Source: Primary Survey interaction with Kisan Vikas Samiti, Barna

Table 23: Cost break up of paddy straw baling, collection and transportation in Kurukshetra district

Cost component	Details	Rs/quintal
Tractor renting cost	3 tractors (1 for cutter, 1 for racker, 1 for baler)	7
Labor cost	3 drivers + 1 Helper	8
Diesel cost	For 3 tractors	25
Roping cost	To bind the balers	15

Maintenance cost	For baler, tractor and other machineries	10
Transportation + loading + unloading	23 Km transport distance from village to paper industries	60
Total baling cost		125

Source: Primary Survey Interaction with biomass aggregator

3.2.4 Paddy straw generation

In Kurukshetra district, total area under paddy is 117932 Hectares, out of which around 70% area (82552 Hectares) is under Non-Basmati Paddy. Total paddy straw generated out of this area is 898.873 kilo tons per annum. Table 24 shows the Area, Production and Yield of major crops in Kurukshetra District.

Table 24: Area, Production and Yield of Major crops in Kurukshetra District

Crop	Area (000 Hectares)	Production (000 MT)	Yield (tons/Hect)
Paddy	117.9	506	4.18
Wheat	114	550	4.82
Sugarcane	12	1109	92.43

Source: District Agriculture Office, Kurukshetra

* Block wise data of Area, Production yield of Major crops is not available as two new blocks (Pipli and Islaimabad) are formed very recently (2018)

3.2.5 Paddy straw utilisation

Mostly, paddy straw is utilized through two modes:

In-Situ Mode: By mulching the paddy straw into the soil through happy seeder. As per the information provided by Chief Agriculture Officer, total number of happy seeders in the district is 124. Average mulching capacity of happy seeder is 0.4 hectares per hour. Happy seeder is more effective during daytime with proper sunshine with maximum 8 hours per day during harvesting season. Total area of straw mulched in the district is 7936 hectares (9.6%)

Ex-situ Mode: By baling the paddy straw through baler and utilize it as a raw material to briquetting and paper industries. As per discussion with farm owners and biomass aggregator, total number of balers in the district is 48. Out of which, 8 balers are owned by CHCs/individual farmers, 20 balers are owned by "Sainsons Paper Industries and rest 20 balers are rented by "Sainsons Paper Industries from Punjab. The average baling capacity of a baler is 1 acre per hour. Total annual paddy straw baled in the district is 13824 Hectares (16.7%). These bales are purchased by a “Sainsons Paper Industries” situated in the district. It is estimated that about 70% the paddy area is burnt due to limited number of in-situ machines in the district.

3.2.6 Horticulture activities and potential in the district

The block wise details of fruits and vegetables production was obtained and given in tables 25 and 26. It can be seen from these tables that the major fruit production in the district is Guava, Ber, banana and Kinnow. In case of vegetable crops cauliflower, cabbage, chillies and vine crops are the major horticulture produce in the district apart from onion and potato. Generally these produce are sold by farmers in the mandi (market) immediately after their harvest due to limited storage facility.

The total area of major fruits and vegetable grown in the district along with its production quantity and price range of during season and off-season for Kurushestra District is given in Table 25 and 26. It can be seen from the major fruit production in the district is Guava (42%) while potato is the major vegetable produced with 53% share. Generally these produce are sold by farmers in the mandi (market) immediately after their harvest. It has been found that there is almost 8 to 10 times fluctuation in prices of these produce in the local mandi (market) during season and off-season period due to limited storage facility available at farmer's place.

Table 25: Area, Production and price range of vegetables produced in Kurushestra district (2017-18)

S. No.	Name of vegetable	Area (hectares)	Production (MT)	Price (Rs./kg)	
				Min	Max
1	Potato	8210	302000	2	25
2	Onion	725	16230	6	44
3	Tomato (open + Protected)	1000	24240	1.2	25
4	Radish	1925	17250	2	25
5	Carrot	1625	21900	4	30
6	Cabbage	1066	11793	3	25
7	Cauliflower	1930	23520	2	50
8	Green Chillies	425	960	6	65
9	Capsicum	625	7500	6	40
10	Bhindi	745	5525	10	60
11	Brinjal	175	390	4	25
12	Arbi	20	595		
13	Peas	1525	23300	12	100
14	Leafy Vegetables	2150	56880		
15	Bottlegourd	640	8850	8	26
16	Ridgegourd/ Sponggourd	450	4770		
17	Cucumber	1553	20725		
18	Pumpkin	180	1955		
19	Bitter gourd	230	3350	10	60
20	Others	2085	16290		
	Total	**27284**	**568023**		

Source: District Horticulture Office, Kurukshetra

Table 26: Area, Production and price range of fruits produced in Kurushestra district (2017-18)

Sr No	Name of fruit crop	Total Area (in hectares)	Production (MT)	Price (Rs./kg)	
				Min	Max
1	Mango	504.6	5500	15	150
2	Guava	428.1	15250	15	120
3	citrus	13.4	130	15	80
4	Ber	14	600		
5	grapes	0	0	25	120
6	Aonla	20	1650		
7	Chiku	138.2	1240	15	40
8	Litchi	6.6	270		
9	Peach	35	705		
10	Pear	75	750		
11	Plum	10	640		
12	Strawberry	0	0		
13	water Melon	15	2250		
14	Musk Melon	0	1750		
15	Bael	0	50		
16	Others	74	5810		
	Total	**1333.9**	**36595**		

Source: District Horticulture Office, Kurukshetra

3.2.7 Milk production, collection and processing, cooling energy needs

In the study district, the number of milching cattle and annual milk production is given in table 27 below. It is estimated total milk production in the district is about 256341 MT.

Table 27: Estimates of milk production in the district

S. No.	Particulars	Kurukshetra
1.0	**Number of milch animals**	
1.1	Number of cows (in milk)	31042
1.2	Number of buffaloes (in milk)	69263
2.0	**Annual Milk Production (MT)**	
2.1	From cows	73307
2.2	From buffaloes	183034
2.3	**TOTAL**	**256341**

Source: Milk union, Kurukshetra

Note: As per Cattle Census 2012 the average yield is as follows:

Cross Bred Cows : 8.18 kg PD

Indigenous cows : 4.77 kg PD

Buffaloes : 7.24 kg PD

(Herd average production calculated based on adult population)

There are total of 10 BMCs in Kurukshetra district each having cooling load of 1.5 TR. Each BMC has capacity to collect 1000 litres of milk. There are no collection centres in Kurukshetra district as milk is directly transported from BMCs to milk processing plant. The running capacity of typical milk plant is 35000 litres/day. The total cooling demand of

typical milk plant is 60 TR. The milk plant collects milk from 10 BMCs in Kurukshetra district while rest of the demand is completed from 25 BMC units of nearby districts. Total running capacity of milk plants in the district is 1010000 litres/day. Table 28 shows the typical demand of cooling and heating in Bulk milk chiller and milk plant while table 29 shows estimated demand of cooling and heating in bulk milk chillers and milk plants in Kurukshetra district

Table 28: Typical demand of cooling and heating in Bulk milk chiller and milk plant

Typical Cooling demand of BMC unit	**5.25 kW**
Typical cooling and heating demand of milk plant	435 kW

Source: Primary survey interaction with CEO, Vita milk plant, Kurukshetra

Table 29: Estimated demand of cooling and heating in bulk milk chillers and milk plants in Kurukshetra district

Estimated Cooling demand of BMC units in Kurukshetra district	**52.5 kW**
Estmated cooling and heating demand of milk plants in Kurukshetra district	4039 kW

Source: Primary survey interaction with CEO, Vita milk plant, Kurukshetra

3.2.8 Fuel demand in the industries, power generation

a) **Coal demand in brick kilns**

There are 100 brick kilns in the district. These brick kilns use imported USA coal as fuel in brick kilns. Average coal consumption in a brick kilns is 125-150 tons per month. These brick kilns are generally operates 5 months in a year. The t***otal estimated annual coal consumption by brick kilns in the district is 68750 tons.***

b) Paddy Straw demand in paper industry

There is one paper industry in Kurukshetra district namely "Sainsons Paper Industries Pvt. Ltd.". Captive power generation capacity of the paper industry is 5 MW. Industry uses Paddy straw, wheat straw, rice husk, press mud as a fuel feed for boiler. Fuel consumption for the boiler is 275 tons per day out of which paddy straw consumption during season (for 6 months) is 250 TPD and during off season is 125-150 TPD. Plant is operational for 350 days in a year. ***Total annual paddy straw consumption in the paper industry is 67812.5 tons***

c) **Estimated paddy straw consumption in proposed power plant**

A 15 MW biomass power plant "HIND SAMACHAR LTD" is proposed in Kurukshetra district which is expected to come in the year of 2020. **Total annual estimated demand of paddy straw in the power plant is 144540 tonnes**

Key observations made during field visit and stakeholders interactions:

- KVK is creating awareness among farmers about adverse effects of crop residue burning
- Organizing workshops in villages to practically demonstrate the in-situ farm machineries
- KVK has adopted two villages namely Barna and Kamoda

- KVK has provided free machineries for in-situ operations to those farmers who own the tractors.
- Around 20% of the total farm lands in these villages are covered by free machineries provided by KVK
- KVK provided the machineries only to those farmers who have their own tractors
- KVK provided 1 bag of wheat seed (Rs. 1200/-), 2 bag of urea (Rs. 600/-) and 1 bag of zinc fertiliser (Rs. 600/-) as an incentive to each farmers with zero burning
- Around 60% of the total straw generated in the Barna and Kamoda villages is sold to "Sainsons Paper Industries" @ Rs. 1.5/kg
- Out of total 419 villages, no fire incidences have been found this year in 112 villages.

Key information gathered during stakeholder's interaction is summarized in table 30 shown below.

Table 30: Summary of stakeholder's interaction

Date	Stakeholders	Key Takeaways
20-09-2018	NTPC, Limited	• NTPC plans to burn biomass crop residues along with coal to generate electricity. • NTPC has invited bids for procurement of agro residue for procuring 1,000 TPD of agro residue based fuel (500 TPD of agro residue pellets and 500 TPD of torrefied agro residue pellets or briquettes) for its 2,650 MW Dadri power plant. • There are three parties which have come forward with quantity of around 250 tonne per day. • A capping price of Rs 5,500 per tonne has been kept for agro residue-based pellets and Rs 6,600 per tonne for pellets or briquettes of torrefied agro residue. • One of the selected vendor "Neway Engineers MSW Private Limited" will supply the paddy straw based torrified pellets from their facility, which is currently under construction in Bhatinda district of Punjab. It is expected that company will start their commercial operation to produce and supply the pellets by end of December 2018.
19-09-2018	IOCL	• IOCL will buy back CBG from manufacturers/suppliers at a price (including GST) of Rs. 48.30/- per kg. Additionally, an element of Rs. 2 per kg of CBG towards cost of setting up of infrastructure shall be provided to OMC or Applicant • IOCL has proposed three 2G Ethanol pilot plants in India • IOCL had signed MoU with PEDA to set up 42 bio CNG plant in Punjab.

14-09-2018	NAFED	• NAFED National Agricultural Cooperative Marketing Federation of India Ltd a marketing federation and is an apex organization set up with the object to promote co-operative marketing of Agricultural Produce to benefit the farming community and working to develop models for aggregation of agro-waste materials from farmers for the surplus crop residues collection through Farmer Producer Organizations promoted across the country. • NAFED has also signed a MoU with IOCL for production and marketing of compressed bio-gas (CBG)/bio-CNG and Bio-manure. • NAFED will facilitate for arrangement of suitable land, with all infrastructural requirements, such as raw material availability, connecting road, provision of water and electricity supply etc. • NAFED will co-ordinate with various agencies for effective aggregation of biomass/ waste.
17-10-2018	CEEW	CEEW pioneered business engagement and extensive analytics on HFCs in India After the 2016 Kigali Amendment, The CEEW's research has focused on challenges inherent in the transition; ranging from challenges related to the air-conditioning and refrigeration servicing sector, to the critical issue of R&D.
06-09-2018	Agriculture department of Haryana and Punjab	• Responsible for implementation of agricultural mechanization for In-situ crop residues management scheme of GoI and to sensitize the farmers about adverse effects of stubble burning • Establishment of CHCs and procurement of farm machinery under the in-situ management scheme. • Providing Central financial assistance to farmers and their cooperative for procurement of agricultural farm machinery and equipment for in-situ crop residue management • Information, Education and Communication for awareness activities including advertisement and publicity, awareness camps, mobilization of school/college student etc. • Farmers awareness camps at village and block level
07-09-2018	Punjab Pollution Control Board	• In-situ management is not a key to success to stop stubble burning completely as it is difficult to manage in-situ every year. • Limited staff strength to check and monitor the cases of stubble burning at different locations • Punjab government has signed a MoU with "Neway engineers MSW private limited" to set up 400 processing plants for converting paddy straw into bio energy in the state to address this challenge.
08-09-2018	Haryana Pollution Control Board	• Mobile Application has been developed by Haryana State Remote Sensing Applications Centre (HARSAC), a nodal agency of the Department of Science & Technology,

		Government of Haryana for Remote Sensing and GIS applications, crowd sourcing for reporting stubble burning locations from the field functionary • HSPCB is also giving telecast of advertisement on Doordarshan regarding harmful effect of burning of wheat stubble in open fields. • HSPCB has issued following directions to its Regional Officers:- o To place hoardings in all prominent and relevant places o To conduct district level competitions for school children on the theme of 'Stubble burning and its harmful. o To conduct rallies at district level o HSPCB has issued directions under Section 31A of Air (Prevention and Control of Pollution) Act, 1981 regarding mandatory use of Super SMS with Combine Harvesters for harvesting paddy in the State of Haryana and these directions were also published in leading Hindi and English newspapers.
07-09-2018	New way engineers MSW Pvt Ltd.	• "Neway engineers MSW private limited" has been awarded a contract to supply paddy straw based torrified pellets as fuel to NTPC plant in Dadri. • The company is currently setting up a facility in Bhatinda, district of Punjab. • The company expected to start commercial operation to produce and supply the pellets by end of December 2018.
08-09-2018	Sampoorna Agri Venture Pvt Ltd Mr. Sanjeev Nagpal, Founder	• The company has developed bio-digestor to convert paddy straw co-digest with 10% cow dung to produce biogas, which is further utilized to produce electricity. • The plant utilize about 25 tonnes/day paddy straw to produce 12000 m3 of biogas to produce 450 units of electricity. Existing tariff for the plant is Rs. 8.25/- per unit. About 1 ton of straw produces 600 kg of manure which can be sold to farmers @ Rs. 8/- per kg for manure applications
22-10-2018	District Agriculture Office, Sangrur	• The department has allocated subsidy of Rs. 7.83 crore for the current financial year for procurement of in-situ farm management machines. • Out of 141 CHCs proposed for Sangrur district, around 87 CHCs has been sanctioned. • The department has conducted awareness camps and demonstration of Happy Seeder technology for farmers and FPOs in the district • The department has given cash incentive INR 1 lakh per village panchayat to three villages in the district namely Kanoi, Pupali and Tungan where zero burning was noticed during this year.

24-10-2018	Krishi Vigyan Kendra, Sangrur	• KVK, Sangrur is working dedicatedly to bridge the unfilled technology gap between scientific knowledge and farmers' practices for increasing production vis-à-vis income from agriculture and allied fields on sustainable basis. • KVK is creating awareness among farmers about adverse effects of crop residue burning and organizing workshops in villages to practically demonstrate the in-situ farm machineries. • For this purpose, KVK has acquired a land of 50 hectares each in 4 villages to demonstrate the uses of in-situ farm machineries such as happy seeder, Super SMS combined with harvester. • 25 farmers from each village is selected for the demonstration purpose. KVK conduct 5 days' workshop in each village for this purpose.
14-11-2018	District Agriculture Office, Kurukshetra	• In Kurukshetra district, around 30% of total area under paddy production is basmati and balance 70% is under cultivation of non-basmati variety paddy. • Out of total 419 villages in Kurukshetra district, there were no fire incidences reported in 112 villages in the district. • A target to establish 140 CHCs in the district was set, of which 100 CHCs has already been established. • A subsidy of INR 10.89 crore is allocated to Kurukshetra district for purchase of in-situ farm machineries. INR 7.86 crore has already been distributed to CHCs and individual farmers as a subsidy to purchase in-situ farm machineries.
12-11-2018	KVK, Kurukshetra	• KVK has adopted two villages namely Barna and Kamoda in Kurukshetra district where they have controlled 70 % stubble burning by creating awareness and by organising workshops to use in-situ farm machineries. • KVK also provided free farm machineries in the adopted villages to the farmers who have their own tractors. • Fund worth INR 85 lakh are reserved for awareness campaigning to aware farmers about adverse effects of stubble burning in Kurukshetra district. • Total 836 awareness camps have been organized in this season (May, June, September and October). INR 10000 per camp is allotted for awareness.
25-10-2018	District Horticulture Department, Sangrur	• The block wise horticulture produce information and data was obtained. Malerkotla block of the district has highest production of fruits and vegetable crops in the district. • The monthly price variation of different horticulture produce was obtained. • There are 14 number of cold storage in the district, which are mainly used to store potato. • There is limited cold storage facility to store horticulture produce in the district.
22-10-2018	Farmer's group, Sangrur	• The majority of farmers use the combine harvester with SMS for harvesting. • Happy-seeder is being used by very few farmers in the

		district. • Majority of farmers are reluctant to use happy seeder because of its high operational cost. • Farmers are not very sure about sowing method through happy seeder as sowing is not uniform and difficult to be monitored and controlled.
15-11-2018	Farmer's group (Barna Village), Kurukshetra	• Around 20% of the total paddy area of this village is covered by free machineries provided by KVK • KVK provided the machineries only to those farmers who have their own tractors • The remaining 80% of paddy area is covered through renting of farm machineries. • A total of 150 farmers in the Barna village and 120 farmers in Kamoda village have been incentivized by provided free seeds, urea and zinc by KVK. • Around 60% of the total straw generated in the village is sold to "Sainsons Paper Industries" at a price of Rs. 1.5/kg.
23-10-2018	Biomass aggregator, Sangrur	• The cost details for collection, baling and transportation of paddy straw were obtained. • The bales are mainly purchased by a briquetting unit
15-11-2018	Custom Hiring Centre (Kishan Vikas Samiti, Barna, Kurukshestra)	• The CHC centre has purchased Baler, Reversible plough, land leveller, Reaper, Chopper, Happy seeder, rotavator, shredder • **Subsidy:** 40% for baler (under SMAM), 80% for other equipment (under central sector scheme of in-situ management) • The details of renting cost of different farm equipment were obtained
24-10-2018	Brick Kiln Owner Association, Sangrur	• There are about 212 brick kilns in the district, out of which around 175 brick kilns are operational. • About 50% of the total brick kilns in the district have been shifted to zig-zag firing technology. • Most of the brick kilns in the district are using imported coal as a fuel. • The details of brick kiln energy consumption, cost and other technical details were obtained.
12-11-2018	Hind Samachar Ltd (proposed 15 MW Paddy Straw based Power Plant), Kurukshetra	• The developer has been awarded a project to set up 15 MW paddy straw based power plant in the district through competitive bidding process. • The plant is expected to be commissioned in the year 2020, • It is expected that about 145 KT of paddy straw annually will be consumed by this proposed power plant in the district.
14-09-2018	IKEA	• IKEA is aims to address the challenge of burning of rice straw • IKEA has launched major initiative named 'Better Air Now'. • Through this project, IKEA aims to turn rice straw (rice harvesting residue) into a new renewable material source for its products. • This initiative is aiming to find new ways to make use of rice straw that would become a valuable resource for the farmers instead of being burnt. • IKEA working closely with their business partners & suppliers, universities, central and state governments in

		India, innovators, NGO's and farmers, the long term ambition for IKEA is to contribute to villages reaching zero rice straw burning. • The first IKEA product prototypes based on rice straw will be ready by the end of 2018 and the ambition is to start selling the products in our India range during 2019-2020, and gradually extend the offer to more markets
11-10-2018	Kriya Labs (IIT Delhi)	• KRIYA LABS, a start-up company incubated at IIT Delhi, has developed an innovative process that can convert agro-waste like paddy straw into pulp into table wares and other forms through extensive research work carried out at IIT Delhi. • The innovators based on their initial cost estimation claimed that by such a process, a significant market demand of pulp can be fulfilled by utilizing rice straw as raw material. • As per the lab process developed about 500 kg of pulp can be produced from each tonne of paddy straw stubble with estimated cost of pulp of Rs 45 per kg and with a total material compensation of ~Rs 2000 per ton to the farmers. • Kriya Labs aims to franchise their process to local entrepreneurs for setup small pulp manufacturing units and the final table wares to be sold to mass market, government agencies like Railways and/or Quick Service Restaurants etc.
12-11-2018	Sainsons Paper Industries, Kurukshetra	• There is a paper mill in the district having captive biomass based power plant of 5 MW capacity • The boiler is fed with Paddy straw, wheat straw, rice husk, press mud as fuel. • The technical and cost details of the power plant were obtained. About 70000 tons of paddy straw is consumed per annum by this plant.
23-10-2018	Briquetting plant, Sangrur Punjab Renewable Energy Systems Pvt. Ltd (PRESPL)	• This unit consumes saw dust, paddy straw and cane trash as main raw materials for briquetting. Out of total raw material used for briquetting, 40% is the contribution of paddy straw. • PRESPL supplies the briquettes to "Pepsico India" plant located in Channo village, Sangrur. This briquetting plant is operational from last 6 months only.
25-10-2018 13-11-2018	Milk dairy PD Fresh Pvt. Ltd., Sangrur Vita milk plant, Kurukshetra	• Details of cooling and heating energy demand, milk collection and storage mechanism were obtained • Process and energy consumption details of the unit is collected
11-12-2018	Bulk milk chiller, Sangrur	• Cost and technical details such as power consumption, collection, transportation and storage cost were obtained • A 2.5 ton vapour compressor based refrigeration unit is used to operate the BMC of 1000 litres storage capacity.
11-12-2018	Milk collection centre, Sangrur	• Cost and technical details such as power consumption, collection, transportation and storage cost were obtained • Milk storage capacity of collection centres is generally 11000 litres.

A few pictures taken during the field trips and stakeholder interactions are given in Annexure IV.

4. Key Study Findings: Gaps and proposed Intervention Areas

The Government of India has a number of policies and initiatives already in place that aims for effective management of bio-waste materials. The Ministry of Agriculture and Farmers Welfare has taken the initiative to address the crop-residues burning through in-situ management practices by use of Happy Seeders and other farm machineries. Based on the review of existing policies, consultations with National, State and district level stakeholders, it is clear that paddy straw utilization offers tremendous potential for increasing the share, clean energy requirements in power generation, industrial and commercial sectors, and growing demand for cooling energy in rural areas for agriculture value chain enhancement in both the States. However, setting up bio-waste collection and supply chain mechanism holds the key to success. Presently, surplus bio-waste materials are burnt in the field to clear the farms. The report revealed that there is huge local demand of solid fuels like coal and fuel wood in the local economy and even the prices of these fuels are high. The prices of these fuels are found to be high as these fuels are transported in the districts from large distances and in case of coal it is brought from other States. Therefore, it is imperative to create biomass supply chain mechanism involving entrepreneurs and setting up facility to convert these materials into useful forms.

A program on bio-waste management, cooling energy in agriculture sector could develop various new initiatives to address the common bio-waste burning problem identified in this report or support the enhanced impact of already-existing programs. New initiatives, for instance, might include pilot demonstration of Swedish technologies/solutions, further development of dialogue with local government. Several criteria could inform the development and design of appropriate program interventions.

There are various ways in which new initiatives or ideas could be developed that strengthen existing initiatives:

- Both Union and State Governments are committed to provide adequate policy framework and support system to continue and address the challenge of crop-residues burning and air pollution challenge in the NCR region.
- Along with the identification of challenges, an exercise to be undertaken to identify and map Sweden's technologies and expertise in management of bio-waste, non-HFC and not-in-kind cooling technologies. The exercise helped in summarizing focus areas of in-situ, ex-situ management and ICAP as a long term programme of Government of India for clean air.
- To carry out feasibility studies and develop business plans to cover (i) ODS-HFC-free tri-generation for cold storage applications in agriculture value chain; (ii) Management of uncontrolled bio-mass-waste burning; inter alia technical, logistical, economic, financial framework and sustainable business models for development and implementation of action plan.

- Additional policies are needed on crop residues collection and aggregation that will encourage private investment in crop residues collection business and further provide choices to farmers to get opportunity to dispose of their bio-waste materials and build viable business models to establish bio-waste supply chain mechanism that allows private sector to invest in processes to bio-waste material valorization through production of bio-CNG, bio-ethanol, bio-pellets, bio-power, paper, tableware, fabric production etc..
- Analysis from the field visits and discussions with the farmers showed that solutions could be in the use of paddy straw as fuel for running decentralized cold storage to store horticulture produce and milk chilling applications at the village level. This results in providing alternate options to farmers to shift to horticulture and other crops, which due to limited cold storage capacity at the local level, farmers are reluctant to shift from paddy cultivation and result in increased farmer income. A case specific analysis is required to assess which modality of mobilizing the residues from the field can be viable, especially as a means to improve the socio-economic condition of the farmers, while minimizing negative environmental impacts.
- There are existing policies and directives to utilize the bio-waste management and its use for different purposes. It is important to analyse the existing alternative uses of crop residue management, undertaking techno-financial evaluation and socio-economic assessment of selected options (e.g. 100% paddy straw based power generation, co-firing in existing thermal plants, brick kiln industries as fuel) and environmental and health benefits. Supply chain analysis and impediments to scale-up of chosen alternatives and/or best practices will be undertaken to develop feasible business models.
- Focus on creating awareness and sensitizing different stakeholders in whole value chain including State and District level agencies about the new methods and advanced technologies about crop-residue management and its applications as clean fuel source.
- To set up an independent platform to facilitate Industry-Academia Collaboration which will develop a process for identification of innovative techno-economic cooling options customizing Indian conditions. The platform intends to develop a process for identification of low GWP refrigerants and advanced energy efficient cooling technologies viz., refrigerant based cooling, non-refrigerant based conventional cooling technologies, Not in Kind (NIK) technologies, etc.

  The platform with an objective to:

  - Bridging multi-level stakeholders from Government, Public Sector Units, Private Partners, Multilateral Organizations, Industry, Think tanks & Academic Institutions
  - Develop an evaluation process to conduct techno-economic feasibility of proposals
  - Brainstorm on the opportunities of clean energy based fuel systems as NIK technology
  - Conduct policy research analysis relating to cooling sector.

Annexure I: List of stakeholder details

Table A1: List of stakeholder details

Department	Name	Designation	Contact
Government Stakeholder			
NTPC	Mr. Amit Kulshreshtha	Additional General Manager	9650992138
IOCL	Subodh Kumar	Executive director (Alternate energy and sustainable development)	011-24362170
NAFED	Ravi Kainth	Executive Director	9810808709
PPCB	Mr. Krunesh Garg	Member Secretary	9878950503
HSPCB	Mr. Ashok Kheterpal	Chairman	
Agriculture department of Punjab	Manmohan Kalia	JD (AE)	9814066839
Agriculture department of Haryana	R.S. Chahal	JD (AE)	9569012086
Department of Agriculture, Sangrur	Dr. Baldev singh	Chief Agricultural Officers	9888674820
Horticulture department, sangrur	Dr. Karnail singh		7508018914
PEDA, Sangrur	Mr. Rajesh Bansal	Sr. Manager	9417480801
PPCB, Sangrur	Mr. Harjeet singh		9878950547
Brick Kiln Association, Sangrur	Mr. Prem Gupta	President	9216432045, 9814687045
	Sardar Harminder singh sikh	Chairman	9216700222
DDA, Kurukshetra	Karam Chand	Deputy Director of Agriculture	01744-220504, 9416189243
	Dr. Yudhveer Singh	Technical assistant	9896007540
	Mr. Bharat Vahi	SMAM officer	9466241535
Deputy director of dairy, Kurukshetra	Dr. Dharmendra	Intense cattle project	9416157873
	Dr. MR Mahila		9896473207
District horticulture office, Kurukshetra	Dr. Joginder bisla	District horticulture officer	01744-222957, 9467996049
	Dr. Vikram		9416948421
APMC, Kurukshetra	Mr. Rajiv Choudhary	District Enforcement Officer	9812021138
Academic/research institute			
KVK Sangrur	Dr. Mandeep Singh	Programme Coordinator	99881 11757
KVK, Kurukshetra	Dr. Hariom	Senior program coordinator	9896560123
Kriya Lab (IIT Delhi)	Mr. Ankur Kumar	Founder & CEO	8130731083

Industries			
IKEA	Mr. Rakesh Jetli	Project leader, purchasing & logistic	9818282654
Sangrur vegetable producer company	Mohd Asharaf	Managing director	8872153651
Verbio Bio-CNG plant, Sangrur	Mr. Yuvraj		9650106013
PD fresh Pvt Ltd, Sangrur	Mr. Sikandar Singh	Director	9878432372
Arshad Milk Centre (BMC), Sangrur	Mr. Arshad	owner	9855218877
Super Milk Collection Centre	Mr. Dinesh	Owner	7087280416
	Mr. Dashrath	Worker	9417600416
Sainsons Paper Industries pvt ltd, Kurukshetra	Mr. Hari saini	Manager	9896820777
	Mr. J.N. Saha	Vice President	9254039100
Hind Samachar Limited power plant, Kurukshetra	Harbans Kamboj	Manager F&A	9599032201
	Satinder Bakshi	Plant head-Biomass	9814854545, 9354926935
Vita dairy (co-operative milk union), Kurukshetra	Mr. Sanjay Setia	CEO	9812302142, 01744275544
Brick Kiln, kurukshetra	Mr. Rakesh Goyal	Owner	9416328022
	BBC Brick kiln	Barna village	
NGO/Think tanks			
CEEW	Ms. Shakha Bhasin	Program lead	9811161977
Farmer's group/trader, CHCs			
Farmers, Sangrur	Mr. Kulwant Singh Mr. Jagjeevan Singh Mr. Harbans Singh Mr. Gurmeet Singh Mr. Jaswinder singh Mr. Deedar Singh Mr. Kuldeep Singh		Ubbawal Village, Sangrur Block
Biomass trader, Sangrur	Davender singh		9501306660, 9877432390
Farmer, Kurukshetra	Mr. Gurvinder Singh	Barna village, Kurukshetra	9996465314
CHC, Kurukshetra	Kisan Vikas Samiti	Barna village, Kurukshetra	
Biomass aggregator, Kurukshetra	Mr. Samsher singh	Khijarpura Village, Kurukshetra	9802500006
	Mr. Baljeet Singh	Barna Village, Kurukshetra	9671690002

Annexure II: Selection of survey districts

The shortlisted districts are decided based on two broad criteria:

- Availability of paddy straw in the district and
- Demand of cooling energy with focus on agricultural value chain that includes horticulture produces and milk production.

The district wise data on paddy straw availability (land under non-basmati variety grown) and (quantity of horticulture and milk production (based on milching cattle population) have been analysed for this purpose.

The factors such as availability of paddy straw in the district and need for cooling energy for both horticulture produce and milk production have been considered. For raking of the districts, analysis was carried out with 50% weightage given to district with higher availability of paddy straw and remaining 50% weightage to district with higher demand of cooling energy in the agriculture value chain.

Total priority weightage

District wise $[(\%\ \text{area under non basmati crop} \times 0.5) + (\%\ \text{milk production/ milching cattle population} \times 0.25) + (\%\ \text{Horticulture production} \times 0.25)]$

By using the sorting tool of excel spread sheet, the list of top 5 district is shortlisted based on the above equation used by providing priority weightage and finally one district has been finalized. Table A2 below shows the methodology to select the district.

Table A2: Methodology adopted to select the district

Parameters	Criteria	Indicator
District wise area under non-basmati paddy	Priority is given to districts with higher area	50% weightage
District wise milk production/milching cattle population	Districts with high milk production/milching cattle populations are prioritized	25% weightage
District wise horticulture produce	Districts with high horticulture produce are prioritized	25% weightage

Based on applying above mentioned parameters with respective indicators, districts are ranked accordingly. Table A3 shows the ranking of districts in Punjab.

Table A3: Ranking of districts in Punjab

District	Horticulture production (in MT)	Milk production (in 000 MT)	area under non-basmati (in Hectare)	% horticulture production	% milk production	% area under non-basmati	Weightage
Firozepur	598350	791	136100	16.9	8.2	5.8	9.2
Ludhiana	185597	1050	232500	5.3	10.8	9.9	9.0
Jalandhar	546361	521	156600	15.5	5.4	6.6	8.5
Sangrur	37692	775	237400	1.1	8.0	10.1	7.3
Hoshiarpur	609508	508	64700	17.2	5.2	2.7	7.0
Patiala	143509	601	208400	4.1	6.2	8.8	7.0
Moga	157639	444	162900	4.5	4.6	6.9	5.7
Bathinda	202265	444	125700	5.7	4.6	5.3	5.2
Gurdaspur	37468	723	130800	1.1	7.5	5.5	4.9
Amitsar	205425	772	67100	5.8	8.0	2.8	4.9
Kapurthala	238744	329	109500	6.8	3.4	4.6	4.9
Sri Muktsar Sahib	143211	310	99100	4.1	3.2	4.2	3.9
Tarantaran	50090	555	94700	1.4	5.7	4.0	3.8
Barnala	29487	261	107400	0.8	2.7	4.6	3.2
Fatehgarh Sahib	111656	287	75600	3.2	3.0	3.2	3.1
Mansa	22144	333	92000	0.6	3.4	3.9	3.0
Faridkot	28433	245	87200	0.8	2.5	3.7	2.7
SBS Nagar	84298	259	53600	2.4	2.7	2.3	2.4
SAS Nagar	51728	258	26700	1.5	2.7	1.1	1.6
Ropar	50070	212	32800	1.4	2.2	1.4	1.6
Fazilka			33700	0.0	0.0	1.4	0.7
Pathankot			25000	0.0	0.0	1.1	0.5
Total	**3533675**	**9678**	2359500				

Based on priority weightage analysis, the top 5 districts in Punjab are Ferozpur, Ludhiana, Jalandhar, Sangrur and Hoshiarpur.

Further judgemental analysis was made with top 5 districts and districts were further prioritised based on percentage of rural population and proximity to NCR and proximity to NCR. 50% weightage is given to percentage of rural population and 50% weightage is given to proximity to NCR. As shown in table A4 Sangrur district stood first in the rank.

Table A4: Final selection of district

District	Proximity to NCR (in Km)	% rural population	% weightage of distance from NCR	Final weightage
Sangrur	266	71.4	84.6	78.0
Firozepur	411	74.2	76.2	75.2
Jalandhar	373	52.5	78.4	65.5
Hoshiarpur	386	51.0	77.7	64.3
Ludhiana	293	44.2	83.1	63.6

Therefore, it is proposed to select in Punjab, Sangrur district for the purpose of scoping study so that more comprehensive analysis can be arrived to meet the objective of this study.

Table A5 shows the ranking of districts in Haryana. Based on priority weightage analysis, top 5 districts in the state of Haryana are Karnal, Kurukshetra, Kaithal, Yamuna Nagar and Ambala.

Table A5: Ranking of districts in Haryana

District	Horticulture	Milching Cattle	Area under non-basmati rice (in hectare)	% horticulture production	% milching cattle	% Area under non-basmati rice	Weightage
Karnal	72865	49568	90400	3.5	9.6	18.8	12.7
Kurukshetra	161085	31042	86200	7.7	6.0	17.9	12.4
Kaithal	91695	21450	89400	4.4	4.2	18.6	11.4
Yamuna Nagar	194922	45386	55000	9.3	8.8	11.4	10.2
Ambala	104892	22581	60100	5.0	4.4	12.5	8.6
Sirsa	197477	62016	12400	9.4	12.1	2.6	6.7
Fatehabad	76970	20458	40300	3.7	4.0	8.4	6.1
Sonipat	200963	29700	12500	9.6	5.8	2.6	5.1
Jind	84621	20544	28800	4.0	4.0	6.0	5.0
Mewat	200396	16438		9.5	3.2	0.0	3.2
Panipat	95447	17917	3900	4.5	3.5	0.8	2.4
Hissar	70795	28994	1200	3.4	5.6	0.2	2.4
Gurgaon	105063	20060	400	5.0	3.9	0.1	2.3
Bhiwani	70749	36635		3.4	7.1	0.0	2.6

Rohtak	96645	13826		4.6	2.7	0.0	1.8
Faridabad	58170	14088		2.8	2.7	0.0	1.4
Rewari	29636	16795	800	1.4	3.3	0.2	1.3
Palwal	44865	13025		2.1	2.5	0.0	1.2
Narnaul	32834	11265		1.6	2.2	0.0	0.9
Panchkula	44196	7029		2.1	1.4	0.0	0.9
Jhajjar	66226	15322		3.2	3.0	0.0	1.5
Total	**2100512**	**514139**	**481400**				

In the case of Kurukshetra district, a 100% paddy straw based 15 MW power plant has been awarded

Therefore, through judgemental analysis, Kurukshetra district is further prioritized for the purpose of scoping study so that more comprehensive analysis can be arrived at to meet the objective of this study.

Annexure-III: Establish Farm Machinery Banks or Custom Hiring Centres of in-situ crop residue management machinery

ITEM	MAXIMUM PERMISSIBLE PROJECT COST	PATTERN OF ASSISTANCE
Procurement subsidy for establishment of Custom Hiring Centre of in-situ crop residue management machinery	Project based 10 - 75 lakhs (in-situ crop residue management implements component cost would be at least 35% of the total project cost)	80% of the project cost of the in-situ crop residue management implements 40% of the project cost for the remaining project (This financial assistance will be available under SMAM)

Procurement of Agriculture Machinery and Equipment for in-situ crop residue management

S.No.	Name of the machine/equipment	Maximum Permissible subsidy per Machine/ Equipment per beneficiary	Pattern of Assistance
1.	**Super Straw Management System (Super SMS) to be attached with Combine Harvester**	56,000	50%
2.	Happy Seeder		
	a) 09 tine	72,800	50%
	b) 10 tine	75,600	50%
	c) 11 tine	78,400	50%
3.	**Paddy Straw Chopper/ Shredder/Mulcher**		
	a) Mounted type (Straw Chopper & Mulcher)		
	i) 5 ft	67,200	50%
	ii) 6 ft	72,800	50%
	iii) 7 ft	78,400	50%
	iv) 8 ft	84,000	50%
	b) Trailed type	1,26,000	50%
	c) Combo type	1,40,000	50%
4	**Shrub Master / Cutter cum Spreader**	22,400	50%
5	**Hydraulic Reversible M.B. Plough**		
	a) Two bottom	70,000	50%
	b) Three bottom	89,500	50%
6	**Rotary Slasher**	22,400	50%
7	Zero Till Seed cum Fertilizer Drill		
	9 tine	21,280	50%
	11 tine	24,080	50%
	13 tine	26,880	50%
	15 tine	28,000	50%

8	**Rotavator**		
	5 feet	42,000	50%
	6 feet	44,800	50%
	7 feet	47,600	50%
	8 feet	50,400	50%

Project cost of CHC upto Rs. 10 lakhs

S. No.	Name of the equipment/ machines	No. of equipment	Unit cost of Equipment (Rs. in lakhs)	Total cost of Equipment (Rs. in lakhs)	Rate of financial assistance	Maximum permissible subsidy @ 80% of the cost (Rs. in lakhs)
1	Super Straw Management System (Super SMS) to be attached with Combine Harvester	01	1.12	1.12	80%	0.90
2	Happy Seeder (10 tine)	01	1.51	1.51	80%	1.21
3.	Paddy Straw Chopper (combo)	01	2.80	2.80	80%	2.24
4.	Paddy Mulcher (7ft)	01	1.57	1.57	80%	1.26
5.	Hydraulically Reversible M.B. Plough (3 bottom)	01	1.79	1.79	80%	1.43
6.	Rotary Slasher	01	0.45	0.45	80%	0.36
	Total	**06**		**9.24**	**80%**	**7.40**

Note: (No tractor will be allowed under project cost upto Rs. 10 lakhs)

Annexure IV: A Selective list of Pictures clicked during Field Survey

Fire incident in the field

Fire incident in the field

Heap of Paddy straw

Farmer's group with Happy Seeder

Super Straw Management System with combined Harvester

Baler

Bulk Milk Chiller

Milk Collection Centre

Sainsons Paper Industries Pvt Ltd., Kurukshetra

A heap of bales

A Briquetting unit

A brick kiln unit