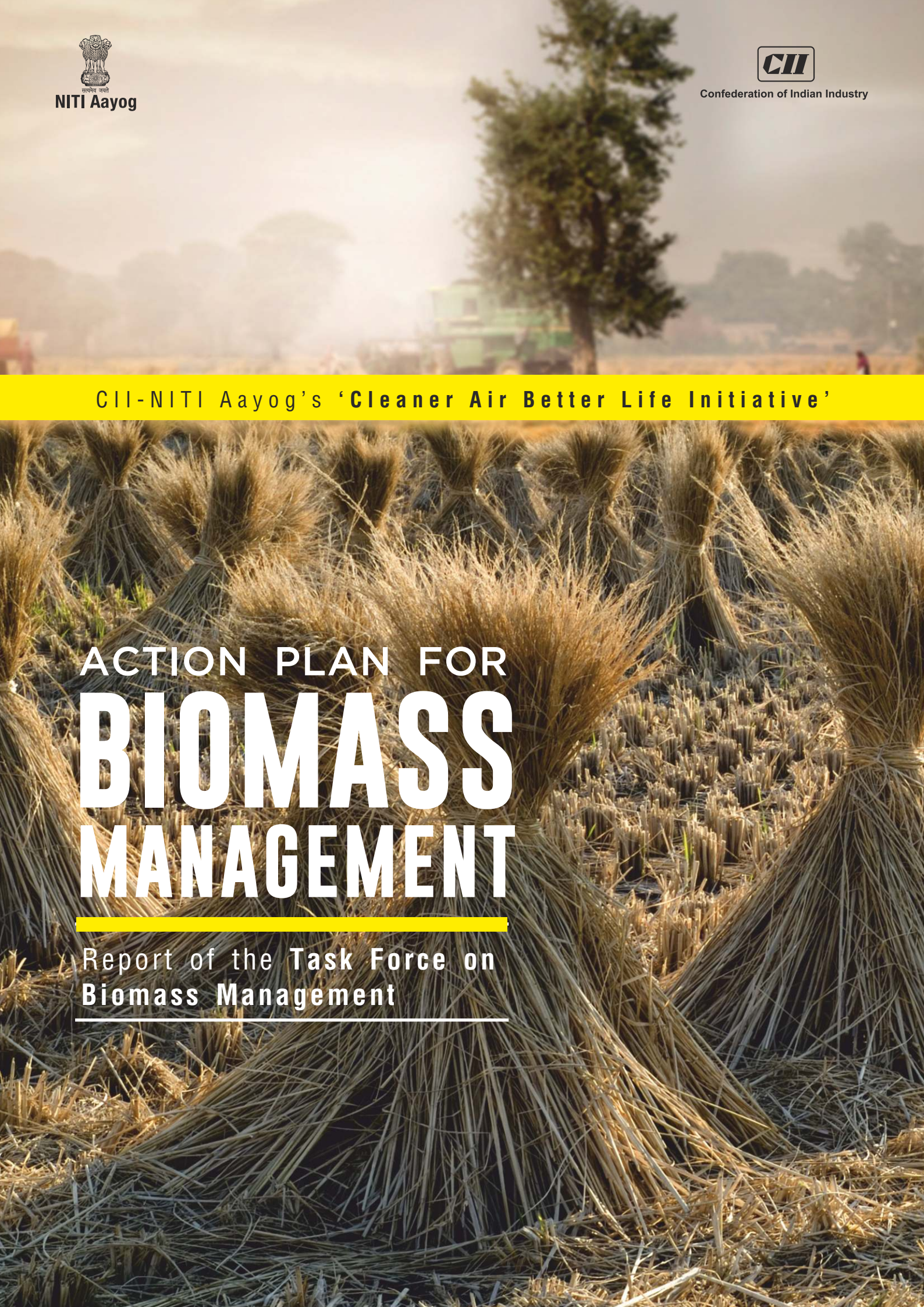
NITI Aayog

Confederation of Indian Industry

CII-NITI Aayog's **'Cleaner Air Better Life Initiative'**



ACTION PLAN FOR BIOMASS MANAGEMENT

Report of the **Task Force on Biomass Management**

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Message

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MESSAGE

Formulation of appropriate strategies for maintaining a clean, green and healthy environment is a priority in NITI Aayog. We are all aware that air pollution is a major threat to a healthy environment. For controlling air pollution, NITI Aayog has been working closely with Confederation of Indian Industry (CII) and other stakeholders. On the World Environment Day (5th June, 2017), NITI Aayog and CII organized the first meeting of their joint initiative "Cleaner Air Better Life" with an objective to address the issue of air pollution in the Country with active participation of the Government agencies, the industries and other stakeholders.

Subsequently, four Task Forces were constituted in NITI Aayog with experts as members to recommend suitable interventions for Clean Fuel, Clean Transport, Clean Industries and Biomass Management. The practice of burning biomass (crop residues) has a very detrimental impact on the air-shed of Delhi and nearby areas. The issue of biomass burning was taken up by the Task Force on Biomass Management.

The Task Force has given valuable recommendations in their report which would be highly useful for controlling biomass burning leading to cleaner air in Delhi and nearby areas. The report highlights that in addition to the technological solutions, specific policy interventions need to be introduced to drive the behavioural change towards better management of crop residue.

I congratulate CII team for their excellent work on the Cleaner Air Better Life Initiative. I would also like to congratulate Mr. A.K. Mehta, Additional Secretary MoEF&CC and convenor of the Task Force on Biomass Management, for showing great leadership while undertaking extensive consultations with the stakeholders and coming up with specific recommendations to address the critical issue of biomass burning. I would also like to place on record appreciation for Mr. Yaduvendra Mathur, Mr Jitendra Kumar, Dr. Dinesh Arora, Ms. Pratima Gupta and other officers of the NRE Vertical, NITI Aayog for providing necessary support and relevant inputs to the Task Force.

(Amitabh Kant)

Place- New Delhi

Message

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Message

With rapid urbanisation, most of the Indian cities face the challenge of management of air-quality. Various sources of air-pollution have been identified under the source apportionment studies conducted in some of the cities. Various action plans have been formulated to address the identified sources; however the air-shed management requires participation of all stakeholders on a sustained basis. CII-NITI Aayog Cleaner Air Better Life initiative brings together diverse stakeholders to propose workable solutions for combating air pollution. I had the opportunity to convene the task force on biomass management constituted by NITI Aayog under the initiative and based on the inputs from different stakeholders an action plan has been prepared for biomass management.

There is a strong scientific evidence that incidents of burning crop residues by the farmers across Northern states not only affects the regional air quality but are also responsible for aggravating the air-quality in Delhi NCR in the months of November and October. This period is also accompanied by use of fire crackers during Diwali. Both of these phenomena are responsible for episodic rise of air pollution in NCR region.

The task force on biomass management has engaged with solution providers, civil society, academia and farmers in rural regions as important stakeholders to identify key solutions including short-term and long-term solutions. Consultations were undertaken in New Delhi and Ludhiana where the task force engaged with farmers' community to include their perspective on feasibility of different solutions. Based on inputs received from these multi-stakeholder engagements, recommendations have been drawn up and placed for consideration of all stakeholders for further action.

I congratulate CII team for research and analysis. The merit of the report lies in highlighting the fact that solutions already exist for treating crop residues in the field or outside the field but concentrated efforts need to be made by all concerned stakeholders to make these solutions palatable and market mechanisms to work on long-term and sustainable basis.

(A. K. Mehta)

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CONTENTS

EXECUTIVE SUMMARY

Air quality in Delhi and National Capital Region (NCR) has been a prime concern for its severe health impact on general public, especially the children and senior citizens. Over past couple of years, there have been episodic incidents of air quality dipping to alarming levels across Delhi-NCR. CII-NITI Aayog 'Cleaner Air Better Life' initiative aims to bring together all relevant stakeholders[1] for designing a set of solutions to the identified sources of air pollution. The farm burning, specific to the paddy-wheat cultivation cycle in the rural regions of Northern and North-Westerns states of India, has been identified as a major source of air pollution. It not only affects the air-quality in rural areas but also causes an episodic rise in air-pollution during October and November in Delhi-NCR. Under this initiative, a dedicated task force on biomass management was constituted by NITI Aayog with Additional Secretary, Ministry of Environment Forests and Climate Change as convenor and eminent experts as members. This report is prepared after due consultation with all relevant stakeholders and it consists of identified solutions to address farm waste burning. In the long-run, recommended action would induce behavioural change in the farmers' community through adoption of in-situ and ex-situ options[2] to utilise the crop residue.

Unlike other crop residues, paddy straw is utilised to a very small extent outside the field. This is mainly due to its low calorific-value compared to other crop–residues and high silica content which limits its use in many applications. This situation is further exacerbated by obsolete traditional uses of residue such as roof thatch, proliferation of mechanised farming and a very small window of transition for the farmers between harvesting paddy and sowing wheat. It is estimated that roughly 39 million tonnes of paddy straw is burnt in Haryana, Punjab, Rajasthan and Uttar Pradesh. This excludes paddy-straw from basmati that is utilised for animal fodder. Therefore, multi-pronged strategy needs to be adopted to drive the behavioural change in farmers' community for extracting more value out of the farm waste and key recommendations from the task force are highlighted in the table below.

Recommended actions by the task force on biomass management

Immediate action	Medium and long-term actions				
Financial support to farmers	**Impact fund for Air-pollution**	**Upscale technologies**	**Reward and monitor at local level**	**Regulatory support**	**Awareness tools**
1. Incentives to farmers through Direct Benefit Transfer	2. Set up Clean air impact fund to support clean technologies and link it with the National Clean Energy Fund	3. Service-based shared infrastructure (with 50% capital subsidy on select implements) 4. Process- based incentives 5. Accelerated depreciation for farm implements	6. Reward for panchayats: INR 1 La per panchayat with zero-burning 7. Monitoring: through advanced remote sensing data and mobile based app for general public	8. Reassessing Fuel criteria for briquettes/ pellets from paddy-straw 9. Directive to thermal power plants to procure paddy straw briquettes/pellets 10. Removing the size limitation for Bio-power captive generation	11. Awareness campaigns for farmers 12. Farmer recognition programme 13. Manuals and information tools for in-situ mulching and on-farm management

[1] Government, industry, academia and civil society.

[2] In-situ implies treatment of crop-residues within the farm thus returning nutrients back to the soil. Ex-situ implies treatment of crop residues outside the farm for utilisation in various waste to energy options.

CII-NITI Aayog Cleaner Air Better Life initiative is driven by multi-stakeholder consultations for airshed management

Financial support to farmers

The in-situ treatment of straw has long-term benefits- increase in soil health, reduction in fertiliser requirement and augmentation in farmer's income. Shared infrastructure economy has a potential to provide the required machinery at affordable cost, however the current capacities are not adequate to cater all farmers. Therefore, as an immediate measure, it would be best to incentivise[3] the farmers based on the cost-effective straw management initiatives. Recommended benefit would be conditional and shall be subject to confirmation of non-burning by farmers. It would be credited into their bank account through Direct Benefit Transfer (DBT) in the next harvesting season.

'Impact Fund' for air pollution

It is recommended that a 'Clean Air Impact Fund' could be created to provide Viability Gap Funding (VGF) for projects with longer gestation periods and lower Return on Investment (RoI). This is especially relevant in the case of bio-power or bio-ethanol where annual financial support requirements range from 18% to 30% of the capital expenditure. It is expected that impacts of these projects would be wide ranging on rural as well as urban economy. Also, it is recommended that seed money for the clean air impact fund is provided from the National Clean Energy Fund (NCEF).

Upscaling technologies with service-based shared economy and process-based incentives

Currently the number of farm implements available to farmers are limited. Therefore, the medium to long-term actions required to achieve zero-burning include upscaling of technologies. Shared infrastructure would enable stubble shaving during combine harvesting and in-situ mulching of paddy-straw would bring long-term benefits to farmers in terms of soil management (by nutrient conservation and preventing soil erosion) and efficient use of fertilisers and water. A shared economy could be created to cater the demand of all the farmers affordably for required machinery. It is estimated that INR 214-356 Crores [4] will be required in Punjab alone, in the form of 50% capital subsidies in order to enable a shared economy provide affordable services to farmers. Block Development Officers (BDOs) will chalk out the local level plans for treatment of paddy-straw and will act as service aggregators, mobilising resources in designated rural areas.

Equipment funded through existing government subsidies is heavily under-utilised and it is recommended that incentives are linked to performance in long-term to promote efficient utilisation of infrastructure. Performance-based incentive should be provided to entrepreneurs or service providers based on the field area covered in the intermittent time period between two cropping seasons (15-20 days). This acts as a supporting scheme to earlier recommendations, motivating entrepreneurs for better asset utilisation and offering in-situ soil incorporation services to farmers at an affordable price. Additionally, it is suggested to make the purchase of targeted farm implements financially more attractive, an accelerated depreciation is provided to entrepreneurs / service-providers under the service-based shared infrastructure model.

[3] Only applicable to the non-basmati paddy-straw.

[4] CESD estimates that INR 141-424 Crore are required for under-the-mulch seeders (zero till or happy seeders). Additionally, INR 287 Crores are required for Super SMS implements which would be attached to the combine harvesters for shaving stubble during the harvesting operation.

Burning agricultural waste contributes to poor air quality across Northern India

Rewarding and monitoring at local level

To monitor farm burning, a strengthened monitoring mechanism with advanced remote sensing data and local monitoring by BDOs is suggested. A financial reward of INR 1 Lakh[5] per panchayat is suggested in order to catalyse the vision of zero-burning in rural areas. This amount is subject to zero burning incidences in village. Considering 70,869 panchayat in the states of Punjab, Haryana and UP, the total outlay for this reward scheme (in the case all these panchayats conform to no burning) is estimated to be INR 700 Crores.

Regulatory support towards ex-situ treatment

Although it is desirable to treat farm waste in-situ, there are limitations to ploughing all the straw back into the soil and hence proliferation of ex-situ treatment methods is equally desirable. Commercially available technologies for ex-situ treatment such as biochar, pelletisation, briquetting and Bio-CNG are assessed in this report and their business cases are presented. It is recommended that fuel specifications by the Central Pollution Control Board (CPCB) are revised for use of paddy-straw based pellets and briquettes in industrial boilers where temperature requirements are below 500 degree Celsius. Also, thermal power plants may use these pellets/briquettes for co-firing along with coal where it is possible to replace 5-10% of daily coal requirement with paddy-straw based pellets/briquettes. States such as Punjab has expressed interest in setting up demonstrations for paddy-straw based ethanol production units which is also important from the perspective of energy security and options should be explored to address viability gap funding of such projects. One of the barriers for independent power producers to set up the bio-power plants is the capacity limitation of 10 MW for availing Power Financing Corporation (PFC) and Indian Renewable Energy Development Agency (IREDA) loans. It is recommended that this limit is removed for paddy-straw to bio-power plants in order to facilitate more players in the market.

Awareness tools

Major barrier to proliferation of non-burning practices among farmers is their wrong perception about these practices and requires dedicated awareness campaigns involving State Agriculture Departments and Krishi Vigyan Kendras (KVKs) which should also design interactive and appropriate information tools for farmers. Information tools should include in-situ mulching and on-farm management techniques. Recognition to farmers already following such practices can have a huge impact on success of these programmes and it is suggested that formal recognition should be given to such farmers.

[5] 10% of the estimated cost for deploying ex-situ treatment options at village level.

1. INTRODUCTION

Air pollution is one of the major man-made environmental risks to the health of general public. The release of various gaseous emissions and particulate matter in the air has been on the rise due to rampant anthropogenic emissions of various kinds being pumped into the atmosphere. It serves as a prominent global threat to environment human health in many ways.

CII in partnership with NITI Aayog launched this initiative in November, 2016 for 'improving the air quality of Delhi-NCR'. This initiative held its first meeting on 5 June 2017, World Environment Day. The initiative is working towards engaging business, civil society and government agencies to learn from peers and take actionable steps to improve the air pollution in Delhi and (NCR). Under the initiative, four task forces have been constituted by NITI Aayog—clean transportation, clean fuel, biomass management and clean industry.

There are several studies conducted by various institutions regarding the deteriorating air quality of Delhi. A recent and most comprehensive source apportionment study has been done by IIT-Kanpur (IIT-K) on behalf of the Government of Delhi. For this initiative, the findings of IIT-K study are being considered as basis of designing the action plans. One of the major sources of air quality deterioration in Delhi in the months of October and November is burning of agricultural biomass residue, or Crop Residue Burning (CRB) in the neighboring states of NCR.

India is said to have an estimated 600 million tonne of surplus agricultural biomass which can be collected and used. Farmers turn to residue burning on account of shortened cropping intervals given a very short window of about 10–15 days between subsequent cropping seasons. They do not have enough time to prepare for next crop or use other methods of removal of farm stubble. Burning of crop residues leads to release of soot particles and smoke causing human health problems; emission of greenhouse gases (GHGs); loss of plant nutrients and; adverse impacts on soil properties.

Anchored by the Ministry of Environment Forests and Climate Change, the task force on Biomass Management has identified certain avenues for the alternate usage of paddy straw/crop residue. For instance, paddy straw can be utilised for animal feedstock, fertilizers, fibre (household use/boards), feedstock to chemical industry and fuel or energy. The strategy, broadly, is to assign a real economic and commercial value to the agricultural residue.

The task force has suggested a two-pronged approach to tackle the issue: a) ploughing the residue back into the field and; b) extraction and usage for other purposes. Task Force report identifies the actions and associated plan of implementation involving all relevant stakeholders.

2. INCLUSIVE APPROACH OF THE INITIATIVE

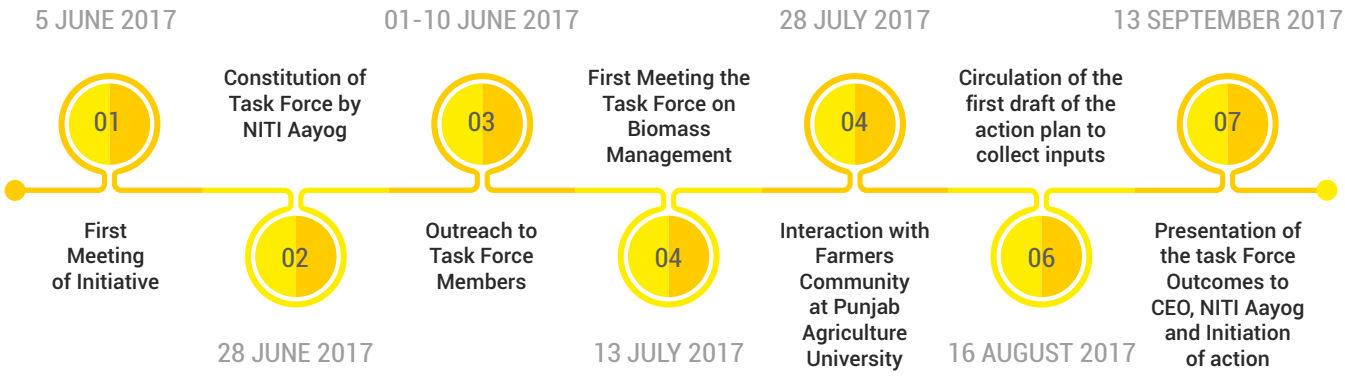
Air-shed is a common geographical area where prevalent topographical and meteorological conditions limit dispersion of pollutants, thereby necessitating an overall strategy for air-quality management. An integrated approach is needed to involve all concerned stakeholders in common airshed for designing market-oriented solutions which are scalable and replicable. This would ensure sustainable and self-sufficient actions. Various actionable plans have been designed by different institutions, however, this initiative aims to create the required synergy and build a consensus amongst the stakeholders to drive actions on-ground.

The initiative aims towards:

- Developing an integrated approach that brings together policy makers, industry, academia, community and civil society
- Building consensus and getting buy-in from stakeholders on actions for improving air quality
- Delivering voluntary commitments from stakeholders towards reducing air pollution
- Influencing adherence to existing policies and advocacy towards newer policies

The task force on biomass management has adopted a structured approach in identifying key issues and possible solutions to address the issue of farm residue burning in the field. The approach is outlined in Figure 1. The list of stakeholders consulted in this process is provided in Annexure 3.

Figure 1. The consultative approach of the task force on biomass management



Stakeholders consulted

Union Government: NITI Aayog, Ministry of Environment, Forests and Climate Change

State Government: Punjab, Haryana

Civil Society: Centre for Science and Environment

Industry: CII and its members

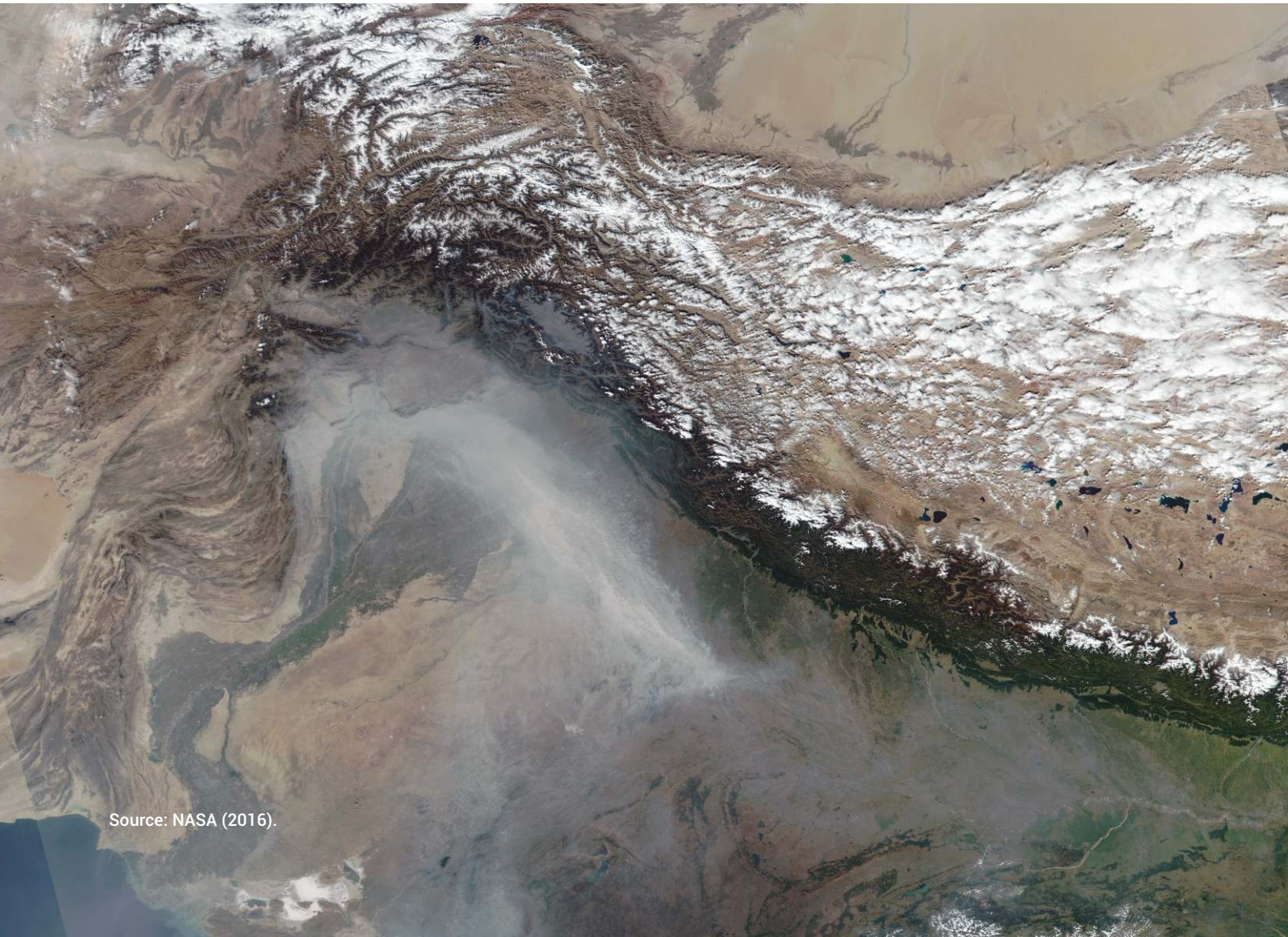
Farmers: farmers in Punjab

Academia: Punjab Agricultural Unviersity, IIT- Kanpur

3. RECOMMENDED ACTION PLAN

Over the last decade, crop harvesting has been substantially mechanised. Combine harvesting, which is the most commonly utilised harvesting technology, leaves unevenly spread crop-residue and the standing stubble in the field. Burning of this crop-residue to prepare the field for next sowing season has become a common practice across states. Farm burning practice is especially prevalent in the Wheat Rice Crop (WRC) system where the window for harvesting rice and sowing wheat crop is very small (15-20 days). Most of the times, wind from the North West enters Delhi, before blowing over Punjab and Haryana bringing the pollutants from crop burning in these states (Sharma and Dikshit 2016) and adversely affecting air-quality during winters in Delhi.

Figure 2. Smoke stream from farm burning in North West India (mainly Punjab) towards low-lying regions of Delhi NCR in early November

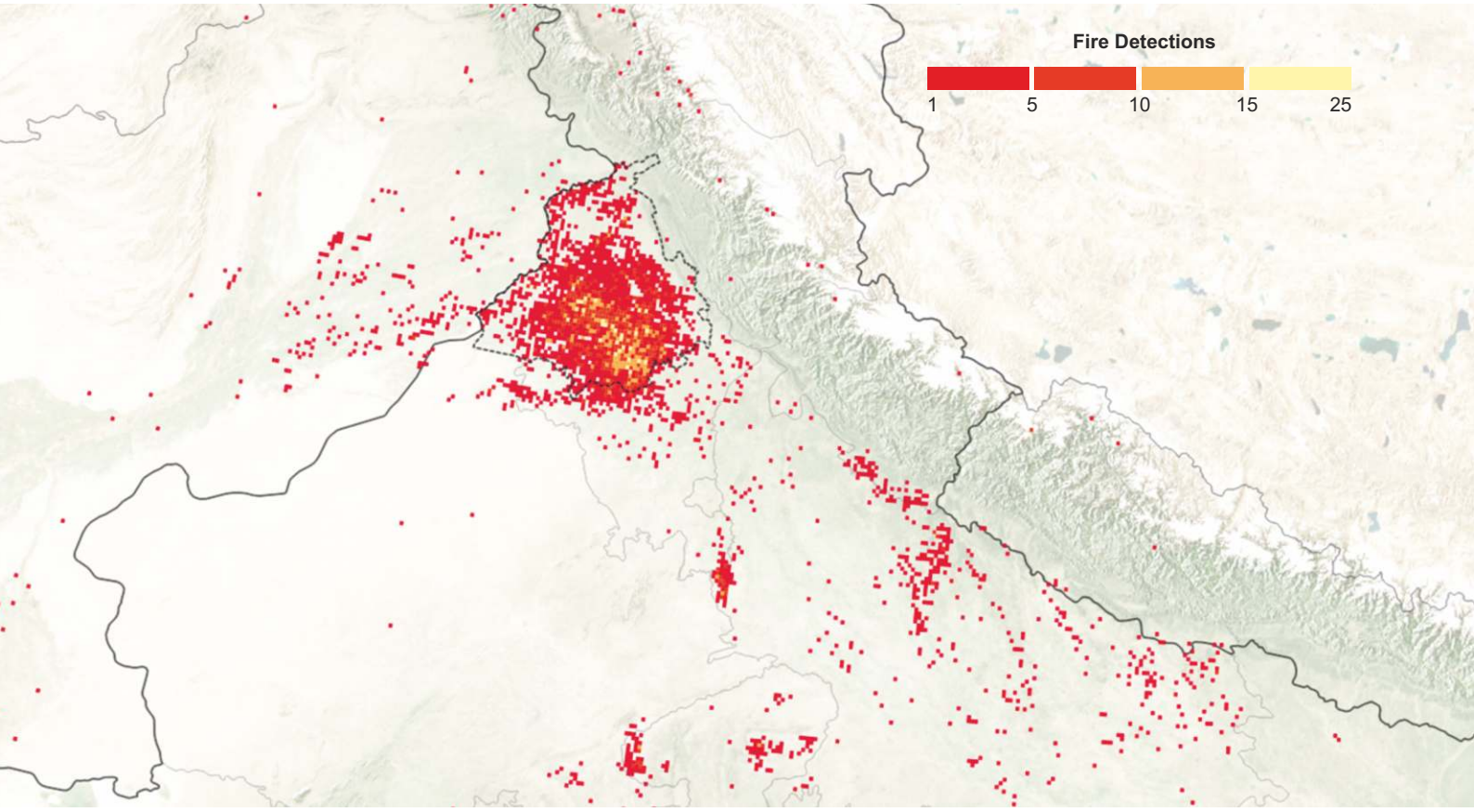


Source: NASA (2016).

Farm burning practice is especially prevalent in the rice-wheat cropping system where the window for harvesting rice and sowing wheat crop is very small (15-20 days).

Evidence for farm fire and consequent travelling of pollutants was collected by NASA during the last WRC cycle and can be seen in Figure 2 where smoke stream in early November travels from North-Western region towards Delhi NCR. Farm fires are detected by NASA in the first week of October and it increases rapidly in the following weeks. By the first week of November, there are thousands of fires across North India (mainly in Punjab and some parts of Haryana) as seen in Figure 3. According to the observations these farm fires last till mid-November when the wheat crop is sown (NASA 2016). As per the infrared image captured in the first week of November, fire incidents were mainly concentrated in 20 districts (including 17 districts of Punjab[6], 2 districts of Haryana[7] and one district of Uttar Pradesh[8]) of Northern states (Figure 3). Five districts of Punjab, that is, Moga, Ludhiana, Sangrur, Barnala and Patiala were hotspots where maximum number of fire incidents took place.

Figure 3. Fire detection in the early November as captured by the infrared imagery



Source: NASA (2016).

[6] Gurdaspur, Hoshiarpur, Kapurthala, Jalandhar, Nawanshahr,TarnTaran, Firozpur, Moga, Ludhiana, Fardikot, Muktsar, Bathinda, Mansa, Sangrur, Banrnala, Patiala and Fatehgarh Sahib

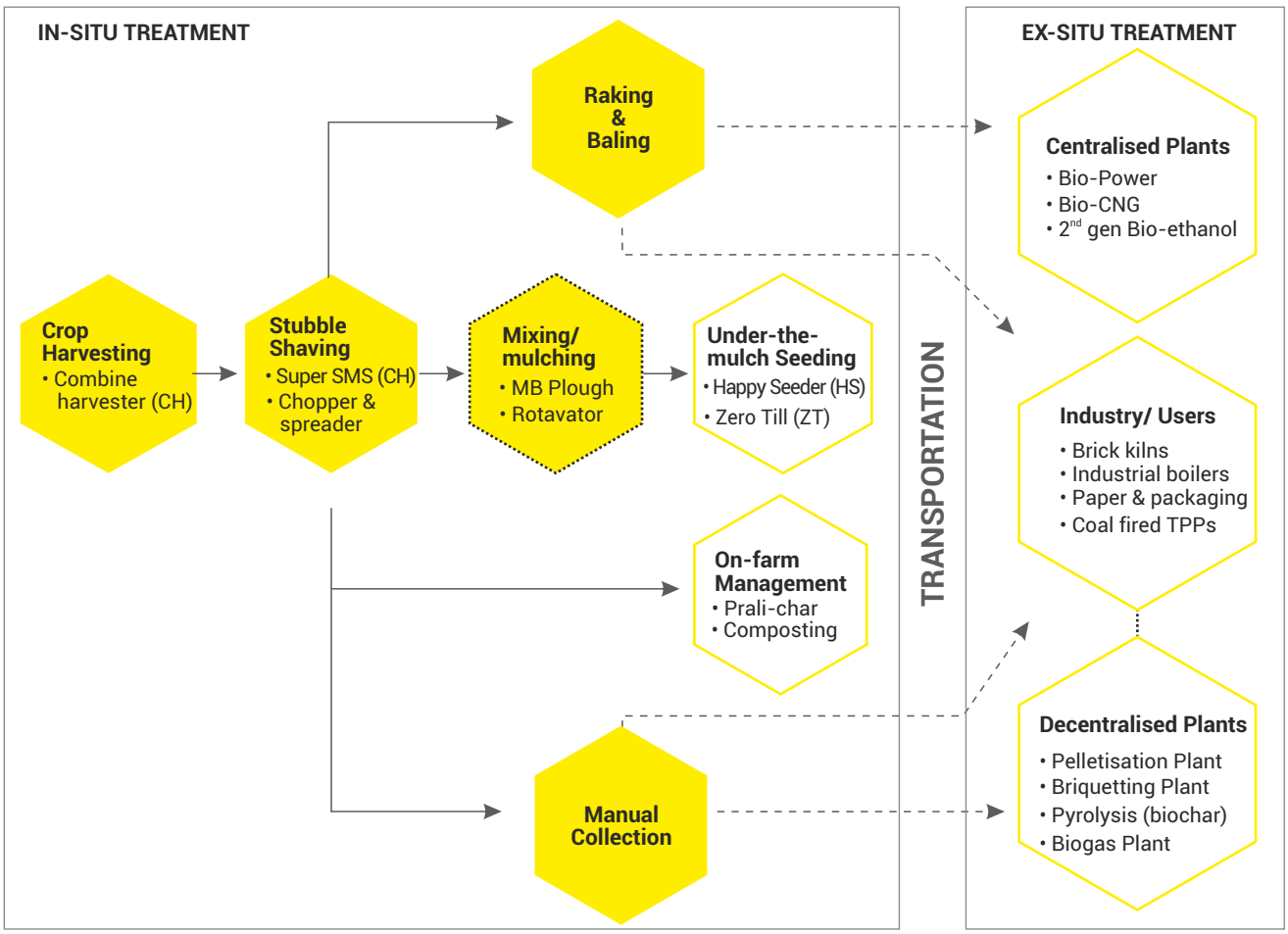
[7] Fatehabad and Jind

[8] Mathura

2.98 million
ha area in Punjab and
1.35 million
ha area in Haryana was under paddy cultivation in 2015-16

As per the agricultural statistics, roughly 2.98 million ha area in Punjab, 1.35 million ha area in Haryana was under paddy cultivation in 2015-16 (GoI 2016a). Another neighbouring state of NCR, Uttar Pradesh (UP) is a major rice producer in the country and uses 5.87 million ha for rice cultivation. Rice cultivation is insignificant in Rajasthan compared to other states. Although, Punjab utilises a smaller area for rice cultivation compared to other states, it is the third-largest rice producing state in the country after West Bengal and UP (GoI 2016a), and generates nearly 19.7 mt of paddy straw annually (Punjab Government 2017). Out of this, only 4.3 mt is utilised for animal fodder, industry, mulching over soil and in-situ incorporation. Rest 15.4 mt is reportedly burnt in the fields (Punjab Government 2017). Growth of straw to be managed in future is greatly dependent on the technological breakthroughs for crop-varieties with shorter maturation times, lower straw-to-paddy ratio including crop diversification.

Figure 4. The flow of crop-residues from the farm to various commercially available options including the in-situ and ex-situ treatment options (dashed lines in back ink represents the transportation routes that are involved in the process)



Source: CESD analysis, 2017.

Financial support can be transferred to farmers through the DBT system. It can be credited to farmer's account in the subsequent cropping season after a verification that farmer has not burnt his/ her crop-residues.

Basic flow of crop-residue, right from crop harvesting to all commercially available treatment options, including the in-situ and ex-situ solutions, is depicted in Figure 4. Different configurations of in-situ, associated costs and benefits of using these methods are listed in Table 4 under Section 4. As elaborated in Figure 4, ensuring that the crop residue is not burnt in the field requires a two-pronged strategy. Firstly, in-situ utilisation or soil incorporation of crop-residue (that remains standing in the field after combine harvesting) needs to be prioritised and popularised among the farmers. This is important, not only to ensure that crops are not burnt but for long-term conservation of micro nutrients in the soil. In-situ utilisation of straw which remains rooted in the soil, requires a change in farming practices. For this purpose, specialised machinery is required at different stages of farming. Few farmers have already adopted such mechanisation and farm practices but other farmers are still burning farm residues. This situation arises primarily due to lack of awareness among farmers, their preference for effortless ways of managing residue and long-term gestation period for the benefits derived from improved farm practices.

Apart from directly ploughing and mixing (mulching) the residues back into the soil, on-farm management techniques (composting, pyrolysis or bio-char) are effective in bringing the nutrients back to the soil which are otherwise lost during burning or transporting the residues for use outside the farm. There is increasing evidence that soil incorporation has long-term benefits for improving the quality of soil, increasing water-use efficiency and reducing the intensity of fertilisers being used.

Secondly, enhancing the value of paddy-straw as a raw material for energy extraction or similar products is another important aspect of the solution. The use of straw for other purposes need to be prioritised based on the economic merits of such solutions. Business models as explained in the annexures, for existing and emerging technologies including pyrolysis (bio-char), Biomethanation (biogas), conversion to bio fuels (such as briquettes, pellets, Bio-CNG, and biodiesel), need to be explored. Recommended actionable solutions for tackling farm-waste burning include the following. These are further summarised in Table 3 along with relevant details required for execution of each task.

1. Financial support to farmers in short-term for in-situ treatment of paddy-straw

Paddy-straw has low calorific value and high silica content[9] compared to other crop-residues. This limits utilisation of paddy-straw in different applications such as animal fodder, energy conversion etc. As an immediate measure, to curb episodic rise in air pollution in approaching winters, it is imperative that individual farmers are provided with financial support for implementing some of the in-situ and on-farm straw management techniques. The estimated paddy straw production across neighbouring states of NCR is presented in Table 1[10] below. Financial support can be transferred to farmers through the DBT system. It can be credited to farmer's account in the subsequent cropping season after a verification that farmer has not burnt his/her crop-residues.

[9] High Silica content leads to clinker formation in boilers
[10] The paddy cultivation area and straw generation could serve as a basis for calculating financial support

To ensure proper implementation of schemes, a strong monitoring and verification mechanism is crucial

To ensure proper implementation of the scheme, a strong monitoring and verification mechanism is critical. Existing monitoring system (monitoring by district and block level public enforcement agencies and help line for reporting) can be strengthened with an App-based platform for reporting the farm fire incidents. Any complaint against the concerned farmer would make him/her ineligible for the benefit. It is important that a reliable, predictable and transparent monitoring and verification mechanism is ensured for effective implementation of recommended actions. Further detail of suggested mechanisms are provided in recommendation 4(b) under this section.

Awareness campaigns should be conducted to raise farmer's awareness and educate them on viable options for either utilising the farm residue in-situ or convert it into other useful products using on-farm management techniques. The financial support farmers receive, can be utilised by them in implementing the in-situ/ on-farm management practices with low-cost methods available to them (See Section 4 for the short-term technological options). It is observed that farmers have a wrong perception of these practices and lack awareness on long-term benefits of soil management. For long-term change in farmers' behaviour, it is essential that they are educated and trained. Training modules can be designed to be implemented by Krishi Vigyan Kendra (KVK) and Block Development Officers (BDOs) in rural areas. Apart from application in the farm, there is already a market for products such as bio-char and surplus can feed into this market if their supply chain is strengthened.

Table 1. Estimation of paddy straw production for neighbouring states of NCR

State	Area under paddy cultivation [million ha]	Productivity (grain) [Tonne/ ha]	Estimated straw production [million tonne/ year]
Haryana	1.35	3.07	6.86
Punjab	2.98	3.97	19.70
Rajasthan	0.34	1.82	0.56
Uttar Pradesh	5.87	2.13	20.67
Total	**10.54**		**47.79**

Source: CESD 2017 estimation based on Department of Agriculture - Government of Rajasthan (2012), Ministry of Commerce and Industry (2016), GoI (2016),MoA (2016) and Punjab Government(2017).

14,660 under-the-mulch seeders exist in Punjab and **35,340** more required in future

Figure 5 shows a typical bio-char sack available in cities costing as high as INR 175 for 900 g.[11] As elaborated in Section 4 here, it is the single-most cost-effective measure farmers could undertake by converting crop residue into biochar at the farm (prali-char). It enriches the soil with nutrients thereby increasing farmers' productivity and incomes.

Figure 5. Bio-char is readily available in cities but it still needs to be promoted as an integral part of rural economy

2. Impact fund for air-pollution

It is observed that there are projects with wide ranging social-economic benefits but they require consistent financial support for commercial viability (refer to sub-section 7 and 8 of the Annexure 1). For instance, the 'Paddy-straw to bio-ethanol' has the potential to achieve zero-burning in rural areas and contribute to availability of cleaner fuels[12] in urban areas. As per inputs provided by solution providers to NITI Aayog in 2017, a support of INR 60/litre of bio-ethanol produced, is required. A financial support of 18% and 30% of the capital cost would be required to make the bio-power and second generation bio-ethanol commercially viable (Table A1-T1 and A1-T2 of Appendix 1). Independent assessment of such estimations would be required to validate the quantum of financial support required for Viability Gap Funding. Subsidies are not the advisable economic instruments to promote and ensure viability of business models. Rather than subsidies or tax exemptions from Government of India, it is recommended that impact fund could be created (with a dedicated fund manager) for promoting future investments in clean technologies[13]. Impact funds lower financial risks compared to debt markets and make Return of Investment (RoI) viable for projects with longer gestation period. The aforesaid impact fund is recommended to receive financial resource from the National Clean Energy Fund (NCEF).

3. Upscaling of technologies for crop harvesting and utilisation of farm residue

State governments have been promoting technologies by providing capital subsidies on purchase of equipment/machineries. As per the action plan of Government of Punjab, an amount of INR 2,265 Crore is required to meet 50% capital subsidy towards various farm machinery. There is need of an assessment for effective utilisation of capital infrastructure subsidised by the government. It should also prioritise key technologies to be eligible for subsidy. At present, the list of technologies proposed for capital subsidy include some of the equipment used by farmers at a substantial scale and do not need further subsidy. There are currently 14,660 under-the-mulch seeders (660 happy-seeders and 14,000 zero-till implements) in the state of

[11] Cf. for cost estimation (Section 4), average market price for bio-char is assumed INR 12/kg which is based on interviews with the industry stakeholders.
[12] Result from lower particulate matter (PM) emissions from blended fuels.
[13] For example, the Environment Relief Fund (ERF) under the Public Liability Insurance Act 1991,which is managed by the United India Insurance Co. Ltd. under the directions of the Ministry of Environment, Forests and Climate Change (MoEFCC).

Farmers need for affordable and efficient agri-services can be met through shared infrastructure for farm machinery

Punjab. Based on the available machinery, its cost and the field capacity, [14] it is estimated[15] that 35,340 more such implements (141-424 Crores depending on the technology) would be required for covering nearly 3 million hectare paddy cultivation area in Punjab alone.

Based on our estimation (calculation in the Table 2 below), total subsidy outlay for Punjab, comes out to be 285 Crores on average (214-356 Crore depending upon whether farmers prefer the Zero-till implements or the happy seeders).

Table 2.The requirement of implements and capital subsidies for Punjab

Implements	Existing in operation [number of implements]	Required [number of implements]	Capital requirement [INR Crore]
Super SMS (attached to the combine harvester)	– – –	25,534	287
Under-the-mulch seeders (attached to the tractor)	14,660	35,340	141 - 424
Total outlay for 50% capital subsidy toward 100% coverage to paddy cultivation area in Punjab			214 - 356

Source: CESD 2017 estimation based on consultations with farmers/ service providers, Mahal (2017) and Punjab government (2017).

Notes:
1. The total requirement of super SMS (straw management system) is based on the estimation of total number of combine harvesters in operation (assuming operational capacity of 300 acres in one harvesting season, based on the inputs from farmers/service providers).
2. Under-the-mulch seeders include happy-seeders (660 in operation at present) and zero-till implements (14,000 in operation at present), up-front cost for which is assumed to be INR 1,20,000 (Mahal 2017) and INR 40,000 (average market price),respectively.

a) Support service-based shared infrastructure

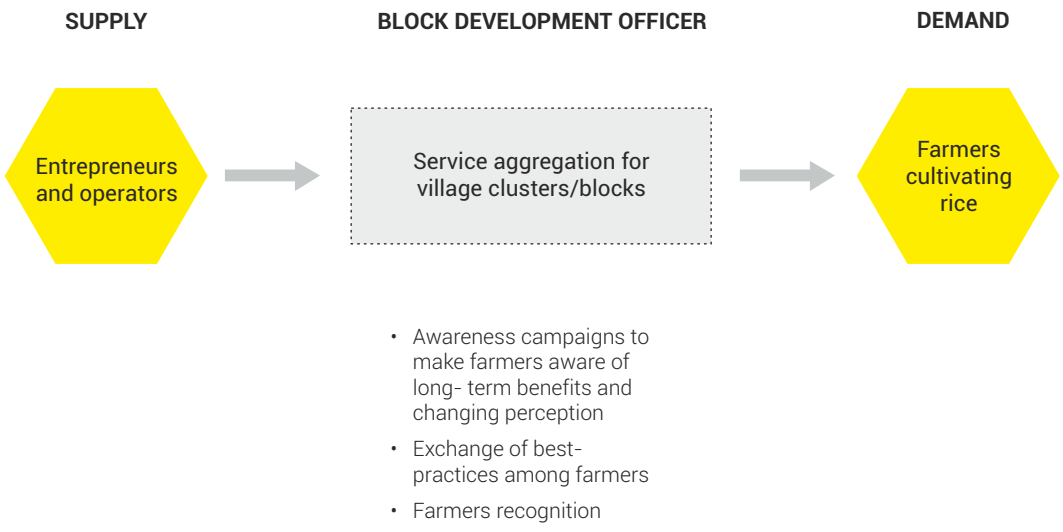
Sustainable business models need to be worked out for deployment of farm implements including those required for in-situ mulching and collection of residues (raking and baling) for ex-situ treatment. It is expensive for individual farmers to buy required implements and individual ownership does not promote effective utilisation. The government can therefore bring out a support scheme for entrepreneurs interested in owning the farm implements and providing service to the farmers at a reasonable rate. For such business model to be viable, 50% capital subsidy can be provided to entrepreneurs in short-term but for long term sustenance of business model it is essential that incentives are linked to the performance (as elaborated under the Subsection 3.b) of entrepreneurs/service-providers. Figure 6 outlines proposed business model,

[14] Inputs from farmers and service providers: one implement covers up to 8-10 acres a day
[15] It is assumed that intermittent period between two crops is 15 day and maximum 12 operational hours per day are possible during this period.

> Farmers need awareness, information and recognition of their efforts for large-scale adoption of sustainable agricultural practices

linking key supply chain actors with recommendations in following sections. It is proposed that cluster areas covering all the villages under a block will be formed across the NCR states. Service aggregator serves a crucial link between farmers and entrepreneurs. Aggregator registers demand from farmers well in advance, maps and assigns areas to service providers for an efficient utilisation of machinery. One operator can cover up to 8-10 acres area in a day.[16] It is recommended that Block Development Officer (BDO) will provide the aggregating services considering the availability of implements, tractors, operators in the area, demand for in-situ/ ex-situ treatment and the paddy cultivation area to be covered. BDO has the responsibility of aggregating the demand and mapping the services for all the villages under his/ her jurisdiction. BDO will ensure that quality of services is met and services provided by entrepreneurs are affordable to the farmers. In addition, responsibilities of BDO include providing training to farmers and making farmers aware of the benefits of in-situ treatment. BDO will also act as facilitator for exchange of best practices among farmers and recognition for those following best practices. Progress made under the implementation model will be monitored using the advanced remote sensing data as elaborated under the Subsection 4(b).

Figure 6. Proposed business model for service-based shared infrastructure



Source: CESD 2017.

[16] Based on interaction with service provider in Punjab.

Considering 70,869 panchayats

in the states of Punjab, Haryana and Uttar Pradesh, the total outlay for panchayat reward scheme is estimated to be

INR 700 Crores

b) Provide process-based incentives for entrepreneurs

Performance-based incentive should be provided to entrepreneurs or service providers based on the field area covered in the intermittent time period between two cropping seasons (15-20 days). These act as a supporting scheme to earlier recommendation, motivating entrepreneurs for better asset utilisation and offering in-situ soil incorporation services at a price that is affordable to farmers. Such a scheme has already provided good results while deploying laser leveller technology in the state of Punjab.

c) Accelerated depreciation for farm implements

It is proposed that an accelerated depreciation is provided on the farm implements to make the purchases financially more attractive to village entrepreneurs and service providers under the proposed shared service infrastructure model.

4. Reward and monitoring at the local level

Adequate infrastructure is the first and foremost requirement for stopping the farm burning incidents. This has been discussed in the previous sections that incentivising the farmers in short-run and making the shared infrastructure affordable to farmers in the long run should be given the due focus. These efforts can be supplemented by leveraging the existing local governance structures and providing them sense of ownership and participation in the ongoing efforts to stop farm fires.

The success of all these efforts would require a strong monitoring mechanism to track and ensure progress. This forms second recommendation along with the reward scheme for village panchayats.

a) Reward scheme for village panchayats with zero-burning

A reward scheme needs to be designed for the villages which do not burn their waste and become a role model for other villages. Village panchayat will need to submit a proposal in this regard. The eligibility criteria for choosing a village will be a sound track record with no incidence of farm fires. It is recommended that a single case of fire incident should make the village disqualify for the reward. This reward can be seen as a seed funding for the panchayat to implement a decentralised management of crop-residue at a village scale which could potentially include facilities such as paddy straw based biogas plant, briquetting plant, pyrolysis for biochar, composting etc. The proposal submitted by the village panchayat should include the specific details on the activities it wants to undertake for decentralised treatment of the residue and should be based on the strengths and opportunities inherent at the local level. Local authorities should be able to seek help of BDO and undertake local level planning for the same. A maximum support of INR 1.00 Lac per panchayat[17] is suggested, which is 10% of the estimated cost for deploying ex-situ treatment option as outlined in Table 6 under Section 4. Considering 70,869 panchayats in the states of Punjab, Haryana and Uttar Pradesh, the total outlay for this reward scheme is estimated to be INR 700 Crores. The actual disbursement would depend on the proposal of Panchayat outlining the amount of farm stubble generated in their jurisdictions and the technological options of utilising the farm stubble in an economic activity.

[17] The total number of panchayats in Punjab, Haryana and Uttar Pradesh are 12,800; 6,155 and 51,914 respectively.

b) Monitoring mechanism for farm fires

A reliable monitoring needs to be ensured so that the farm fires can be tracked at the block and the village level. The network of Indian Remote Sensing Agency and State Level Remote sensing stations have the capabilities to provide the evidence for the purpose. State pollution control board scan identify farm burning incidents at the local level based on the remote sensing data shared by these agencies. It is recommended that remote sensing capabilities are utilised for monitoring the farm-fires in neighbouring states of NCR including Punjab and Haryana; with minimum human interference. This monitoring mechanism is especially relevant for validating the zero-burning villages in order to reward them. During the consideration of proposal by village panchayat, farm burning information will need to be ascertained with remote sensing data. The monitoring will enable tracking the overall progress towards zero-burning.

5. Regulatory support to business models for crop residue utilisation

a) Re-assess the fuel quality criteria for briquettes/pellets made out of crop residue:

Central Pollution Control Board has defined criteria for fuel quality of various energy sources to be utilised by the industry. It has been discussed during various interactions with stakeholders that the briquette/pellet made out of crop residue have comparatively higher ash content and lesser calorific value and hence are not qualified to be used as fuel in industry. Experts from Punjab Agriculture University have advised that briquettes/pellets can be easily utilised in the boilers with temperatures less than 500 degrees Celsius.

CPCB may re-assess the fuel criteria for the briquettes/pellets made out of farm residue, which can be used in industrial boilers. This has the potential to create a market pull and a better pricing for such renewable energy sources.

b) Directive for power plants to procure paddy-straw briquette/pellet

It is recommended that power utilities should invite expression of interest akin to National Thermal Power Corporation (NTPC). In April 2017, NTPC invited expressions of interest for supplying 850-1000 tonne briquettes/pellets from paddy straw through a single party or combination of parties, with at least 50 tonnes per day (TPD) established capacity (NTPC 2017). NTPC would use these pellet/briquettes as secondary fuel in limited quantity at the coal power plants to replace 5-10% of its daily coal consumption. It is suggested that carbon credits for using a renewable energy source can be sought by utilities to source the viability gap funding.

c) Remove the size limitation for Bio-power captive generation

Indian Renewable Energy Development Agency (IREDA) and Power Finance Corporation (PFC) provide loan for setting up biomass power and bagasse cogeneration projects for 10 MW capacities only (NITI Aayog 2017). It is recommended that the size limitation (towards paddy-straw to bio-power plants) for independent power producers is removed in order to facilitate more players in the market.

6. Creating awareness amongst farmers for better soil-management practices

a) Plan awareness campaigns for farmers

Awareness campaigns for farmers through print-media, radio, television and workshops involving local farmers at panchayat or block level should be planned to correct their perception about in-situ treatment and on-farm management practices. Also farmers need to be made aware on the benefits of increased yield and income as a result of in-situ treatment.

b) Farmer recognition programme

Recognise farmers, who have been following strict practices of not burning their crop-residue, giving them appropriate recognition for their efforts. During the interaction with such farmers, it was found that such recognition scheme, which is not in the form of any monetary benefits, but rather showcases their efforts can go a long way in ensuring a long term success of zero farm burning practices.

c) Design information tools for in-situ mulching and on-farm management

Information tools should ideally be designed in multiple forms including videos, information booklets/ manuals and other interactive ways of sharing information (such as mobile apps) with translation of material into local languages.

i. Manual/information tools on in-situ mulching

An operating manual clearly describing different machinery configurations required for ploughing and mulching the standing crop-residues back into soil, must be designed. A case study of ITC's sustainable agriculture initiative is enclosed as Annexure-III. This case provides an insight about how zero till can be utilised to plough back crop residue to soil, contributing to nutrient enrichment and soil health.

A clear comparison of collection technologies listing their trade-offs should be readily available to farmers and decision makers. The technology readiness needs to be clearly defined so that farmers do not bear the burden of testing the technologies. Configuration and machinery requirement could differ based on the crop patterns followed by different farmers, agro-climatic conditions, soil types, etc. It is observed that currently, no direct comparison based on such parameters is available for Happy Seeder+ Super SMS[18] and Zero-Till in Punjab.

ii. Manual/information tools for on-farm management

Composting, bio-char, mushroom farming etc. can be implemented by farmers in a cost-effective manner. Set of guidelines for farmers describing implementation of on-farm management practices would be required.

These manuals should be prepared by the Ministry of Agriculture and Farmers' Welfare along with the state departments of agriculture in respective states by roping in the experts from various agricultural universities of those states. Finally, these tools should be made available to farmers in local languages through the KVKs and BDOs.

[18] Straw Management System.

Table 3. Suggested immediate actions with execution details[19]

Area	Action	Implementation agency	Status
Subsidy on various Technologies for in-situ mulching and residue collection under the shared service model and Roll out the scheme for financial support the farmers and financial reward to panchayats for no-burning in farm fields.	50% capital subsidy on targeted farm implements[20] for residue collection and in-situ treatment under the shared service model	Ministry of Agriculture & Farmers' Welfare (MoAFW), RKVY, Department of Agriculture (States)	Subsidies are not disbursed to farmers on time and subsidised assets are under utilised
	Provide financial support to farmers and financial rewards to Panchayats (INR 1.0 La per panchayat) for ensuring no-burning in their fields.	MoAFW; RKVY, Department of Agriculture (States)	
Monitoring and verification mechanism	Devise mechanism for monitoring farm fires through remote sensing data Development of App based platform for reporting by general public	State Remote Sensing Centres, District Collectors and BDOs, State Pollution Control Boards and Central Pollution Control Board, Department of Agriculture and KVKs	
Fiscal interventions by the government	Process-based incentive for entrepreneurs Accelerated depreciation for farm implements under the service based shared infrastructure model Set up an Impact fund air-pollution and link it with the NCEF	MoAFW; RKVY, Department of Agriculture (States), Ministry of Finance (MoF)	
Regulatory support to business models for crop residue utilisation	Re-assess the fuel quality criteria for briquettes/pellets made out of crop residue	Central Pollution Control Board (CPCB) and respective State Pollution Control Boards (SPCBs)	
	Directive for power plants to procure paddy-straw briquette/ pellet	Ministry of Power (MoP), Thermal Utilities	
	Remove the size limitation for Bio-power captive generation	Ministry of New and Renewable Energy (MNRE), Ministry of Finance (MoF)	
Awareness campaigns and information tools for emphasising strong soil-management practices	Awareness campaigns for farmers-media (print/radio/TV) and local workshops. Create Brand ambassadors from the farmer community who are using in-situ/ex-situ use of farm residue.	Ministry of Agriculture & Farmers' Welfare (MoAFW), Department of Agriculture (States), KVKs, Agricultural Universities	
	Manual/information tools on in-situ mulching	Ministry of Agriculture & Farmers' Welfare (MoAFW), Department of Agriculture (States), KVKs, Agricultural Universities	
	Manual/information tools for on-farm management	Ministry of Agriculture & Farmers' Welfare (MoAFW), Department of Agriculture (States), KVKs, Agricultural Universities	

[19] The recommended action plan has been designed in September 2017 for the cropping season 2017-18 and all the actions in the table are specific to mentioned timelines.

[20] Super SMS, happy-seeder/ Zero-till, rakers and balers.

4. COST ESTIMATION FOR TECHNOLOGICAL OPTIONS

This section aims to highlight solutions where biomass is used for alternate purpose and converted to bio-char or energy products. If paddy-straw is sold for consumption outside the farm, farmer gets a price for this straw, adding to his/her income. Else the farmer can return the nutrients back to soil in case of Prali-char or biochar and improve farm output and reduce fertilizer requirement.

The straw price for farmer could be anywhere in the range of INR 750-2250 per tonne and hence sensitivity analysis has been performed on the straw price. Labour to operate at field or any of these units is considered at INR 300-350/day. Transporting the straw to the units is considered in the range of INR 300-700, while transporting end product (char, briquette, pellet) to end user (industrial or commercial) is considered in the range of INR 600-1000/tonne, depending on the solution, distances and logistics.

Paddy straw is converted into Prali char and Biochar through the process of pyrolysis which involves burning straw in controlled manner in Prali brick (clay kiln) or top lift up-draft gasifier. The briquette and pellet are produced by compressing paddy straw to 5-6 times using mechanical / hydraulic press or other techniques depending on scale of the plant. This makes the biomass much more compact to storage, handle and transport for using in various end-use applications. These applications are highlighted in the Figure 4. Converting Biomass to BioCNG through a semi-continuous gasification process yields an efficient and clean transport fuel equivalent to CNG.

Implementation of technological solutions comes with an associated cost and returns on investment which can make them financially attractive and sustainable. However, some options do not provide monetary benefits in short term but rather provide non-monetary benefits in terms of increasing soil fertility such as Biochar. The technical details of solutions have been enclosed in Annexure 1 but the estimation of associated costs and benefits are summarised in Tables 4, 5, and 6 below.

Bio-ethanol could become viable for commercial deployment in future and has potential to address the air-pollution in rural and urban areas at the time by diverting paddy straw to ethanol production and blending ethanol for cleaner transport fuel. Demonstration plants for such technologies might need viability gap funding from the government. Details of these technologies and their costs have been presented in Annexure 1 as per the information from solution provider and this will need an independent assessment.

Table 4. Cost and co-benefits (key benefit is reduction in air-pollution and associated health benefit) of treating the paddy straw through available options including both in-situ and ex-situ methods

Practice		Technology	Cost	Co-benefits
			[INR / tonne paddy straw]	[INR/ tonne-paddy straw]
In-situ treatment	Residue collection	Stubble Shaver + Rake + Baler	840	Reduced transportation costs
	Residue retention as straw mulch	SMS + Happy seeder	393	Long-term benefits to farmers including soil management, water conservation, reduced fertiliser demand due to nutrients' recycling and higher crop yields
		Stubble shaver+Happy seeder with press wheels	515	
		Loose Straw Chopper + Happy seeder	580	
		Chopper (Double cylinder) + Spatial drill	512	
	Residue incorporation	Chopper (Single cylinder) + Wet mixing (Rotavtor) + No till drill	731	
		Chopper (Single cylinder) + Reversible MB Plough + Rotavator + seed drill	1,116	
		Chopper (Double cylinder) + Reversible MB Plough + Rotavator + Seed drill	1,156	
Ex-situ treatment	On-farm management	Prali-char	852	
	Decentralised treatment	Portable biochar unit	2,991	3,600
	Conversion to solid bio-fuels	Pelletisation plant	4,505	6,923
		Briquetting plant	3,246	4,231
	Energy conversion	Bio-CNG Plant	4,559	7,074

Source: CESD 2017.

Notes:
The costs for in-situ and on-farm practices are from farmers' perspective and costs for all other methods (ex-situ) are form the perspective of businesses or entrepreneurs who will implement them. These are undiscounted costs (including capex and opex) /benefits normalised over tonnes of treated paddy straw.

Table 5. NPV calculation for available technological options

			Yearly operations per unit						
Timeline	Solution	Days of operation	Paddy Straw consumption, t	Capital cost, L INR	Revenue, L INR	Operating cost, L INR	Profit, L INR	Payback period	Net Present Value, L INR
Short term	Prali Char	30 – converted at field	36	0.25	NA	NA	NA	NA	NA
	Bio-Char	30 – converted at field	8	0.10	0.29	0.23	0.06	1 y 11 m	0.14 (5 years)
	Pellets	245 – non-rainy days	319	7	22.0	13.2	8.8	11 m	28.4 (5 years)
	Briquettes	245 – non rainy days	3,815	26	135	125	9.4	3 y 10 m	10.8 (5 years)
Mid-term	BioCNG	350 – year round less scheduled maintenance	13,300	1600	1100	500	600	2 y 6 m	--

Source: CESD 2017.

Table 6. Estimation of total capital infrastructure with reference to available technological options

		Total for Punjab		Total for Haryana		Total for UP		Total for Rajasthan		Total for 4 states	
Timeline	Solution	Total Units	Total Capital, Cr.	Total Units	Total Capital, Cr.	Total Units	Total Capital, Cr.	Total Units	Total Capital, Cr.	Total Units	Total Capital, Cr.
Short-term	Prali Char	4,10,556	1,026	1,13,333	283	5,47,222	1,368	14,222	36	**10,85,333**	**2,713**
	Bio-Char	18,47,500	1,848	5,10,000	510	24,62,500	2,463	64,000	64	**48,84,000**	**4,884**
	Pellets	46,405	3,248	12,810	897	61,852	4,330	1,608	113	**1,22,675**	**8,587**
	Briquettes	4,641	1,207	1,281	333	6,185	1,608	161	42	**12,268**	**3,190**
Mid-Term	BioCNG	1,111	17,780	307	4,908	1,481	23,699	38	616	**2,938**	**47,004**

Source: CESD 2017.

Notes:
1. The associated costs and required infrastructure for respective technologies is estimated considering if only that particular solution is implemented in entire state.
2. Total area under paddy cultivation considered in Punjab, Haryana, UP and Rajasthan is 3, 1.35, 5.87 and 0.34 million ha respectively. Straw output considered for Punjab, Haryana, UP and Rajasthan is 14.8, 4.1, 19.7and 0.6 million tonne respectively. (Source: CESD estimation based on Ministry of Agriculture, Government of India and others, Refer Table 1).

Suggestions

1. The required financial support for each state with respect to associated solutions has been provided in the table above.
2. In-line with discussions with Punjab Agriculture University, in addition to on-going subsidies for machineries/technologies for in-situ and ex-situ utilisation of paddy straw, option of Prali char offers on-site controlled burning and can be made by just bricks and clay. This has the potential to reduce the air emissions substantially.
3. In reference to the suggested action plan to provide financial support to panchayat for ensuring no-burning of fields in their jurisdiction and creation of infrastructure for utilising the farm stubble. A maximum support of Rs1 Lac per panchayat has been suggested. The actual outlay of disbursement would depend on the proposal of panchayat outlining the amount of farm stubble generated in their jurisdiction and the technological option of utilising the farm stubble in an economic activity.

Table 7. Sensitivity analysis for yearly Capex and Opex over the price of straw

Total yearly cost (Capex + Opex) / t				
Straw cost INR / t	Bio Char	Pellet	Briquette	CNG
750	2,241	3,555	2,496	3,809
1,050	2,541	3,937	2,796	4,109
1,200	2,691	4,133	2,946	4,259
1,350	2,841	4,329	3,096	4,409
1,500	2,991	4,525	3,246	4,559
1,650	3,141	4,722	3,396	4,709
1,800	3,291	4,918	3,546	4,859
1,950	3,441	5,114	3,696	5,009
2,250	3,741	5,506	3,996	5,309

Source: CESD 2017.

5. STRATEGIC IMPLEMENTATION

The suggested recommendations under this report would require a predictable, efficient and reliable governance mechanism, for ensuring implementation at grassroots level with adequate transparency in reporting and verification. This section details the governance process, identified actors, monitoring and verification, technological leverage and the regulatory environment. Figure 7 outlines the proposed governance mechanism.

1. Governance mechanism

The recommendations shall be governed through following process and identified actors:

a) National level: The Ministry of Environment, Forests and Climate Change (MoEFCC), Government of India shall be the national focal point for implementation of suggested recommendations with NITI Aayog in the advisory role. The role and responsibilities of MoEFCC are detailed below:

i. Secretary, MoEFCC shall be the national nodal officer for implementation of the recommended actions.

ii. The Ministry shall be coordinating with all state governments for implementation of the recommended actions.

iii. The Ministry shall review the state action plan which would also include recommendations under this report, and advise the state governments on any additional actions specific to particular state.

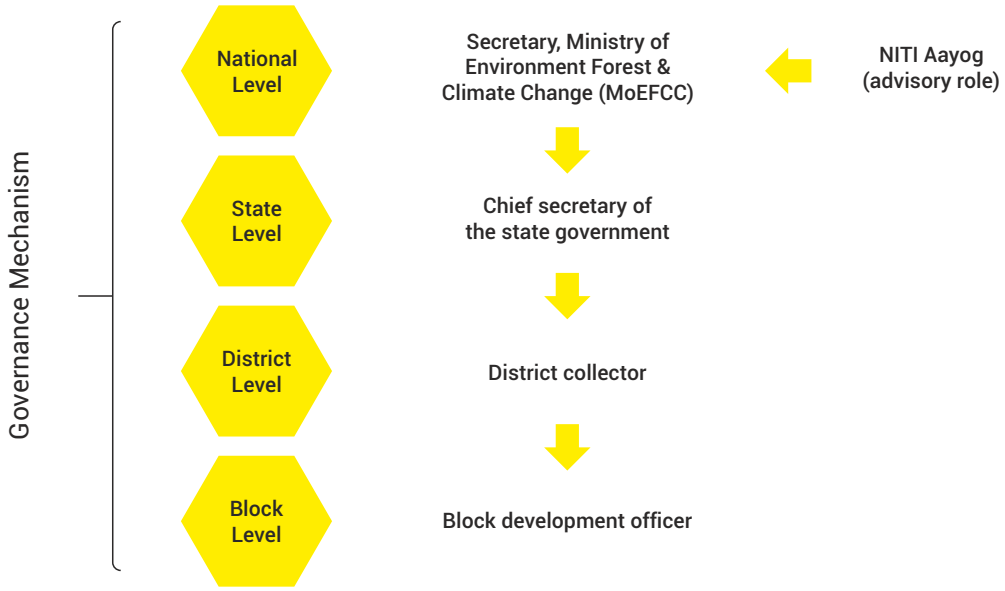
iv. The Ministry shall review the existing regulations considering the recommended actions and would notify new regulations or amend existing ones, if required.

v. Progress report about the implementation of recommendations, from all the states shall be submitted to MoEFCC and all the analytics would be undertaken by Central Pollution Control Board on behalf of MoEFCC.

vi. Before the crop harvesting season, the status report of implementation at National Level (primarily focusing on Delhi-NCR) would be released by MoEFCC at a weekly basis.

vii. During crop harvesting season, the aforesaid reporting would be on a daily basis.

Figure 7. Governance mechanism for implementation



The decision shall be based on **technological evidence** such as satellite imagery and government may provide mobile applications capable of registering location details while recording the incident

b) State level: The state governments of Delhi, Punjab, Haryana, Rajasthan and Uttar Pradesh have been identified as key actors for implementation of action plan. Their roles and responsibilities are provided below:

i. Chief secretary of the state government shall be the state nodal officer for implementation of recommended actions.

ii. State level action plans for improvement in the ambient air quality are being prepared with various state governments. In view of the identified actions under this report, the state action plans shall be revised by respective state governments.

iii. State level schemes for disbursement of financial support to create machineries/ infrastructure shall be reviewed in light of the findings of this report and more targeted approach shall be adopted.

iv. State governments shall leverage existing network of farmers outreach for communicating about uses of farm stubble (in-situ and ex-situ) and increasing their income.

v. Progress report about the implementation of recommendations, from all the states shall be submitted by Chief Secretary, respective states to MoEFCC with a copy to respective central pollution control board.

vi. Before the crop harvesting season, the frequency of reporting by state to MoEFCC would be on a weekly basis.

vii. During crop harvesting season, the aforesaid reporting would be on a daily basis.

c) District level: The District Collector shall be the nodal officer for preparing a district level action plan customised to the needs of residents, currently available infrastructure and future requirements along with technological options to utilise the farm residue, best suited for particular district. Key responsibilities of district collector (DC) for implementation of the action plan are provided below:

i. The district collector shall prepare a district plan of action on air pollution considering aforesaid aspects.

ii. The district level plan shall have a roadmap for ensuring sufficient capacity of farming and harvesting infrastructure in their jurisdiction, for farm collection straw either for ex-situ uses or in-situ soil mulching.

iii. The plan shall also include the strategy for awareness creation amongst the farmers to utilise the farm stubble/straw for any other use/economic activity which would help them increase their farm income.

iv. The district collector shall be the nodal officer for verification of any complaints related to farm fields burnings. The decision shall be based on technological evidence such as satellite imagery or and government may provide mobile applications capable of registering location details while recording the incident.

v. Progress report about the implementation of recommendations, from all the DCs shall be submitted to chief secretary of respective states with a copy to member secretary of respective state pollution control boards.

vi. Before the crop harvesting season, the frequency of reporting would be on a weekly basis.

vii. During crop harvesting season, the aforesaid reporting would be on a daily basis.

d) Block level: All the actions for stopping the burning of farm waste would be implemented and monitored by the officers at block/village level. The block development officer shall be the nodal officer and shall have following key responsibilities:

i. The BDO shall estimate the requirements of block/village level infrastructure required for utilisation of farm residue/stubble (for both in-situ and ex-situ).

State remote sensing centres be leveraged for monitoring, reporting and verification of farm fires with accuracy upto field level.

ii. The BDO shall be estimating the demand and supply of farm equipment for in-situ mulching of farm stubble and connect entrepreneurs with the farmers.

iii. The BDO shall prepare a block level action plan to stop the burning of farm stubble in the fields and utilisation of farm straw in economically profitable options for the farmers.

iv. The BDO shall be the interface with respective panchayats for implementation of incentive schemes for no-burning of farm waste.

v. The BDO shall be the nodal officer for identifying the techno-commercially viable options for farming and utilisation of farm straw.

vi. On-ground verification of any incidence of farm waste burning shall be undertaken by BDO in presence of the members of respective panchayat and report shall be submitted to DC.

vii. Progress report about the implementation of recommendations, from all the BDOs shall be submitted to DCs, with a copy to regional officer of respective state pollution control boards.

viii. Before the crop harvesting season, the frequency of reporting would be on a weekly basis.

ix. During crop harvesting season, the aforesaid reporting would be on a daily basis.

2. Monitoring and verification

With an objective to facilitate mass movement at grass root level and participation of farmers community at-large, this report has recommended certain incentives for village panchayats or farmers community which would be conditional to no-burning in their farm fields. This requires a predictable, reliable and transparent mechanism for monitoring and verification.

This would require adoption of advanced technology made available to the farmers community through mobile-based applications. Following options should be adopted by respective state governments:

a) Satellite imageries from state remote sensing centres: Indian remote sensing technology has been globally recognised as best of class by the experts. Indian remote sensing agency with its state remote sensing centres monitor the Indian geo-climatic parameters on a regular basis. Detailed imagery of any region can be made available after every 24 hrs of satellite imaging. Some of the states have recommended using the technology for monitoring and reporting of farm fires.

   Therefore, it is recommended that state remote sensing centres should be leveraged for monitoring, reporting and verification of farm fires with accuracy upto field level.

b) Mobile-based applications: With an objective to empower general public and farmers to report any burning activity of farm fields, the technological options in the form of a mobile-based application need to be designed.

   A similar application has been utilised by Government of NCT of Delhi, which records the location of mobile while it is capturing the improper disposal of municipal waste of its burning. Such mobile-based applications can easily be integrated with the reporting mechanism upto District collector level for creating evidence of farm field burning.

3. Roadmap for technology adoption

The neighboring states of NCR have substantially adopted the mechanised harvesting which has been quite instrumental in bringing up the farm income level as well as better farming conditions. However, this has also led to generation of huge amount of farm stubble being left in the fields by the harvesting machines. Farmers have also planned their crops based on the quick harvesting of crops and hence not budgeting more than 2-3 weeks before they enter into sowing activity for next crop. As a result, farmer has to remove the paddy straw and farm stubble quickly from the fields and they are just resorting to burning activity for the purpose.

There are techno-commercially viable options for utilisation of paddy straw and farm stubble to be used for making new products or for waste to energy. Some sections of the farmers are utilising such technological options but the larger community is just burning this valuable resource in the fields.

Some of the state governments have identified the equipment/machineries which can be subsidised by the government for technology penetration. However, following actions need be undertaken by state department of agriculture for making such subsidy schemes more effective:

a) State governments need to undertake technology need assessment and estimate the quantum of infrastructure in the form of farm equipment along with their capacity utilisation.

b) Identify techno-commercial options for utilisation of farm residue under waste to energy (briquetting, power plants, cement kilns) or new product manufacturing (fiber boards), to be implemented at block level.

c) Sensitisation of farmers about the use of technology and making the best use of farm stubble, leading to increase their income.

d) Such action plan for technology need assessment need to be prepared from bottom-up approach involving stakeholders like panchayat, block development officers and state pollution control boards.

4. Assessment of Regulatory Framework

Many of the solutions especially briquette making, can be upscaled only with the support of regulatory framework. Some of the action points have been included in the section of recommendations. State governments are required to assess the regulatory framework and identify any required amendments in existing ones or need of new regulations.

5. Approach to create implementation roadmap

A consultative approach is followed to create an implementation roadmap and is hereby provided below:

a) Discussion within Government of India: all concerned ministries that is, as a nodal ministry, Ministry of Environment, Forest and Climate Change would be coordinating with Ministry of Agriculture, Ministry of Power and Department of Industrial Policy and Promotion for seeking their advise on implementation roadmap of identified actions.

b) Interaction with State Governments: state governments of Delhi, Punjab, Haryana and Uttar Pradesh will interact with MoEFCC for identifying key actions in respective states.

c) Interaction with DCs and BDOs: Interaction with DCs and BDOs shall be called by the state governments with participation of union government for assessing the block level action plan. For the year 2017-18, the focus will be on technological options with low cost and reduced pollution level.

Our recommendations focus on monitoring and verification of farm burning incidents. It is recommended that appropriate monitoring and verification mechanism for the local level implementation of block level plans, such as technology roadmap by BDOs, should be devised by the MoEFCC anchoring this task force and central nodal agency for implementation.

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ANNEXURES

Annexure 1
Solutions and Technologies for Utilisation of Farm Waste

Annexure 2
ITC's Sustainable Agriculture Programme in Paddy-Wheat Cropping Cycle in Three States of the Indo Gangetic Plains

Annexure 3
List of Stakeholders Consulted

ANNEXURE 1

Solutions and Technologies for Utilisation of Farm Waste

A. Solutions for ploughing the residue back into the field

1. Paddy Straw Incorporation and Mulching

Crop residue contains high concentrations of organic nutrients, which ought to be returned to the soil in order to retain and sustainably increase its fertility and yield potential. In-situ degradation of paddy straw will help in enhancing soil fertility and tackle the post-harvest residue. In-situ ploughing back of paddy straw leads to increase in soil productivity over 3-4 years and therefore farmers need to be engaged to sensitise them about overall improvement of soil health. Following are different paddy straw management practices:

1) **Residue retention as straw mulch:** Mulch can increase yield, water use efficiency, and profitability, while decreasing weed pressure. Surplus residue from the previous wheat crop can be incorporated into the paddy fields with no adverse effect on rice yield. This can be carried out with the help of following available combination of machinery:

   a) Happy Seeder + Super Straw Management System: Super SMS is an attachment to rear side of combine harvester to chop and spread the loose straw uniformly across the harvested field. It facilitates the use of a zero-till drill and Happy Seeders to sow the seeds under-the-mulch.

   b) Loose Straw Chopper + Happy seeder: This machine leads to lesser number of straw lumps in the field due to uniform spread of chopped straw but results in more working hours per day.

   c) Stubble shaver + Happy seeder with press wheels: The modified Happy Seeder leads to uniform emergence and growth of crop, reduction in weeds and better appearance of germinated crop at initial stage.

2) **Residue incorporation:** Wet mixing of chopped straw requires more than three weeks depending upon soil conditions and helps conserving nitrogen and other nutrients contained in the straw. Residue incorporation can be carried out with the following machinery:

   a) Chopper (Single cylinder) + Wet mixing (Rotavtor) + No till drill,

   b) Chopper (Single cylinder) + Reversible MB Plough + Rotavator + Planker + Seed drill.

B. Ex-situ utilisation of farm waste

1. Pyrolysis (Biochar)

Background: Conversion of Biomass to Biochar is a simple solution which is not technology-intensive. Biomass is converted to biochar by pyrolysis (burning in the complete absence or limited presence of air) of paddy straw in a brick kiln that can be designed at site.

Technology: The paddy straw is burnt with little or no oxygen and higher temperature compared to the uncontrolled burning in fields. This helps in converting the solid mass to biochar. Due to the controlled environment and lack of oxygen in the kiln, organic content of residue is converted to carbon in biochar which is equivalent to activated carbon.

Applications: Biochar has four major applications:

1. **Soil conditioner** The biochar enhances carbon content in soil and returns nutrients back to the soil. It has excellent water retaining capacities. The soil appears darker after mixing Biochar. It is not advised to continue mixing biochar every year repeatedly in soil as there are various claims on benefits/ drawback but both needs to be established. The practice of biochar mixing was first observed in Amazon jungles and has given positive results in Africa.
2. **Bio-remediation** of degraded soils.

3. **Char briquettes:** They may not have higher calorific value compared to the biomass briquettes and can solve the major problem of transporting bulky biomass to briquetting site. A portion of it can be used for field consumption as well.
4. **Value added products:**
   a. Renewable incense sticks
   b. De-odorizer: It absorbs pungent organic substance from air rather than masking it. The used biochar can act as home garden fertilizer.
   c. Cost range of 30g de-odorizer in city is Rs 30 – which includes clothe pouches

Process: The kilns can be of various shapes depending on the need. These kilns can ideally take any dry biomass as feed. Examples include:

- A Sheet metal kiln (portable) with an open bottom and hole in the lid cover can take a batch of 6 kg straw and complete the charring it in 15-20 mins.
- A higher sized barrel oven which can take 30-40 kg batch takes 45 mins to operate.
- A brick and clay Prali kiln (non-portable) which is constructed at site and can take up to 1200 kg batch in a 10-12 hours operation.

Scalability of the plant is a challenge and the amount of paddy straw consumed is lower than other solutions. Either multiple units are required to match consumption or new ovens need to be designed to consume larger quantities at reduced labour requirements.

Support required:

1. Some financial support to farmers can help in implementation.
2. Capital equipment for portable units can be made tax free

Barriers:

1. Scalability could be an issue.

Enablers:

1. The life of kiln is 2-3 years, so it can substantially reduce pollution till the long-term solutions are in place. For example, for initial couple of years, the biomass can be used for the soil application to enhance carbon content of soil, by then a market can be developed for its products and then long-term solutions can be implemented.
2. Research and development for better design of kilns/ovens.
3. Awareness on benefits of biochar.
4. Research and development on biochar applications.
5. Market development for biochar products.

Operations and Business case: (for a sheet metal 800 lit kiln)

Dry paddy straw with ~10% moisture is burnt directly in a simple sheet metal kiln with a lid opening at top. The biomass should be loosely filled in the kiln and is ignited. The lid should be covered. Flames could be observed from the hole(s) on the cover lid at top. A portion of this burns and provides energy for remaining straw to be converted into biochar. The burning is complete when the flames seizes. Biochar made from the process should be cooled by pouring some water to ensure no further burning. The kiln can be lifted and moved, the char collected at ground can be collected. **100 kg of Rice straw results in approximately 30 kg char powder.** The straw which has 2500-3000 kCal/kg calorific value is converted to Biochar having 4500 kCal/kg calorific value.

This solution has the simplest supply-chain and hence has advantage over other solutions. Since the production is at field itself, there is no backend logistics required. If the consumption is for the field itself, then no forward logistics as well. If the char needs to be sent to make briquettes or other value added products, it can be stored in gunny bags and transported in much compact manner compared to raw straws. The product manufacturer can pick the packed char from fields.

Let us assume that the unit has the capacity to process 25 kg of biomass every 45 minutes. Assuming that the unit is active for 8 hours a day, 270 kg of biomass can be processed everyday. 30% of the paddy straw is converted to biochar, hence output expected from the plant is 80 kg per day.

The capital cost including cost of procuring the unit is INR 10,000 and the annual operating cost will be approx. INR22,680 – this includes raw material cost, transportation cost to end use and labour cost. Since paddy straw is consumed at the field site, no transportation cost is considered for raw material transportation.

Assuming that each unit of biochar is sold at 12/kg, annual expected revenue will be approx. INR 28,880. Hence the profit per year would be calculated as (Revenue – Operating cost), which will be equal to INR6,120.

Basis projected cash flows and discount rate of 8%, the Net Present Value (NPV) post 5 years, that is, in 2022, will be INR 14,400 against the investment made. The amount of time required to recover the initial investment (payback period) will be approx. 1 year 11 months.

Other Assumptions:

- Life of unit is 8 years
- Char market rate @ INR 12/kg
- No debt is considered for capital investment
- Packaging cost and taxes not considered

This is the working calculation for 1 unit, which can consume up to 8 tons of paddy straw per year.

2. Briquetting

Background: Traditional biomass in the form of rice straw, sawdust, rice husk, palm fiber occupies large volume which leads to a high storage or transportation cost. Traditional use of biomass as an energy source doesn't lead to its proper combustion. For the purpose of efficiently using straw as fuel and to ease its transportation over larger distances, biomass can be transformed into briquettes of regular shape. Briquettes are easier to use, convenient to transport and store, and have higher calorific value (heat value). Although the low calorific value of paddy straw compared to other crop-residue is a challenge, briquettes have good potential of being co-fired into industrial boilers along with coal and other high calorific crop residues.

Technology: Briquette is compressed bio-mass in nearly 6:1 ratio. Compression is done through mechanical or hydraulic pressing machines. The loose biomass is converted to compressed briquettes which are 3-4 inch long cylinders. Various shapes can be produced by changing the dye. The combustion of briquette in a controlled environment in presence of ample oxygen at high temperature generates low emissions.

Application: Briquettes find application as fuel in gasification furnace, heaters, hot-water boilers, industrial boilers. It is a very good substitute for furnace oil, coal or direct wood. For industry the fuel preference is cost for tonnes of stream generation. Furnace oil prices drive the briquette economics. One advantage of liquid fuel over solid fuels is that it can be atomised during burning and gives better combustion requiring smaller equipment. Briquette burning happens in a furnace attachment where water is passed through coils and briquettes is burned. Induced draft fans which are based on steam pressure pulls air from below the briquette mesh and stops when steam pressure is sufficient. Using briquettes works out to be more economical than furnace oil.

Process and operations: Multiple parameters need to be considered for delivering a high-quality briquettes. These parameters include the products' chemical composition, calorific value, and its water content. The key steps involved in the conversion are: drying,

chipping, densification, pressurizing, cooling, density check, packing etc. One key advantage of briquetting unit is that it balances man power availability as there is man-power shortage during harvesting season. Briquetting is not done in monsoon and is generally done after the harvesting season. Feed is dry paddy straw but the unit can also take other types of biomass.

Scalability: There are many briquette machine makes in country. Some of the examples include: Jai Khodiyar, Radhe Engg., Rounaq Industries in Gujrat, Hi-tech in New Delhi etc.

Support required:

- Accelerated depreciation was available up to 80% till last year, now it is reduced to 50%. But this does not have much impact on entrepreneurs
- Capital requirement can be supported by the government

Barriers:

- Key barrier is availability of dry biomass. In Northern India, during winter, dew would be a major issue and drying unit would cost extra
- Optimization of transportation (especially using trucks which are on empty return trip etc.) is very crucial for success of business model
- Availability of raw material is also very crucial for the model to work
- Working capital for small entrepreneurs is a challenge as approx. 8-10 La per month are required.

Enablers:

- Key enabler is proper recognition for industry and those using briquettes. Green certifications should be given and they should be rewarded based on the quantity of briquettes used.

Business case (for 1T/hr unit)

For 1 T/ hr (output) operation, feed requirement is 1.3 T of paddy straw. This should then be dried to 10% moisture level before feeding in the unit.

Supply-Chain: As the straw is available only during 2 weeks window, its procurement and storage management is very critical. A typical supply-chain of briquette conversion could have a briquette technology provider as the key player who designs the briquette unit (could also be the operator of the plant). The unit operator secures and stores the raw material and then supplies the briquettes to the end customers directly. Briquette producer manages the logistics on both sides.

For unit has the capacity to process 13 T (13,000 kg) of biomass everyday.

13 T of biomass is able to produce 10 T of briquettes daily, assuming the unit will operate for approx. 10 hours per day.

Capital cost i.e. cost of procuring equipment and setting up the unit is INR 26,00,000.

Annual operating cost would be approx. INR 1,25,50,000 – this includes raw material cost, transportation cost of raw material and finished product, energy cost, labour cost and rental cost for land required for storage and unit installation.

Assuming that briquettes are sold at 5.5/kg, annual expected revenue will be approx. INR 1,34,75,000.

Hence the profit per year will be calculated as (Revenue – Operating cost), which would be equal to INR9,25,000.

Basis projected cash flows, break-even is achieved post 4 years of operations and NPV post 5 years i.e. 2022 will be INR 10,82,000.

The amount of time required to recover the initial investment (payback period) will be approx. 3 years, 10 months.

This is the working calculation for 1 unit, which can consume up to 3,200 tons of paddy straw per year.

Key Assumptions:

- Briquetting machine life: 15 years
- Rental cost for land is assumed to be 35,000/acre
- No Debt is considered for capital investment

3. Pelletisation

Background: Traditional biomass in the form of rice straw, sawdust, rice husk, palm fiber etc. often has a large size that leads to a high storage and transportation cost. Traditional use of biomass as an energy source doesn't lead to its proper combustion. For its efficient use as fuel and to ease its transportation for a larger distance, biomass is transformed into pellets which are of regular shape and a form of compressed solid fuel. They are easier to use, convenient to transport and store, and have higher calorific value (heat value). Although the low calorific value of paddy straw compared to other crop-residue is a challenge, it has good potential for being used as fuel in cooking stoves and heating applications in domestic as well as industry.

Technology: Pellet is compressed biomass in 6:1 ratio. Compression is done through mechanical machines. The loose biomass is converted to compressed pellets which are 20-40 mm long tablets with 6-8 mm diameter. The shape and size can be altered. The combustion of pellets is in specially designed stoves in presence of right amount of oxygen at high temperature produces low emissions.

Application: Pellets find application as fuel in cooking stoves and heating applications in domestic sector as well as industries. It could be a good substitute for coal or direct wood when used in properly designed cook-stove for the purpose. It has a huge potential to be used in mass cooking operations like schools providing mid-day meals, mega kitchens, Gurudwaras etc. Cost of such stove is Rs 45,000-50,000.

Process: The processing involves three major steps.

a. While drying, the moisture content is reduced to 10-15%.

b. It is then crushed and fed into the pellet machine which converts the biomass in compact pelletised form.

c. The pellets can be packed as per end-user requirement.

One key advantage of pelleting unit is that it balances man-power availability as there is man-power shortage during harvesting season. Pelletisation is generally undertaken after the harvesting season and avoided in monsoon season. Feed can be any biomass, for example, paddy straw, forest waste, garden waste, saw mill waste, bagasse.

Scalability: Pelletisation can be easily scaled up as it is not labour intensive and requires very few skills to operate. The machine does not need any installation and production can be scaled up with few orders.

Support required:

a. Currently many industries are burning forest wood near Aurangabad. (A ten year old tree provides 1-2 tonne wood). This practice can be banned and use of pellets can be mandated for these industries.

b. There are capital subsidies available under Khadi Gram Udyog Yojana from government. Currently, the process is very complex and it is very difficult for the farmers to avail the same.

c. Capital equipment and installation of the same should be made tax free.

Barriers:

- Key barrier is availability of dry biomass. In northern India, dew during winters will be a major issue. Drying unit will cost extra.
- Optimization of transportation (especially using trucks which are on empty return trip etc.) is very crucial for success of business model.
- Availability of raw material is crucial for business model

Enablers:

a. Enable service ecosystem to cater to maintenance requirements of pelletisation machines

b. Subsidy on cook stoves targeting specific users for replacing wood or coal usage.

Business case (for machine capacity of 100 kg / hour)

Pellet manufacturing is generally taken up either by owners who have raw material to consume or by consumers who can secure the raw material from nearby sources and consume the pellets. As the straw is available only during the 2 weeks window, procurement focus needs to be there to secure the biomass in that window. There after storage management will be critical. Typically, the stove designers/providers use distributors which connect the pellet makers to consumers ensuring regular availability for end consumers.

A machine of 100 kg/hr capacity installed will process 1.3 T (1,300 kg) of biomass everyday to produce 1 T of pellets daily, assuming the unit will operate for approx. 10 hours per day.

Capital cost i.e. cost of procuring equipment and setting up the unit is INR 7,00,000.

Annual operating cost would be approx. INR 13,26,000 – this includes raw material cost, transportation cost of raw material and finished product, energy cost, labour cost and rental cost for land required for storage and unit installation.

Assuming that pellets are sold at INR 9/kg, annual expected revenue would be approx. INR 22,05,000. Hence the profit per year would be calculated as (Revenue – Operating cost), which would be equal to INR 8,80,000.

Basis projected cash flows, NPV post 5 years i.e. 2022 would be INR 28,10,000. The amount of time required to recover the initial investment (payback period) would be approx. 11 months.

Other assumptions:

- No debt is considered for capital investment
- Pellets are sold at anywhere between INR 8-14/kg. Conservative rate of INR 9/kg has been assumed.

This is the working calculation for 1 unit, which can consume upto 320 tons of paddy straw per year.

4. BioCNG

Background: India is rich in bio-waste in rural as well as urban areas, a huge amount of energy can be harnessed by using organic waste to fulfil energy demand, without disturbing integrity and stability of the environment. Bio-CNG (which is compressed and purified is a clean, low carbon technology and its potential is under utilised). It serves three purposes:

- gaseous fuel generation
- management of biodegradable waste and
- organic manure production.

BioCNG (Compressed Bio Methane) is produced in the bio-digestion process. Fossil CNG is characterized under specifications IS:15958 while BioCNG specifications are defined under IS 16087:2016. The earlier standard IS 16087:2013 was replaced by IS 16087:2016 to incorporate significant changes in specifications to bring BioCNG at par with fossil CNG used in pipelines/vehicle filling applications.

Technology: Compressed Bio Methane is derived from organic sources other than fossilised formations. Gasification of biomass which results in biogas has ~60% CH_4. The CO_2 is stripped and then compressed to convert the biogas to CNG.

Technologies have been developed which ensure digestion of biomass without any pre-treatment which brings down the cost of production of BioCNG.

Applications: Commercial–hotels, canteens, bakeries, resorts, residential clusters.

Industrial-glass and ceramic, cement, metal process, textiles, food processing,

Automotive-public transport vehicles, commercial and private CNG fitted vehicles.

sludge can be dried and packed in bags and transported to fields as fertilizers.

Process is as follows:

i. Receiving raw material.

ii. Shredding of raw material.

iii. Feed preparation and input to digester which gives output as biogas generation.

iv. It is purified by CO_2 and H_2S stripping.

v. The purified bio-gas is compressed to obtain BioCNG.

vi. The sludge (undigested biomass) out from digester can be dried and sold as manure.

Barriers: There are two key challenges today in setting up biogas plants:

1. Financing–entrepreneurs need to be encouraged to set up bio-gas plants through innovative financing measures or subsidies and incentives provided by the government.
2. Organized supply chain-Transportation of raw material from farmer to biogas plant needs to be streamlined. Time of procurement is key.

Enablers: Ensuring success: For BioCNG following steps are taken. Government issued a resolution in 2015 allowing BioCNG for use in vehicles at par with CNG. New standard IS 16087:2016 was formulated for standardization. Gas cylinder rules were amended in 2016 to accommodate CBG as fuel.

Support required from government:

1. Recognition to biomass aggregation/baling & briquetting units as approved micro industry to be financed under schemes like Mudra.
2. Funding support to entrepreneurs willing to establish 2G biogas/BioCNG units under NABARD soft loan scheme.
3. Recognition to energy plantation and harvesting under Rashtriya Krishi Vikas Yojana (RKVY) programme.

4. Uniform nomenclature of BioCNG in all government departments–Finance, Explosives, MNRE, MoPNG, MoEFFCC..
5. Exemption of GST on Biogas/BioCNG and capital equipment and installation.
6. Tax breaks to BioCNG plants for an initial period of min. 5 years (direct taxes).
7. Modify the capital subsidy scheme of MNRE to include equipment required for gas upgradation and compression, filling and dispensing biogas/BioCNG.

Business case and operations: (for a 5 T / day gas output)

Raw material source can be Polysaccharides, Semi Cellulosic or Dominantly Cellulosic. Rice Straw, Wheat Straw, Soya Thrash, Napier Grass can be classified Under Semi Cellulosic.

This is a semi-continuous operation which needs a mixture requires paddy straw and cow dung in 4:1 ratio. A culture (Inoculum and IPR) needs to be added once every time the plant operation is restarted, which costs 10% of the plant cost.

Using this technology, approximately 7.5 ton of dry agricultural biomass produces 1 ton of BioCNG that is equivalent to 1 ton of crude derivative fuels. However, technological advancements continue to be made to improve efficiency and effectiveness as of today, plants have been able to achieve throughout 4.5:1. The biogas produced can then be converted to CNG in a bottling plant. The CNG can be either piped or transported using CNG cylinders. One time cost of CNG cylinder is 3.5 lakh.

For a unit with capacity to process 38 tonne of biomass everyday, it produces 5 tonne/ day biogas and 30 tonne sludge which can be used as fertilizer.

Capital cost, that is, cost of procuring equipment and setting up the unit is INR 16 Crore.

Annual operating cost would be approx. INR 5 Crore–this includes raw material cost, transportation cost and labour cost. Assuming that BioCNG is sold at INR 38 – 42/kg, and sludge can be sold at 2.5 INR/Kg, annual expected revenue would be approx. INR 11 Crore. Hence the profit per year would be calculated as (Revenue – Operating cost), which would be equal to INR 6 Crore.

Basis projected cash flows breakeven is achieved after 2 years 6 months of operations. Considering capital subsidy availed from existing MNRE scheme. (approx. 2.6 Crore in this case).

Key Assumptions:

- The payback calculation does not consider forward or reverse logistics of CNG transportation.
- 2500/ T paid to farmers includes transportation
- Debt is not considered on the capital investment

This is the working calculation for 1 unit which consumes 13,000 tonne of paddy straw per day.

5. Liquid fuels from biomass

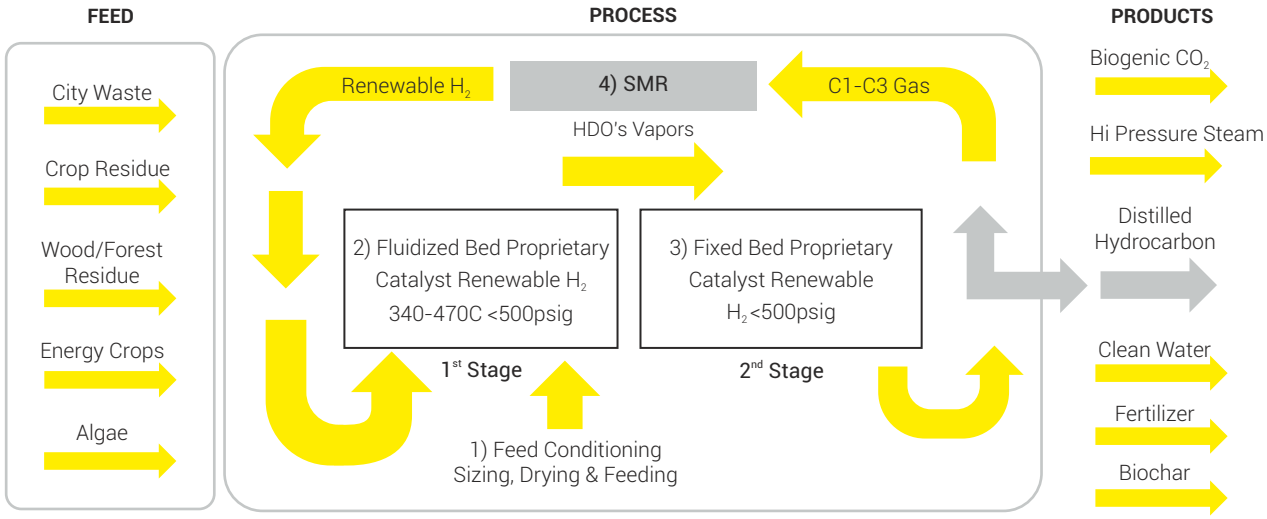
Background: Conversion of biomass to liquid fuels is in its nascent stage and the technology is currently being explored in India by a few private players. One of the technologies used to convert biomass is through a continuous catalytic thermo-chemical process which produces cost-effective fungible hydrocarbon transportation fuels from agricultural, forest and sorted municipal residues.

Technology: A private player in India has entered into a front end loading FEL-2 license agreement for IH2 technology (invented by Gas Technology Institute, USA) with a Singapore-based affiliate of CRI Catalyst Company LP (CRI), a global catalyst technology company of the Shell Group. CRI has been granted exclusive worldwide licensing rights. This agreement is the first IH2 FEL-2 license granted in India for a commercial scale plant. The plant will be designed with the potential to convert 500 tonne/day of dry bagasse into approximately 150 tonnes/day of liquid hydrocarbon transportation fuel.

Woody biomass, bagasse and aquatic plant residues have all been successfully processed in the IH2 and converted to gasoline, kerosene and diesel products with undetectably low oxygen content. The process produces little waste and all of the hydrogen needed in the process can be self-generated from the incoming biomass.

The IH2 process has four primary elements (figure A1.1). The first is biomass conditioning, that is, sizing and drying to 10–30% moisture by weight. The second element involves hydro-deoxygenation of the volatilized biomass to produce a raw hydrocarbon product over proprietary CRI (Catalytic Research Institute) catalysts in the presence of low–pressure hydrogen. This serves both to remove oxygen and cap reactive free radicals to provide a stable hydrocarbon product. The third element is a fixed–bed hydro-treater, which uses other proprietary CRI catalysts to polish (process to remove and filter various kind of contaminations from hydrocarbon fuel) the first–stage product and transform it into a finished hydrocarbon fuel (gasoline, jet and diesel) or other hydrocarbon-blended fuels. The fourth element is a hydrogen manufacturing unit (HMU), which converts light gases generated in the first–stage to renewable hydrogen, in sufficient quantity to supply all process needs. All the individual components of this design are commercially available. So it mitigates any kind of risk which can arise out of unavailability of components of the design and allows rapid implementation of the project.

Figure A1.1: IH2 process



Applications: The petrol and diesel produced through this method will conform to Bharat VI norms and can be used directly in cars, trucks, engines etc.

Supply-chain: In order to optimize, the plant could be integrated near existing mills/fields or refineries to save on transportation cost of raw material.

Scalability: It can be scalable basis the availability of different kinds of feed/waste in an area/state. Since the process uses all kinds of feed (city waste, crop residue, forest residue, energy crop, algae etc) and not entirely dependent on paddy straw, unavailability of straw round the year would not impact the production and plant operations.

Support required:

a. The government can provide tax credits and incentives for fuels from biomass to build and maintain a market for greener fuels.

b. The fuel should be made cost competitive with petrol/diesel.

Barriers:

a. Diesel from biomass is an upcoming technology in the country and not widely used at present; effectiveness and efficiency needs to be proven.

b. Lack of knowledge/awareness on fuel from biomass and its advantages.

c. Varying feedstock costs (collection and transportation costs might vary).

d. Storage and transportation: Year-long operation will require that biomass feedstock produced seasonally be stored until use. Storage of biomass could be susceptible to spoilage.

Enablers:

a. Requires no infrastructure other than road/rail transport into and out of the production.

b. Feedstock agnostic, able to consume broad range of biomass straight, mixed and varied feeds including MSW and algae.

c. Low opex (pre dominated by feed cost).

d. Fuel directly usable in cars, trucks, engines and other vehicles.

e. Sustainable and superior (environment friendly fuel) to the fuels produced from crude oil.

f. Monetize urban/rural wastes (assigns economic value to wastes).

g. Reduce overall dependence on imported energy.

h. Reduce carbon footprint.

6. Dry fermentation biogas plant for anaerobic digestion of paddy straw

Paddy can be utilized as energy source (biogas) by anaerobic digestion of paddy straw through Dry Fermentation batch process. Depending on the plant capacity, once the digester is loaded and activated, it would produce sufficient gas for a period of 3-4 months.

The digested material produced from the plant is good quality manure and can be disposed of easily. It can be lifted from the plant with the help of semi-automatic system. This technology has been approved by Research Evaluation Committee (REC) of Punjab Agricultural University (PAU), Ludhiana for field trials at farmer fields.

Process: For a 2T equivalent plant, which takes 80% paddy straw and 20% cow dung in the form of layers, the digester is closed and made air tight with the help of steel cover and then water is supplied. The paddy straw becomes wet and biogas production starts after a period of about 7-10 days. The gas is stored in the steel gas holder connected to the digester. The gas production is in the range of 4-5 m3/day for 3-4 months which is equivalent to 3-4 cylinders of LPG per month.

Cost: The cost for setting up this plant is estimated at INR 1.20 lakh.

Scalability: The Punjab Agriculture University has 5 such biogas plants successfully running. These gas plants can be installed in areas near villages to be able to provide bio gas to local community. The households in a village which are using wood/other fuel can be made to switch to bio gas. Installation of a plant takes around 20 days.

Challenges: To set up a biogas plant, it is a must that every household in a village buys biogas to ensure optimum utilisation of the plant and a sustainable working model. The fuel has to be made socially acceptable.

7. Bio-ethanol from Paddy-straw

Ethanol production from paddy–straw using advanced biofuel technology could pave a way in the future for second generation biofuels derived from crop-residues. It can have a double effect in tackling air pollution in rural and as well as urban areas by achieving cleaner transport fuels through blending biofuels. Although there are inherent challenges for bio-fermentation of high lignocellulosic content[21] of paddy-straw, technology using pre-treatment of paddy straw is being deployed at commercial scale and viability gap funding can be explored for such projects. Bio-CNG and bio-fertiliser are two co-products of bio-ethanol plant. First such plant, with 100 kilo Litre per day capacity, was set up in Bathinda (Punjab) by Public Sector Oil Manufacturing Company, Hindustan Petroleum Corporation Limited (HPCL) with an investment of INR 600 Crore (GoI, 2016b). Government had announced setting up 12 bio-ethanol plants across eleven states by OMCs last year to meet the targets for ethanol blending and this needs to be expedited. NITI Aayog proposes the subsidy of INR 201 Crore per year for facilitating the second generation ethanol plants (as per the technology details furnished to NITI Aayog by the solution provider, in the table below). As per the detail provided by the solution provider, an annual support in the range of 30% of the project up front cost would be required in order to make the investment financially viable.

The following details on bio-ethanol technology demonstration in Punjab are furnished by PPCB (2016). Bangalore based company namely M/s CVC

Table A1.1: Details of a 2-G Ethanol Plant

Capacity of Plant	100 KLPD (33 Million Litres per Year)
Total Biomass Intake	430 Metric Tonnes/ Day 1,41,900 Metric Tonnes/ Year
Total Capex for the Plant	750 Crores
Current Ethanol Ex. Factory Selling Price	INR 39
Proposed Price for Financial Viability	INR 100
Difference in Pricing/ Subsidy Required per Litre	INR 61
Total Subsidy Required/ Year	INR 201 Crore

Source: NITI Aayog (2017).

[21] Hydrolytic pre-treatment of crop-residue is required in order to enhance anaerobic digestion in ethanol fermenter.

Punjab has a target of
509 MW power
from biomass whereas currently only 62.5 MW is being generated from paddy straw in Punjab (PPCB 2016).

Infrastructure Pvt. Ltd., has a proposal to setup a Bio-refinery in the State of Punjab based on technology of Beta Renewable with design capacity of 60,000 tonnes of Cellulosic ethanol/ year (75,000 Kl/year) using paddy straw as feedstock. A meeting on the project was held under the chairmanship of minister for non-conventional energy, Punjab on 29th January 2015 at Punjab Bhawan, New Delhi, which was attended by the concerned officers of the State of Punjab including the Chief Secretary, Punjab. During the meeting, the project proponent had given a presentation on the project proposal. It was mentioned that the plant shall also generate co-products of Bio-CNG and compost through processing bio-refinery effluents and Pellets. There is proposal to install 5 Bio refineries with an investment of INR 1 billion USD through private participation. Starting with a technology, demonstration plant using 3 lac tonnes of paddy straw as feedstock shall be installed. The plant can also use napier grass as feedstock and other crops to be grown in high saline and water logged areas. This will help in crop diversification programme of the State. The company is in the process of preparation of detailed project report (DPR) and land for the project is being finalized in District Sangrur. The land measuring 40-50 acres in each of the villages namely Kakrala, Binaheri, Ajnoda, District Patiala have been shown to the project proponent. It is estimated that in these projects about 1.5 million tonne/year of paddy straw shall be used.

8. Bio-power from paddy-straw

Energy from paddy straw can be harnessed in a bio-power plant. Although these plants have not seen much success in the past due to several operational challenges inherent in the straw. Punjab has a target of 509 MW power from biomass whereas currently only 62.5 MW is being generated from paddy straw in Punjab (PPCB 2016). It is observed that paddy straw based power plants have many challenges in terms of collection of straw form the field, storage and protection from rains and organic degradation, and high Alkali and Silica content of paddy-straw. Later leads to clinker formation in the super heater zone and a severe problem of deposition in the convection zone, requiring frequent shut-downs for cleaning the boilers (MNRE; UNDP 2015). A typical 12 MW plant, as given in the table below, requires an investment of INR 72 Crore without the collection mechanism (NITI Aayog 2017). NITI Aayog (2017) suggest that apart from capital subsidies, a subsidy on tariff would be required to make bio-power an attractive option, details for which can also be found in the table below. As per the information provided by the solution provider, an annual support in the range of 18% of total upfront cost (12.8 Crores for 12 MW plant) will be required to make paddy-straw to bio-power plant commercially viable.

Table A1.2: Details of Biomass to Power Plants (Example From Bermaco Energy)

Capacity of Plant	12 MW
Total Biomass Intake	1.2 Lakh Tonnes
Total Capex for the Plant	INR 72 Crores
Total Electricity Generated in an year at 60% PLF	63072000 KWh
Current Tariff for Biomass to Power Projects (Punjab Government)	611 Paise
Lowest consumer Tariff in Punjab	407 Paise
Difference in Tariff	204 Paise
Total Subsidy Required	12.8 Crore

Source: NITI Aayog (2017).

ANNEXURE 2

ITC's Sustainable Agriculture Programme in Paddy-Wheat Cropping Cycle in Three States of the Indo Gangetic Plains

Background: In addition to several large agri-businesses, many of ITC's other businesses are also reliant on agriculture for raw material. Promoting and nurturing a sustainable and inclusive agri-supply chain is therefore vital for ITC's competitiveness. Accordingly, the company has put in place a mutually reinforcing eco-system comprising:

- Knowledge empowerment through e-Choupals, a network of village internet kiosks providing farmers with online information and services, to raise productivity and enhance their competitiveness; and
- Natural Resource Management to create stable agricultural production regimes.

These interventions promote climate smart agriculture by strengthening and building resilience of farming systems to extreme climate episodes. Promotion of sustainable agricultural practices is integral to this effort.

Wheat sowing challenges: In the Indo-gangetic plains of Uttar Pradesh, Bihar and West Bengal states, farmers mainly cultivate paddy and wheat in the kharif and rabi seasons respectively. Traditionally, after completion of the paddy harvest, farmers burn the crop stubble and undertake 2-3 tillage operations to clear the field to sow wheat. Also in many cases, rather than following line sowing, farmers prefer the broadcasting method.

These traditional practices have many inherent problems for wheat cultivation, including:

1. Loss of soil moisture due to the exposure of soils due to ploughing;
2. Higher cost of cultivation for wheat due to multiple land preparations and sowing by broadcasting, which leads to higher seed rate and hence costs;
3. Land preparation causing delays in sowing of wheat, thus not optimsing the critical cold period required during flowering and grain filling stages;
4. Burning of paddy stubble in some states, which not only adds to atmospheric carbon but leads to loss of organic matter—a valuable component for maintaining soil health.

After assessing several technologies and solutions to overcome these challenges, ITC finally decided to promote the zero tillage (ZT) method of cultivation wherein wheat is sown directly after the harvest of paddy with the plots still holding the crop stubble.

Solution: ecosystem approach to ZT promotion: Having identified the technology that could address these concerns, the real challenge was that of large scale technology transfer and an architecture for execution which could enable rapid replication. Learnings from implementation of such projects in the past helped ITC put in place an eco-system of services backed up with capacity building of the relevant stakeholders to ensure effective and efficient delivery on the ground.

The elements of the solution consists of the following:

- **Partnerships and collaborations**
  - **Technical:** ITC established working collaborations with agriculture universities and globally reputed CGIAR institutes like CIMMYT and BISA. Their technical and scientific knowledge was leveraged to establish demonstration plots in large numbers to validate the ZT practice amongst farmers through Farmer Field Schools (FFS).
  - **Execution:** For on-ground training and delivery of extension services, ITC partnered with grassroots NGOs who were given training in the ZT practice by ITC agronomists and scientists from research institutions and agriculture colleges.

11 NGOs
in 13 districts of Uttar Pradesh, Bihar and West Bengal in which over
18,300 farmers
were trained directly through 670 FFS and nearly 17,000 demonstration plots were established.

- **Access to the technology:** The technology comprises ZT equipment mounted on a tractor. Given that the majority of farmers in the project areas are small holders with less than 2 ha of operational area, it was realized early on that they could not purchase the equipment on their own and in sufficiently large numbers to make a significant impact. This challenge was surmounted through ITC promoted farmer collectives – Agri-Business Centres (ABCs), with each ABC servicing up to 5 villages in a 5-7 kms radius:

- The ABCs enable farmers to collectively purchase the required implements and hire these out on rent to members of the ABCs and to other farmers in the village, thus making the enterprise financially viable; and

- The ABCs also identify a tractor owner in each village and appoint him as a service provider who, during the season, hires his tractor to farmers on competitive rental rates.

  Adding a new dimension to what has traditionally been a male-dominated pursuit, ABCs promoted exclusively with women agriculturists that has gained rapid momentum especially in regions which witness large-scale seasonal migration by male members.

- Process

  The farmers register their demand for the ZT with their respective ZTs well in advance of the season, which forms the basis for the route map for the rental of the ZT. Once the season starts, farmers hire the tractor from their village service provider at agreed rates and the ZT equipment from the ABC, which cover all the households as per the agreed route map. One ZT is able to cover about 8 to 10 acres per day.

Scale and coverage: The initial demonstrations and technology dissemination began in the rabi season of 2013, with FFS members being trained on every step of the process along with farmer field days to share the results with as wide a group of farmers as possible. Beginning with a small number of farmers in 2014, the momentum picked up significantly from 2015 onwards:

- In just two years since 2015-16, the total coverage has added up to over 2 lakh acres of area under wheat. This could happen because of the integrated solution that ITC adopted.

- Currently, the collaboration is with 11 NGOs in 13 districts of Uttar Pradesh, Bihar and West Bengal in which over 18,300 farmers were trained directly through 670 FFS and nearly 17,000 demonstration plots were established.

- 32 ABCs have been set up in these states, which have also purchased 220 zero ZT implements in addition to mobilization of other locally available ZT implements.

Impacts

Significant benefits, as was documented from third part evaluations and farmer interviews, are as follows.

1. A significant improvement was seen in early sowing, with the proportion of farmers completing sowing by the end of November doubling in two years (Chart 1);
2. Line sowing led to a 67% reduction in seed rate thus resulting in significant cost saving as compared to the broadcasting method;
3. The average saving in the cost of field preparation and sowing was estimated at INR 3,000/ha (Chart 2);
4. Significant reduction in the number of irrigations due to retention of surface moisture was observed in most places with an average of 2 irrigations in ZT lands compared to 3 irrigations in the control plots;

Chart 1: Impact on sowing time

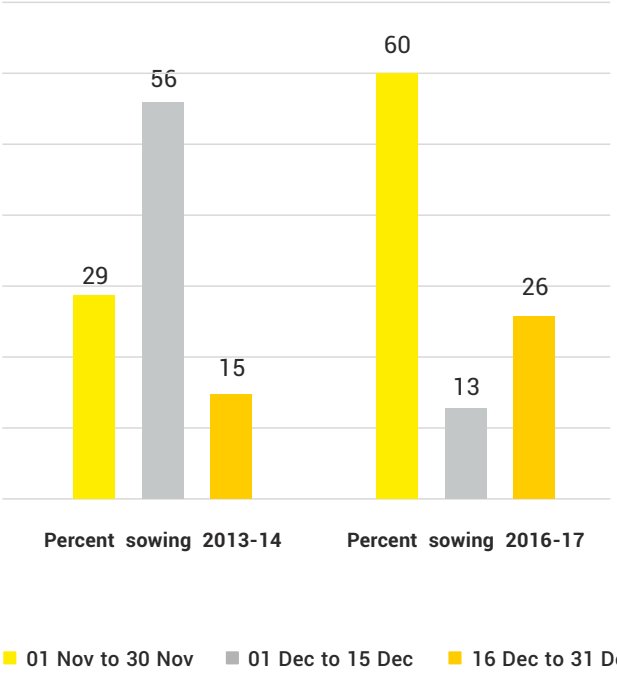
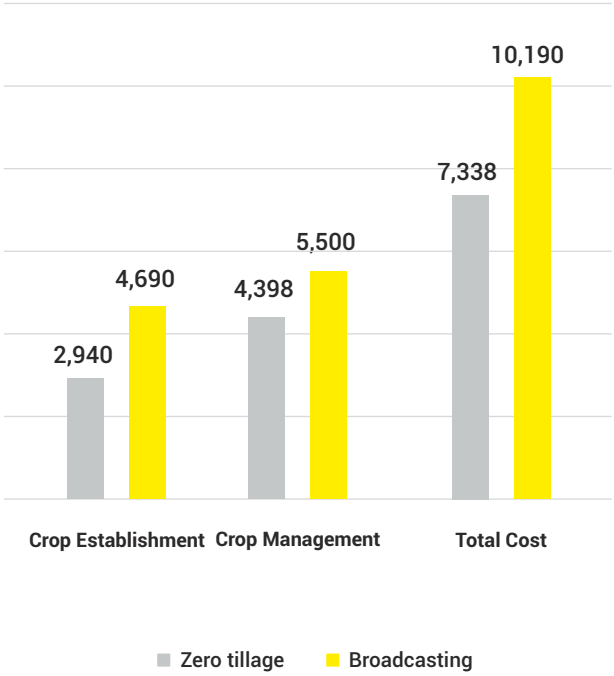
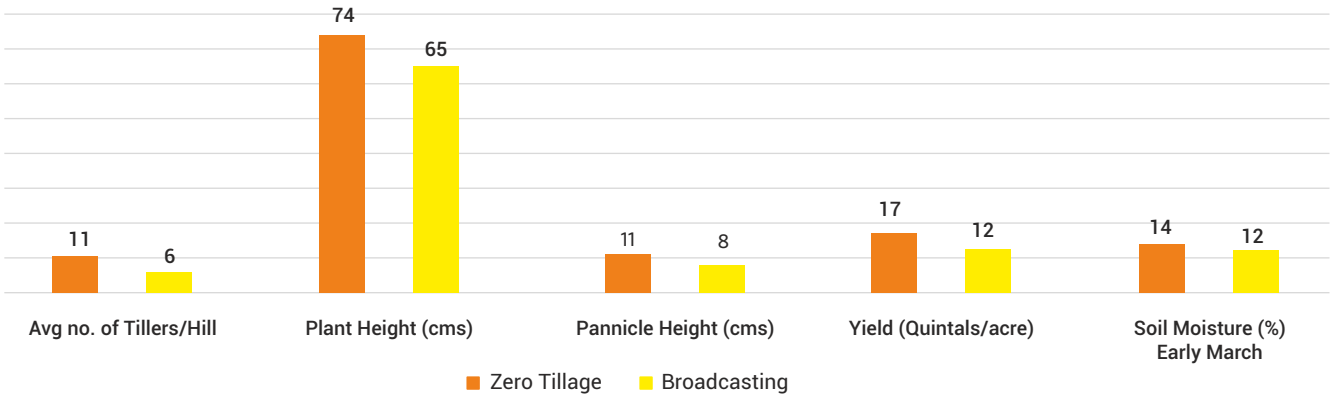


Chart 2: Cost of Cultivation per acre (Rs)



Tillers: All shoots that grow after the initial parent shoot grows from a seed. Each bears flowering and grains;
Panicle: The flowering (inflorescence) of wheat crop

Chart 3: Impact on other parameters



5. Yield improvement in the range of 16 to 40% against control was observed (Chart 3); and
6. While stubble burning is not a prevalent practice in ITC's programme areas, the potential savings in carbon emission by ZT if paddy stubble had been burnt in the project areas would have been an estimated 1.58 lakh tons (Table A2.1).

Other long-term benefits related to improvement in organic carbon, soil texture and structure are being assessed.

Table A2.1: Estimate of potential savings in emissions from prevention of paddy stubble burning

Estimates	UoM	Ton
Paddy stubble left in field after harvest	tons/ac	2.30
Paddy stubble burnt*	tons/ac	1.96
Area covered by zero till	Acres	202,500
Stubble saved by zero-till	Tons	395,888
C in Paddy stubble**	%	40%
Saving in Atmospheric Carbon release	**tons**	**1,58,355**

* Based on Kumar et al. (2014).

**Based on Mendoza et al. (1999).

ANNEXURE 3

List of Stakeholders Consulted during Various Meetings

S.No.	Name	Organisation
GOVERNMENT OF INDIA		
1.	Amitabh Kant	NITI Aayog
2.	Yaduvendra Mathur	NITI Aayog
3.	J. P. Mishra	NITI Aayog
4.	Jitendra Kumar	NITI Aayog
5.	Rajnath Ram	NITI Aayog
6.	Pratima Gupa	NITI Aayog
7.	Dinesh Arora	NITI Aayog
8.	Anurag Mishra	NITI Aayog
9.	Arun Kumar Mehta	Ministry of Environment Forest and Climate Change
10.	Ritesh Kumar Singh	Ministry of Environment Forest and Climate Change
11.	R. N. Pankaj	Ministry of Environment Forest and Climate Change
12.	Shruti Bardwaj	Ministry of Environment Forest and Climate Change
13.	BVN Rao	Ministry of Agriculture (MoA)
14.	P. C. Bodh	Ministry of Agriculture (MoA)
15.	Shantanu P. Gotmare	Ministry of Rural Development (MoRD)
16.	Garima Sharma	Central Pollution Control Board (CPCB)
17.	Sanghita Roy Choudhury	Central Pollution Control Board (CPCB)
18.	Tarua Darbari	Central Pollution Control Board (CPCB)
19.	Vinay Upadhyay	Central Pollution Control Board (CPCB)
20.	M. P. George	Delhi Pollution Control Board (DPCC)
21.	Shailender Arora	Haryana State Pollution Control Board (HSPCB)
22.	K. K. Tiwari	Department of Heavy Industry (DHI)
23.	J. B. Ravinder	CPHEEO, Ministry of Housing and Urban Affairs
24.	Anil Kumar	Delhi Government (GNCTD)
25.	Chetna Anand	Delhi Government (GNCTD)
26.	Kulanand Joshi	Delhi Government (GNCTD)
27.	Sandeep Mishra	Delhi Government (GNCTD)
28.	Manmohan Kalia	Department of Agriculture, Punjab
29.	Anand Prakash	Agriculture Department, Haryana
30.	R. K. Chauhan	Environment Department, Government of Haryana
31.	J. S. Kohli	Renewable Energy Department, Haryana

S.No.	Name	Organisation
Civil Society		
32.	Anumita Roy Choudhury	Centre for Science and Environment (CSE)
INDUSTRY		
33.	Anant Talaulicar	Cummins
34.	Manoj Agarwal	Ambuja Cement
35.	Sandeep Shrivastava	Ambuja Cement
36.	Sunil Singhal	Sunlight Fuels
37.	Ashish Aggarwal	Cummins
38.	RajendarJagdale	Science and Technology Park, Pune
39.	Ruchi Dhoreliya	Cummins
40.	Harsh Doshi	Cummins
41.	Khagender Kumar	Cummins
42.	Vinay Bhandolkar	Mahindra & Mahindra
ACADEMIA		
43.	Jaskaran Singh Mahal	Punjab Agricultural University
44.	Sunil Dhingra	The Energy Resources Institute
45.	Sumit Sharma	The Energy Resources Institute
46.	Mukesh Sharma	Indian Institute of Technology, Kanpur
47.	Manju Mohan	Indian Institute of Technology, Delhi
48.	Jasvir Singh Gill	Punjab Agricultural University
49.	Jagroop Kaur	Punjab Agricultural University
50.	Neemisha	Punjab Agricultural University
51.	Ritu Dogra	Punjab Agricultural University
52	Sammi Kapoor	Punjab Agricultural University
53.	G. S. Mangat	Punjab Agricultural University
54.	R. K. Gupta	Punjab Agricultural University
55.	Vishwajeet Singh Hans	Punjab Agricultural University
56.	Vishal Bector	Punjab Agricultural University
57.	Arshdeep Singh	Punjab Agricultural University
58.	Jagdev Singh Toor	Punjab Agricultural University
59.	Manjeet Singh	Punjab Agricultural University

60.	Harmanpreet Singh	Punjab Agricultural University
61.	Varinder Singh	Punjab Agricultural University
FARMERS COMMUNITY		
62.	Jaswant Singh	Farmer
63.	Mohan Singh	Farmer
64.	Jagdeep Singh	Farmer
65.	Dalvinder Singh	Farmer
CONFEDERATION OF INDIAN INDUSTRY (CII)		
66.	Seema Arora	Confederation of Indian Industry (CII)
67.	Sachin Joshi	Confederation of Indian Industry (CII)
68.	Kamal Sharma	Confederation of Indian Industry (CII)
69.	Mohit Sharma	Confederation of Indian Industry (CII)
70.	Priyanka Yadav	Confederation of Indian Industry (CII)
71.	Baldev Singh	CII Regional Office, Ludhiana

Confederation of Indian Industry

The Confederation of Indian Industry (CII) works to create and sustain an environment conducive to the development of India, partnering industry, Government, and civil society, through advisory and consultative processes.

CII is a non-government, not-for-profit, industry-led and industry-managed organization, playing a proactive role in India's development process. Founded in 1895, India's premier business association has over 8,500 members, from the private as well as public sectors, including SMEs and MNCs, and an indirect membership of over 200,000 enterprises from around 265 national and regional sectoral industry bodies.

CII charts change by working closely with Government on policy issues, interfacing with thought leaders, and enhancing efficiency, competitiveness and business opportunities for industry through a range of specialized services and strategic global linkages. It also provides a platform for consensus-building and networking on key issues.

Extending its agenda beyond business, CII assists industry to identify and execute corporate citizenship programmes. Partnerships with civil society organizations carry forward corporate initiatives for integrated and inclusive development across diverse domains including affirmative action, healthcare, education, livelihood, diversity management, skill development, empowerment of women, and water, to name a few.

As a developmental institution working towards India's overall growth with a special focus on India@75 in 2022, the CII theme for 2017-18, **India@75: Inclusive. Ahead. Responsible** emphasizes Industry's role in partnering Government to accelerate India's growth and development. The focus will be on key enablers such as job creation; skill development and training; affirmative action; women parity; new models of development; sustainability; corporate social responsibility, governance and transparency.

With 67 offices, including 9 Centres of Excellence, in India, and 11 overseas offices in Australia, Bahrain, China, Egypt, France, Germany, Iran, Singapore, South Africa, UK, and USA, as well as institutional partnerships with 355 counterpart organizations in 126 countries, CII serves as a reference point for Indian industry and the international business community.

CII-ITC Centre of Excellence
for Sustainable Development

CII-ITC Centre of Excellence for Sustainable Development is a not-for-profit, industry-led institution that helps business become sustainable organisations. It is on a mission to catalyse innovative ideas and solutions, in India, and globally, to enable business, and its stakeholders, in sustainable value creation. It's knowledge, action and recognition activities enable companies to be future ready, improve footprints profiles, and advocate policymakers and legislators to improve standards of sustainable business through domestic and global policy interventions.

CESD leverages its role of all-inclusive ecosystem player, partnering industry, government, and civil society. It has been a pioneer of environment management systems, biodiversity mapping, sustainability reporting, integrated reporting, and social & natural capital valuation in India, thus upgrading business in India to sustainable competitiveness.

With three locations in India, CESD operates across the country and has also been active in parts of South and South East Asia, Middle East, and Africa. It has held institutional partnerships and memberships of the United Nations Global Compact, Global Reporting Initiative, International Integrated Reporting Council, Carbon Disclosure Project, development agencies of Canada, the USA, the UK, and Germany.

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