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Catalyzing Climate Results with Pull Finance

BENJAMIN STEPHENS · SEBASTIÁN CHASKEL · MARIANA NOGUERA · MARIA DEL MAR OYOLA · LUCÍA PÉREZ · MATEO ZÁRATE

Abstract

As Dissanayake (2021) and Dissanayake and Camps (2022) have argued, pull financing is an underutilized tool with the potential to drive the development and adoption of critical technologies necessary to address the globe's climate crisis. The paper builds the case further and provides tangible examples by presenting two case studies that illustrate how pull climate finance can be used to deliver urgently needed climate results and support development objectives across low and middle-income countries.

The case studies respond to two pressing issues contributing to the globe's climate challenge: (1) the growing use of energy intensive residential air conditioning and (2) the common use of stubble burning agricultural practices. For both cases, we propose that an Advanced Market Commitment (AMC), a form of pull finance, could be used as a promising tool to enable technology development and adoption, driving a market shift towards a new and cleaner equilibrium. In the case of cooling, we outline the potential of an AMC to drive a sustained shift in the Indian market by enabling the scale-up of cleaner cooling technologies, driving down their costs to ensure their future competitiveness. In the case of stubble burning, also focused on India, we show that an AMC could offer incentives for producers to innovate to drive short-run take-up of stubble burning alternatives, facilitating a sustained market shift to stubble burning alternatives in the medium-term. We find both cases hold promise to achieve substantial and cost-effective emission reductions, as well as important development benefits in the form of both economic and health outcomes—a finding which should justify significant investments.

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Contents

List of Figures

List of Tables

Foreword

Climate finance is an increasingly important part of the official development assistance (ODA) landscape, but this development has not come without controversy. Funding for climate mitigation activities can come at the expense of 'traditional' development work, and we know relatively little about the cost effectiveness of some of this work. One way of addressing both of these concerns is to use pull financing for pre-specified outcomes that have both climate and local development benefits. Such a system allows us to pre-commit to how much we are willing to pay for specific results (addressing cost-effectiveness concerns) and to target funding where we see genuine climate and development win-wins, while also incentivizing the search for new, scalable, solutions to existing problems. A recent CGD policy paper (Dissanayake and Camps 2022) set out a number of possible applications for pull financing in the climate and development space.

Pull financing, though, stands or falls on the details: what incentive structure is offered, what precisely is contracted for, and how exactly results will be verified. This paper, by Benjamin Stephens, Sebastián Chaskel, Mariana Noguera, Maria del Mar Oyola, Lucia Perez and Mateo Zarate provides these details for two potential applications for pull financing: clean residential cooling and technologies for replacing the practice of stubble burning in India. In doing so, they show how pull financing can work, what it could potentially achieve, and demonstrate the tractability of different pull financing approaches for specific, important problems. It is an important contribution to the gathering intellectual momentum for pull financing to form an increasing part of the financing landscape for technological progress.

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1. Introduction

Rapidly developing cleaner technologies, such as energy saving appliances and more accessible renewable energy, are playing a critical role in responding to the globe's climate crisis. Many of these technologies, however, are predominately developed and adopted in high-income countries, with limited adoption in low- and middle-income (LMIC) countries. Effectively responding to this gap represents an important potential to support progress on climate mitigation efforts in LMICs.

Simultaneously, climate-focused official development assistance (ODA) is on the rise, although much more is needed to meet the Paris Agreement's 1.5° Celsius goal, and the effectiveness of much of this spending is in question, raising the need for methods able to ensure the greatest possible climate impact for each dollar of investment.[1] While ODA can play an important role in responding to the global climate crisis, this focus should not displace other development priorities, especially given that most of the Sustainable Development Goals remain off track.[2] Given these constraints, it is critical that climate finance be used as effectively as possible, improving on current mixed levels of effectiveness demonstrated so far.[3]

Pull finance offers a set of results-based tools with the potential to make the most of donor efforts to meet climate and development needs by supporting the development and adoption of cleaner technologies suited to LMIC needs.[4] Specifically, pull finance mechanisms can 1) deliver low-cost solutions in line with LMIC's needs; 2) incentivize the private sector to undertake the necessary technology innovation to solve specific climate and development problems at scale; and 3) shift the market to scale up production and promote the uptake of cleaner technologies.[5] Box 1 presents an overview of common pull finance mechanisms and examples of applications in LMICs.

1 Ares, E. and Loft, P. (2021) COP26: Delivering on $100 billion climate finance. Insight. House of Commons Library. UK Parliament; Dissanayake, R. (2021). Navigating the Straits: Pull Financing for Climate and Development Outcomes. CDG Policy Paper 239. Center for Global Development.

2 The Hindu. (2022). Nearly every indicator of the U.N. sustainable development goals is off track': Bill and Melinda Gates Foundation's report.

3 Juden, M. and Mitchell, I. (2021). Cost-Effectiveness and Synergies for Emissions Mitigation Projects in Developing Countries. CGD Policy Paper 204. March 2021. Center for Global Development.

4 Dissanayake, R. (2021). Navigating the Straits: Pull Financing for Climate and Development Outcomes. CDG Policy Paper 239. Center for Global Development.

5 Dissanayake, R. (2021). Navigating the Straits: Pull Financing for Climate and Development Outcomes. CDG Policy Paper 239. Center for Global Development.

BOX 1. Pull finance mechanisms and applications in LMICs

Pull finance mechanisms are designed to promote innovation and scale by increasing demand for specific technologies or solutions that are otherwise not being produced due to market failures. Three commonly used forms of pull finance are:

- **Results-based financing (RBF):** RBF interventions provide payments for the delivery and verification of agreed-on results. While RBF interventions can support innovation, they usually focus on supporting adoption of effective practices and are directed at a predetermined agent rather than technology development. RBF programs do not necessarily have a minimum volume required to trigger a payment.
  - For example, the Universal Energy Facility,[6] a multi-donor RBF initiative, provides incentive payments to eligible organizations deploying energy solutions and providing verified end-user electricity connections. EnDev's RBF instrument[7] has paid for the uptake of grid technologies in Rwanda and a portion of gasifier cookstoves bulk purchases. Likewise, the Irish Aid program RBF calculated payments based on emissions reduction from households switching to the improved cookstove technology.[8] The World Bank's Global Partnership for Results-Based Approaches (GPRBA) uses RBF to incentivize providers, such as energy utility companies, to reach low-income neighborhoods.[9]
- **Advance Market Commitment (AMC):** AMCs are commitments to purchase, or to subsidize purchase, of a certain volume of a product at a pre-determined price, if the product meets predefined characteristics. In this way, AMCs encourage technology innovation and uptake. The quantity-forcing nature of AMCs allows for incentivizing deployment at scale rather than incremental results. Additionally, AMCs allow the payer to incentivize a desired solution without having to know who is best suited to develop this solution ex-ante. AMCs can either provide a guaranteed market or condition payment on market demand.
  - For instance, AMCs have been successful in addressing market failures related to vaccines. GAVI,[10] the vaccine alliance, has used AMCs to incentivize producers to deliver suitable and affordable vaccines for LMICs. The development of the pneumococcal vaccine to be used in LMICs is perhaps the most notable example. In terms of climate technologies, India's Super-Efficient Air Conditioning Program[11] ensured bulk procurement of cleaner air conditioners (ACs) to incentivize lower

6 Universal Energy Facility. Sustainable Energy for All.

7 EnDev Results Based Financing.

8 International Institute for Environment and Development. (2020). Stoking finance for affordable cookstoves: experience from Malawi and Zimbabwe.

9 Global Partnership for Results-Based Approaches (GPRBA). Kenya Energy Expansion.

10 GAVI Pneumococcal Advance Market Commitment.

11 India's Super-Efficient Air Conditioning Program.

prices. Likewise, Frontier[12] is an AMC led by private companies that guarantees demand for carbon dioxide (CO_2) removal technologies.

- **Prize-based Challenge:** Challenge prizes incentivize innovators to develop new solutions to neglected problems by offering a reward to innovations that meet pre-established criteria. These mechanisms allow payers to define solution specifications in cases where the specific solutions or the best-positioned actors to solve the issues are unknown.
    - Examples of prizes applied to climate initiatives in LMICs include the Global Cooling Prize,[13] that offered USD 200,000 for cooling technologies which met a set of clean standards and the Million Cool Roofs Challenge that offers prizes for the scale-up of cool roof technologies.

Note: Along with these measures, carbon credits and carbon markets are also a form of climate finance providing financial incentives for market actors to reduce emissions. While offering many strengths as an efficient and administratively simple form of climate finance, carbon markets rely on policy decisions by governments, rather than funding decisions, and are therefore outside the scope of this paper.

Dissanayake (2021) and Dissanayake and Camps (2022) have demonstrated the value that pull finance could have for meeting climate goals and proposed the development of a centrally managed portfolio of pull finance options. This paper builds on this analysis, contributing to the case to use pull finance for climate and development outcomes by providing two illustrative prototypes.

Dissanayake and Camps (2022) mention seven potential applications of pull finance that would have climate and socioeconomic development benefits: new crop varieties, weather forecasting, stubble burning, clean cooking, cooling systems, green all-weather road sealants, and electric vehicles for Africa. We selected two of these applications for the case studies for three reasons. First, they both relate to well defined market failures where a lack of action to address negative externalities associated with Greenhouse Gas Emissions (GHGEs) has caused an underinvestment in the development and adoption of cleaner technology alternatives. Second, addressing both market failures should lead to socioeconomic development gains. Third, both problems are well defined and documented, providing a solid foundation of data and research to inform robust cases.

The two case studies—cleaner cooling appliances and alternatives to stubble burning—illustrate the potential of pull finance to encourage uptake and innovation to mitigate climate change and create development gains. The cooling case is concerned with the problem of GHGEs associated with the growing use of ACs, a technology that can bring development gains across LMICs. The stubble burning case focuses on the problem of GHGEs and health issues due to the use of stubble burning for agricultural purposes. The cases were developed based on extensive desk research and engagements with leading experts.

For both cases, we propose the use of an AMC to incentivize either new technology development, the take-up of cleaner technologies, or both. The purpose of the AMCs we are proposing are not meant to

12 Frontier Climate.
13 The Global Cooling Prize.

fully guarantee a market for products, but rather to address a market failure to incentivize a new steady state. They are not meant to fully guarantee a market since 1) this is not a market with zero demand, and fully guaranteeing demand would imply overpaying beyond what is necessary, and 2) requiring producers to demonstrate some consumer demand helps ensure that results will be sustainable. This is similar to the way in which the GAVI pneumococcal vaccine AMC committed donor funds not only if a vaccine came to the market, but also if it was demanded by countries. The mechanism is different than most RBF programs in that the payments are only triggered if a certain scale is achieved.

Each case has three sections. First, the cases present a detailed assessment of the climate and socioeconomic development cost of cooling and stubble burning and the potential benefits of resolving them.

Second, the cases detail the technology and market challenges related to cooling and stubble burning and define the objective of a pull finance mechanism to respond to these challenges. This includes assessing the state of the prevailing technology and describing the market dynamics which have limited the required technology innovation or adoption. This analysis then defines the expected results of the pull finance mechanism, detailing what the mechanism would have to achieve to address the identified market challenges, and how this could be done.

Third, the cases present a design prototype, providing recommendations for each of the key design choices that need to be resolved to launch an effective pull finance mechanism. These prototypes 1) detail each of the design choices that need to be resolved as summarized below in Table 1, 2) present frameworks and methodologies for making design choices, and 3) provide recommendations on suitable design features. These prototypes are meant to enable the market engagement and refinement necessary for tailoring to specific country contexts and contract design as a prerequisite for launch.

TABLE 1. Pull finance climate mechanism: design components

Design Choices	Description
1. Which mechanism can best deliver on identified objectives?	Pull finance mechanisms include RBF, AMCs, and Prize-Based Challenges, each with different characteristics suited to advancing different objectives.
2. What results should be paid for?	Defining appropriate results is central to ensuring the mechanism effectively incentivizes progress against the defined market and technology challenges.
3. How much should be paid for targeted results?	Determining reasonable result prices for the results achieved and an appropriate overall value for the mechanism is critical to ensure the mechanism's effectiveness and value for money. Note that this refers to the prices to be paid for the results and may differ from the price of the technology used to achieve said results.
4. How should results be verified?	Verification is the process used to confirm that targeted results have been achieved. The verification strategy defines how, when, and by whom data are collected and corroborated and is critical to ensure the mechanisms' rigor.

2. Cleaner cooling pull finance mechanism

Section 2 presents the case for pull finance to drive the uptake of residential cleaner cooling in LMICs and details how this could be achieved with a design prototype. Section 2.1 introduces the case followed by Section 2.2, which describes the climate and development impacts of growing cooling demand and the benefits that could be achieved from greater use of cleaner cooling in LMICs. In Section 2.3 we describe the challenge of driving increased cooling uptake and outline how pull finance could address this problem. Section 2.4 then presents a detailed design prototype of the proposed pull finance mechanism.

2.1. Introduction

Rapidly growing demand for cooling in LMICs is increasingly contributing to GHGEs. This problem is exacerbated by heavy reliance on standard ACs, which entail higher GHGEs. While cleaner cooling options exist and are increasingly adopted in high-income countries, they have low rates of adoption in LMICs due largely to their higher price in these markets. This problem is driven by a common market failure: negative externalities of GHGEs are not priced appropriately, depriving the market of the necessary pressure to shift towards cleaner cooling options.

In response to this challenge, pull finance represents an opportunity to drive a market shift towards cleaner cooling options, especially necessary given the limited use of other policy responses such as domestic regulations. Pull finance could be used to provide a time-limited incentive for producers to scale production of cleaner cooling options, driving down their cost close to parity with standard ACs, achieving a long-term sustainable shift to cleaner cooling.

To enable a focused case, we concentrate on residential cooling in India. As detailed below, improvements to residential cooling would deliver significant climate and development gains, and these could be driven by the proposed pull mechanism. We also expect that pull finance mechanisms could be developed and applied in a similar way for other aspects of cooling, such as non-residential space cooling and refrigeration for food and medical purposing including cold chain, areas with significant climate and development impact. Likewise, this case focuses on India since it is a substantial growth market for cooling and this focus enables us to present a concrete and locally tailored case, providing an actionable reference point for use in other LMICs.

Section 2 now presents the benefits available if the globe's cooling needs are met with cleaner options (2.2), details the challenge this poses and how a pull finance mechanism could help (2.3) and presents a proposed design prototype (2.4).

2.2. Climate and development benefits

This section details the potential climate and development impacts of successfully advancing the use of cleaner cooling technologies. It addresses the anticipated climate and development benefits in turn by *outlining the climate and development problems caused by the status quo reliance on standard ACs and presents the potential benefits of transitioning to cleaner cooling technologies.*

2.2.1. LMIC cooling needs are driving increased GHGEs and development challenges

ACs contribute to climate change through direct and indirect emissions. Direct emissions are caused by ACs' intense use of super-polluting refrigerants. Indirect emissions are those associated with the electricity ACs use. These are a substantial source of GHGEs when electricity is reliant on fossil fuels. Around 80% of total cooling emissions are indirect from energy use and 20% are direct from refrigerants.[14]

Rapidly growing demand for cooling in LMICs is contributing to the globe's energy demands and GHGEs. Total GHGEs from cooling tripled between 1990 and 2018, reaching 1.13 billion tonnes of CO_2, equivalent to the total emissions of Japan.[15] This trend is expected to accelerate, with the global stock of ACs expected to triple from 1.6 billion in 2018 to 5.6 billion by 2050. Approximately 70% of the AC demand growth in the next 30 years is expected to stem from LMICs,[16] with China and India alone accounting for more than half the increase in residential ACs.[17]

The growth in demand for cooling reflects several key drivers, all of which will continue to intensify in the decades ahead. These drivers include: 1) population growth, especially in countries with warmer climates, 2) increased incomes, making ACs more affordable for many, 3) higher average temperatures and the increased frequency of extreme temperatures, 4) a shift towards less insulating construction materials such as wood and composites, and 5) growing numbers of electronic devices that contribute to higher temperatures inside buildings.[18]

Given these factors, the growing demand for cooling in LMICs has alarming climate and development implications:

1. **GHGEs from cooling are set to increase dramatically.** By 2050 total annual GHGEs from ACs are projected to increase to up to 2.5 times those of 2016.[19] AC energy consumption from non-OECD countries in 2050 will be 4.3 times that of 2010, compared to a 1.5 times reduction for OECD countries.[20] In terms of emissions, the share of CO_2 emissions[21] derived

14 Technology and Economic Assessment Panel. (2018).
15 IEA. (2018). The Future of Cooling, IEA, Paris and (UNEP, IEA, 2020), United Nations Environment Programme and International Energy Agency (2020). Cooling Emissions and Policy Synthesis Report. UNEP, Nairobi and IEA, Paris.
16 Sachar, Sneha, Iain Campbell, and Ankit Kalanki. (2018). Rocky Mountain Institute. Solving the Global Cooling Challenge: How to Counter the Climate Threat from Room Air Conditioners.
17 IEA. (2018). The Future of Cooling, IEA, Paris.
18 IEA. (2017). Insights Brief: Space Cooling, IEA, Paris.
19 Sachar, Sneha, Iain Campbell, and Ankit Kalanki. (2018). Rocky Mountain Institute. Solving the Global Cooling Challenge: How to Counter the Climate Threat from Room Air Conditioners.
20 IEA. (2016). Energy Technology Perspectives 2016, IEA, Paris.
21 CO_2 equivalent.

from space cooling in LMICs is projected to double from 8% in 2018 to 15% in 2050.[22] Among the countries with the greatest expected increase are India, where the AC-related CO_2 emissions share is expected to grow from around 5% in 2016 to 23% in 2050, and Mexico, with an increase from around 6% to 27% in the same time period.[23]

2. **Rising electricity demand from cooling poses a heavy toll on electricity infrastructure, especially during peak hours and hot seasons.** This is particularly relevant for LMICs, where electricity grids are already stretched. The share of cooling in peak electricity load is projected to rise sharply in many countries. India and Indonesia, for example, are expected to see peak electricity demand from cooling reach up to 40%.[24] Indeed, in cities like Delhi and Beijing cooling is already taking over more than half of peak electricity load on extremely hot days.[25] Besides power capacity constraints, meeting electricity needs in peak hours is costly as it involves building, maintaining, and operating extra electricity capacity that is only used for a limited time span.[26]
3. **If left unaddressed, increasing electricity demand from traditional cooling will further constrain grid capacity and business operations.** Limited access and unreliable energy supply are already significant obstacles to businesses and industrial development in many LMICs. This is especially so in some African countries, where the poor state of electricity grids hinders production and is reported by firms as one of the main obstacles for business expansion. Estimates suggest that grid disruptions cost sub-Saharan African countries as much as 2.1% of GDP, while 4.9% of total sales are estimated be lost due to electrical outages.[27]

2.2.2. Cleaner cooling can deliver significant climate benefits

The expansion of existing cleaner cooling technologies in LMICs would help cut energy needs and GHGEs. Generalized adoption of already-existing cleaner ACs and other sustainable cooling technologies would deliver substantial climate benefits in the form of reduced energy use and GHGEs. According to the IEA efficient cooling scenario, the adoption of cleaner cooling technologies would drive up ACs' average efficiency in 80% by 2050 compared with a business-as-usual scenario.[27] This could reduce **energy needs** for space cooling by more than 45% in 2050. In terms of **emissions**, energy efficiency improvements in cooling technologies together with reduced use of refrigerants could avoid GHGEs equivalent to 4–8 years of global emissions in 2018 levels.[28]

22 IEA. (2018). The Future of Cooling, IEA, Paris.
23 Sachar, Sneha, Iain Campbell, and Ankit Kalanki. (2018). Rocky Mountain Institute. Solving the Global Cooling Challenge: How to Counter the Climate Threat from Room Air Conditioners.
24 IEA. (2018). The Future of Cooling, IEA, Paris.
25 Dreyfus, G., Borgford-Parnell, N., Christensen, J., Fahey, D.W., Motherway, B., Peters, T., Picolotti, R., Shah, N., and Xu, Y. (2020). Assessment of climate and development benefits of efficient and cleaner cooling.
26 IEA. (2019). The Future of Cooling in China, IEA, Paris.
27 IEA. (2014). World Energy Outlook 2014, IEA, Paris.
28 UNEP and IEA. (2020). United Nations Environment Programme and International Energy Agency. (2020). Cooling Emissions and Policy Synthesis Report. UNEP, Nairobi and IEA, Paris.

2.2.3. Cleaner cooling can deliver significant development benefits

Substituting standard cooling systems with cleaner technologies that reduce energy consumption can also deliver significant development benefits.

Liberated energy use alleviates power constraints and leads to increased economic capacity while reducing the need for new power plants. According to IEA estimates, in an *efficient cooling* scenario that doubles the efficiency of ACs by 2050, the need for extra generation capacity will be reduced by 1,300 GW (equivalent to all the coal-fired power generation capacity in China and India in 2018).

Reduced need for power and distribution capacity ultimately would help governments avoid large costs associated with grid development and operation. The IEA *efficient cooling scenario* estimates world cumulative savings from reduced power needs of USD 2.9 trillion over 2017–50.[29] This means lower electricity costs per capita from around USD 62 to USD 35 in 2050 on average.[30]

More efficient cooling technologies, that demand less electricity, can also facilitate access to cooling. Cleaner ACs, that consume less electricity, could potentially be applied in contexts where grid capacity is compromised such as households, hospitals, and schools in poor urban, rural, and remote areas. Estimates suggest that around 1.09 billion people are at high risk due to lack of access to cooling in poor rural and urban areas, with lack of access to electricity playing a major role.[31] Of 2.8 billion people living in the hottest parts of the world, 8% currently own ACs.[32]

Further, access to cooling has direct social benefits for health, education, and work-place wellbeing:

1. **Health and healthcare:** access to cooling can reduce heat-related mortality. Heat waves currently kill 12,000 people every year. By the 2050s, the heat-related mortality rate could reach up to 35.6 per 100,000 inhabitants,[33] potentially doubling the current mortality rate for malaria (15.3 per 100,000 inhabitants). In hospitals, cooling systems can help the recovery of patients, limit the spread of diseases, and enable surgical procedures.
2. **Education:** access to cooling increases learning outcomes. School air conditioning in LMICs would offset over USD 25,000 per classroom per year in future lost earnings due to temperature increases.[34]

29 IEA. (2018). The Future of Cooling, IEA, Paris.
30 Dreyfus, G., Borgford-Parnell, N., Christensen, J., Fahey, D.W., Motherway, B., Peters, T., Picolotti, R., Shah, N., and Xu, Y. (2020). Assessment of climate and development benefits of efficient and cleaner cooling.
31 SEforAll. (2021). Chilling Prospects, Tracking Sustainable Cooling for All.
32 IEA. (2018). The Future of Cooling, IEA, Paris.
33 Witt C, Schubert AJ, Jehn M, Holzgreve A, Liebers U, Endlicher W, Scherer D. The Effects of Climate Change on Patients With Chronic Lung Disease. A Systematic Literature Review.
34 Harvard Kennedy School. (2018). "When the heat is on, student learning suffers."

3. **Work-place safety and well-being:** access to cooling reduces heat stress and related health issues. LMICs are already experiencing heat stress that affects safety and labor productivity. In 2020, 295 billion hours of potential work were lost due to heat conditions.[35]

2.3. The cooling challenge and how a pull finance mechanism can help

This section illustrates the cooling challenge and defines the objective of a pull finance mechanism to meet this challenge. We first review the cooling market in LMICs with reference to the Indian context. Next, we compare business-as-usual to a target scenario in which cleaner cooling options are increasingly adopted. We then define the pull finance mechanism's objective and how this objective can be achieved.

2.3.1. Standard ACs dominate LMICs' cooling markets

The above climate and development challenges are driven by the increasing reliance on standard ACs.[36] At the global level, these ACs are defined by their relatively high direct and indirect emissions. For example, in India a standard 3-star AC emits approximately 10.5% more GHGEs compared a market-leading 5-star AC.[37,38]

The growing use of standard ACs primarily reflects their dominance over alternatives in terms of:

1. Cooling capacity—While electric fans and cool building materials and design can provide suitable cost-effective alternatives to standard ACs in many contexts, they cannot meet all cooling needs. For instance, in humid and humid tropical environments, these technologies cannot compete with ACs in meeting common cooling needs.[39]
2. Price competitiveness—Standard ACs enjoy a strong price advantage over cleaner cooling alternatives such as cleaner ACs. For instance, in India, a 3-star AC costs on average of USD 802 compared to USD 962 for a cleaner 5-star AC with the same cooling capacity.[40]

These cooling alternatives are further detailed below in Table 2, including their climate impact and market position.

35 International Labor Office. (2019). "Working on a warmer planet. The impact of heat stress on labor productivity and decent work."

36 Improving Air Conditioners in India. (2017). Cooling India with Less Warming Series-affordable and Efficient Room Air Conditioners.

37 Bureau of Energy Efficiency. (2020). *"The star rating of an electrical appliance is quantified in Energy Efficiency Ratio (EER). A 3-star AC has an EER that ranges between 2.9 to 3.09 and a 5-star AC has an EER of 4 and above. In general terms, it is a measure that provides the useful ratio of cooling output (in BTU/h) to electricity input (measured in W)."*

38 Estimation done by the authors based on Voltas ACs Indian market research.

39 Thorsby, D. (2022). 6 Alternatives to Traditional Air Conditioning to Consider.

40 Voltas. (2022). Average price of the current Voltas Indian market.

TABLE 2. Cooling technologies in LMICs

Cooling Technology	Description	Prevalence	Advantages/ Disadvantages	Climate Impact	Price
Standard ACs	Popular, effective, and cheap technology commonly used to cool residential spaces in LMICs. For instance, in the Indian market most ACs have 3-star or lower ratings from the Bureau of Energy Efficiency.	They have a large market share in LMICs. In India, this type of AC represents approx. 79% of the total market: of the 7.5 million sales per year, approx. 5.9 million are of standard ACs.	Offer substantial cooling capacity at a low cost, making it a popular choice to meet cooling needs in LMICs.	Standard ACs have high energy needs and associated GHGEs. For instance, ACs with 3-star ratings have an Indian Seasonal Energy Efficiency Ratio (ISEER) below 3.99. The average Kilowatts per lifecycle for this type of AC is 57,864 and the estimated GHGEs per lifecycle is 27.2 tonnes.	In India, the average retail price for a 3-star inverter split AC with a capacity of 1.5 tonnes of refrigeration is USD 802.
Cleaner ACs	More advanced technology with lower energy needs and GHGEs. For instance, in India, cleaner ACs include ACs with 5-star ISEER ratings.	They have a low market share in LMICs. In India, they represent 18% of the cooling market: of the 7.5 million sales per year, approx. 1.35 million are of cleaner ACs.	Uptake in LMICs is limited by relatively high retail prices and limited availability. Operation costs are lower due to their greater efficiency.	Cleaner ACs can entail 5% to 10% less energy use than standard ACs in the current Indian market. The average Kilowatts per lifecycle for this type of AC is 54,971 and the estimated GHGEs per lifecycle is 24.62 tonnes.	In India, the average retail prices, for a 5-star inverter split AC with a capacity of 1.5 tonnes of refrigeration is USD 962.[41]
Low-emission cooling alternatives	An emerging set of technologies, such as heat pumps and evaporative cooling.	Some uptakes in high-income countries, very low use in LMICs.	Can use substantially less energy than ACs but entail higher retail prices, making them unlikely to be part of a mass solution for residential cooling in the near future.[41]	Includes some technologies that can entail close to zero GHGEs.	Varies. A heat pump, for example, has a retail price of USD 1,790 and evaporate cooling technology of USD 2,500.
Cool building materials and design	Design choices on structure (e.g., mechanical ventilation) and materials (e.g., insulation).	Uptake in LMICs is low, as these do not meet all cooling needs, especially in climates which are consistently warm and humid, and can involve high costs.	Reduces the need for additional cooling systems but can be hard/costly to install and does not meet all cooling needs.	Can substantially reduce cooling needs and consequent GHGEs. For example, light-colored reflective and green roofs can effectively cool interiors by redirecting sun rays and decreasing heat absorption.	Varies.
Electric fans	Electric fans help with cooling by enabling air movement with motorized blades.	Widely popular in LMICs.	Low cost with high cooling effectiveness in some contexts, but cannot meet all cooling needs (e.g., in the context of persistently high temperatures).	Fans use approx. 30 times less electricity than standard ACs, entailing consequently lower GHGEs from energy use and no primary emissions.	In India, the average retail price for an electric fan with 3 blades is USD 17.

Sources: Data on prevalence: Business Standard (2022) Record sales of residential air conditioners in April amid scorching heat. Data con climate impact: estimations based on product specification information from Voltas. (2022). Average price of the current Voltas Indian market. Data on prices: Voltas. (2022). Average price of the current Voltas Indian market; Amazon (2022) Average price of the current electric fans in India; AMI Cooling System. (2022). Average price of the current Heat Pumps Indian market and Fixr. (2021). How much does it cost to install a Swamp Cooler?

41 IEA (2019). Helping a warming world to keep cool.

2.3.2. The market dominance of standard ACs represents a market failure

The price advantage of standard ACs over cleaner cooling options (like cleaner ACs) largely reflects the standard market failure associated with a lack of market signals connected with their GHGEs. While consumers do pay higher electricity prices for cooling with standard ACs than with cleaner ACs, the difference in operating costs has not led to a strong demand for cleaner ACs. This may be because the difference in operational costs is not high enough to drive a change in consumption, or because the buyers may face liquidity constraints due to credit market imperfections[42] or present-biased,[43] preferring savings today even if they mean higher costs in the future, or limited awareness of product differences. This leaves producers and suppliers with limited incentives to scale up production of cleaner ACs, instead continuing to use their existing production capacity to produce standard ACs and sell them in LMICs at lower prices than cleaner alternatives.

The higher production and sales of standard ACs instead of cleaner ACs primarily reflects market path dependencies rather than intrinsic differences in production costs. However, this can change when there is more innovation and demand for more efficient systems, as seen in higher income countries. For instance, an OECD report reveals that while high-income countries grapple with frontier technologies, LMICs have not yet adopted the existing ones.[44] The design presented here seeks to foster this change through a mechanism that can lead to a new market equilibrium and respond to some of the following factors which have created the current path dependency:

1. Reliance on local production where existing production capacity is predominately focused on 3-star and lower efficiency ACs.[45] This means standard AC production benefits from economies of scale, which drives down their costs.
2. Since standard ACs are well established in LMIC markets, distribution, installation, and maintenance services are relatively cheap and available compared to those for cleaner technologies.[46]
3. LMICs are a common exit market for ACs that no longer meet regulatory efficiency standards in high-income countries, which further contributes to the cheaper and low-efficiency profile of cooling technologies in LMICs.[47] Note, this factor is relatively less salient in India, where high import tariffs mean local production supplies 65% of the AC market.[48]

As an alternative to an AMC, governments could choose to improve utility efficiency guidelines, in effect banning the sale of new 3-star and lower ACs. This policy, however, would limit access to the

42 Bank of Canada. (2009). Credit Constraints and Consumer Spending.

43 Tendency of people to give stronger weight to payoffs that are closer to the present time when considering trade-offs between two future moments. Behavioral economics. (2022).

44 OECD. (2018). Accelerating the development and diffusion of low emission innovations.

45 Sachar, Sneha, Iain Campbell, and Ankit Kalanki, Solving the Global Cooling Challenge. Rocky Mountain Institute. (2018). How to Counter the Climate Threat from Room Air Conditioners.

46 IEA. (2018). The Future of Cooling, IEA, Paris.

47 IEA. (2018). Technology Collaboration Program.

48 PLI to help to Indian AC industry to compete globally, local component ecosystem in 3–4 years. (2021).

higher efficiency ACs to better off populations, at least for the short-term. An AMC would allow for the pro-climate shift to take place while continuing to offer the technology to middle- and lower-income households.

2.3.3. Defining a cleaner cooling future scenario

Given this market failure, under a **business-as-usual scenario**, cooling will continue to be met by standard ACs given their continuing price dominance. In contrast, an alternative **target scenario** would see rising demand for cooling in LMICs met with a shift towards cleaner ACs and other low-emission alternatives.

This shift can be achieved by bringing these alternative technologies close to price parity with standard ACs. To ensure the market for cleaner cooling is sustainable, any remaining small price differences between cleaner and standard cooling can be offset through one or more of the following:

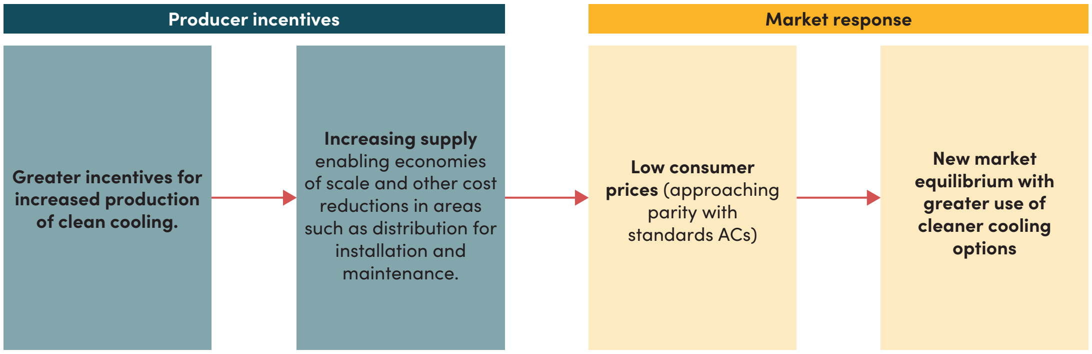
1. The long-term savings associated with the reduced operating costs of cleaner cooling.
2. Credit facilities that focus on providing consumers loans to buy cleaner cooling options and allow for repayment based on future savings achieved through lower operating costs.
3. Buyers' clubs where a group of purchasers combines and commits to purchase cleaner cooling options at a negotiated price (an approach similar to the AMC proposed below but which does not require donor funding).
4. Domestic government subsidies (e.g., tax breaks) for cleaner options or imposing a cost (e.g., taxes) on standard options.
5. Additional complementary policies to address potential price differences in relation to the distribution, installation and maintenance services to ensure these services for cleaner cooling technologies are affordable and available.

2.3.4. Objectives of pull finance mechanism for cleaner cooling

The objective of the pull finance mechanism is to provide a one-time intervention to shift the market from the business-as-usual scenario to the target scenario. This would see a new market equilibrium where cleaner cooling technologies are available and price competitive with standard ACs, enabling a long-term market shift to cleaner cooling, reducing GHGEs and related climate impacts, while delivering related development gains.

Designing a pull finance mechanism to meet this objective requires defining *how* this can be achieved: defining a theory of change (ToC) detailing how adjusted market incentives could achieve the objective. A ToC illustrates the causal pathway of an intervention, and clarifies the steps required to achieve the objective. Figure 1 presents a simple ToC of how the pull finance mechanism could drive the required shift towards the target scenario by driving down prices for cleaner cooling technologies in India and other LMICs.

FIGURE 1. Pull finance theory of change to drive sustained uptake of cleaner cooling technologies



Source: Author's elaboration.

This ToC depends critically on the assumption **that substantial price reductions can be achieved through increased production and distribution of cleaner cooling technologies.** This assumption is supported by the fact that price differentials between cleaner and standard cooling options are not driven primarily by different costs of production when both are done at scale.[49] Instead, as detailed above, price differentials in the cooling market primarily reflect which products are mass produced. Where production is scaled up, substantial economies of scale can be achieved, enabling cost reductions and lower consumer prices. Illustrative of this dynamic, the lack of economies of scale has also been identified as the cause of high costs in the production of cooling technologies in India, especially for compressor manufacturing.[50] Likewise, electric vehicle costs have benefitted from economies of scale in the production of their components, such as battery packs.[51]

As such, a pull finance mechanism should be designed to incentivize mass production of cleaner cooling, disincentivize ongoing production of standard technologies and drive down the price differential between these products. For this market change to happen, we need to design an intervention that adjusts incentives on the production side, allowing for economies of scale and enabling a cleaner cooling market in LMICs.

Some critical implications for the design, then, are that the pull finance mechanism implies:

1. Providing producers with a market opportunity of sufficient financial size and certainty to justify the investment in shifting production towards cleaner cooling technologies.
2. That the market shift must be large enough to (1) drive economies of scale and other savings for cleaner cooling and (2) diseconomies of scale for standard cooling to drive a substantial change in production costs sufficient to achieve approximate price parity. This means,

49 Supported by expert advice provided for this project (the complete expert list is included in the acknowledgement section) and the references below.
50 Dixit, H., Bhasin, S. (2022). Technology Gaps in India's Air-Conditioning Supply Chain.
51 Nykvist, B., and Nilsson, M. (2015). Rapidly falling costs of battery packs for electric vehicles.

the pull finance mechanism must be large enough to achieve some threshold of increased market size for cleaner cooling technologies.

3. A technology- agnostic approach: while further technology innovation to push the frontier of GHGEs reductions is of course desirable, this is not the main focus of this case. This is because (1), as described above, substantial GHGEs reductions can be achieved in LMICs by adopting existing underutilized technology namely,5-star ACs; and (2) LMIC markets are so far from the technology frontier that it is unlikely that a pull finance mechanism targeted at this market could create meaningful incentives to advance this frontier. Instead, LMIC markets will likely continue to act as second movers, benefiting from innovation introduced in high-income countries once these technologies can be scaled. In other words, the pull finance mechanism design keeps focus on the more conservative target scenario of scaling up the uptake of 5-star ACs in LMICs, however the AMC should leave room for new technologies addressing the challenge.

2.4. Pull finance design prototype

This section details a proposed design prototype for a pull finance mechanism which would respond to the challenge and meet the objective outlined above. We first detail the choice of pull finance mechanism and funding recipient (2.4.1) before defining the results to which pull finance should be tied, along with associated targets (2.4.2), a proposal for the AMCs' prices and values (2.4.3) and conclude with a proposed verification strategy (2.4.4). These details are first summarized in the text below and Table 3.

The pull-finance mechanism design presented here aims to drive a market shift towards cleaner cooling technologies and a lower emission future. To achieve, this we propose an AMC since it can incentivize producers to increase the production of cleaner technologies, drive down their prices to ensure the competitiveness of cleaner technologies in the medium to long-run. To create the right incentives, the AMC would pay producers for the sale of cleaner cooling options that meet GHGEs, operational criteria and reach a threshold of sales above current rates at a unit price of USD 54 to USD 104. For illustrative purposes, the design will be focused on increasing the market share of 5-star ACs in India by 48 percentage points, which translates to an increase of 3.6 million cleaner cooling units. With this objective and the unit price in mind, the overall AMC will range between USD 196 million and USD 373 million.

We conservatively estimate the AMC would mitigate 9.4 million tonnes of GHGE across the program, at a cost between USD 21 and USD 40 per tonne of CO_2 abated. These figures illustrate the potential strong cost-effectiveness of the AMC compared against benchmarks such as the Green Climate Fund and the Clean Technology Fund which have an estimated average cost effectiveness across all programs of approximately USD 42 and USD 144 respectively.[52]

52 Juden, M. and Mitchell, I. (2021). Cost-Effectiveness and Synergies for Emissions Mitigation Projects in Developing Countries. CGD Policy Paper 204. March 2021. Center for Global Development.

TABLE 3. Summary of the pull finance prototype for cleaner cooling

Pull Finance Design Components	Prototype Design Proposal
1. Which mechanism can best deliver on identified objectives?	We recommend using an AMC with the objective of incentivizing producers to increase production of cleaner cooling technologies, driving down its costs and enabling a shift to a new market equilibrium involving much higher use of cleaner cooling options (and a reduction in production and use of standard ACs) beyond the AMC's life. The AMC could operate for 4 years, enabling 4-year contracts with producers.
2. What results should be paid for?	To incentivize the substantial scale-up of cleaner cooling options, we propose that the AMC pay for the result of uptake of cleaner cooling options. Specifically, we propose that payment be made to producers for the sale of cleaner cooling options that (1) meet GHGEs and operational criteria and (2) meet a defined threshold of sales above current rates.
3. How much should be paid?	Result price per units and the AMC's overall value must be enough to drive the necessary production scale-up while offering value for money. Given these considerations, for the Indian context, we propose a price per cleaner cooling unit of USD 54 to USD 104, equating to an overall AMC value of USD 196 million to USD 373 million. These prices would translate to a range of approximately USD 21 to USD 40 per tonne of CO_2 abated, illustrating the potential of this mechanism to provide a cost-effective means to deliver climate results for prices below relevant benchmarks.
4. How should results be verified?	We propose the use of an independent third-party verifier to assess that reported sales have been made and meet the defined results criteria.

2.4.1. Which pull finance mechanism can best deliver on the defined objective?

The first design choice is determining which type of pull finance mechanism can best deliver on the objective outlined above by enabling the scale-up of cleaner cooling, reducing costs, and shifting the market to a new equilibrium. Pull finance mechanism options include RBF, Prize-based Challenges, and AMCs (see Box 1 in Section 1 for an overview).

We propose using an AMC as it is best suited to creating the required producer incentives to scale-up production of cleaner cooling technologies and driving down prices. AMCs are commitments to purchase, or to subsidize purchase, of a certain volume of a product at a fixed prize, if the product meets predefined characteristics. In this way, AMCs can encourage technology innovation and uptake.

Responding to the cooling challenge identified above, the AMC would entail paying producers for some threshold of uptake of cooling technologies that meet targets of GHGEs, and other criteria. This incentive structure would play the role of an indirect capacity-forcing contract through quantity-forcing,[53] where producers would be incentivized to increase sales of cleaner cooling options. As detailed below, conditioning payment on consumer demand provides an important market test for the cooling options being funded by the AMC. This is similar to other AMCs such as the GAVI pneumococcal vaccine AMC where funding to producers was conditioned on actual country demand for the available vaccines from GAVI-eligible countries.

Producers could achieve these increased sales by improving cleaner cooling options' affordability to make them more price competitive with standard ACs, but also through other means such as advertising campaigns or reducing the sales of traditional ACs. Consistent with the theory of change presented above, this would enable producers to scale up production, driving down the costs of cleaner ACs, and enabling a new market equilibrium with sustained greater use of cleaner cooling options. While the AMC aims to reduce the use of standard ACs, it does not focus on substituting them exclusively with improved cleaner ACs. The design allows for other technologies to participate. Producers, for example, could participate with cheaper technologies that meet cooling needs.

Importantly, in contrast to an RBF approach entailing per unit payments, the AMC would condition payment on producers achieving a defined threshold of uptake. This enables the AMC to ensure funds are only disbursed if producers achieve the scale-up required to achieve the necessary market shift, facilitating an ongoing transition to cleaner cooling, rather than just a one-off effect during the mechanism's life. Additionally, it facilitates achieving the necessary scale for a market shift, as opposed to the marginal payments of an RBF approach.[54] Further, by paying for increased production, it reduces the deadweight loss of paying for sales that would have happened without the AMC's intervention. These considerations are further detailed in relation to other pull finance options in Table 4, along with examples of where these options have been used.

Likewise, a Prize-based Challenge approach would not help achieve the objective of scaling up production of cleaner cooling options since it would not provide incentives for uptake. It would instead incentivize the development of technologies beyond the current technology frontier, which is unlikely to help the cooling market in LMICs like India in the short term given their underutilization of existing best-in-class technology (like 5-star ACs). It could be coupled with a mechanism focused on uptake to overcome this limitation. However, this creates an additional layer of complexity to the design and might be more suitable for cases where the technological solutions are more uncertain.

53 Kremer, M., Levin, J., Snyder, C. M. (2022). Designing Advance Market Commitments for New Vaccines.

54 While an RBF instrument can establish thresholds to promote this type of impact, its focus remains on marginal improvements compared to AMCs which have a stronger emphasis on innovation and large-scale uptake.

The AMC would operate by setting contracts with individual producers committing to make a defined payment for negotiated sales targets over a defined duration. These contracts would need to provide producers with a clear and credible market signal about the mechanism, the incentives, and its value proposition. Establishing contracts with individual producers facilitates adapting the contracts to their specific context and negotiating with them—without these individual contracts it would be harder to calibrate prices and quantity to achieve the market shift objective, risking the AMC's success. To ensure the producers have the necessary confidence in the mechanism to make investments and scale up production, we suggest the AMC should have a multi-year duration, such as four years (i.e., offering four-year production contracts to the producers), consistent with other AMCs that have operated for three to five years.

2.4.2. What results should the AMC pay for?

Defining appropriate results is central to ensure the AMC can deliver on the defined objective scaling up production of cleaner cooling options to shift the market to a new equilibrium.

To this end, we propose that the AMC pay for the result of uptake of cleaner cooling options. Specifically, we propose that payment be made to producers for the sale of cleaner cooling options that (1) meet GHGEs and operational criteria and (2) meet a defined threshold of sales above current rates. Significantly, these criteria are technology-agnostic while still being close to industry standards that can be easily understood and responded to by producers.

1. Paying for sales that meet GHGEs and operational criteria

The AMC would pay for sales of cleaner cooling options that meet certain criteria. Paying for sales provides a critical market test, providing the strongest indication that the technologies being offered to the market meet consumer needs in terms of characteristics such as affordability, cooling capacity and user-friendliness.

For payments to be made, sales would need to meet criteria in two categories:

1. **GHGEs:** cooling options must be at market frontier in terms of minimizing GHGEs.
2. **Operational:** cooling options must meet basic operational standards in terms of their refrigerant use and cooling capacity.

These proposed criteria tailored to the Indian context are summarized in Table 4 below.

TABLE 4. Proposed criteria for cleaner cooling options

Category	Criterion	Target
GHGEs	Maximum power draw (watts)	Maximum of 1,751 W at full load power.
	Global Warming Potential (GWP) of refrigerants	Maximum of 750 GWP.
	Indian Seasonal Energy Efficiency Ratio (ISEER)	Minimum ISEER of 4.5.
Operational	Cooling capacity	Cooling capacity to deliver 1.5 Tons of refrigeration at outdoor temperatures above 20°C dry bulb temperature (DBT) and maintain below 27°C DBT and 60% relative humidity (RH) indoor conditions.
	Additional safety and operational standards	Compliance with local test market regulations regarding safety and operational standards.[55]

By defining these criteria as the basis for payment for uptake, the AMC would be incentivizing the uptake and scale-up of production of cleaner cooling options at the technology frontier of the Indian market. In particular, the criteria are consistent with the highest rated ACs in the Indian market, those rated 5 stars by the Indian Bureau of Energy Efficiency, which currently enjoy a market share of 18%.[56] These criteria focus on this type of existing technologies since they are the most likely to achieve the desired results. However, the design would not limit payment to this sort of existing technology. Other emerging better technologies that may not be available in the Indian market, such as heat pumps and evaporative cooling, would also be eligible to participate. Payments would only be made on an annual basis for those companies that reach the GHGEs, and operational targets established above.

These criteria and the rationale for their selection are further detailed in the rest of this section. To identify suitable results and criteria, we developed an initial long list of options (see Appendix A) from a review of the key characteristics of cooling technologies and similar efforts to improving cooling technologies such as the Global Cooling Prize and India's Super-Efficient AC Program. We then refined this list based on an assessment of the critical criteria necessary to meet the objective defined in section 2.3 and practical considerations such as measurability and verifiability.

One important criterion considered but not included was affordability. The AMC's core objective to promote more affordable cleaner cooling technologies in the market makes market price a key criterion. Since the high upfront market price of cleaner cooling technologies faced by consumers is the main factor limiting their adoption, ensuring a reasonable price level will help advance the AMC's objective of ensuring the affordability and uptake of cleaner cooling technologies. The pneumococcal vaccine AMC, for instance, included a price cap during the tail period of its implementation.[57]

55 In their absence, international guidelines can be used.
56 11th Technical Committee meeting for Room air conditioners. (2019).
57 Kremer, M., Levin, J., Snyder, C. M. (2022). Designing Advance Market Commitments for New Vaccines.

Given the mechanism described below of contracting the producers for a defined level of sales, however, we propose not including a specific metric for affordability and instead providing producers the flexibility to achieve these sales in the most efficient way possible (e.g., price reductions, but also advertising or reduced production of standard ACs). We expect that this would ultimately achieve the AMC's objective of driving price competitiveness of cleaner cooling options purely through their scaled-up production and subsequent price reduction. Additionally, capping the price may limit the producers' flexibility to overcome the upfront price challenge through alternative means (e.g., financing options, advertising). Also, potential heterogeneity across cooling solutions (e.g., compared to pneumococcal vaccines) may make designing a generally applicable price cap complex.

GHGEs

Clearly, to advance the AMC's objective of promoting the uptake of cleaner cooling options, it must include metrics that ensure its climate credentials. To this end, we propose the following three criteria:

1. **Maximum power draw**, measured in watts (W), represents the maximum power used by the cleaner cooling technology at 100% load. This incentivizes lower indirect GHGEs from energy use. Including power draw in addition to the ISEER as a criterion is intended to prevent improvements in the ISEER without improvements in indirect emissions.
   - **Target:** maximum of 1,571 W at full load power. This is equivalent to the average power draw of a 5-star split AC unit in the Indian market.
2. **Global Warming Potential** (GWP) of refrigerants measures the relative global warming effects of different gases released by the operation of cooling technologies that employ refrigerants. This is the main source of direct emissions from modern AC units.
   - **Target:** maximum of 750 GWP. This is the threshold established by regulations in the European Union[58] and Japan[59] regarding fluorinated gas use in residential ACs.
3. **Indian Seasonal Energy Efficiency Ratio (ISEER)** measures how efficiently a cooling technology can remove heat in the Indian context. More efficient technologies represent lower GHGEs from indirect emissions. Including this criterion also ensures the payment conditions can be clearly understood by producers and other stakeholders, since ISEER and other energy efficiency ratios are the most common approach to evaluate the efficiency of a cooling appliance.
4. **Target:** minimum ISEER of 4.5. This is the minimum ISEER for a 5-star split AC unit as defined by the Indian Bureau of Energy Efficiency Star Rating system.[60]

58 Regulation (EU) No 517/2014 of the European Parliament and of the Council on fluorinated greenhouse gases and repealing Regulation.

59 Revised F-Gas Law in Japan addresses the full lifecycle of HFCs. (2022).

60 Bureau of Energy Efficiency. (2017). particulars and Manner of their Display on Labels of Room Air Conditioners regulations.

Operational

Finally, it is important that payments are only made for cleaner cooling technologies that meet certain basic operational standards in terms of their cooling capacity and other safety and environmental qualities. These include:

- **Cooling capacity:** Tons of refrigeration under specific temperature and humidity conditions. This ensures that the cooling technologies provide at least the same cooling benefits as the standard alternatives under relevant conditions for the Indian market. As described in section 2.3, it is critical that any cooling technology to be able to meet these conditions for it to be competitive with existing standard ACs.
    - **Target:** Cooling capacity to deliver 1.5 Tons of refrigeration at outdoor temperatures above 20°C dry bulb temperature (DBT) and maintain below 27°C DBT and 60% relative humidity (RH) indoor conditions.[61]
- **Additional safety and operational standards:** This does not relate to the technology's climate credentials, but instead ensures that the cooling technologies satisfy basic safety and environmental standards and prevents sacrificing these qualities to achieve better performance in other areas.
    - **Target:** compliance with local or international market regulations regarding safety and operational standards, such as refrigerant characteristics, ensuring the use of zero-Ozone Depletion Potential (ODP), lower toxicity (class A), ISO 5149 or IEC 60335-2-40 standard compliant refrigerants.

2. Paying for uptake based on a threshold of product sales

The AMC would pay producers only for uptake of cleaner cooling options defined in terms of a threshold exceeding previous sales. The sales targets would be negotiated directly with each producer and should cumulatively shift the market for 5-star ACs to a position of market dominance. This could be achieved by establishing contracts with at least four or five of India's 8 large AC domestic and international producers who collectively dominate 95% of the market.[62]

The proposed AMC would establish individual contracts with producers. Since no market-wide coordination is established between producers, the target for these thresholds should reflect what market share would be required to drive down prices of cleaner cooling options to those of standard ACs, which will depend on the manufacturing processes of each producer to be identified during the negotiation process. However, for illustrative purposes for this case, we propose a target market share of cleaner ACs of 66%, which is the market share currently enjoyed by the most common standard AC type in India (3 stars).[63] Lifting 5-star ACs from their current market share of 18% (1.35 million units

61 Sachar, Sneha, Iain Campbell, and Ankit Kalanki, Solving the Global Cooling Challenge. Rocky Mountain Institute. (2018). How to Counter the Climate Threat from Room Air Conditioners.
62 Sun, Shangliao. (2021). Market share of leading AC manufacturers in India FY 2021, by company. Statista.
63 Sun, Shangliao. (2021). Market share of leading AC manufacturers in India FY 2021, by company. Statista.

sold per year) to 66% (4.95 million) would require an increase of 48 percentage points (3.6 million units), which could be achieved with an annual 12 point increase over 4 years (i.e., 900,000 extra units annual). Payments would only be made on an annual basis for those companies that reach their negotiated target as part of the cumulative annual 12 percentage point increase.

Consistent with the benefits of an AMC described above in section 2.4.1, compared to making payments for all sales of cleaner cooling options, paying for a defined threshold of sales above past sales helps ensure that the AMC:

1. Reduces the deadweight loss of paying for sales of 5-star ACs that would have happened without the AMC, helping to ensure the AMC's overall value is reasonable and represents value-for-money.
2. Effectively achieves the desired market shift of driving up production to a level high enough to reduce costs and consequent market prices. The alternative of making payments for each sale without a threshold, risks making substantial payments without achieving the desired threshold of market scale-up.

2.4.3. How much should the AMC pay?

Determining reasonable result prices[64] and an appropriate overall value for the AMC is critical to ensure the AMC's effectiveness and value for money. To this end, prices and the AMC's values should reflect two key considerations:

1. **Sufficiency for market behavior change.** The result prices and the AMC's value must be enough to create sufficient producer incentives to scale up production to the extent required to drive down costs to achieve the targeted new market equilibrium.
2. **Value for money.** Result prices and the AMC's value should be reasonable, ensuring value for money in terms of its cost relative to the climate benefits it would deliver.

Reflecting these considerations, we propose that an AMC focused on India could offer:

1. **A result price per cleaner cooling unit of USD 54 to USD 104**
2. **An overall AMC value of USD 196 million to USD 373 million**
3. **A mitigation cost of USD 21 to USD 40[65] per tonne of CO_2**

As described below, the lower end of the ranges reflects our estimate of price required to drive the necessary producer behavior change and market adjustment. The upper range reflects an estimate of

64 This section refers to the result price/subsidy provided to the producer per unit of result. Note this is different from the price of the appliance.

65 In this report, mitigation costs are understood as the costs associated with the mitigation of a tonne of CO_2 (or equivalent). For this AMC, the mitigation cost estimated can be considered cost-effective in comparison to other climate programs, as detailed in Box 2.

the social value of the anticipated GHGEs reductions directly attributable to the AMC, 2.6 tonnes per unit or approximately 9.4 million tonnes across the program.

These prices provide a range that should be subject of refinement and negotiations for application to the Indian context or other LMICs. These refinements and negotiations should be informed by further market research tailored to each producer seeking to understand factors such as the costs they would face to expand production to the required levels and the reasonableness of the targets we propose.

To create incentives for producers to improve on the maximum threshold of GHGEs defined in section 2.4.2, the AMC could also pay a higher price for products that offer lower emissions. This could entail an additional linear payment function with increased payment (measured as a percentage) in result price per unit for a proportional decrease in GHGEs (measured in percentage of GHGEs reduced). For example, if there is a further 10% improvement in GHGEs savings, the result price per unit of the technology would increase by 10%.

The rest of this section details the methodology and frameworks used for these estimates. To provide several data points necessary for a range of pricing and AMC values, we have developed separate estimates based on methodologies accounting for (1) sufficiency for behavior change and (2) value for money.

1. Sufficiency for producer behavior change

Defining a sufficient per result price per unit is necessary to ensure producers are incentivized to enter contracts and scale up production to reach the targeted new market equilibrium. While the exact price would be subject to negotiation and may vary by company, we suggest a benchmark of USD 54. This value is the product of (a) the current gap in market price between 3-star and 5-star technology in India and (b) a benchmark of per unit payments used to support market transitions for other products and markets. For (a), we find that in India,[66] a common 3-star AC costs around USD 802 and a 5-star AC costs around USD 962, entailing a price gap around USD 160.[67] For (b) we reviewed several similar government programs focused on incentivizing the uptake of cleaner technologies, summarized in Table 5, and found an average of 34% to identify a benchmark portion of the gap to subsidize.[68] Together these figures give a product of USD 54 (i.e., 160 × 34% = USD 54).

66 We considered the most common 3-star and 5-star ACs from the brand with the biggest market share in India as a reference point to calculate these prices. These correspond to Voltas 1.5-ton, inverter split ACs.

67 Voltas. (2022). Average price of the current Indian market.

68 This result price estimation can be refined through projected costs when designing a similar mechanism to ensure the incentives are calibrated to the specific context and industry.

TABLE 5. Summary of subsidy program benchmarking

Program	Description	Country	Market Average Price	Market Best-In Class Price	Percentage (%) Subsidized of the Price Gap
Subsidies for electric vehicles[69]	Tax breaks for electric vehicles of approx. USD 7.5K	United States	USD 47,000[70]	USD 66,000[71]	40%
Subsidies for more efficient break boxes[72]	Subsidies for high-quality electric panels or breaker boxes of approx. USD 1k	United States	USD 851[73]	USD 4,000[74]	32%
Subsidies for induction cooktop[75]	Subsidies for high-quality induction cooktop of approx. USD 750	United States	USD 375[76]	USD 3,000[77]	29%
Appliance replacement programs for washing machines and freezers[78]	Subsidies for the replacement of washing machines and freezers of approx. USD 80[79]	Hungary	USD 331[80]	USD 518[81]	42%
Appliance replacement programs of dishwashers and refrigerators[82]	Subsidies for the replacement of dishwashers and refrigerators of approx. USD 106[83]	Croatia	USD 360[84]	USD 787[85]	25%

Along with a sufficient result price per unit, the AMC's overall value must be sufficient to justify the investment necessary to substantially scale-up production. To this end, we propose the AMC should have a value of at least USD 195.7 million. This estimate is a product of the result price per unit estimated above (USD 54) and the objective defined in section 2.4.2 to increase production of cleaner cooling options by 48 percentage points, requiring an increase of 3.6M units (i.e., USD 54 × 3.6 million = USD 195.7 million). On an annual basis, the AMC would pay out USD 48.9 million, consistent with

69 U.S Department of Energy. (2022). Federal Tax Credits for New All-Electric and Plug-in Hybrid Vehicles.
70 Cox Automotive. (2022). New-Vehicle Prices Flirt with Record High in May, According to Kelley Blue Books, as Luxury Share Remains Strong.
71 Electrek. (2022). Average electric car price.
72 The Center of American Progress Action Fund. (2021).
73 HomeGuide. (2022). How Much Does It Cost To Upgrade Or Replace An Electrical Panel?
74 HomeGuide. (2022). How Much Does It Cost To Upgrade Or Replace An Electrical Panel?
75 The Center of American Progress Action Fund. (2021).
76 Fixr. (2022). How Much Does It Cost to Install a Cooktop?
77 Fixr. (2022). How Much Does It Cost to Install a Cooktop?
78 Subsidies for Energy Efficient Appliances: Consumer Response and Program Design. (2019).
79 32,000 Hungarian Forint.
80 Price info. (2022). Price Hungarian info.
81 Price info. (2022). Price Hungarian info.
82 Subsidies for Energy Efficient Appliances: Consumer Response and Program Design. (2019).
83 800 Croatian Kuna.
84 Sancta Domenica. (2022). Sancta Domenica.hr.
85 Sancta Domenica. (2022). Sancta Domenica.hr.

section 2.4.2's proposal for a gradual increase in 5-star AC market share of 12 percentage points per annum (i.e., USD 54 × 900,000 = USD 48.9 million).

2. Value for money—how much value could the AMC deliver in terms of GHGEs abated?

This approach entails estimating the social value of the GHGEs that would be avoided if the desired results are achieved, providing an indication of the reasonableness and upper bound for result price per units and total value for the AMC. Using this method, we estimate that the AMC would deliver a social value per unit of USD 104. This estimate is based on the following assumptions (which give USD 40 × 2.6 = USD 104):

1. Substituting sales of standard ACs with cleaner cooling options that meet the criteria described in section 2.4.2, would deliver an average estimated 2.6 tonnes of GHGEs of avoided emissions per unit over 10 years, as reflected in Table 6 (27.2 GHGEs—24.6 GHGEs).
2. That each tonne of GHGEs avoided can be valued at USD 40, reflecting benchmarks presented by the Carbon Pricing Leadership Coalition.[86]

The AMC's total social value from this methodology is estimated at USD 373.2 million based on the assumption the AMC would directly pay for 3.6 million units of cleaner cooling options if the targets described in section 2.4.2 are met and avoid 9.4 million tonnes of GHGEs (i.e., USD 104 × USD 3.6 million = USD 373.2 million).

TABLE 6. Summary of GHGEs per cooling technology

Model (Voltas)	kW Consumed at 100% Capacity (1)	Hours Used Daily (2)	Power Consumption in kWh at 50% capacity (3) [(1) × (2)] 50%	GHGEs per Hour (4)	Days Used Monthly (5)	Months Used Yearly (6)	Lifecycle (years) (7)	GHGEs per Lifecycle (3) × (4) × (5) × (6) × (7)
3-Star Inverter Split AC	1.7	5.4	4.5	0.0021	20	12	10	27.2
5-Star Inverter Split AC	1.6	5.4	4.2	0.0019	20	12	10	24.6

Note: (1) Voltas ACs power draw technical specifications;[87] (2) average hours of ACs use in India;[88] (4) kWh converted to GHGEs;[89] (5) and (6) are average days and months of ACs use in the Indian context[90] and (7) is the average life cycle of ACs.[91]

86 Carbon Pricing Leadership Coalition. (2017). Report of the High-Level Commission on Carbon Prices. World Bank Group.
87 Voltas (2022) https://voltaslounge.com/.
88 Carbon Copy (2021) Study Charts Rapidly Changing Cooling Patterns In India's Urban Jungles https://carboncopy.info/study-charts-rapidly-changing-cooling-patterns-in-indias-urban-jungles/.
89 GHGEs calculator: https://www.epa.gov/energy/greenhouse-gas-equivalencies-calculator.
90 Carbon Copy (2021) Study Charts Rapidly Changing Cooling Patterns In India's Urban Jungles https://carboncopy.info/study-charts-rapidly-changing-cooling-patterns-in-indias-urban-jungles/.
91 Karkour, Salim. (2021). Life Cycle Assessment of Residential Air Conditioners Considering the Benefits of Their Use: A Case Study in Indonesia. Energies; Huang, Huiting. (2020). Gap between discarding and recycling: Estimate lifespan of electronic products by survey in formal recycling plants in China. Resources. Conservation and Recycling; Cielo. (2022). How Long Do Air Conditioners Last—AC Lifespan Guide.

The estimated social value presented here should be considered as a conservative lower bound of the AMC's potential value as the estimate only accounts for the AMC's:

1. **Climate benefits.** This pricing methodology focuses on climate benefits and does not include the substantial development benefits detailed in section 2.2 that the AMC could deliver for India and other LMICs. If these additional development benefits were valued and included, the AMC's value would be higher.
2. **Direct benefits** of the cleaner ACs explicitly paid for by the AMC. By only considering the direct benefits of cleaner ACs purchased by the AMC, we omit the future GHGEs savings achieved as a result of the market's new equilibrium of much lower use of standards ACs and increased use of cleaner ACs. Depending on estimates of how quickly this shift would have occurred without the AMC, this benefit could be several multiples of the direct benefits estimated here.

The total AMC values recommended here are reference values based on the two methods used to estimate the results price and number of units required to achieve its goal, but these values should be calibrated through further market analysis, stakeholder engagement and negotiations. The AMC could operate at different scales depending on the number of units and subsidy per unit resulting from the pre-design analysis, and the existing capacity and needs of the parties involved. As outlined below, AMCs smaller than USD 196 million could achieve results in incentivizing producers to improve the sales of cleaner cooling technologies and provide learnings about this type of incentives in the cooling space. However, setting a lower level of AMC funding risks not generating a significant market shift, undermining the potential for a long-term impact in the cleaner cooling market. Nevertheless, starting small and then scaling after initial results are verified and confidence in the potential of the mechanism increases could provide a pathway to the necessary scale.

BOX 2. Value-for money: benchmarking the cost-effectiveness of the proposed AMC

The cost of mitigating a tonne of CO_2 (or equivalent) provides a useful reference for benchmarking the cost-effectiveness of alternative climate investments.[92] For the proposed AMC, this cost ranges from USD 21 to USD 40, the quotient between the proposed overall AMC value (USD 196 million to USD 373 million) and the expected emissions abated (9.4 million tonnes of GHGEs).

This range represents a highly competitive price compared to other climate investments. For instance, the Green Climate Fund (GCF) and the Clean Technology Fund (CTF) have an estimate average cost effectiveness across all programs of approximately USD 42 and USD 144 respectively.[93]

92 Juden, M. and Mitchell, I. (2021). Cost-Effectiveness and Synergies for Emissions Mitigation Projects in Developing Countries. CGD Policy Paper 204. March 2021. Center for Global Development.

93 Juden, M. and Mitchell, I. (2021). Cost-Effectiveness and Synergies for Emissions Mitigation Projects in Developing Countries. CGD Policy Paper 204. March 2021. Center for Global Development.

Considering just the energy efficiency programs of these funds, costs range from USD 3.40 to USD 71.[94] Likewise, a specific energy efficiency program in China focused on clean cooking had a range of USD 12 to USD 85. Together, these data points illustrate the relative cost effectiveness implied by a range of USD 21–40, which lies below the GCF and CTF averages and at the lower end of most data points.

TABLE 7. Mitigation costs benchmark

Program	Mitigation Cost (USD) per Tonne of CO_2
Across GCF's programs	42
Across CTF's programs	144
Across GCF's and CTF's energy efficiency programs	3.40–71
Clean cooking program in China	12–85

BOX 3. Pricing risks

Consistent with the framework presented in this section, to ensure the AMC´s success and value for money, the finalization of pricing before launch should account for the risks of underpaying or overpaying for results.

Underpaying: Underpaying for the desired results would mean producers are unwilling to enter into contracts to deliver the AMC's defined targets. If few producers sign-up, the expect market shift would not occur. While this would reduce the cost of the AMC, it could mean any funding paid out has limited impact without achieving a long-lasting market impact.

As defined above, this risk can be mitigated by the AMC defining a threshold for minimum production expansion by producers and the industry as a whole—if these thresholds are not agreed to by producers for the prices on offer, the AMC should not proceed, avoiding the waste of donor resources.

Overpaying: Given information asymmetry between the AMC and producers regarding producer costs and operations, it may be difficult to reach a fair price, risking overpayment relative to what is necessary for producer participation and achieving the required market shift.

While this risk cannot be eliminated, it can be mitigated by thorough market research, engagements, and negotiations. Further, provided payments are within the upper range defined here, these payments would represent good value for money relative other climate investments.

94 Juden, M. and Mitchell, I. (2021). Cost-Effectiveness and Synergies for Emissions Mitigation Projects in Developing Countries. CGD Policy Paper 204. March 2021. Center for Global Development.

2.4.4. How should results be verified?

Verification is the process of confirming the performance of the producers prior to making the corresponding payments. The proposed AMC must include verification methods for the uptake of cleaner cooling options and for the criteria these options must meet to be eligible for payments, as proposed in this section.

Roles and responsibilities

- **Producers:** The participating producers submit the required evidence and documentation on sales and the criteria to the pull finance mechanism managing body.
- **Third-party verifier:** The third-party verifier confirms the number of sales and that sale meet the defined criteria and informs the AMC's managing body. This is consistent with mechanisms like the Pneumococcal AMC,[95] AgResults,[96] and multiple RBF mechanisms[97] which employed third party actors. The use of third parties strengthens the rigor and legitimacy of the verification process by avoiding conflicts of interests and allows access to external specialized organizations to carry out this process. Depending on the specific verification requirements and funding, potential third-party verifiers include organizations specialized in program evaluation (e.g., IDinsight, Innovations for Poverty Action), auditing firms (e.g., Deloitte), technical organizations (e.g., third-party certifiers of AC technical specifications), or another independent actor as available.
- **AMC managing body:** This actor coordinates the verification process, receives reports from the producers, shares the reports with the third-party verifier, and makes payments based on the reports of the verifier.

Process

The pull finance mechanism must verify two main elements: the achievement of the criteria for payments, and the uptake of cleaner cooling technologies.

- **Criteria:** the verification of the GHGEs and operational criteria is required to ensure producers are being paid for products that meet the basic requirements of the mechanism. This can be performed as an initial step of the producer engagement with the pull finance mechanism. The producers can provide the relevant evidence to the pull finance managing body. This can then be confirmed by the third-party verifier through additional testing and secondary sources. Additionally, the third-party verifier can confirm that these criteria continue being met during the implementation by performing spot-checks. If non-ACs

95 GAVI The Vaccine Alliance. (2021). Independent Assessment Committee.

96 AgResults Innovation in research and delivery. (2021). Impactful design at a glance: verification and project management.

97 Instiglio. (2017). A practitioner's guide to Results-based Financing: Getting to Impact.

technologies are incentivized through the mechanism, the verifier will also define the appropriate mechanisms for assessing their performance.

- **Uptake:** the mechanism will need to verify sales of cleaner cooling units. The producer can provide administrative documentation on sales to the pull finance managing body. The third-party verifier can then validate this information by reviewing additional documentation and reaching out to other actors involved in the process (e.g., consumers). This can be performed throughout the implementation to enable annual payments.

Any discrepancies between reported and verified information can be reviewed and discussed by the three actors. Any discrepancy remaining after review can lead the payments to be reduced in a proportional measure (e.g., if 10% of the reported sales cannot be verified, they will not be paid for by the mechanism).

BOX 4. Verification design risks

The centrality of successful verification the AMC´s rigor requires careful management of the risks relating to perceptions of the legitimacy of the verification process and timeliness of the verification.

1. **Legitimacy of the verification process:**[98] producers may question the reliability of the verification process, since the AMC managing body represents the interests of the organizations that pay for the results. This can be mitigated in two ways:
    a) Including a third-party verifier in the process. Since this actor would not have vested interests in the process, they would confer legitimacy to the verification results.
    b) Establishing a clear mechanism for addressing discrepancies and disputes, and where producers can appeal verification results
2. **Timing risks:** external factors can limit the mechanism's capacity to perform the verification process in a timely way. This would delay payments and can affect the accurate measurement of the results. It can be mitigated by defining strategies to address these situations and clear decision-making processes to trigger them.

3. Stubble burning pull finance mechanism

This section presents the case for a pull finance mechanism to drive the development and uptake of technological alternatives to stubble burning in LMICs and details how this could be achieved with a design prototype. Section 3.1 introduces the challenge presented by stubble burning and a proposed pull finance mechanism. Section 3.2 describes the potential climate and development benefits from the reduction of stubble burning in LMICs. In Section 3.3 we describe the challenge of driving increased uptake of technological alternatives to stubble burning and outline the objective of a pull finance

98 Loening, E., and Tineo, L. (2012). Independent Verification in Results-Based Financing.

mechanism able to address this problem. Section 3.4 then presents a detailed design prototype of the proposed pull finance mechanism.

3.1. Introduction

Stubble burning is a widespread and common practice used to discard crop residues by burning leftover straw or stubble to clear the soil and fields for the next crop. Being an easy, affordable, and quick way of managing stubble, it is widely adopted in some LMICs such as India, Pakistan, and Indonesia. This practice, however, contributes to air pollution and climate change, posing risks for humans, agriculture, and ecosystems.

Stubble burning is particularly prevalent in India due to intense rotational rice and wheat cultivation in North-Western states (e.g., Punjab, Haryana, and Western Uttar Pradesh). In the Punjab region alone, an area of approximately 120 million hectares[99] (representing approximately 43% of rice crops) are managed using stubble burning with major climate implications. While alternatives to stubble burning exist, their adoption has been low due to high costs and lack of user-friendliness, among other factors. This is the case despite attempts by government and other actors to reduce stubble burning, ranging from banning and issuing fines for stubble burning to developing alternatives and rewarding or incentivizing farmers to take them up.[100]

Pull finance could respond to this challenge by incentivising a shift towards stubble management alternatives. In particular, to help overcome current barriers to adoption, pull finance could be used to provide a time-limited incentive to promote improvement, innovation, and sustained use of alternatives to stubble burning, potentially driving down the cost of these alternatives, increasing the economic returns they provide, and improving their user-friendliness closer to parity with burning.

In this case, we concentrate on stubble burning in North-Western India. As detailed below, reducing stubble burning using the proposed pull finance mechanism would deliver significant climate and development gains. This case focuses on North-Western India as it represents a significant share of the stubble burning problem and this focus enables a more concrete and locally tailored case to serve as an actionable reference point to expand the mechanism to other LMICs.

The rest of section 3 presents the benefits that could be achieved from successfully reducing stubble burning (3.2), describes the challenge of responding to this need and how a pull finance mechanism could help (3.3), and details a proposed design prototype (3.4).

99 Anju, C. (2021). Year ending but no end to stubble burning Punjab burns 43% of total area under paddy till Nov 15.
100 BBC News (2020). Stubble burning: Why it continues to smother north India.

3.2. Climate and development benefits

This section details the potential climate and development impacts of successfully advancing the use of technologies that replace the practice of stubble burning. It addresses the anticipated climate and development benefits in turn by outlining the climate and development problems caused by the current and likely future reliance on stubble burning and presents the potential benefits of transitioning to the use of cleaner alternate technologies.

3.2.1. LMICs reliance in stubble burning sets significant climate and development challenges

Stubble burning is a major driver of climate change and poses significant health risks along with negative economic consequences. Stubble burning releases harmful gases such as CO_2 and particulate matter, including black carbon.[101] Air pollution caused by stubble burning is responsible for a range of health conditions from eye irritation to severe respiratory diseases and lung cancer.[102] Moreover, stubble burning has the potential to reduce soil fertility and water quality, negatively affecting agricultural production, ecosystems, and wildlife. As such, stubble burning represents a major financial burden for LMICs in which this practice is common. In India alone, the health and economic costs of crop residue burning is estimated to be USD 300 billion annually.[103]

Limiting stubble burning would reduce GHGEs, benefit human health, and yield economic returns.[104] We outline these climate and development benefits in the next subsections.

3.2.2. Avoiding stubble burning can deliver significant climate benefits

Stubble burning is a significant driver of climate change. This practice accounts for around 10% of global GHGEs[105] and constitutes more than one-third of the global emission from biomass incinerations.[106]

Beyond CO_2, stubble burning is an important source of other harmful emissions. Open burning is the world's major source of black carbon, a pollutant with a warming impact 460–1500 times

101 Black carbon is a highly pollutant type of particulate matter has a warming impact on climate 460–1,500 times stronger than CO_2 per unit of mass.

102 4.5 million people are estimated to have died prematurely in 2019 from outdoor air pollution (from PM2. 5 and ground-level ozone). Global Burden of Disease. (2019). Data Review: How many people die from air pollution?

103 Chakrabarti, S. et al. (2019). Risk of acute respiratory infection from crop burning in India: estimating disease burden and economic welfare from satellite and national health survey data for 250 000 persons. International Journal of Epidemiology. And Corrigendum (2020).

104 Chakrabarti, S. et al. (2019). Risk of acute respiratory infection from crop burning in India: estimating disease burden and economic welfare from satellite and national health survey data for 250 000 persons. International Journal of Epidemiology. And Corrigendum (2020).

105 Abdurrahman, M. (2020). Stubble burning: Effects on health & environment, regulations, and management practices. Environmental Advances.

106 Yale School of the Environment. (2021). A marketplace solution to burning crop stubble earns YSE team top honors.

stronger than CO_2.[107] It is estimated that stubble burning is responsible for one third of total black carbon emissions globally. Adoption of alternatives to stubble burning could reduce associated black carbon emissions by 50%.[108] Along with CO_2 (91.6% of emissions), stubble burning also releases carbon monoxide and sulphur.[109]

India is a major contributor to stubble burning. Around 4 million hectares of rice and wheat cropping annually produce 34 million tons of stubble in India. Approximately 23 million tons of this residue is burnt every year in open fields.[110] As a result, India contributes approximately 12.2% of the total GHGEs produced from stubble burning.[111] The total national annual CO_2 emission from crop residue burning is more than 64 times the total annual CO_2 pollution emission of Delhi.[112]

3.2.3. Avoiding stubble burning can deliver significant development benefits

Apart from its climate impacts, stubble burning is also associated with adverse social and economic development effects. A recent study estimates the health and economic costs of crop residue burning in North-Western India to be around USD 300 million annually.[113] These estimates also indicate that, in five years, the economic loss due to stubble burning is going to be nearly 1.7% of India's GDP.[114] Alternatives to stubble burning are estimated to be able to save 190,000 lives globally every year.[115]

Stubble burning has serious effects on health, productivity, and economic activity:

Stubble burning is associated with adverse effects on human health. Stubble burning is responsible for higher risk of respiratory infections, lung cancer, eye irritation, and cardio-pulmonary disorders among people who live in its proximity.[116] In 2017, more than 1.24 million people died globally because of air pollution. Approximately 670,000 of these deaths were attributed to particulate matter emissions,[117] which is one of main effects of stubble burning in India. These health effects are not limited to burning areas, but affect cities distant from the countryside, since ash clouds can travel

107 CCAC (2019). India is Burning, here is how to Stop it. Climate and Clean Air Coalition.
108 CCAC (2015). Why Move from Agricultural Burning towards no-Burn Alternatives? Open Agricultural Burning Factsheet. Climate and Clean Air Coalition.
109 Abdurrahman, M. (2020). Stubble burning: Effects on health & environment, regulations, and management practices. Environmental Advances.
110 IOP Conference Series: Earth and Environmental Science. (2021). Field crop residue burning Induced Particulate Pollution in NW India- Policy challenges & way forward.
111 Business Standard. (2022). Crop fire take India's global contribution to GHG emissions.
112 Down to earth. (2017). India's burning issue of crop burning takes a new turn.
113 Chakrabarti, S. et al. (2019). Risk of acute respiratory infection from crop burning in India: estimating disease burden and economic welfare from satellite and national health survey data for 250 000 persons. International Journal of Epidemiology. And Corrigendum (2020).
114 International Food Policy Research Institute. (2019).
115 CCAC (2015). Why Move from Agricultural Burning towards no-Burn Alternatives? Open Agricultural Burning Factsheet. Climate and Clean Air Coalition.
116 IOP Conference Series: Earth and Environmental Science. (2021). Field crop residue burning Induced Particulate Pollution in NW India- Policy challenges & way forward.
117 Environmental advances. (2020). Stubble burning: Effects on health & environment, regulations, and management practices.

for more than 1,000 kms. Acute Respiratory Infection symptoms in Haryana, for example, are positively correlated with the number of fires observed by the MODIS satellite in this state, with these symptoms being more frequently reported in urban than in rural areas.[118] The economic impact of these health risks is high. For example, annual healthcare expenses in Punjab for treating ailments caused by stubble burning are nearly USD 1M.[119]

Stubble burning hinders agricultural productivity. This practice damages soil fertility and water quality due to the loss of important soil nutrients critical for food production from temperature increases and the alteration of rainfall patterns. This leads to events such as acid rain and haze, impeding eutrophication, ultimately affecting ecosystems and wildlife. Specifically, stubble burning is estimated to reduce water retention and soil fertility by between 25% and 30%.[120] The monetary cost of burning to Punjab farmers in India is estimated to be between USD 100M and 307M every year in terms of nutritional loss and between USD 63M and 188M in the form of government subsidies of nitrogen, phosphorus, and potash fertilizers. These costs could be avoided or reduced by replacing stubble burning with alternatives.[121]

Stubble burning can negatively impact other economic activities. For instance, the number of tourists in Delhi has decreased in recent years by about 25–30%, and this has been attributed in part due to the increase in air pollution.[122] Worker productivity, because of factors such as sickness and visibility, can also be negatively affected due to air pollution. Additionally, smog caused by stubble burning causes major transportation disruptions.[123]

3.3. The stubble burning challenge and pull finance mechanism objective

This section illustrates the challenge of reducing stubble burning in LMICs and defines the objective of a pull finance mechanism to respond to this challenge. We first provide an overview of the existing technological alternatives to stubble burning. We then present two scenarios: business-as-usual, where current stubble burning trends continue, and a target scenario in which alternatives to stubble burning are adopted. The objective of the pull finance mechanism is then defined along with how it can be achieved.

118 International Journal of Epidemiology. (2019). Risk of acute respiratory infection from crop burning in India: estimating disease burden and economic welfare from satellite and national health survey data for 250 000 persons.
119 Down to earth. (2017). India's burning issue of crop burning takes a new turn.
120 UNEP. (2021). Toxic blaze: the true cost of crop burning.
121 Down to earth. (2017). India's burning issue of crop burning takes a new turn.
122 Environmental advances. (2020). Stubble burning: Effects on health & environment, regulations, and management practices.
123 Shyamsundar, P. et al. (2019). Fields on fire: Alternatives to crop residue burning in India. Science. 365. 536–538.

3.3.1. Despite alternatives, stubble burning is the leading method of disposing stubble

Stubble refers to the cut stalks left behind after harvesting rice or other crops with the most prevalent machinery (i.e., the *combined harvester*).[124] After harvesting, stubble needs to be disposed quickly (10–15 days) to allow for the wheat farming cycle to start. Farmers have three main broad options for managing the stubble, involving five technology alternatives[125] that are detailed in Table 8 (rows (1) to (5)). Farmers can:

1. Burn the stubble (1)
2. Cut the stubble, or mix it with the soil using additional machinery such as a happy seeder[126] (2), a rotavator[127] (3) or a baler[128] (4)
3. Decompose the stubble using enzymes (5)

The alternatives to stubble burning are not heavily adopted. For example, in North-Western India 30% of land is harvested manually, and therefore no burning is expected, while the *combined harvester* is used for the remainder.[129] Approximately 56% of paddy area is burned, while the rest is managed with a combination of alternatives, as described in Table 8, along with the climate and market position of these practices.[130]

Despite the alternatives, stubble burning is the primary method of crop residue management in many LMICs,[131] driving the climate and development challenges mentioned above. The dominance of stubble burning over alternatives reflects the following factors:

- **Upfront cost.** Stubble burning is the established practice, so farmers already have the necessary equipment for burning stubble in their fields. Alternatives, on the other hand, require significant upfront investments.[132] For example, the Happy Seeder needs to be used with a tractor for a total cost of ~USD 15,000, leaving this option out of reach for most

124 An agricultural machine that reaps, threshes, and cleans a cereal crop in one operation. It leaves behind a stubble that is usually burnt.

125 We select 3 main stubble burning alternatives based on their market share and use frequency as described in Shyamsundar, P. et al. (2019). We additionally include the bio-decomposer as an example of an innovative option, although it is at an early stage.

126 A Happy Seeder is a machine developed by the Indian Council of Agricultural Research (ICAR), as an alternative to stubble burning.

127 A rotavator is a machine which can breakup, churn and aerate the soil. It has a set of blades that remove weeds and prepares the soil for planting.

128 A baler is a machine that cuts, collects, and compacts crops.

129 If the harvest is done manually, the straw is collected from the stem and the disposure can be sold or re-incorporated.

130 Shyamsundar, P. et al. (2019). Fields on fire: Alternatives to crop residue burning in India. Science. 365. 536–538.

131 Cassou, Emilie. (2018) Field Burning. Agricultural Pollution; World Bank, Washington, DC; CCAC (2015). The Demise of Open Agricultural Burning: South America Leading the Way. Climate and Clean Air Coalition and Open agricultural burning and CCAC (2015). Why Move from Agricultural Burning towards no-Burn Alternatives? Open Agricultural Burning Factsheet. Climate and Clean Air Coalition.

132 Shyamsundar, P. et al. (2019). Fields on fire: Alternatives to crop residue burning in India. Science. 365. 536–538.

farmers.[133] Additionally, low enforcement of stubble burning regulation has contributed to maintaining this status quo by facilitating the continued use of this established practice without significant individual consequences.

- **Availability.** The time window between rice harvesting and wheat sowing is short (10–15 days), and farmers need timely access to alternatives to access this time window and avoid incurring additional costs and crop losses.[134] Pooling resources among farmers to buy a Happy Seeder and rotating the equipment is therefore not possible as farmers require the equipment at the same time.[135] In comparison, stubble burning is an immediate, individual solution and hence is unaffected by this challenge.
- **User-friendliness.** While technologies such as bio-decomposers and the Happy Seeder can effectively dispose of stubble, they are complex processes. They may involve operating several machines, in addition to careful financial and agricultural planning.[136] Thus, farmers often require training and demonstrations to acquire the knowledge and skills for their implementation.[137] In contrast, stubble burning does not require mechanization, it is intuitive, and can be delivered without previous practice.
- **Awareness and trust.** Farmer knowledge and trust on the benefits of alternatives to stubble burning is limited due to low adoption levels. According to one survey among Punjab farmers, only 50% of farmers were aware of the potential of increasing yields by using the Happy Seeder, around 10% were using the Happy Seeder, and only 12% had a close contact in their network that was using the technology. Since farmers learn from each other, lack of adoption examples in their network limits confidence in the technology.[138]

133 BBC News. (2020). Stubble burning why it continues to smother north India.

134 Bhatt, et al. (2022). Incentivizing Alternatives to Agricultural Waste burning in Northern India: Trust, Awareness, and Access as Barriers to Adoption. Research Square.

135 Your connection with rural India. (2022). Subsidy worth crores, monetary fines and seeder technology too; but no end to stubble burning In Punjab.

136 Bhatt, et al. (2022). Incentivizing Alternatives to Agricultural Waste burning in Northern India: Trust, Awareness, and Access as Barriers to Adoption. Research Square.

137 Shyamsundar, P. et al. (2019). Fields on fire: Alternatives to crop residue burning in India. Science. 365. 536–538.

138 Shyamsundar, P. et al. (2019). Fields on fire: Alternatives to crop residue burning in India. Science. 365. 536–538 and Supplementary Material File aaw4085-data_figures_tables.xlsx, Table S18 and S19.

TABLE 8. Stubble disposure alternatives in India

Stubble Disposure Alternative[139]	Description	Prevalence	Advantages/Disadvantages	Climate Impact	Upfront Cost and Net Profits[140]
(1) Stubble burning: Combined harvester+ Burn + Disc Harrow + Conventional Seeder	The process that leads to stubble burning entails three main productive stages: *straw/stubble management, land tillage* and *seeding*. It consists of harvesting with the combined harvester, which cuts the straw, and then burning it in the field.	Approx. 70% of rice-wheat systems in Punjab and Haryana use conventional tillage (combined harvester), and hence, the Burn + Disc Harrow + Conventional Seeder remains the most common stubble management method.[141]	One of the advantages of this approach is its relatively user-friendliness and low cost. It also destroys weeds, including those that are resistant to herbicides. However, this method results in loss of nutrients from the soil, increasing fertilizer requirement and damaging soil microbes and fauna. Also, it has an adverse effect on human health and economic activities.	Burning has severe climate implications, emitting much more CO_2 than alternative methods. The CO_2 equivalent emitted by the Burn + DH + CS system is of 4.7 tonnes.	Burning has almost zero upfront costs as it does not involve any machinery or specific training. The net profit per hectare per year associated with stubble burning is around USD 707.
(2) Mulch + Happy Seeder (HS)	The Mulch + HS process[142] entails two productive stages: *straw/stubble management* and *seeding*. In it, a layer of undecomposed material is applied to the surface of the soil and then the HS shreds the straw and seeds wheat simultaneously.	The Mulch+ HS has had an increasing usage level thanks to government subsidies. Approx. 5,000 hectares of paddy area were under this alternative in 2017[143] and it was expected to grow by 700,000[144] hectares in 2019.	One of the benefits of this alternative is the conservation of soil moisture, improving fertility and health of the soil, reducing weed growth, and enhancing the visual appeal of the area. However, many farmers cannot afford the upfront cost of a tractor or the ongoing diesel fuel costs required to operate the HS.[145]	The mulch +HS has low climate implications as it is the less polluting alternative.[146] The CO_2 equivalent emitted by the Mulch + HS process is of 0.93 tonnes.[147]	Mulch + HS has a high upfront cost (around US 1,800[148]) but also requires extra machinery that increases the general costs. However, the net profit per hectare per year is around USD 847,[149,150] which is higher than burning.

139 To explore detailed information about the disaggregate stubble disposure alternatives see Appendix A.
140 Economic impact defined as the net profit (the difference between monetary input costs and monetary output revenue).
141 Shyamsundar, P. et al. (2019). Fields on fire: Alternatives to crop residue burning in India. Science. 365. 536–538.
142 Mulch can be spread mechanically or manually, but mechanic mulch has a higher market share and level of usage from farmers In any case, both processes are similar.
143 Shyamsundar, P. et al. (2019). Fields on fire: Alternatives to crop residue burning in India. Science. 365. 536–538.
144 Shyamsundar, P. et al. (2019). Fields on fire: Alternatives to crop residue burning in India. Science. 365. 536–538.
145 Effective altruism Forum. (2021). Notes: Stubble Burning in India.
146 Listed in this document with the available information.
147 Authors estimation based on data available in Shyamsundar, P. et al. (2019). Fields on fire: Alternatives to crop residue burning in India. Science. 365. 536–538.
148 Ideas for India, for more evidence based-policy. (2016). Happy Seeder: A solution to agricultural fires in north India.
149 Authors estimation based on data available in Shyamsundar, P. et al. (2019). Fields on fire: Alternatives to crop residue burning in India. Science. 365. 536–538.
150 For more desegregate information of profit, GHGE, Water withdrawals and particulate matter see Appendix A.

Stubble Disposure Alternative	Description	Prevalence	Advantages/Disadvantages	Climate Impact	Upfront Cost and Net Profits
(3) Incorporation + Rotavator/ Disc harrow (DH) + conventional seeder (CS)	The Incorporation + Rotavator/Disc Harrow + Conventional Seeder system acts in three productive stages: *straw/ stubble management, land tillage* and *seeding*. It consists in chopping the straw and preparing the soil with a Rotavator or Disc Harrow. Then, after the land is prepared, wheat seeds are spread in the crop.	Low prevalence (no information available)	One of the advantages of this alternative is that it creates a solid soil structure that allows higher agricultural output, and hence higher net profit.	The incorporation + Rotavator/Disc Harrow+ Conventional Seeder has some climate implications. The CO_2 equivalent emitted by the Incorporation + Rotavator/Disc Harrow + Conventional Seeder system is of 1.5 tonnes[151] which is still high compared with the less polluting technology (Mulch + HS).	In terms of private benefits, it does not provide any advantage over stubble burning as the net profit per hectare per year is around USD 682.[152]
(4) Bailing + zero till	The bailing + zero till process is an alternative for *straw/stubble management* and *seeding* that consists in cutting the stubble with a shaver or baler and then seeding without tilling the land.	Low prevalence (no information available)	One of the advantages of this alternative is that the stubble can be converted into bioenergy with a specific process and machinery. However, bale systems provide no private significant advantage over burn systems as rice residue that is removed for baling is usually bartered and not sold.[153]	The Bailing + zero till alternative has low climate impact implication. The CO_2 equivalent emitted is of 0.99 tonnes,[154] which is not far from the GHGEs of Mulch + HS.	In terms of private benefits, bailing + zero till does not provide significant advantages over stubble burning as the net profit per hectare per year is around USD 774.[155]

151 Authors estimation based on data available in Shyamsundar, P. et al. (2019). Fields on fire: Alternatives to crop residue burning in India. Science. 365. 536–538.

152 For more desegregate information of profit, GHGE, Water withdrawals and particulate matter see Appendix A.

153 Shyamsundar, P. et al. (2019). Fields on fire: Alternatives to crop residue burning in India. Science. 365. 536–538.

154 Authors estimation based on data available in Shyamsundar, P. et al. (2019). Fields on fire: Alternatives to crop residue burning in India. Science. 365. 536–538.

155 For more desegregate information of profit, GHGE, Water withdrawals and particulate matter see Appendix A.

Stubble Disposure Alternative	Description	Prevalence	Advantages/Disadvantages	Climate Impact	Upfront Cost and Net Profits
(5) Bio-decomposer	The bio-decomposer is an alternative method for *straw/stubble management* that decomposes the stubble and turns it into manure.	Very low prevalence (no information available)	One of the advantages of the bio-decomposer is that it is user-friendly due to its simple implementation: diluting tablets of bio decomposers in water and applying it to stubble.[156] However, the timing of the process is very long for agricultural purposes. For example, the IARI[157] recently released a proprietary microbial solution that decomposes rice stubble in 15–25 days.[158]	The bio-decomposer has climate advantages as it cuts back on the emission of GHGE and prevents the release of toxins and soot into the air.[159]	The bio-decomposers have low upfront costs in comparison to other alternatives, like Mulch + HS. For instance, it is estimated to be around USD 0.625 per hectare.[160] There is no reliable information available regarding its profitability.

Note: Alternatives to stubble burning apply in different farming phases: 1) *Straw and stubble management phase:* mulch, bailing, incorporation, and burn. 2) *Land tillage and preparation phase*: rotavators, disc harrows, tine harrows and plankers and 3) *Seeding phase:* Happy seeders, conventional seeders and rotaseeders

156 Ministry of Agricultural and farmers welfare. (2021). Indian Agriculture Research Institute.
157 Ministry of Agricultural and farmers welfare. (2021). Indian Agriculture Research Institute.
158 Effective altruism Forum. (2021). Notes: Stubble Burning in India.
159 Hindu BusinessLine. (2021). From Waste To Wealth: An alternative to Punjab's crop stubble burning.
160 Indian Agriculture Research Institute. (2021).

3.3.2. The dominance of stubble burning reflects a market failure

The dominance of stubble burning represents a market failure due to its substantial negative climate and development externalities. The private cost of burning stubble does not reflect the negative public externalities it generates, in terms of emissions, along with the other development challenges like health and economic impacts. This, added to its relatively low upfront cost and its status as the established practice gives it an advantage compared to stubble burning alternatives. As explained above, alternatives that could eliminate negative externalities do not directly benefit the farmers, and hence have had limited take-up. The absence of carbon credit markets or sufficient subsidies that could help farmers access superior technologies for stubble management compounds this challenge. Additionally, the high private health costs and profit losses linked to stubble burning take time to manifest, limiting farmers' willingness to pay for alternatives given present-biases and liquidity issues. As a result, producers face limited incentives to innovate or scale-up production of alternatives to stubble burning.

Interventions aimed at responding to this market failure and reducing stubble burning have so far had limited impact. Some programs tested so far with mixed results include:

- In 2019, the Indian Government gave 2,400 rupees (approximately USD 30) per acre to every farmer who did not burn stubble. However, limited resources and priority changes within the Government constrained the impact of the program.[161] In most of the cases, the payment never arrived, reducing framer confidence in the program.
- The Indian Government also provided subsidies for Happy Seeder adoption, through the "Promotion of agriculture mechanization for in-situ management of crop residue in the states of Punjab, Haryana, Uttar Pradesh and NCT of Delhi" initiative. These subsidies funded 50–80% of the Happy Seeder's cost. While this increased adoption by 800,000 hectares, it did not achieve a larger impact as it did not reduce the upfront cost enough for an efficient and sustained adoption of the stubble burning alternative.[162]
- Payment for Ecosystem Services have reduced stubble burning. The Department of Economics at the American University of Sharjah[163] found a correlation between the regions that received monetary incentives[164] and stubble burning. Nevertheless, this has not led to the development of sustainable solutions as the payments are not anchored to an innovation component that generates a long-term substitute technology for stubble burning. In fact, farmers need a varied market of alternatives that allows them to choose their way of harvest and production without using stubble burning.
- In September 2022, the Indian government introduced a set of financial penalties to stubble burning, framed as environmental compensations and in line with regulations from the

161 BBC News. (2020). Stubble burning why it continues to smother north India.
162 BBC News. (2020). Stubble burning why it continues to smother north India.
163 Nudge and Compensation: Evaluating experimental Evidence on Controlling the Rice straw burning. (2021).
164 They derive a cost of US 125 per hectare for the farmer who does not burn.

CAQM Act of 2021.[165] These penalties range from 2,500 to 15,000 rupees (approximately USD 30–185) per incident depending on the acres owned by the farmer.[166] These have been announced and are expected to be applied ahead of the 2022 burning season, in late-October and November. Enforcing this type of regulation requires adequate government monitoring of high-risk areas at the farmer level. However, the Government may not have the technology required to monitor stubble burning.[167]

3.3.3. Defining an alternative future scenario for stubble burning

In a **business-as-usual scenario**, stubble burning will continue to be the leading stubble residue management method. In contrast, in an alternative **target scenario**, stubble burning alternatives become more competitive and accessible, ultimately reducing the GHGEs and air pollution generated by this practice. The necessary shift between scenarios will require addressing one or more of the identified barriers to uptake.

In terms of addressing **up-front cost** and ensuring long-run profitability, producer innovation, economies of scale, and strategies to increase the profitability of burning alternatives or increase the cost of burning are likely required. First, there is a clear need for producer innovation to identify new or dramatically improved methods which offer lower upfront costs. Second, with appropriate technologies identified, producers may also be able to drive down upfront costs through the economies of scale associated with increased production. Third, the price gap between burning and alternatives can be further narrowed by strategies to increase the profitability of burning alternatives or increase the cost of burning, including:

- Stronger regulation, including higher or more rigorously enforced fines enabled through effective monitoring.
- Economic support such as Payment for Ecosystem Services, or domestic government subsidies or tax breaks for the use of alternatives to stubble burning. For example, the REDD+ program, an example of this type of program, has paid between USD 9 and USD 75 per tonne of emissions avoided.[168]
- Improved access to credit, enabling farmers to amortize upfront costs of alternatives against the improved long-term savings and productivity gains associated with avoiding soil fertility losses associated with stubble burning.

However, even with these combined strategies, a substantial price gap may persist between burning and some alternatives like the Happy Seeder. For instance, even if Happy Seeder producers reduce

165 The Commission for Air Quality Management in National Capital Region and Adjoining Areas Act, 2021.
166 Vishnoi, A. (2022). Stubble burning fine set to be notified; between 2,500 to 15,000 per incident. The Economic Times (September 9th 2022).
167 Dissanayake, R & Camps, B. (2022). Building a Portfolio of Pull Financing Mechanisms for Climate and Development.
168 Forests. (2020). Costs and Carbon Sequestration Assessment for REDD+ in Indonesia.

its cost by 50%, from USD 2,083[169] to USD 1,041.5,[170] a significant gap would still have to be bridged to approach the cost of continuing with the established stubble burning practice. This highlights the potential importance of additional complimentary strategies.

In terms of **addressing user friendliness,** producer innovation or improved user support could play a role. Innovation could focus on making easier to use alternatives, such as bio-decomposers. Improved user support could also play a role, for example, with personal or online training in the use of alternatives to overcome adoption barriers.

Finally, **user awareness** could be addressed through product promotion to support take-up, along with the flow-on benefits of higher adoption driven by the above factors.

3.3.4. Objectives of a pull-finance mechanism to reduce stubble burning

Responding to the challenges outlined above, a pull finance mechanism could be used to provide short-term incentives to drive uptake of stubble burning alternatives and ideally shift the market from the business-as-usual scenario to the target scenario in the medium to long term. On its own, achieving the short-term objective would deliver substantial temporary climate and development benefits, making this a worthwhile objective even if a market shift is not achieved. The second more ambitious objective of catalyzing a market shift would deliver greater long-term benefits but would be hard to achieve given its contingency on successfully achieving some combination of reducing upfront costs, increasing profitability, and improving user friendliness and user awareness of stubble burning alternatives—the potential for which is unknown.

Figure 2 presents a ToC for how these objectives can be achieved. In the short term, with the right incentives, producers could experiment with innovation, increased production, improved outreach, and support for users, to help overcome the current barriers to adopting stubble burning alternatives described above. This could entail:

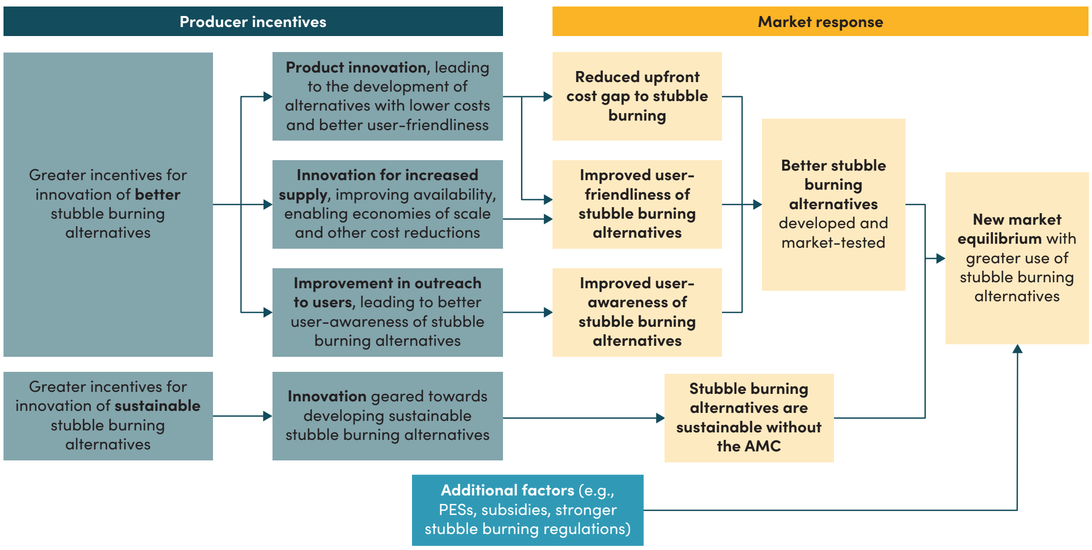
1. **Innovation**, aimed at developing alternatives with lower costs and better user friendliness, improving the supply and availability of stubble burning alternatives, reducing their costs, and ensuring these improvements are sustainable over time.
2. Improvement in **outreach to users**, leading to better user awareness of stubble burning alternatives.
3. **Complementary factors** that support the viability of stubble burning alternatives, such as Payments for Ecosystem Services, subsidies, or stronger regulation aimed at preventing stubble burning.

169 Renewable and Sustainable Energy Reviews. (2018). Burning issues of paddy residue management in north-west states of India.

170 Renewable and Sustainable Energy Reviews. (2018). Burning issues of paddy residue management in north-west states of India.

In the long-term, as depicted in Figure 2, depending on the success of these approaches, the pull finance mechanism may be able to drive a market shift in which stubble burning alternatives are more attractive to farmers even without the ongoing support of a pull finance mechanism (the target scenario).

FIGURE 2. Pull finance theory of change to reduce stubble burning



Source: Author's elaboration.

Given this objective and related theory of change, some implications for the design include the following:

1. For this market change to happen, we need to design an intervention that adjusts incentives on the production side, incentivizing the necessary innovation and enabling these changes to happen in the stubble management market.
2. Given the substantial benefits of shifting to stubble burning alternatives, even temporary increased use of these methods would be valuable and could justify the use of pull finance, as described in section 3.2.3. Temporary improvements achieved by the AMC could also be valuable if the government is able to improve its monitoring and enforcement in the near future, as described above in section 3.3.2.
3. A long-term market shift could also be achieved, potentially by incentivizing producers to ensure their stubble burning alternatives are sustainable over time.

3.4. Pull finance design prototype

This section details a proposed design prototype for a pull finance mechanism which would respond to the challenge and meet the objective outlined above. We first detail the choice of pull finance mechanism and funding recipient (3.4.1) before defining the results to which pull finance should be tied, along with *associated targets (3.4.2), a proposal for the AMCs' prices and values (3.4.3) and conclude with a proposed verification strategy (3.4.4). Design conclusions are first summarized in the text below and Table 9.*

The pull-finance mechanism design presented here aims to reduce stubble burning by driving innovation and uptake of alternatives. We recommend using an AMC for this purpose since this instrument is capable of incentivizing producers to develop and provide stubble burning alternatives in the short-term and has the potential to drive a long-term market shift. The AMC will pay for the uptake of alternatives, measured through stubble burning reductions (in hectares), incentivizing producers to innovate on existing and new alternatives, increase production and improve outreach and support for users. To ensure the sustainability of the program, the mechanism would also pay for the maintenance of stubble burning reductions after significant time has elapsed (e.g., eight years after the program's start). The AMC would pay a price of USD 143 per hectare, equating to an overall AMC value of USD 573.5 million for 800,000 hectares.

We estimate the AMC could mitigate approximately 11.5 million tonnes of GHGEs across the program's duration and present a cost of USD 40 per tonne of CO_2 abated. This price is on the lower end of comparable initiatives: agricultural emission reductions, soil management, and cover crop programs have estimated mitigation costs from USD 49 to USD 175, illustrating the strong potential cost-effectiveness of this mechanism in providing cost-effective climate results.

TABLE 9. Summary of the pull finance prototype for avoiding stubble burning

Pull Finance Design Components	Prototype Design Proposal
1. Which mechanism can best deliver on identified objectives?	We recommend using an AMC with the objective of incentivizing producers to develop and provide stubble burning alternatives in the short term and with the potential to drive a long-term market shift. The AMC could operate for 8 years (4 initial years of annual payments, followed by a final payment 8 years after the launch of the AMC's contracts to incentivize sustainability).
2. What results should be paid for?	To incentivize the development and scale up of alternatives to stubble burning, we propose that the AMC pay for two main results: (1) stubble burning reductions (in hectares) and (2) sustainability of the stubble burning alternative.
3. How much should be paid?	The result price per units and the AMC's overall value must be enough to drive the necessary market shift while offering value for money. Given these considerations, for the Indian context, we propose a price per hectare of stubble burning avoided to be around USD 143, equating to an overall AMC value of USD 573.5 million. These figures are based on a benchmark of USD 40 per tonne of CO_2 abated, a price on the lower end of comparable programs, illustrating the potential of this mechanism to provide a cost-effective means to deliver climate results.
4. How should results be verified?	Stubble burning reductions can be verified through satellite images and modelling managed by an independent third-party verifier and technical partners to assess that the not-burn reported hectares meet the defined results criteria. The verification process should also review the sustained use of stubble burning alternatives in the last stage of the AMC.

3.4.1. Which pull finance mechanism can best deliver on the defined objective?

The first design choice is determining which type of pull finance mechanism can best deliver on the objective outlined above by enabling the innovation and production of stubble burning alternatives and shifting the market to a new equilibrium. Pull finance mechanism options include RBF, Prize-based Challenges, and AMCs (see Box 1 in Section 1 for an overview).

An AMC is the best suited mechanism to generate the producer incentives to undertake the required innovation and other practices required to drive increased adoption of stubble burning alternatives. In an AMC, commitments are made for the purchase, or to subsidize for the purchase, of a certain volume of a product at a fixed price, subject to the achievement of the desired product characteristics. In this way, AMCs can encourage technological innovation. Additionally, they can condition payments on uptake, effectively implementing a market test of the new solution, such as was the case with the GAVI pneumococcal vaccine AMC where payment was conditioned on government demand for supplied vaccines. Since no clear dominant alternative to stubble burning exists, an AMC would promote strong options through a market test of existing and newly developed technologies.

An AMC that responds to the stubble burning challenge would pay producers for uptake of stubble burning alternatives that comply with GHGEs targets and other criteria. This focus on products contrasts with past initiatives that have focused on providing consumer incentives.[171] This is because producers are responsible for developing and providing these alternative solutions. Additionally, producers would be incentivized to improve user awareness and user friendliness of the alternatives to promote uptake. Ideally, these producer incentives would help shift the market to a new long-term equilibrium.

An AMC is more suitable than an RBF approach entailing per unit payments since it would require producers to commit a significant target for uptake.[172] By doing so, the AMC can promote that the aggregate results achieved catalyze the necessary market shift. These considerations are further detailed in relation to other pull finance options in Table 10, along with examples of where these options have been used.

Likewise, we propose an AMC over a Prize-Based Challenge mechanism, since the prize would not help achieve the objective of scaling up production and innovation of stubble burning alternatives since it would not provide incentives for uptake.[173] A Prize-Based Challenge would incentivize the

171 As the 50% subsidy for Happy Seeder in India and the PES implemented by organizations as a pilot plan for their investigation in mitigating stubble burning.

172 While an RBF instrument can establish targets and thresholds to promote this type of impact, its focus remains on marginal improvements. AMCs have a stronger emphasis on large-scale uptake.

173 A Prize-based Challenge could be coupled with a mechanism focused on uptake to overcome this limitation. However, this creates an additional layer of complexity to the design and might be more suitable for cases where the technological solutions are more uncertain.

development of technologies beyond the current technology frontier, which is an important target of the project. However, the adoption of the new technologies or services would be out of the scope of the Prize-Based Challenge approach.

Under the AMC, individual producers would be granted contracts[174] with a commitment to be paid upon achieving negotiated stubble burning reduction targets in specific zones over a defined duration. Contracting individual producers makes it easier to adapt the contracts so they are context-specific, preventing collusion among producers applying for the mechanism. Stubble burning reductions can be verified through satellite images and modelling. Additionally, the AMC would offer a last payment tied to the sustainability of the stubble burning alternatives.

These contracts would provide a clear and credible market signal about the mechanism, the incentives, and its value proposition. To ensure the producers have sufficient confidence in the mechanism to make investments in innovation and scale up production, we suggest the AMC should have a multi-year duration. In this case, we propose a 4-year duration for the standard payments and an additional period of 4 years for the final sustainability payment.

The AMC's targets should aim at balancing ambitious but realistic accounting for the innovation risk. The "Promotion of agriculture mechanization for in-situ management of crop residue in the states of Punjab, Haryana, Uttar Pradesh and NCT of Delhi" initiative in India incentivized the adoption of stubble burning alternatives (Happy Seeder and other zero tillage technology) in 800,000 hectares.[175] This suggests that this is a feasible target for incentives aimed at reducing stubble burning through alternatives. The previous sections highlighted that the impact of this program was lower than expected as it did not lower the cost of Happy Seeders enough and because of the limited availability of this machinery. However, since the AMC aims to incentivize the development of stubble burning alternatives, an additional innovation risk should be factored in, offsetting the potential of increasing the target.

3.4.2. What results should the AMC pay for?

To advance the AMC's objective of driving uptake of stubble burning alternatives in the short and long term we propose that the AMC pay for two results: (1) stubble burning reductions and (2) sustainability of the stubble burning alternative.

1. Paying for reductions in stubble burning (in hectares) that result from alternative products or services that meet cost-benefit, climate, and health impact criteria

174 Contracts for individual producers allows for negotiation, contract adaptability to specific conditions, and avoids collusion among producers.

175 International Maize and Wheat improvement Center. (2019). Happy Seeder can reduce air pollution and greenhouse gas emissions while making profits for farmers.

The AMC would pay for stubble burning reduction (in hectares). Producers would be accountable for a pre-defined zone. A baseline level of hectares where stubble is burned can be defined and then compared to the levels after the producer has begun the implementation of its contract. Stubble burning reductions can be verified through satellite images and modelling.[176] This method can only provide reliable estimates at a higher level than individual farms. Hence, producers would be accountable for stubble burning in predefined zones (e.g., 1 km^2 [177] or 23 m^2 [178] depending on the precision available). The targets and zones would be negotiated directly with each producer.

Per hectare payments would be subject to alternatives meeting criteria in two categories:

- **Climate impact:** alternatives must generate lower GHGEs than stubble burning.
- **Type of solution:** alternatives must be a product or service.

These proposed criteria tailored to the North-Western Indian context are summarized in Table 10.

TABLE 10. Proposed criteria for alternatives to stubble burning

Category	Criterion	Target
Climate impact	GHGE	Maximum CO_2 equivalent of 0.933 tonnes per hectare per year
	Water withdrawals	Maximum water withdrawals of 2,987 m^3 per hectare per year
Type of solution	Type of solution	The solution must be a product or service

By defining these minimum criteria as the basis for payment for reductions in stubble burning, the AMC would be incentivizing the development and uptake of alternatives to this practice. The criteria are consistent with the characteristics of existing stubble burning alternatives highlighted in section 3.3.1.[179] Additionally, these criteria aim to be technology-agnostic, allowing for emerging stubble burning alternatives to participate. Payments would only be made on an annual basis for producers that achieve the criteria established above and generate stubble burning reductions. This is relevant to ensure a periodic incentive for producers to reach the proposed AMC objectives.

One important assumption made for the criterion selection is that if stubble burning is reduced (i.e., the AMC's producer stubble burning reduction targets are achieved), then alternatives to this practice are user-friendly enough to be widely used and user awareness is better than current levels. As a result, minimum criteria related to user-friendliness and user awareness were not included.

176 The risks of this methodology and potential mitigation mechanisms are covered in the section 4.4.3 and 4.4.4.
177 Fire Information for Resource Management System. (2022). FIRMS.
178 Department of Space Indian Space Research Organization. (2022). The Saga of Indian Remote Sensing Satellite System.
179 Considering the data availability; the metrics, targets and pricing of the following prototype will contemplate all the listed alternative technologies in the section 3.3.1 except bio-decomposer. It is included as an illustrative example of additional straw management system but is not use as a reference for the following sections.

Climate impact

Payments should be made when stubble burning is reduced through alternatives that have better climate standards than this practice. To ensure this, we propose the following criteria:

- **GHGEs:** the alternatives should be at most equal to the least polluting technology according to available data, i.e., using mulching and a Happy Seeder. This means that it should comply with a maximum level of emissions[180] of CO_2, Nitrous Oxide (N_2O), Methane (CH_4) and Sulfur (S) translated in CO_2 equivalent, considering the IPCC Emissions Factor database. Achieving at most this level of GHGEs should be feasible given compliant technologies already exist.
  - **Target:** maximum CO_2 equivalent of 0.93 tonnes per hectare per year for the total emissions produced.
- **Water withdrawals:** this measures the required amount of water for irrigation pumps in the stubble burning alternatives.[181] This target is established as the actual maximum water withdrawals of the most common technology (burn + DH+ CS). Irrigation processes may change depending on the stubble burning alternative, so excessive water use should be avoided because of water scarcity in the Indian North-Western region.
  - **Target:** maximum water withdrawals of 2,987[182] m^3 per hectare per year.

Type of solution

Finally, the mechanism must ensure that the incentivized actors are not only temporarily reducing stubble burning through short-lived solutions (e.g., by paying farmers to stop farming altogether). The proposed criterion is the following:

- **Type of solution:** the method used by the incentivized actor to reduce stubble burning, as specified when applying for the pull-finance mechanism and as verified throughout implementation.
  - **Target:** the producers must demonstrate that they are providing a product or service to farmers.

2. Paying for the sustainability of the stubble burning alternative

The mechanism should pay for the sustainability of stubble burning alternatives, in addition to incentivizing their development. To do so, the AMC would pay producers if stubble burning reductions are maintained after a significant time has elapsed. This metric aims to reward producers that develop a solution with a sustained take-up that does not depend on the AMC's incentives.

180 Average emissions of the stubble burning alternatives listed in the section 3.3.1.

181 *"Water withdrawals for irrigation vary across farming practices and are an important consideration because of water scarcity in the region.* Shyamsundar, P. et al. (2019). Fields on fire: Alternatives to crop residue burning in India. Science. 365. 536–538.

182 Shyamsundar, P. et al. (2019). Fields on fire: Alternatives to crop residue burning in India. Science. 365. 536–538.

This means that they will be rewarded with a last payment in the 8th year of the mechanism that incentivizes the sustainability of alternatives to stubble burning in the market.

3.4.3. How much should the AMC pay?

The AMC's effectiveness and value for money depends on the result prices[183] and its overall value. Hence, these values should ensure value for money in terms of the AMC's cost relative to the climate benefits it would deliver.

For this case, we recommend following a methodology similar to Frontier (Box 5): a reference value is established per unit of outcome based on a social value benchmark and then refined when engaging with potential producers.[184] In contrast to the cooling case, this approach does not consider sufficiency of behavior change since the heterogeneity of potential solutions (e.g., Happy Seeder, bio-decomposers) and diverse products and services does not allow us to estimate the necessary incentive size to incentivize producers.

Based on this methodology, we propose that an AMC focused on North-Western India could offer:

1. **A result price per hectare of USD 143**
2. **An overall AMC value of USD 573.5 million**
3. **A mitigation cost of USD 40[185] per tonne of CO_2**

As this section describes, these values reflect:

1. USD 459 million in per hectare payments—reflecting an estimate of the social value of the anticipated GHGE reductions directly attributable to the AMC, 3.58 tonnes per hectare per year, equivalent to 11.5 million tonnes across the four years of the program and 800,000 hectares,
2. An additional USD 114.7 million to reward sustainable stubble burning solutions.

These prices represent a lower bound in terms of value-for-money in reducing stubble burning. Actual prices offered to producers should be refined through negotiations, stakeholder engagements, and market research tailored to each provider of alternatives. This should be informed by an understanding of factors such as the costs they would face to expand production and invest in research and development to achieve the targets we propose, and to tailor the design to the geographical context where the AMC would operate.

183 This section refers to the result price/subsidy provided to the producer per unit of result. Note this is different from the price of the stubble burning alternative.

184 Frontier. (2022). An early market commitment to accelerate carbon dioxide removal.

185 In this report, mitigation costs are understood as the costs associated with the mitigation of a tonne of CO_2 (or equivalent). For this AMC, the mitigation cost estimated can be considered cost-effective in comparison to other climate programs, as detailed in Box 6.

BOX 5. Value-for money: benchmarking the cost-effectiveness of the proposed AMC

Frontier[186] is an AMC that aims to accelerate carbon removal by pooling and guaranteeing future demand, funded by Stripe, Alphabet, Shopify, Meta, McKinsey, and other companies that use Stripe Climate. It will operate during the 2022–2030 period and has raised USD 925 million. The mechanism aims to send a demand signal to researchers, entrepreneurs, and investors, showing there is a market for low-cost, high-volume carbon removal technologies, de-risking their development. Some of the funded innovations include direct carbon removal, biological carbon processing, and optimized weathering.

To define its prices, Frontier first established a benchmark of a maximum of USD 100 per tonne of carbon to promote scalable affordability. It then researches and identifies providers and negotiates with them to refine individual prices and commit to purchase amounts of carbon removed.

The rest of this section details the methodology and frameworks used for these estimates.

Value for money—how much value could the AMC deliver in terms of GHGEs abated?

The reference price for this mechanism is based on estimating the social value of the GHGEs that would be avoided if the reductions in stubble burning are achieved. This can be used as an indication of the reasonableness and lower bound for result price per units and total value for the AMC. Using this method, we estimate that the AMC would deliver a social value per hectare per year of USD 143. This estimate is based on the following assumptions (which yield USD 40 × 3.58 tonnes prevented per hectare per year = USD 143):

1. Substituting stubble burning with alternatives that meet the criteria described in section 3.4.2 would deliver an average estimated 3.58 tonnes of GHGEs of avoided emissions per hectare per year, as reflected in Table 11.[187]
2. That each tonne per hectare per year of GHGEs avoided can be valued at USD 40, reflecting benchmarks presented by the Carbon Pricing Leadership Coalition.[188]

The tonnes prevented by substituting stubble burning with alternatives in the proposed 800,000 hectares would save 11.5 million tonnes of GHGEs after 4 years. This would imply that the total social value of the AMC after 4 years would be USD 573.5 million (USD 114.7 million per year).

186 See frontierclimate.com for additional details.
187 For this estimation we are using the desegregate stubble burning alternatives to obtain the average of GHGE per alternative compared with stubble burning.
188 Carbon Pricing Leadership Coalition. (2017). Report of the High-Level Commission on Carbon Prices. World Bank Group.

TABLE 11. Summary of GHGEs per disposure method

Stubble Disposure Alternatives	GHGEs per Hectare per Year	Reduction in GHGEs per Hectare per Year Compared to Stubble Burning	Average Reduction in GHGEs per Hectare per Year Compared to Stubble Burning
Stubble burning (Burn + Disc Harrow + Conventional Seeder)	4.75 tonnes	N/A	N/A
Manual Mulch + Happy Seeder	0.93 tonnes	3.82 tonnes	
Mechanic Mulch + Happy Seeder	0.93 tonnes	3.82 tonnes	
Bale + zero till	0.99 tonnes	3.76 tonnes	3.58 tonnes
Incorporation + Rotavator + Conventional Seeder	1.6 tonnes	3.15 tonnes	
Incorporation + Disc Harrow + Conventional Seeder	1.38 tonnes	3.37 tonnes	

The estimated social value presented here should be considered as a conservative lower bound of the AMC's potential social value as the estimate only accounts for the AMC's:

1. **Climate benefits.** This pricing methodology focuses on the climate benefits of the AMC, but it does not consider the development and health benefits detailed in section 2.2.[189]
2. **Direct benefits** of the new stubble burning alternatives explicitly paid for by the AMC. We omit the future GHGEs savings achieved because of the future lower use of stubble burning and increased market share of stubble burning alternatives. The true value of these indirect benefits depends on how quickly this shift would have occurred without the AMC.

How much should the AMC pay for the demonstrated sustainability of the stubble burning alternatives?

The payment for the sustainability of stubble burning alternatives should be high enough to incentivize this result. However, this should be a limited incentive since the opportunity cost of granting it is limiting the funds available to be directed towards innovations. If this payment is too low, it will provide insufficient incentives for producers to achieve sustainability, limiting effort and associated results. On the other hand, if this value is too high, the AMC will have to earmark a

189 The estimation considers the GHGE as CO_2 equivalent tonnes but does not include the emissions by Particulate Matter and Black Carbon that also generate substantial climate and health benefits if stubble burning is avoided. It also does not consider potential development benefits from improved agricultural yields or income for farmers.

significant part of its funding until the sustainability results can be verified. The opportunity cost of this funding is not being able to incentivize other producers who could develop promising stubble burning alternatives. A starting benchmark can be the equivalent of one year of the expected payments (USD 114.7 million). The specific amount for each contract can be negotiated with the producers and calibrated according to the needs of the mechanism.

The total AMC value recommended here is a reference value based on the method used to estimate the results of stubble burning reduction required to achieve its goal, but it should be calibrated through further market analysis, stakeholder engagement and negotiations. The AMC could operate at different scales depending on the hectares of stubble burning prevented and the payment per hectare based on further analysis and parties involved. As outlined below, AMCs smaller than the estimated size could achieve results in reducing stubble burning and provide learnings about this type of incentive in the straw management space. However, setting a lower level of AMC funding risks not generating a significant market shift, undermining the potential for a long-term impact of the stubble burning alternatives. Nevertheless, starting small and then scaling after initial results are verified and confidence in the potential of the mechanism increases could provide a pathway to the necessary scale.

BOX 6. Can the AMC be considered cost-effective?

The cost of mitigating a tonne of CO_2 (or equivalent) provides a useful reference for benchmarking the cost-effectiveness of alternative climate investments.[190] This cost is estimated to be around USD 40 for the present AMC, or the quotient between the AMC's value (USD 458.6 million[191]) and the expected emissions abated (11.5 million tonnes of GHGEs).

A mitigation cost of around USD 40 can be considered competitive when contrasted against the mitigation cost of other climate investments. For example, the GCF and CTF have an estimated average cost effectiveness across all programs of approximately USD 42 and USD 144 respectively.[192] Likewise, agricultural emission reductions, soil management, and cover crop programs have estimated mitigation costs from USD 50 to USD 65,[193] around USD 57,[194] and from USD 49 to USD 175[195] each. Together, these data points illustrate the relative cost effectiveness implied by a mitigation cost of USD 40, which lies below the GCF and CTF averages and at the lower end of most data points.

190 Juden, M. and Mitchell, I. (2021). Cost-Effectiveness and Synergies for Emissions Mitigation Projects in Developing Countries. CGD Policy Paper 204. March 2021. Center for Global Development.

191 For the calculation of the mitigation costs, only the value of the first four years of the AMC, equivalent to USD 458.6 million, is considered. The remaining USD 114.7, allocated to the reward of sustainable stubble burning solutions, are not considered due to the inability to calculate the GHGE that could be abated from this portion of the program.

192 Juden, M. and Mitchell, I. (2021). Cost-Effectiveness and Synergies for Emissions Mitigation Projects in Developing Countries. CGD Policy Paper 204. March 2021. Center for Global Development.

193 Journal of economic perspectives. (2018). The Cost of Reducing Greenhouse Gas Emissions.

194 Journal of economic perspectives. (2018). The Cost of Reducing Greenhouse Gas Emissions.

195 MacLeod, M. et al. (2015). Cost-Effectiveness of Greenhouse Gas Mitigation Measures for Agriculture: A Literature Review. OECD Food, Agriculture and Fisheries Papers, No. 89. OECD. Paris.

TABLE 12. Mitigation costs benchmark

Program	Mitigation Cost (USD) per Tonne of CO_2
Across GCF's programs	42
Across CTF's programs	144
Across global agricultural emissions programs	50–65
Across global soil management programs	57
Across global cover crop programs	49–175

BOX 7. Pricing risks

Consistent with the framework presented in this section, to ensure the AMC´s success and value for money, the finalization of pricing before launch should account for the risks of underpaying or overpaying for results.

Underpaying: Underpaying for the desired results would mean that the minimum required for producers to participate is not necessarily reached. If too few producers sign up, the desired market shift would not occur. While this would reduce the cost of the AMC, it could mean any funding paid out has limited impact without achieving a long-lasting market impact.

As defined above, this risk can be mitigated by the AMC defining a threshold for minimum production expansion by producers and the industry as a whole—if these thresholds are not agreed to by producers for the prices on offer, the AMC should not proceed.

Overpaying: Given information asymmetry between the AMC and producers, and limited knowledge regarding producer costs, operations, and sufficiency to generate change, it may be difficult to reach a fair price. This poses the risk of overpayment relative to what is necessary for producer participation and achieving the required market shift.

While this risk cannot be eliminated, it can be mitigated by thorough market research, engagements, and negotiations. Further, provided payments are within the upper range defined here, these payments would represent good value for money relative to other climate investments.

3.4.4. How should results be verified?

The verification process aims to confirm the performance of the producers to define the corresponding payments. The AMC must define how to verify the reduction of stubble burning and the criteria stubble burning alternatives must meet to be eligible for payments.

In this case, stubble burning reductions can be verified through satellite images and modelling. As detailed below, this will entail defining a baseline value of hectares where stubble burning is used and comparing it to the satellite images and modeling to determine stubble burning reductions.

This information, gathered and assessed by a third-party verifier, is needed to activate the corresponding producer payments. However, producers will only be able to participate in this scheme if they comply with the stubble burning alternatives criteria defined previously. Box 8 describes potential challenges stemming from this approach.

Roles and responsibilities

- **Producers:** The participating producers submit to the pull finance mechanism managing body the required evidence and documentation on the stubble burning alternatives and the zone where these are being implemented.
- **Third-party verifier:** The third-party verifier confirms:
  - the compliance of the stubble burning alternative with the criteria,
  - the baseline of hectares where stubble burning is used in the selected zones,
  - the hectares of stubble burning prevented, and
  - the sustained use of stubble burning alternatives.

  It then informs the AMC's managing body.

  The Pneumococcal AMC,[196] AgResults,[197] and multiple RBF mechanisms[198] employ similar third-party actors for the verification process. This strengthens the rigor and legitimacy of the process. It does so by minimizing potential conflicts of interest and leverages the skills of external specialized organizations to carry out this process. Potential third-party verifiers depend on the needs and resources available and may include organizations specialized in program evaluation (e.g., IDinsight, Innovations for Poverty Action), auditing firms (e.g., Deloitte), or another independent actor. Using satellite images and modelling for verification requires technical resources and skills that these organizations may lack. Therefore, these potential third-party verifiers could leverage their expertise leading the verification process and partner with organizations that specialize in providing satellite images for modelling or monitoring purposes.

- **AMC managing body:** This actor coordinates the execution of the verification process, receives producer reports, shares them with the third-party verifier, and disburses payments based on the reports of the verifier.

Process

The following process aims to facilitate the verification of two main elements: the achievement of the criteria for payments, and the uptake of alternatives to stubble burning.

196 GAVI The Vaccine Alliance. (2021). Independent Assessment Committee.

197 AgResults Innovation in research and delivery. (2021). Impactful design at a glance: verification and project management.

198 Instiglio. (2017). A practitioner's guide to Results-based Financing: Getting to Impact.

- **Criteria:** verifying compliance with minimum criteria is necessary to ensure producers are being paid for products or services that meet the basic requirements of the mechanism and can happen at the outset of the producer engagement with the pull finance mechanism. The producers can provide the relevant evidence to the pull finance managing body. This can then be confirmed by the third-party verifier through additional measurements and secondary sources. Additionally, the third-party verifier can confirm that these criteria continue being met during the implementation by performing spot-checks.
- **Uptake:** the mechanism will need to verify reductions in stubble burning. The third-party verifier can define a baseline level of stubble burning and then measure reductions throughout the implementation. To do so, it can use satellite images, such as the Moderate Resolution Imaging Spectroradiometer (MODIS) Terra satellite and the Fire Information for Resource Management System (FIRMS) database, and modelling based on the satellite data.[199] It can further validate this information by performing spot-checks to the selected zones. This can be done throughout the implementation to enable annual payments.
- **Sustainability:** the mechanism will also need to verify if there is a sustained use of the stubble burning alternatives. The third-party verifier can use the same mechanism described above to define if stubble burning reductions have been maintained. It can further validate this information by performing spot-checks to the selected zones.

Any discrepancies between reported and verified information can be reviewed and discussed by the three actors. Any discrepancy remaining after review can lead the payments to be reduced in a proportional measure.

BOX 8. Verification risks

The centrality of successful verification to the AMC's rigor requires careful management of risks relating to perceptions of the legitimacy of the verification process and timeliness of the verification.

1. **Technical risks:** characteristics of the available technologies (i.e., satellite images and modelling) can limit the mechanism's precision and reliability. For instance, satellite images may only be accurate up to a specific area size. This can affect the accuracy of the measurement and the payments but can be mitigated by performing spot-checks that corroborate the satellite images and adapting the implementation parameters to ensure results can be measured (e.g., not assign areas smaller than the smallest possible measurement).

199 Potential sources of satellite images and data include the Moderate Resolution Imaging Spectroradiometer (MODIS) Terra satellite, the Fire Information for Resource Management System (FIRMS) database, the Global Positioning System Coordinates and Arc Geographic Information System software (Environmental Systems Research Institute), the remote sensing with Geographical Information System (GIS), and LISS III satellite images.

2. **Attribution risks:** it might be challenging to correctly attribute stubble burning changes to a specific producer, affecting the rigor of the payments. This can be mitigated by thoughtfully assigning producers to specific zones to prevent overlaps with other producers or to significant sources of attribution errors (e.g., zones with high forest fire prevalence).
3. **Legitimacy of the verification process:** producers may question the reliability of the verification process, since the AMC managing body represents the interests of the organizations that pay for the results.[200] This can be mitigated in two ways:
    3.1. Including a third-party verifier in the process. Since this actor would not have vested interests in the process, they would confer legitimacy to the verification results.
    3.2. Establishing a clear mechanism for addressing discrepancies and disputes, and where producers can appeal verification results.
4. **Timing risks:** external factors can limit the mechanism's capacity to perform the verification process in a timely way. This can delay payments and can affect the accurate measurement of the results. It can be mitigated by defining strategies to address these situations and clear decision-making processes to trigger them.

4. Conclusion

This paper explores and describes the potential of pull finance mechanisms for achieving climate and development results through two case studies: the search for cleaner cooling and alternatives to stubble burning. The case studies were developed based on an analysis of the main challenges in each case, market behavior, and the relevant contexts. This assessment indicates that AMCs are a promising approach to drive changes in producer behavior to enable a market shift towards a cleaner new equilibrium in both cases.

In the cleaner cooling case, we outline the potential of an AMC to catalyze a sustained shift in the Indian market by enabling the scale up of cleaner ACs, driving down their costs relative to standard ACs to equalize market prices and facilitate the uptake of cleaner alternatives. The quantity-forcing nature of the AMC facilitates establishing sales targets and thresholds that lead to this shift on the aggregate level, while also ensuring the desired characteristics in terms of climate-friendliness and operation.

In the stubble burning case, we show that an AMC can incentivize producers to innovate and improve stubble burning alternatives in the short to medium term, and ensure these alternatives are sustainable in the long run. This case leverages the AMC's component of predefined solution characteristics to guide producers towards the type of desirable solutions. It also makes use of the

200 Loening, E., and Tineo, L. (2012). Independent Verification in Results-Based Financing.

AMC's quantity-forcing component to market-test these alternatives, ensuring that they lead to user adoption.

Available data suggest that the proposed AMCs could be highly cost effective in their delivery of climate results. In particular, we conservatively estimate that an AMC focused on cleaner cooling in India could reduce CO_2 for a cost of between USD 21 and USD 40 per tonne of CO_2, while an AMC focused on stubble burning could reduce CO_2 for approximately USD 40 per tonne. These figures illustrate the potential strong cost-effectiveness of these AMCs compared against benchmarks such as the Green Climate Fund and the Clean Technology Fund which have an estimated average cost effectiveness across all programs of approximately USD 42 and USD 144 respectively. Additionally, both cases offer substantial development gains, such as lower energy use, productivity improvements and enhanced health outcomes. These findings should justify future significant climate investments.

The prototype AMCs presented here are based on desk research and expert interviews. To facilitate the launch of AMCs such as these, key components such as Theory of Change assumptions, pricing, and verification should be refined through further market analysis and stakeholder engagement to ensure their relevance and feasibility. This will allow the calibration of the incentive structure and maximize the AMC's target results tailored to the specific context, time and country of application.

Appendixes

Appendix A

Detailed metric list for cooling design

Category	Metric	Description
Uptake	Units sold to consumers	Number of units of the new technology sold in the market for end consumers
	Units installed	Number of units of the new technology installed
	Units replaced	Number of units replaced with the new technology
	Users using cooling systems	Number of users who are using the cooling systems developed and installed
Price/ affordability	Price	Amount paid upfront by the user
	Life cycle cost	The total cost of an asset over its life cycle including initial capital costs, maintenance costs, operating costs, and the asset's residual value at the end of its life.
	Installed cost	Unit bill of materials cost, cost of external components and cost of consumables required to operate the solution.
GHGEs	Life Cycle Climate Performance (LCCP)	Evaluation of the carbon footprint and global warming impact of heating, ventilation, air conditioning (AC), refrigeration systems, and potentially other applications such as thermal insulating foam.
	Direct emissions	Direct emissions from the cooling technology
	Indirect emissions	Indirect emissions account for all other sources of emissions generated by the manufacture use and disposal of the unit. This includes the emissions from the generation of electricity, manufacturing of materials to build the unit, manufacturing of the refrigerant, and the end-of-life emissions when the unit is disposed of.
	Indian Seasonal Efficiency Ratio (ISEER)	Evolved rating methodology for air conditioners that factors in variance in higher temperature in India and rates air conditioners accordingly.
	Energy Efficiency Ratio (EER)	EER rating provides you with a ratio of useful cooling output (in BTU/h) to electricity input (measured in W).
	Watts (W)	It is used to quantify the rate of energy transfer.
	Global Warming Potential (GWP)	Measure of the relative global warming effects of different gases. It assigns a value to the amount of heat trapped by a certain mass of a gas relative to the amount of heat trapped by a similar mass of CO_2 over a specific period.
	Embodied Emissions	The embodied emissions include the climate forcing effects of the manufacturing processes, transport, and installation for the refrigerant, materials, and equipment, and for recycle or other disposal of the product at end of its useful life.
	Use of zero-ODP refrigerants	The ozone depletion potential (ODP) of a chemical compound is the relative amount of degradation to the ozone layer it can cause

Category	Metric	Description
	Embodied carbon emissions in materials	MM = CO_2e Produced/Material (kg CO_2e/kg)
	Tons of refrigeration	Unit of power used in some countries to describe the heat-extraction capacity of refrigeration and air conditioning equipment. (Measurement used in the US but equivalent of BTU. A ton of refrigeration is approximately equal to 12,000 BTU/h or 3.5 kW.)
Operation	Refrigerants standards	Refrigerants must – Be a lower toxicity (Class A) refrigerant – Comply with ISO 5149 standards[201]
	Water consumption	The Liter is a metric unit of volume. It is equal to 1 cubic decimeter (dm^3), 1000 cubic centimeters (cm^3) or 0.001 cubic meter (m^3)

Appendix B

Additional disaggregated information about stubble disposure alternatives

Stubble Disposure Alternative			Public Cost (per hectare per year)		Farmers Profit (per hectare per year)	
Straw Management	Land Tillage and Preparation	Seeding	Water Withdrawals (m^3)	GHG Emissions (tonnes of CO_2e)	Indian Rupee	USD
Mulch SMS		Happy Seeder	2,403	0.93	₹68,035.00	852
Mulch Manual		Happy Seeder	2,403	0.93	₹67,403.00	845
Incorporation	Rotavator	Conventional seeder	4,056	1.6	₹53,447.00	670
Incorporation	Disc Harrow (Inc Disc)	Conventional seeder	4,056	1.3	₹55,662.00	697
Bailing		Zero till	2,709	0.99	₹61,847.00	775
Bailing		Rotaseeder	2,987	1.08	₹59,498.00	745
Bailing	Disc Harrow (Burn Disc)	Conventional seeder	2,987	1.48	₹56,537.00	708
Burn		Zero till	2,709	4.28	₹61,847.00	775
Burn		Rotaseeder	2,987	4.37	₹59,498.00	745
Burn	Disc Harrow (Burn Disc)	Conventional seeder	2,987	4.76	₹56,537.00	708

Source: Shyamsundar, P. et al. (2019). Fields on fire: Alternatives to crop residue burning in India. Science. 365. 536–538.

201 This could be updated as improved standards are developed.

Appendix C

Detailed metric list for stubble burning design

Category	Metric	Description
Uptake	Units sold/services provided to consumers	Number of units/instances of services provided to end consumers
	Users using stubble burning alternatives	Number of users who are using the stubble burning alternatives
	Stubble burning reduction	Reduction in hectares of stubble burning
Cost-benefit	Upfront cost	Upfront of the stubble burning alternative
	Life cycle cost	The total cost of an asset over its life cycle including initial capital costs, maintenance costs, operating costs, and the asset's residual value at the end of its life
	Installed cost	Unit bill of materials cost, cost of external components and cost of consumables required to operate the solution
	Net profits	Net profit of the stubble burning alternative
Climate impact	GHGEs	GHGEs emitted by the stubble burning alternative's operation
	Water withdrawals	Water used by the stubble burning alternative
Health impact	Particulate matter and black carbon	Particulate matter and black carbon emitted by the stubble burning alternative's operation
Type of solution	Type of solution	The solution must be a product or service