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Catalyzing Climate Finance for Low-Carbon Agriculture Enterprises

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The authors would like to thank the many entrepreneurs and climate investors who shared their views and experiences, which formed the foundation of much of this report. Thanks also to Dan Haglund, Seth Silverman, Kat Harrison, and Jason Gray for their review and feedback.

Table of Contents

Acronyms

ADALY	Averted Disability-Adjusted Life Year
AfDB	African Development Bank
ADM	Adaptation Development Mechanism
AF	Adaptation Fund
ARAF	Acumen Resilient Agriculture Fund
CRANE	Carbon Reduction Assessment of New Enterprises
DFI	Development finance institution
ESG	Environmental, social, and corporate governance
EX-ACT	Ex-Ante Carbon-balance Tool
GCF	Green Climate Fund
GEF	Global Environment Facility
GHG	Greenhouse gas
IsDB	Islamic Development Bank
IPCC	Intergovernmental Panel on Climate Change
kWh	kilowatt hour
LMIC	Low and middle-income country
MCFs	Multilateral climate funds
MDB	Multilateral development bank
MFI	Microfinance institution
NDC	Nationally Determined Contribution
NBFC	Non-banking financial company
RBF	Results based financing
SDG	Sustainable Development Goal
UNFCCC	United Nations Framework Convention on Climate Change

Section: 1
Executive Summary

Rural households in low- and middle-income countries (LMICs) working in the agriculture sector feed much of the world, bear little responsibility for driving climate change, and are being disproportionately impacted by climate-related shocks. Climate finance represents a critical opportunity to bring investment and innovations to agricultural settings to improve resilience and drive new and more inclusive low-carbon development pathways. With 80% of the food and 40% of jobs in sub-Saharan Africa and South Asia tied to small-scale agriculture, smallholders must be central to these plans.[1] However, small-scale agriculture value chains and the financing institutions serving them currently account for a paltry amount—just 0.2%—of the roughly $600 billion in annual climate-related financing globally.[2]

This study examines this disconnect in the context of small agriculture enterprises using renewable power to improve productivity and resilience of rural communities in India and sub-Saharan Africa. It aims to gauge the potential contribution to climate adaptation and mitigation of these value chains and to identify finance vehicles and policy reforms needed to scale interventions in those value chains. It applies a gender lens to understand how and why gender-related attitudes, practices, and policies are affecting the financing and operations of enterprises in the sector. It is based on interviews with executives from 35 small- and medium-enterprises (SMEs) and climate investment firms, as well as an extensive review of related research.

Scaling low-carbon agriculture enterprises would unlock significant adaptation, mitigation, and development benefits

Solar and other renewables are enabling distributed, low-cost cold storage, irrigation, and processing capabilities that could be transformative for rural communities in Africa and South Asia. The climate mitigation benefits alone from these low-carbon agriculture technologies (AgTech) are potentially significant, both in terms of displacing existing diesel- or grid-powered technologies, as well as new deployments that could reduce the amount of fertilizer and land required to yield a given amount of usable food. As illustrated in Figure 1, our research found that:

- Investing just over $200 million to provide solar irrigation pumps to 1.3 million farmers in Kenya would avert emissions of 6.7 million tons of CO_2 annually
- Investing $10 million into solar conduction dryers in India would reduce CO_2 emissions by 1.6 million tons per year.
- Investing approximately $750 million into solar cold storage in India would permit SMEs to deploy 50,000 cold storage units across the country, averting the emission of 1 million tons of CO_2 per year.
- Replacing just one-quarter of the 8.8 million diesel irrigation pumps in India with solar pumps, which would require an investment of approximately $3.3 billion, would reduce CO_2 emissions by 11.5 million tons per year.

As a point of comparison, removing 1.5 million cars from the road would reduce emissions by 6.9 million tons per year.[3] Completely decarbonizing all of Kenya's transportation sector—including commercial and personal vehicles, air travel, freight shipping, and rail—would reduce emissions by 8.7 million tons annually.[4] The entire global fleet of Tesla vehicles and solar charging equipment avoided the equivalent of 5.0 million tons of CO_2 in 2020.[5]

1 Lacina, Linda. "How finance, ag-tech and more can speed the energy transition – 4 experts explain." World Economic Forum, 12 Nov 2021. https://www.weforum.org/agenda/2021/11/finance-ag-tech-energy-transition-climate-action/
2 Chiarac, Daniela, Baysa Naran, and Angela Falconer. "Examining the Climate Finance Gap for Small-Scale Agriculture." Climate Policy Initiative, n.d. https://www.climatepolicyinitiative.org/publication/climate-finance-small-scale-agriculture/.
3 US EPA, OAR. "Greenhouse Gas Emissions from a Typical Passenger Vehicle." Overviews and Factsheets, January 12, 2016. https://www.epa.gov/greenvehicles/greenhouse-gas-emissions-typical-passenger-vehicle.
4 International Energy Agency. CO2 Emissions from Fuel Combustion 2019. CO2 Emissions from Fuel Combustion. OECD, 2019. https://doi.org/10.1787/2a701673-en
5 Tesla. "2020 Impact Report." Tesla. https://www.tesla.com/impact-report/2020

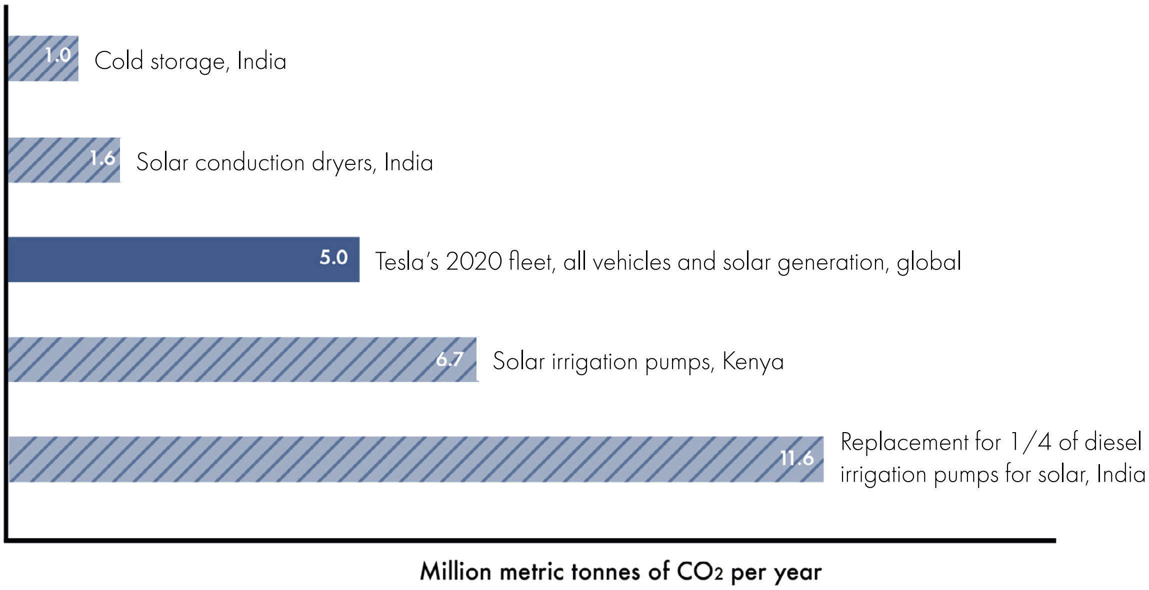


Figure 1. CO_2 Mitigation Potential of Certain AgTech Value Chains by Market, as Compared to Current Tesla Fleet

However, very few SME are mobilizing carbon financing to convert these contributions into cash flows. This lack of monetization is consistent with the experience of the agriculture sector more generally, and especially in LMICs. Food systems globally generate one-third of the 52 gigatons in total greenhouse gas (GHG) emissions, yet agriculture is the destination of just 1% of the $280 billion carbon market annually.[6,7]

While mitigation benefits may be easier to measure and market, the adaptation benefits provided by the sector are where its climate change value is arguably greatest. The small enterprises that make up these value chains tend to have deep understanding of local markets where incomes are generally low and climate vulnerabilities high. Their ability to address food and income insecurity are potentially transformative, but not adequately understood.

The types of adaptation benefits AgTech value chains can deliver include higher yields and higher quality produce; reduced post-harvest loss; increased local bargaining power; reduced operating costs; and increased nutritional diversity. They can also provide benefits with relatively weaker ties to resilience that are nonetheless relevant to broader development objectives: enhanced gender empowerment; improved air quality and health; ecosystem services such as improved soil quality and reduced erosion; and time savings, which can lead to enhanced education outcomes as well as other benefits arising from reallocation of time for beneficial purposes.

These adaptation benefits are much harder to quantify than mitigation benefits and can be highly variable across value chains and geographies. At this time, the evidence base is not sufficiently robust to help investors and SMEs quantify the extent to which AgTech investments lead to improved community resilience and development. This disconnect is a key reason why private sector approaches for delivering adaptation may be failing to attract climate finance.

Recommendations for leveraging climate benefits to mobilize growth capital and deliver scale

A lack of investment capital available to support growth for AgTech enterprises—namely a lack of early-stage equity and short-term debt to meet working capital needs—are stifling innovation and preventing low-carbon AgTech enterprises from scaling. The following recommendations are aimed at mobilizing climate finance to where it is needed most.

6 Crippa, M., E. Solazzo, D. Guizzardi, F. Monforti-Ferrario, F. N. Tubiello, and A. Leip. "Food Systems Are Responsible for a Third of Global Anthropogenic GHG Emissions." Nature Food 2, no. 3 (March 2021): 198–209. https://doi.org/10.1038/s43016-021-00225-9.
7 Chestney, Nina."Global Carbon Markets Value Surged to Record $277 Billion Last Year - Refinitiv." Reuters, January 27, 2021, sec. Environment. https://www.reuters.com/article/us-europe-carbon-idUSKBN29W1HR

1. **Data-driven financial mechanisms that quantify and monetize adaptation impacts are needed to mobilize climate finance and prioritize its deployment for greatest impact.** Monetization of adaptation benefits is critical to attracting private capital, which currently makes up just 1% of the $30 billion in annual adaptation investment.[8] Innovative funds and outcome-oriented financing facilities are emerging that blend public, philanthropic, and private capital to align risk. More robust impact frameworks would reduce investor uncertainty around such vehicles and boost investment (see Measurement Recommendations, #7–9 below).

2. **Investments are needed to supply rural markets with credit and other critical inputs to ready them for AgTech uptake and sector transformation.** SMEs across agriculture value chains are hitting the same roadblock. Their products routinely offer paybacks of 6–24 months, but that makes little difference to customers facing borrowing costs of 30–40% annually. Of SMEs interviewed, nearly 60% either became consumer finance organizations directly or invested in third-party relationships to solve for a lack of consumer credit access. Improved access to consumer credit—through banks, microfinance institutions (MFIs), cooperatives, and other nonbank financial institutions—is needed to overcome higher upfront costs of AgTech and allow SMEs to focus on core competencies.

3. **LMIC carbon mitigation funds/platforms for SMEs are needed to mobilize premium carbon reductions.** Very few AgTech enterprises are enjoying any financial benefit from the mitigation gains they are providing, as accounting and verifying carbon reductions have high transaction costs for typical small-scale initiatives in the sector. Third-parties capable of aggregating projects and supporting in certification and verification could lower transaction costs and build the market for carbon reductions with targeted co-benefits.

4. **Target results-based financing on resilience outcomes.** Consumers of low-carbon AgTech are extremely price sensitive and small price drops can bring large increases in addressable market size. Demand-side subsidies and results-based financing are underutilized tools for targeting resilience outcomes that could be deployed to scale AgTech into new markets.

5. **To accelerate deployment of climate finance with a low-carbon AgTech focus, groups of funders and companies should collaborate to identify best-fit financing instruments, with an eye to demonstration.** Interviewees voiced strong support for collaborative groups of SMEs and funders convened to understand respective needs and identify overlap, especially if funding were made available in parallel for supporting workable financing solutions.

6. **Investing in women-led and locally-led SMEs may require updating internal processes, more flexible finance terms, and additional technical support.** Women-led firms appear to be significantly underrepresented in the AgTech sector. To overcome internal biases and fully leverage the potential of the sector, investors should consider process reforms like leveraging women's professional energy networks for pipeline development and quotas in assembling investment "short lists." Investors may need to consider non-asset-based lending that relies on other forms of security like future cash flows, purchase order contracts or accounts receivables.

Recommendations for improving impact measurement to support monetization of climate benefits

A lack of basic sector-wide agreement on what adaptation means in terms of key performance indicators for AgTech enterprises has led to haphazard tracking. The metrics that SMEs do collect are generally a poor reflection of their true adaptation impact. SMEs are ill-equipped to deal with the many challenges of measuring adaptation impacts that are typically varied, localized, and occur over long time horizons. The recommendations that follow would support improved monetization of climate impacts by SMEs and potentially generate needed cash flows and investment, as illustrated in Figure 3.

7. **Standardized methodologies for measuring climate impacts are needed to help companies quantify climate benefits in monetary terms and establish markets.** Credible measurement of impacts relies on good quality, transparent, and verifiable impact data. SMEs and investors need a set of rules and criteria that permit third-party verification of methodologies or frameworks to rigorously measure specific adaptation benefits.

8 Macquarie, Rob, Baysa Naron, Paul Rosane, Matthew Solomon, and Cooper Wetherbee. "Updated View on the Global Landscape of Climate Finance in 2019." Climate Policy Initiative, 2020. https://www.climatepolicyinitiative.org/wp-content/uploads/2020/12/Updated-View-on-the-2019-Global-Landscape-of-Climate-Finance.pdf.

8. **Develop a publicly available database of evaluations that provide a range of credible values corresponding to specific impacts of targeted value chains, giving SMEs a starting point for more specific impact measurement.** A series of modest and nimble evaluations, which include counterfactual estimation strategies, would allow for the initial identification of investments that appear most promising for generating benefits. SMEs could undertake lighter-touch methods with more pragmatic data collection approaches, to help approximate the impact of interventions in specific places, at a lower cost.

9. **Moving towards more impact-driven adaptation investment models will require targeted technical assistance in key areas, including support to SMEs for impact measurement and investment readiness (especially for women-led and locally-led SMEs); support to facilitate partnership and data sharing between weather index insurers and SMEs; and support to investment fund managers for development of innovative blended instruments.** All SMEs reported that impact measurement was a costly and time-consuming activity. Third-party assistance will be needed to support companies aiming for a level of rigor that would support benefit monetization. Particularly important for women- and locally owned SMEs, investment readiness support can address relatively small but very real barriers in AgTech: language and culture, financial modeling skills, and awareness of international financing sources and processes. Technical assistance focused on building partnerships and data-sharing arrangements between SMEs and weather index insurers—which build and maintain probabilistic models of weather patterns and extreme events—would help leverage robust existing tools to better understand the localized resilience impacts of SMEs. On the fund side, there is a need for blended investment vehicles that incorporate concessional capital because many enterprises face either lower return profiles or relatively high investment risks. Targeted assistance can help funds overcome structural challenges, long lead-times, and mobilize diverse investor groups with a range of objectives, risk tolerances, and return requirements.

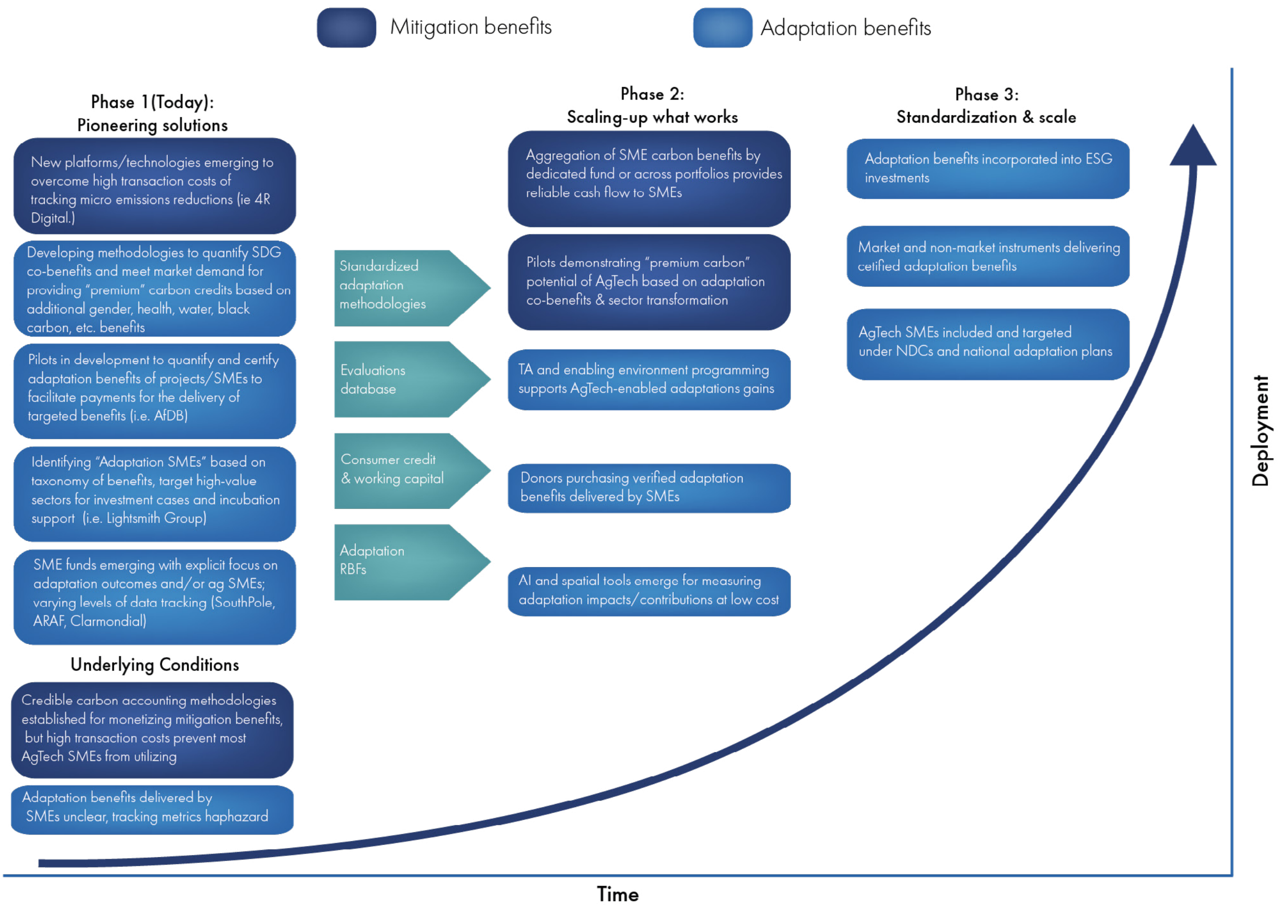


Figure 2. Roadmap for monetizing mitigation and adaptation benefits for low-carbon AgTech.

Recommendations for broader institutional and enabling environment support

The vast majority of climate finance to LMICs comes through large multilateral and bilateral financing institutions that are not designed to deliver capital to SMEs in the form and size needed. For the subset of climate finance originating from the multilateral climate funds,[9] investments are tied closely to country-led adaptation plans, which often give little to no role to SMEs.

10. **Build-out a diverse infrastructure of financial intermediaries to more quickly move large pools of climate capital to small enterprises, and activate frontier markets and sectors.** The number of intermediaries providing the "step down" function to channel climate funds from large international institutions to AgTech SMEs in the size and form needed is extremely limited. More innovative intermediaries are needed to test sector strategies, activate new markets, demonstrate funding models, and scale the most effective approaches. Decentralizing investment decision-making to local fund managers is the best way to leverage local expertise, align climate-related investment objectives with SME business models, and mobilize philanthropic and commercial co-financing.

11. **Encourage inclusion of SMEs in the development of country-level adaptation planning and connectivity to Nationally Determined Contributions.** Support should be made available to ensure broad engagement in national adaptation plans and consideration of SME-delivered interventions, as appropriate.

12. **Complementary policy and financing must focus on ensuring that farmers and rural businesses have access to critical inputs and markets so that AgTech deployment will maximize productivity and resilience gains.** Across the value chains examined, AgTech sales cluster around geographic areas where there is a critical threshold of other key sector participants, markets, infrastructure, information, and inputs to maximize farm yield (seed, fertilizer, and agro-chemicals). AgTech productivity is a force multiplier of market building. Conversely, this implies a particular need to think about challenges existing in remote and poor locations where markets and inputs are not aggregated, where AgTech does not represent a near-term solution, and where climate impacts may be disproportionately felt.

13. **Low-carbon AgTech should be competing on a level playing field, with emissions-heavy investment bearing the costs of damages it imposes.** Organizations interviewed made clear that rural farmers and business customers are highly attuned to AgTech costs vis-a-vis incumbent diesel-powered options and purchase decisions are made on the margin. A rebalancing of subsidies and tax benefits that levels the playing field may be needed in many markets for AgTech to gain traction.

9 Those affiliated with the United Nations Framework Convention on Climate Change (UNFCCC)--the Green Climate Fund (GCF), Global Environment Facility (GEF), and the Adaptation Fund

Relevant Actors

	Recommendation	Multilateral Climate Funds, Development Banks and DFIs	Fund Managers and Other Intermediaries	Impact Investors	LMIC Governments	AgTech Enterprises	Research Partners	Donors and Philanthropy	Commercial Investors	Corporates (including ESG)
Finance	1. Data-driven financial mechanisms that quantify and monetize adaptation impacts are needed to mobilize climate finance and prioritize its deployment for greatest impact.	●	●	●			●	●		●
Finance	2. Investments are needed to supply rural markets with credit and other critical inputs to ready them for AgTech uptake and sector transformation.	●			●			●	●	
Finance	3. LMIC carbon mitigation funds/platforms for SMEs are needed to mobilize premium carbon reductions.	●	●	●				●		●
Finance	4. Target results-based financing on resilience outcomes.	●			●			●		
Finance	5. To accelerate deployment of climate finance with a low-carbon AgTech focus, groups of funders and companies should collaborate to identify best-fit financing instruments, with an eye to demonstration.	●	●	●		●		●	●	●
Finance	6. Investing in women-led and locally-led SMEs may require updating internal processes, more flexible finance terms, and additional technical support.	●	●	●				●	●	●
Measurement	7. Standardized methodologies for measuring climate impacts are needed to help companies quantify climate benefits in monetary terms and establish markets.	●		●		●	●	●		●
Measurement	8. Develop a publicly-available database of evaluations that provide a range of credible values corresponding to specific impacts of targeted value chains, giving SMEs a starting point for more specific impact measurement.	●					●	●		
Measurement	9. Moving towards more impact-driven adaptation investment models will require targeted technical assistance in key areas, including support to SMEs for impact measurement and investment readiness (especially for women-led and locally-led SMEs); support to facilitate partnership and data sharing between weather index insurers and SMEs; and support to investment fund managers for development of innovative blended instruments.	●	●	●				●		●
Institutions & Enabling Environment	10. Build-out a diverse infrastructure of financial intermediaries to more quickly move large pools of climate capital to small enterprises, and activate frontier markets and sectors.	●	●	●	●			●		
Institutions & Enabling Environment	11. Encourage inclusion of SMEs in the development of country-level adaptation planning and connectivity to Nationally Determined Contributions.	●			●			●		
Institutions & Enabling Environment	12. Complementary policy and financing must focus on ensuring farmers and rural businesses have access to critical inputs and markets so that AgTech deployment will maximize productivity and resilience gains.	●	●	●	●			●		
Institutions & Enabling Environment	13. Low-carbon AgTech should be competing on a level playing field, with emissions-heavy investment bearing the costs of damages it imposes.	●			●					

Figure 3. Summary recommendations and relevant actors

Section 2: Introduction—Climate investment is not flowing to AgTech and essential sectors needed to build low-carbon development pathways.

Climate change is here and conditions will worsen for much of the Global South. The newest IPCC report predicts that the 1.5° C warming threshold will be reached by 2040, which all but ensures that the impacts of climate change will only continue to escalate in severity.[10] Under a business as usual scenario, low- and middle-income countries (LMICs) will experience the most acute effects of climate change, while also contributing an increasing share of the world's carbon emissions.[11] Decreased precipitation levels and hotter temperatures in Africa will exacerbate water and food insecurity, as well as increase the loss of arable farmland.[12] Asia will also be impacted by less rainfall and hotter temperatures, which is expected to decrease rice crop production. Fertile coastal regions of Asia will be inundated by storm surge and rising seas and battered by increased frequency of extreme weather events like floods, droughts, and heat waves.[13] By 2050, nearly 130 million people across sub-Saharan Africa and South Asia could be pushed to migrate, largely escaping less viable areas with lower water availability and crop productivity.[14]

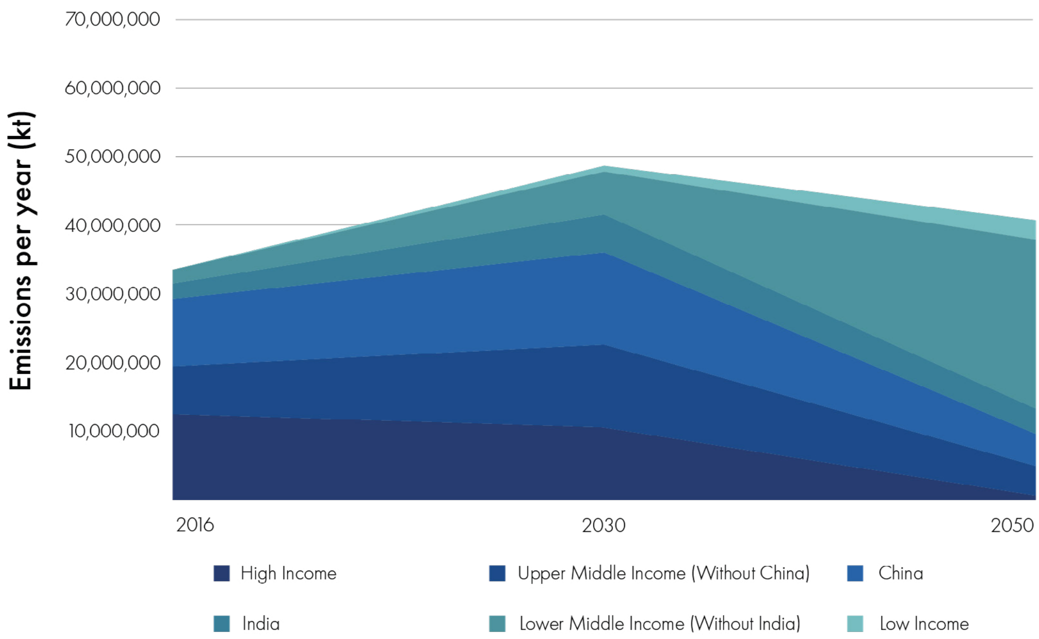


Figure 4. Growth and emissions outlook. Scenario assumes optimistic emissions outlook for high-income and upper-middle income countries, China, and India, along with 'fast' growth of LMIC/LIC at 7% and relatively high carbon intensity [15]

10 Valerie Masson-Delmotte et al. "Climate Change 2021: The Physical Science Basis." IPCC, 2021. https://www.ipcc.ch/report/ar6/wg1/downloads/report/IPCC_AR6_WGI_Full_Report_smaller.pdf

11 World Bank Group. "Transformative Climate Finance: A New Approach for Climate Finance to Achieve Low-Carbon Resilient Development in Developing Countries." Washington, DC: World Bank, June 17, 2020. https://doi.org/10.1596/33917.

12 Isabelle Niang et al. "Africa." AR5 Climate Change 2014: Impacts, Adaptation, and Vulnerability. IPCC, 2014. Accessed October 10, 2021. https://www.ipcc.ch/site/assets/uploads/2018/02/WGIIAR5-Chap22_FINAL.pdf

13 Hijoka, Yasuoki. "Asia." Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part B: Regional Aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change. IPCC, 2014. https://www.ipcc.ch/site/assets/uploads/2018/02/WGIIAR5-Chap24_FINAL.pdf

14 Rigaud, Kanta Kumari, Alex de Sherbinin, Bryan Jones, Jonas Bergmann, Viviane Clement, Kayly Ober, Jacob Schewe, et al. "Groundswell: Preparing for Internal Climate Migration." Washington, DC: World Bank, March 19, 2018. https://doi.org/10.1596/29461.; World Bank Group, "Transformative Climate Finance: A New Approach.

15 IGC. "Projecting Emissions: Assessing Strategies to Protect the Planet and the Poor," May 13, 2021. https://www.theigc.org/blog/projecting-emissions-assessing-strategies-to-protect-the-planet-and-the-poor/.

Small-scale agriculture is a particularly critical sector for building resilience among climate vulnerable communities and demonstrating new low-carbon development pathways. Fully 40% of jobs and 80% of food produced in sub-Saharan Africa and South Asia come from small-scale agriculture.[16,17] Soil degradation, shifting weather patterns, severe storms, and other anticipated impacts—made worse and more unpredictable by climate change—threaten the viability and, sometimes, the survival of smallholder farmers. The challenges facing smallholder farmers are exacerbated by structural inefficiencies and limited access to credit. Globally, more than 50% of people living in poverty are smallholder farmers.[18]

Low-carbon AgTech enterprises address a consistent bottleneck to growth in rural economies—energy access and reliability—en route to increasing the capacity for local value-adding activities, especially for women. Agricultural transformation requires multiple, simultaneous interventions: access to markets, transportation, irrigation, storage capacity, fertilizer and other inputs, and access to capital for farmers. Energy is a binding constraint for many of these elements, as the overlap between energy poverty and subsistence agricultural communities that are most vulnerable to climate shocks is highly correlated. Entrepreneurs steeped in these challenges are responding with innovative approaches to delivering needed solutions, many of which seek to address energy deficiencies as part of their design. Entire value chains have developed to increase efficiency and reduce waste—such as cold storage, mechanical processing, and irrigation—with built-in clean energy capabilities. But these solutions are under-resourced and lack easy access to sufficient finance. Changing this dynamic by directing climate finance towards SMEs has potential to transform the rate at which adaptation work is performed, while also delivering increased benefits.

In Africa, as urbanization continues and the food demands of cities increase, pressure for higher agricultural yields and demands for commercial processing, transport, and retailing post-farmgate will continue to grow. Work in wholesale, logistics, processing, and agricultural retail—conducted overwhelmingly by SMEs—accounts for 40% of non-farm employment and 25% of all employment in rural Africa.[19] Similarly, in South and Southeast Asia increases in food processing have led to a proliferation of SMEs focused on grain and rice milling, dairy, meat and fish processing, and cold storage.[20] Low-carbon AgTech offer a way of making these value chains more efficient, decentralized, lower cost, and less polluting.

With a third of all SMEs in LMICs led by women, the sector offers significant gender empowerment opportunities. Investing in women-led SMEs is important in emerging economies for a host of reasons, including that women are more likely to invest proceeds in health, education, and more inclusive local public goods.[21] But women-led businesses face even greater barriers to accessing finance due to lack of resources, less education, cultural challenges, and participation in different networks than male entrepreneurs.[22]

Climate finance directed to the agriculture sector is virtually nonexistent in comparison to its importance to LMIC economies and its potential to deliver resiliency gains. The most recent climate finance data puts the flow of finance to small-scale farmers, agri-entrepreneurs and value chain businesses at about $10 billion annually. Estimates of the general annual financing needs for this sector, however, range in the hundreds of billions, revealing a critical gap. Only 10% of climate finance to small-scale agriculture targets value chain actors and formal financial institutions serving them.[23]

Mitigation finance through carbon markets is disproportionately small given the scale of emissions coming from the sector. Historically, the greatest allocation of climate finance has been toward mitigation activities that reduce greenhouse gas emissions. Markets that define and value emissions reductions have matured since the Kyoto Protocol and the creation of the Clean Development Mechanism. These markets have grown dramatically in recent years, with the value of the global carbon market reaching nearly $280 billion in 2020.[24] However, o nly 1% of all carbon credits issued have gone to agriculture-related projects, as seen in Figure 5.[25] This is despite the fact that food systems are responsible for roughly a third of all GHG emissions globally.[26]

16 FAO. "Smallholders and Family Farmers," Factsheet_SMALLHOLDERS.pdf (fao.org
17 Goedde, Lutz, Amandla Ooko-Ombaka, and Gillian Pais. "Winning in African Agriculture." McKinsey, February 15, 2019. https://www.mckinsey.com/industries/agriculture/our-insights/winning-in-africas-agricultural-market.
18 Acumen. "Acumen Closes $58 Million Impact Fund, the First to Drive Climate Adaptation for Smallholder Farmers," July 27, 2021. https://acumen.org/blog/acumen-resilient-agriculture-fund
19 AGRA. "The Hidden Middle: A Quiet Revolution in the Private Sector Driving Agricultural Transformation." Africa Agriculture Status Report 2019. AGRA, 2019. https://agra.org/wp-content/uploads/2019/09/AASR2019-The-Hidden-Middleweb.pdf
20 Bresciani, Fabrizio, Thomas Chalmers, Dilva Terzano, Raghav Gaiha, Ganesh Thapa, and Nidhi Kaicker. "An Outlook on Asia's Agricultural and Rural Transformation: Prospects and Options for Making It an Inclusive and Sustainable One." International Fund for Agricultural Development (IFAD), 2019. https://www.ifad.org/documents/38714170/41201480/apr_outlook.pdf/a1f8762e-ee0d-490a-cf3a-399241e34087?t=1561034540000.
21 Chattopadhyay, Raghabendra, and Esther Duflo. "Impact of Reservation in Panchayati Raj: Evidence from a Nationwide Randomised Experiment." Economic and Political Weekly 39, no. 9 (2004): 979–86. https://www.jstor.org/stable/4414710; Fingleton-Smith, Edwina. "The Lights Are on but No (Men) Are Home. The Effect of Traditional Gender Roles on Perceptions of Energy in Kenya." Energy Research & Social Science 40 (June 1, 2018): 211–19. https://doi.org/10.1016/j.erss.2018.01.006; Thomas, Duncan. "Intra-Household Resource Allocation: An Inferential Approach." The Journal of Human Resources 25, no. 4 (1990): 635–64. https://doi.org/10.2307/145670.; Duflo: Women Empowerment and Economic Development, 1067-8.
22 Schiff, Hannah, Rebecca Fries, and Tim Chambers. "Beyond the Threshold: Investing in Women-Led Small & Growing Businesses ." Value for Women, 2013. https://www.aspeninstitute.org/wp-content/uploads/files/content/upload/VFW%20Report%20Brochure.pdf; Aterido, Reyes, Thorsten Beck, and Leonardo Iacovone. "Access to Finance in Sub-Saharan Africa: Is There a Gender Gap?" World Development 47 (July 1, 2013): 102–20. https://doi.org/10.1016/j.worlddev.2013.02.013; Demirgüç-Kunt, Asli, Leora F. Klapper, and Dorothe Singer. "Financial Inclusion and Legal Discrimination Against Women: Evidence from Developing Countries." SSRN Scholarly Paper. Rochester, NY: Social Science Research Network, April 1, 2013. https://papers.ssrn.com/abstract=2254240.
23 CPI. "Examining the Climate Finance Gap for Small-Scale Agriculture." Accessed November 22, 2021. https://www.climatepolicyinitiative.org/publication/climate-finance-small-scale-agriculture/.
24 Watson, Frank. "Global Carbon Market Grows 20% to $272 Billion in 2020: Refinitiv," January 27, 2021. https://www.spglobal.com/platts/en/market-insights/latest-news/coal/012721-global-carbon-market-grows-20-to-272-billion-in-2020-refinitiv.
25 AFN. "Agriculture Has Produced Just 1% of Issued Carbon Credits," September 28, 2021. https://agfundernews.com/carbon-credits-just-one-percent-from-agriculture.html.
26 FAO. "Food Systems Account for More than One Third of Global Greenhouse Gas Emissions." Accessed November 22, 2021. https://www.fao.org/news/story/en/item/1379373/icode/.

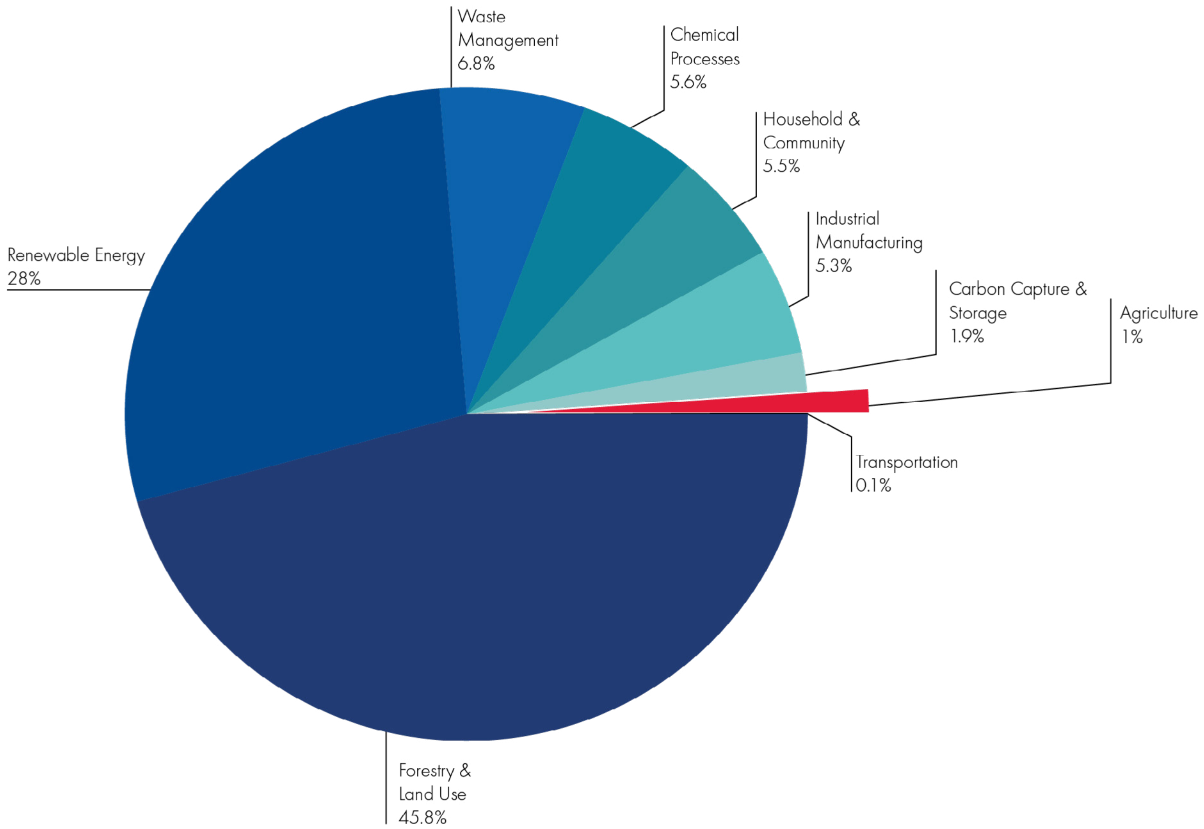


Figure 5. Percentage share of carbon credits issued by area of scope of projects.
Source: AgFunderNetwork [27] based on data from Berkeley Carbon Trading Project[28]

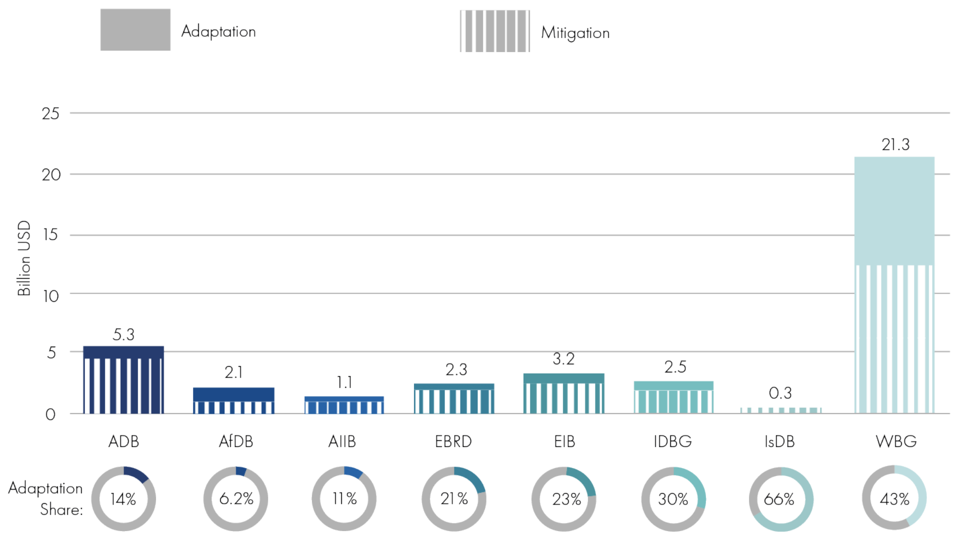
Climate change is increasing adaptation costs far faster than finance is being deployed to adapt, creating an alarming outlook for vulnerable populations in LMICs. In 2019, total climate finance flows globally amounted to roughly $600 billion,[29] of which $30 billion was for adaptation (see Figure 6). Allocations of climate finance for both mitigation and adaptation are on an upward trajectory, but adaptation costs are estimated to rise to $140–300 billion per year by 2030 in developing countries alone, and continuing to increase thereafter.[30]

Adaptation and low-carbon energy transitions are capital intensive, and the cost of capital in LMICs is high. Technologies like solar irrigation pumps or solar grain mills both offer substantial operational cost savings over incumbent fossil fueled options, but would-be buyers may not be able to afford the upfront capital costs.[31] In LMICs, nominal financing costs are up to seven times higher than in the United States and Europe.[32] Increased access to affordable credit can be transformative for asset-heavy sectors like AgTech.

27 Watson, "Global Carbon Markets."
28 Mitchell-Larson, Eli, and Tim Bushman. "Carbon Direct Commentary: Release of the Voluntary Carbon Registry Offsets Database." Carbon Direct, April 2021. https://carbon-direct.com/wp-content/uploads/2021/04/CD-Commentary-on-Voluntary-Registry-Offsets-Database_April-2021.pdf.
29 Macquarie, "Updated View on Global Landscape."
30 UNEP. "Adaptation Gap Report 2020." UNEP - UN Environment Programme, January 9, 2021. http://www.unep.org/resources/adaptation-gap-report-2020.
31 MercyCorps | Agrifin. "Policy Brief: Achieving Food Security in Kenya Through Smart Solar Irrigation." MercyCorp | Agrifin, 2020. https://www.mercycorpsagrifin.org/project/policy-brief-achieving-food-security-in-kenya-through-smart-solar-irrigation/; RMI. "Electrifying Agriculture in Ethiopia," May 10, 2021. https://rmi.org/electrifying-agriculture-in-ethiopia/.
32 IEA. "Financing Clean Energy Transitions in Emerging and Developing Economies." World Energy Investment 2021 Special Report. International Energy Agency, 2021. https://iea.blob.core.windows.net/assets/6756ccd2-0772-4ffd-85e4-b73428ff9c72/FinancingCleanEnergyTransitionsinEMDEs_WorldEnergyInvestment2021SpecialReport.pdf.

Use/Sector	2019	2020	2019/2020 Average
Adaptation	42	49	46
Agriculture, Forestry, Other land uses and Fisheries	5	4	4
Buildings & Infrastructure	1	1	1
Energy Systems	1	0.2	0.3
Industry	0.03	0.01	0.02
Information and Communications Technology	0.25	0.24	0.24
Others & Cross-sectoral	19	25	22
Transport	2	1	1
Waste	0.01	0.02	0.01
Water & Wastewater	15	19	17
Mitigation	566	576	571
Agriculture, Forestry, Other land uses and Fisheries	7	9	8
Buildings & Infrastructure	35	22	28
Energy Systems	321	342	332
Industry	9	5	7
Information and Communications Technology	0.1	0.1	0.1
Others & Cross-sectoral	21	17	19
Transport	169	177	173
Waste	1	3	2
Water & Wastewater	2	1	1
Multiple Objectives	15	15	15
Agriculture, Forestry, Other land uses and Fisheries	2	2	2
Energy Systems	2	1	2
Others & Cross-sectoral	9	10	9
Transport	1	0.1	0.4
Water & Wastewater	1	2	2
Total	**623**	**640**	**632**

Figure 6. Breakdown of global climate finance by sectors (USD billion), Source: CPI[33]



Source: 2020 Joint Report on Multilateral Development Banks' Climate Finance, calculations by WRI

Figure 7. MDB mitigation and adaptation finance to low- and middle-income countries in 2020. Source: WRI[34]

33 Buchner, Barbara, Alex Clark, Angela Falconer, Rob Macquarie, Chavi Meattle, Rowena Tolentino, and Cooper Wetherbee. "Global Landscape of Climate Finance 2019." Climate Policy Initiative, November 2019. https://www.climatepolicyinitiative.org/wp-content/uploads/2019/11/2019-Global-Landscape-of-Climate-Finance.pdf.

34 Neunuebel, Carolyn, Lauren Sidner, and Joe Thwaites. "The Good, the Bad and the Urgent: MDB Climate Finance in 2020," World Resources Institute, July 28, 2021. https://www.wri.org/insights/mdb-climate-finance-joint-report-2020.

Most climate investment to LMICs comes from public financing institutions. Multilateral development banks (MDBs) are the leading public provider of climate finance (see Figure 7 for a breakdown), followed by development finance institutions (DFIs) and the multilateral climate funds (MCFs) affiliated with the United Nations Framework Convention on Climate Change (UNFCCC), like the Green Climate Fund (GCF), Global Environment Facility (GEF), and Adaptation Fund (AF). Most of what is known about climate finance to LMICs is through the actions and reporting of public finance institutions. Private climate finance to LMICs lags public investment significantly. However, with more than 300 private financial institutions representing $93 trillion in financial assets now committed to net zero by 2050 at the latest, strategies for mobilizing private finance to LMICs will become critical.[35]

Adaptation finance is a growing share of climate finance, and almost all of it is from public sources. In 2015, adaptation finance accounted for 20% of the climate finance flows from MDBs, the principal adaptation funding source for LMICs. By 2020, adaptation finance was 35% of MDB's climate finance investments.[36] The African Development Bank (AfDB) has set aside over half of its climate finance for adaptation recently, and the Islamic Development Bank (IsDB) increased the share of adaptation finance from 40% to 66% of total climate finance.[37] Smaller streams of adaptation financing are delivered through MCFs, as many advanced economies are instead directing their climate finance through MDBs and their bi-lateral DFIs.[38] The MCFs serve as principal funding sources for countries implementing their national adaptation plans. The most common financial mechanism from MCFs are large (over $1 million) grants. These funds flow through accredited entities, the certification process for which can be lengthy and expensive. There tends to be very limited roles for SMEs in these funding strategies, which have little to no role in most national-level adaptation planning processes.

As a result of these barriers, climate finance is generally not the primary source of capital for low-carbon AgTech enterprises. The mitigation benefits these companies provide has been the dominant driver of what little climate-focused investment has reached the sector. This focus is striking, and points to substantial missed opportunities for enhancing climate-related outcomes, given the much larger adaptation and food security benefits AgTech SMEs deliver relative to mitigation. Adaptation work remains crucial to improving the well-being and security of rural communities in the Global South, and low-carbon AgTech represents a potentially important sector for climate finance to further leverage.

35 CPI, 2021. Private Financial Institutions' Commitments to Paris Alignment. Matthew Solomon, Donovan Escalante, Pedro Fernandes, Angela Pastor, Paul Rosane. Climate Policy Initiative, United States.
36 Neunuebel, Carolyn, "The Good, the Bad and the Urgent."
37 Neunuebel, Carolyn, "The Good, the Bad and the Urgent."
38 Thwaites, Joe, and Julie Bos. "A Breakdown of Developed Countries' Public Climate Finance Contributions Towards the $100 Billion Goal," World Resources Institute, May 10, 2021. https://www.wri.org/research/breakdown-developed-countries-public-climate-finance-contributions-towards-100-billion.

Section 3: Measuring Impacts of Scaling-Up SMEs

To better characterize the adaptation, resilience, and carbon mitigation benefits that could come from investment in the AgTech sector, we reviewed relevant literature and interviewed 35 investors and SMEs in the sector. The review focused on technologies that can be used in three value chains in the agricultural sector: water pumping for irrigation, refrigeration and cold storage, and grain milling and other forms of mechanical processing. These activities span the gamut from primary production (irrigation) to post-harvest processing and transport, and are all areas where access to reliable modern energy can offer significant improvements to enhance agricultural output quality and quantity as well as food and income security, nutritional diversity, and other benefits for farmers and consumers (see Figure 8).

Much of the insight drawn from this literature would apply in any geographic setting or market context within LMICs, but the literature is drawn principally from—and likely speaks best to—experiences of communities with robust commercial activity, where regulatory and institutional structures are relatively well developed and innovative SMEs are already emerging. Thus, to estimate the GHG reduction potential from a given quantum of investment in AgTech SMEs, we chose to focus on experiences in Kenya and India for illustrative purposes. The experiences in these markets may be indicative of what would be expected in other active markets in sub-Saharan Africa and South Asia, especially as markets develop over time.

AgTech SMEs powered by renewables have significant potential to contribute to climate change mitigation by reducing carbon emissions in agricultural value chains. This is more obvious when the services provided by SMEs displace diesel-powered or grid-powered technologies. For instance, displacement of diesel generators or irrigation pumps with solar technologies reduces emissions from diesel fuel. And to the extent that coal and other fossil fuels power central grids, displacing grid-tied systems with distributed-generation renewables reduces GHG emissions from the grid. But GHG reductions also accrue in settings where services represent "greenfield" technology deployments. For instance, providing cold storage where none existed before reduces food wastage, which means that the same quantity of usable food can be produced with less inputs, thus reducing emissions from food production. Reducing food waste also reduces decomposition of organic matter; such decomposition generates emissions of methane, a potent GHG.

In addition to mitigation benefits, scaling up AgTech SMEs would provide a host of services and benefits that help farm households and communities adapt to climate change. Services such as cold storage, mechanized processing, and irrigation help farmers, households, and communities to produce more agricultural products of higher quality, with reduced post-harvest loss. Higher-quality produce and the ability to store products more effectively for longer periods of time increases bargaining power for farmers, which also results in higher revenues. Irrigation provides a form of insurance that reduces the risk of crop failure, which in turn reduces the commercial risk for many companies working in agricultural and allied sectors.

Section 3.1 provides a framework for considering these and other types of benefits that potentially support adaptation and resilience that would arise from scaling-up SMEs within the studied value chains. Section 3.2 then provides an estimate of how much scaled-up AgTech could contribute to GHG emissions reductions. Section 3.3 elucidates the steps that SMEs would have to take to rigorously measure and quantify benefits. Section 3.4 provides a summary of challenges and solutions for practical use.

3.1 Conceptual Framework for Adaptation Benefits

Conceptualizing climate benefits in a comprehensive framework is critical for measurement and analysis, but distinguishing adaptation benefits from other types of benefits is not always clear. This challenge arises partly because analysis of societal adaptation to climate change remains nascent; e.g., a recent systematic review of academic literature on adaptation found that adaptations were largely fragmented, local and incremental, with negligible evidence of risk reduction outcomes.[39] Furthermore, the risks associated with a changing climate are real but highly uncertain, and all societies are fundamentally adaptive.[40] Yet societal vulnerability is greatest in societies and locations that are most exposed to those risks, and least developed. To be sure, all societies must improve their adaptive capacity today, but these needs are perhaps most acute in natural resource dependent, rural and low-income settings.

Thus, many of the benefits that accrue to communities as a result of investments into AgTech SMEs—that is, the impacts that result from new or expanded provision of services, technologies, or products—can be termed development benefits that would generally help communities regardless of the extent of climate change. For instance, mechanized processing saves time compared to manual processing, and farmers or household members would then be able to spend more time on other activities, such as education, off-farm employment, or leisure. Some of these alternative uses will more clearly enhance adaptive capacity than others, for example those that enhance income as opposed to increase leisure. While time savings on their own are undeniably beneficial for individuals, households, and communities, the nexus between time savings and resilience to climate change is therefore unclear and will tend to depend on how that time can be reallocated and utilized. Justification for labelling time savings as climate adaptation benefits therefore requires additional research, unless funders determine that climate adaptation finance can go directly to general development and/or redistributive initiatives.

By contrast, some of the benefits that arise from investments into AgTech very clearly support climate adaptation and resilience. For instance, irrigation reduces the risk of crop failure by providing a form of insurance against heat and water stress, which is especially valuable as climate change induces higher temperatures and variability in rainfall. Similarly, the value of cold storage for reducing food waste is especially important as ambient temperatures increase, since the rate of food spoilage increases nonlinearly with temperature.

From a broader perspective, the degree to which many specific agriculture sector benefits should be made eligible for climate adaptation finance remains challenging to specify. For instance, mechanized processing increases the digestibility of certain foods, and the resulting nutritional benefits would accrue regardless of the effects of climate change. On the other hand, individuals and communities with better access to nutritious foods will generally be healthier and thus more resilient in the face of climatic change, but the links stemming from interventions to resilience outcomes are highly complex.[41] Similarly, when solar irrigation pumps displace diesel pumps, the resulting improvements to local air quality (e.g., reduced emissions of asthma-inducing nitrogen oxides) would benefit communities independent of the impact of climate change. However, some evidence suggests that heat stress makes people more susceptible to ill effects of air pollution.[42] In such cases, it is difficult to tease apart which benefits specifically improve community resilience or adaptation to climate change, and thus which benefits should be counted for the purposes of allocating climate adaptation finance. Development of appropriate and sufficiently rigorous methods for doing so is therefore of great importance.

Figure 8 provides a visual summary of the types of benefits that arise from AgTech investments. The figure distinguishes direct from indirect benefits.

39 Berrang-Ford, Lea, A. R. Siders, Alexandra Lesnikowski, Alexandra Paige Fischer, Max W. Callaghan, Neal R. Haddaway, Katharine J. Mach, et al. "A Systematic Global Stocktake of Evidence on Human Adaptation to Climate Change." Nature Climate Change 11, no. 11 (November 2021): 989–1000. https://doi.org/10.1038/s41558-021-01170-y.

40 Adger, W. Neil, Saleemul Huq, Katrina Brown, Declan Conway, and Mike Hulme. "Adaptation to Climate Change in the Developing World." Progress in Development Studies 3, no. 3 (July 1, 2003): 179–95. https://doi.org/10.1191/1464993403ps060oa.

41 Béné, Christophe, Derek Headey, Lawrence Haddad, and Klaus von Grebmer. "Is Resilience a Useful Concept in the Context of Food Security and Nutrition Programmes? Some Conceptual and Practical Considerations." Food Security 8, no. 1 (February 1, 2016): 123–38. https://doi.org/10.1007/s12571-015-0526-x.

42 Pascal, Mathilde, Vérène Wagner, Anna Alari, Magali Corso, and Alain Le Tertre. "Extreme Heat and Acute Air Pollution Episodes: A Need for Joint Public Health Warnings?" Atmospheric Environment 249 (March 15, 2021): 118249. https://doi.org/10.1016/j.atmosenv.2021.118249.

- Direct adaptation benefits are those for which there is a well-established and clear link between the benefit and climate adaptation or resilience, though the magnitude of this link may vary across settings and value chains. Beyond this, we differentiate the direct category into:
    - One that is inherently climate adaptation (directly reducing exposure to risk), and
    - One that denotes enhanced adaptive capacity (or ability to withstand shocks when they occur), via higher income or greater empowerment
- Indirect means that although research and some theories of change support a link between this impact and climate adaptive capacity or resilience, the link is less well established and may not always hold. In general, the theories of change supporting these linkages contain several intermediate steps between the benefit and an adaptation or resilience improvement.

Finally, note that the classification of direct and indirect does not signify the magnitude of potential impact or social benefit. Moreover, these terms do not signify anything about the ease of converting the physical impact into monetary values that could be used to motivate adaptation finance.

The remainder of this section offers a conceptual framework for impacts that arise from investment in the three value chains that could potentially contribute to adaptation and resilience. All potential benefit categories are included, even those for which the nexus to climate adaptation is less clear.

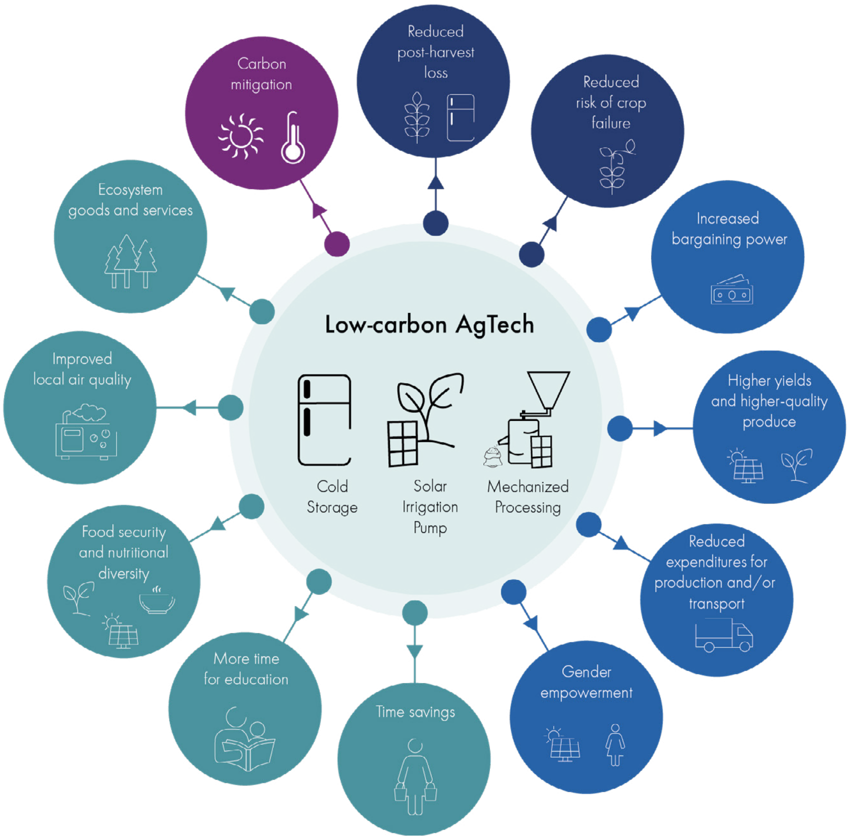


Figure 8. Contributions of AgTech to Climate Adaptation & Mitigation

Notes: Colors indicate the type of benefit category, as described in the text: Dark blue colors denote direct adaptation (i.e., directly reducing exposure to climate risks); light blue colors denote direct enhancement of adaptive capacity (i.e., enhanced ability to withstand shocks when they occur); shades of green denote indirect enhancement of adaptive capacity (where improvements occur via a more complex causal chain); and purple denotes climate mitigation. Note that the figure and typology do not imply anything about the relative magnitude or ease of monetizing these benefits.

Reducing post-harvest loss. SMEs providing equipment and services for processing and cold storage contribute direct economic value to farm operations by helping reduce post-harvest loss. For example, S4S Technologies, an AgTech SME operating in India, estimates that their solar conduction dryers reduce food loss by at least 15% through allowing effective preservation of produce shortly after harvest. Cold storage also has a vast potential to preserve food and reduce post-harvest loss since, for example, the same amount of deterioration can occur in one hour at 25° C as in one week at 1° C, for many horticultural commodities.[43] Processing and cold storage technologies reduce post-harvest loss across a range of contexts, and some of the benefits would accrue regardless of climate change. However, the benefits of cold storage, in particular, are more acute and larger in magnitude in a warmer climate. The rate of food spoilage increases nonlinearly with higher temperatures, so the link between investments in cold storage and climate adaptation is clear.[44]

Reduced risk of crop failure. Irrigation reduces the risk of crop failure by helping farmers meet crop water needs throughout the growing cycle, which is increasingly valuable in the face of increased climate variability, changing rainfall patterns, and higher temperatures, as predicted under climate change. Irrigation can also help farmers grow better-quality produce, especially for crops that are particularly sensitive to water deficit during periods of fruit set (e.g., tomatoes and other horticultural crops) or seed set (grains and pulses). The link between irrigation and resilience in the face of weather shocks and climate changes is well-established in the literature.[45]

43 Winkworth-Smith, C.G., T.J. Foster, and W. Morgan. "The Impact of Reducing Food Loss in the Global Food Chain." University of Nottingham, March 2015.
44 Winkworth-Smith, "The Impact of Reducing Food Loss."
45 Hussain, Intizar, and Munir A. Hanjra. "Irrigation and Poverty Alleviation: Review of the Empirical Evidence." Irrigation and Drainage 53, no. 1 (2004): 1–15. https://doi.org/10.1002/ird.114. Araya, A., and Leo Stroosnijder. "Assessing Drought Risk and Irrigation Need in Northern Ethiopia." Agricultural and Forest Meteorology 151, no. 4 (April 2011): 425–36. https://doi.org/10.1016/j.agrformet.2010.11.014.Burney, Jennifer, Lennart Woltering, Marshall Burke, Rosamond Naylor, and Dov Pasternak. "Solar-Powered Drip Irrigation Enhances Food Security in the Sudano–Sahel." Proceedings of the National Academy of Sciences 107, no. 5 (February 2, 2010): 1848–53. https://doi.org/10.1073/pnas.0909678107.Wang, Yangjie, Jikun Huang, Jinxia Wang, and Christopher Findlay. "Mitigating Rice Production Risks from Drought through Improving Irrigation Infrastructure and Management in China." Australian Journal of Agricultural and Resource Economics 62, no. 1 (2018): 161–76. https://doi.org/10.1111/1467-8489.12241.

Higher yields and higher-quality produce. AgTech SMEs providing off-grid irrigation equipment enable farmers to boost productivity and income by raising output created from a given amount of cultivated area. Dalberg and Mercy Corps found that irrigation allows farmers in Kenya to increase production by 200 to 400%, and incomes by 200 to 600%.[46] A program to install solar irrigation pumps in Zimbabwe increased incomes by 286% among very poor households, 173% for poor households, and 47% for middle-income groups.[47] In addition to increasing yields and revenues for existing crops, irrigation can create opportunities for farmers to grow new crops that can generate new revenue. For instance, an irrigation project in India triggered the establishment of a tree nursery to produce seedlings that were sold in the region and beyond to farmer groups, companies, and individuals.[48] While increased income and productivity is not an adaptation benefit itself, the links between income and reduced poverty, on the one hand, and resilience or adaptive capacity, on the other, are well-established in empirical literature.[49] [50] [51]

Increased bargaining power. Post-harvest processing and cold storage allow farmers to extend the shelf lives of perishable goods and to keep them in good condition, resulting in superior bargaining power with buyers and, in turn, better prices. Post-harvest processing can also increase the distance that farmers are able to transport their products, which can open new markets in neighboring villages. RMI (2021a) reports on a 2016 study in Amhara, Ethiopia, demonstrating that "farmers have limited bargaining power when trading maize [and other products] because they are eager to sell excess grains before they spoil, and traders have the power to find cheaper [products] in other communities."[52] The RMI analysis found that providing post-harvest milling and other processing services can help farmers negotiate more effectively with buyers and receive higher revenues for a given quantity of products. Some of these benefits would occur regardless of climate change, but, as noted in the section on post-harvest loss, higher temperatures increase the rate of food spoilage. Furthermore, climate change could affect prices in dynamic and complex ways—e.g., if some regions become unsuitable for certain crops, crop harvest cycles are altered, new temperature and rainfall patterns cause yields to fluctuate, or through other effects.[53] In this context, having better information and greater bargaining power will benefit farmers and improve efficiency (though at the expense of middlemen), especially if combined with reliable storage. Thus, part of the benefits of increased bargaining power can be linked to climate adaptation. However, the main connections are likely through increased income, which, as noted above, is clearly linked to enhanced adaptive capacity.

CEEW (2018) found that with a 30% capital subsidy, farmers in India would pay back the investment in a 3 hp solar irrigation pump within three years; since that analysis was complete, solar irrigation pump prices have fallen by as much as 70%, indicating that capital subsidies may not even be needed to achieve this level of payback—or payback could be much faster if capital cost subsidies are offered.[54] Electrifying grain milling and other forms of processing can also result in considerable cost savings. RMI (2021b) describes one representative grain miller in the Amhara region of Ethiopia who reports that diesel costs capture 60% of his revenues from milling teff, maize, and wheat.[55] RMI's financial analysis indicates this grain mill operation could cut total operational costs by 57% by replacing diesel with electricity at a tariff of 13 ETB/kWh ($0.33/kWh), and that the net savings would be positive as long as the electricity tariff remains below 27 ETB/kWh ($0.68/kWh).

Gender empowerment. The economic empowerment of women has important implications for the short- and long-term resilience of climate vulnerable households.[56] In many low-income contexts, women are particularly vulnerable to weather- and climate-related disruptions, often due to gender inequality and especially lack of access to resources, information, and effect risk management strategies.[57] [58] [59] Furthermore, women spend disproportionately more time providing unpaid domestic work, including unpaid agricultural labor, because of deeply held social norms, attitudes, and stereotypes about appropriate gender roles, while the burden of caring for family members in the face of shocks also falls disproportionately on them, making them key

46 Mercy Corps, "Policy Brief"
47 Magrath, John. "Transforming Lives in Zimbabwe: Rural Sustainable Energy Development Project." Oxfam, 17 Aug 2015. https://policy-practice.oxfam.org/resources/transforming-lives-in-zimbabwe-rural-sustainable-energy-development-project-567000/
48 Terrapon-Pfaff, "A cross sectional review"
49 Massetti, Emanuele, and Robert Mendelsohn. "Measuring Climate Adaptation: Methods and Evidence." Review of Environmental Economics and Policy 12, no. 2 (July 1, 2018): 324–41. https://doi.org/10.1093/reep/rey007.
50 Castells-Quintana, David, Maria del Pilar Lopez-Uribe, and Thomas K.J. McDermott. "Adaptation to Climate Change: A Review through a Development Economics Lens." World Development 104 (April 2018): 183–96. https://doi.org/10.1016/j.worlddev.2017.11.016.
51 Ojo, T.O., and L.J.S. Baiyegunhi. "Determinants of Climate Change Adaptation Strategies and Its Impact on the Net Farm Income of Rice Farmers in South-West Nigeria." Land Use Policy 95 (June 2020): 103946. https://doi.org/10.1016/j.landusepol.2019.04.007.
52 Santana, Scarlett, Francis Elisha, Zihe Meng, Kester Wade, and Patience Bukirwa. "Productive Uses of Energy in Ethiopia." RMI, 2021. https://rmi.org/insight/productive-uses-of-energy-in-ethiopia/.
53 Zhao, Chuang, Bing Liu, Shilong Piao, Xuhui Wang, David B. Lobell, Yao Huang, Mengtian Huang, et al. "Temperature Increase Reduces Global Yields of Major Crops in Four Independent Estimates." Proceedings of the National Academy of Sciences 114, no. 35 (August 29, 2017): 9326–31. https://doi.org/10.1073/pnas.1701762114.
54 Raymond, Anne and Abhishek Jain. "Solar for Irrigation: A Comparative Assessment of Deployment Strategies." CEEW, 2018. https://www.ceew.in/sites/default/files/CEEW-Solar-for-Irrigation-Deployment-Report-17Jan18_0.pdf
55 Meng, Zihe, and Kester Wade. "Electrifying Agriculture in Ethiopia." RMI, May 10, 2021. https://rmi.org/electrifying-agriculture-in-ethiopia/.
56 Godfrey-Wood, Rachel, and Benjamin C. R. Flower. "Does Guaranteed Employment Promote Resilience to Climate Change? The Case of India's Mahatma Gandhi National Rural Employment Guarantee Act (MGNREGA)." Development Policy Review 36, no. S1 (2018): O586–604. https://doi.org/10.1111/dpr.12309.
57 Hasan, Md. Robiul, Mahbuba Nasreen, and Md. Arif Chowdhury. "Gender-Inclusive Disaster Management Policy in Bangladesh: A Content Analysis of National and International Regulatory Frameworks." International Journal of Disaster Risk Reduction 41 (December 2019): 101324. https://doi.org/10.1016/j.ijdrr.2019.101324.
58 Aryal, Jeetendra Prakash, Tek Bahadur Sapkota, Dil Bahadur Rahut, Timothy J. Krupnik, Sumona Shahrin, M. L. Jat, and Clare M. Stirling. "Major Climate Risks and Adaptation Strategies of Smallholder Farmers in Coastal Bangladesh." Environmental Management 66, no. 1 (July 1, 2020): 105–20. https://doi.org/10.1007/s00267-020-01291-8.
59 Djoudi, H., and M. Brockhaus. "Is Adaptation to Climate Change Gender Neutral? Lessons from Communities Dependent on Livestock and Forests in Northern Mali." International Forestry Review 13, no. 2 (June 1, 2011): 123–35. https://doi.org/10.1505/146554811797406606.

to coping and recovery strategies.[60 61] They then have less time for education [62], economic opportunities [63], and leisure.[64] In food production and post-harvest, storage, transport and distribution, women benefit from reduced time spent on hauling water that can be spent on more productive or pleasurable activities. Moreover, the availability of cooling can offer business opportunities in dairy and other production that can be undertaken by women.[65] In processing, women tend to benefit the most from reduced time spent on manual work for processing products.[66] For instance, access to processing machinery can encourage women to start businesses in food processing.[67] The impacts are difficult to quantify, but investments in AgTech SMEs may enhance household and community resilience by increasing the political and economic empowerment of women, encouraging them to take leadership roles and increasing their influence in decision-making processes .[68] Research also suggests that women play a significant role in disaster response and recovery both at the household and community level, which suggests communities are more resilient to climate change when women have greater levels of human capital.[69] Over the long term, households with more empowered women often make decisions that prioritize investments in education and health and build long-term adaptive capacity. Women's agency has therefore been closely linked in the literature to improved adaptive response.[70 71]

Time savings. Just as AgTech helps farmers to save on operational costs, their services also can result in significant time savings for farm operations and farm households. In the production stage, introducing water pumps can reduce the time spent carrying water and, if applicable, from manual pumps. In the post-harvest and storage stage, drying produce using solar dryers is much faster than drying it on shelves. Mechanized processing of agricultural output—including activities such as grinding, de-husking, milling, threshing, and pressing—saves time over performing those activities manually. Furthermore, having access to the processing machines locally saves farmers the time needed to travel to another village for the services. To the extent that off-farm income generation opportunities are present (depending on the status of the labor market), farm households can use the time saved from farm operations to earn additional income. In fact, investment into renewable energy solutions can trigger income generation in the renewable energy sector itself; there are job opportunities for various skill levels in many segments of the value chain of AgTech projects and renewable energy more broadly.[72] The time savings can also go to other beneficial activities such as education or rest.

As noted in the introduction to Section 3.1, the nexus between time savings and climate change resilience is not clear. Thus, it is not clear that benefits that accrue from time savings should be identified as climate adaptation. Rather, absent additional research that clarifies mechanisms that do lead to improvements in adaptive capacity, time savings is perhaps best conceived of as a co-benefit that arises from investments enabled by climate adaptation financing but is not directly linked to (or creditable under) such adaptation financing.

Food security and nutritional diversity. Just as irrigation systems that help improve the quantity and quality of produce aid farmers to realize higher income from crops sold in markets, irrigation also increases community food security by improving the quantity and quality of produce consumed for subsistence. Mechanized processing activities such as grinding and pressing grains, drying fruits and vegetables, or other forms of processing such as the manufacture of pastes and sauces, can also contribute to improved nutrition by increasing digestibility (e.g., milling grains into flour); transforming visually unattractive produce into more appealing forms (e.g., processing blemished tomatoes into tomato paste); and increasing the diversity of foods and tastes available.[73]

60 Rubiano-Matulevich, Eliana, and Mariana Viollaz. 2019. "Gender Differences in Time Use: Allocating Time between the Market and the Household." World Bank Policy Research Working Paper 8981. August. Also see Gornick and Meyers (2003).
61 Smyth, Ines, and Caroline Sweetman. "Introduction: Gender and Resilience." Gender & Development 23, no. 3 (September 2, 2015): 405–14. https://doi.org/10.1080/13552074.2015.1113769.
62 Rogers, Martha H. "Environment and Development: Essays on the Link Between Household Welfare and the Environment in Developing Countries." University of Minnesota, 2014. https://conservancy.umn.edu/bitstream/handle/11299/165784/Rogers_umn_0130E_15148.pdf?sequence=1&isAllowed=y.
63 DeGraff, Deborah S., Deborah Levison, and Esther W. Dungumaro. "Environmental Chores, Household Time Use, and Gender in Rural Tanzania." In Gender and Time Use in a Global Context: The Economics of Employment and Unpaid Labor, edited by Rachel Connelly and Ebru Kongar, 407–34. New York: Palgrave Macmillan US, 2017. https://doi.org/10.1057/978-1-137-56837-3_16.
64 World Bank (2012).
65 Clancy, Joy, Margaret Skutsch, and Simon Batchelor. "The Gender - Energy- Poverty NEXUS: Finding the Energy to Address Gender Concerns in Development." DFID Project. UK Department for Institutional Development (DFID), 2002. https://research.utwente.nl/en/publications/the-gender-energy-poverty-nexus-finding-the-energy-to-address-gen.
66 IRENA. "Renewable Energy Benefits: Decentralized Solutions in the Agri-food Chain." IRENA, 2016. https://www.irena.org/-/media/Files/IRENA/Agency/Publication/2016/IRENA_Decentralised_solutions_for_agrifood_chain_2016.pdf.
67 Clancy, «The Gender-Equity-Poverty NEXUS.»
68IRENA, «Renewable Energy Benefits.»
69 Hemachandra, Kinkini, Dilanthi Amaratunga, and Richard Haigh. "Role of Women in Disaster Risk Governance." Procedia Engineering, 7th International Conference on Building Resilience: Using scientific knowledge to inform policy and practice in disaster risk reduction, 212 (January 1, 2018): 1187–94. https://doi.org/10.1016/j.proeng.2018.01.153.; Alam, Khurshed, and Md. Habibur Rahman. "Women in Natural Disasters: A Case Study from Southern Coastal Region of Bangladesh." International Journal of Disaster Risk Reduction 8 (June 2014): 68–82. https://doi.org/10.1016/j.ijdrr.2014.01.003.; Al-Maruf, Abdullah. "Enhancing Disaster Resilience through Human Capital: Prospects for Adaptation to Cyclones in Coastal Bangladesh." Universität zu Köln, 2017. https://d-nb.info/1135381666/34.
70 Rao, Nitya, Arabinda Mishra, Anjal Prakash, Chandni Singh, Ayesha Qaisrani, Prathigna Poonacha, Katharine Vincent, and Claire Bedelian. "A Qualitative Comparative Analysis of Women's Agency and Adaptive Capacity in Climate Change Hotspots in Asia and Africa." Nature Climate Change 9, no. 12 (December 2019): 964–71. https://doi.org/10.1038/s41558-019-0638-y.
71 Jemimah, Njuki, Eissler Sarah, Malapit J Hazel, Meinzen-Dick Suseela Ruth, Bryan Elizabeth, and Quisumbing R Agnes. A Review of Evidence on Gender Equality, Women's Empowerment, and Food Systems. Intl Food Policy Res Inst, 2021.
72 IRENA, and CEM. "The Socio-Economic Benefits of Solar and Wind Energy." IRENA, 2014. https://irena.org/-/media/Files/IRENA/Agency/Publication/2014/Socioeconomic_benefits_solar_wind.pdf.
73 Burney, Jennifer, Lennart Woltering, Marshall Burke, Rosamond Naylor, and Dov Pasternak. "Solar-Powered Drip Irrigation Enhances Food Security in the Sudano–Sahel." Proceedings of the National Academy of Sciences 107, no. 5 (February 2, 2010): 1848–53. https://doi.org/10.1073/pnas.0909678107 ; Olney, Deanna K, Abdoulaye Pedehombga, Marie T Ruel, and Andrew Dillon. "A 2-Year Integrated Agriculture and Nutrition and Health Behavior Change Communication Program Targeted to Women in Burkina Faso Reduces Anemia, Wasting, and Diarrhea in Children 3–12.9 Months of Age at Baseline: A Cluster-Randomized Controlled Trial." The Journal of Nutrition 145, no. 6 (June 1, 2015): 1317–24. https://doi.org/10.3945/jn.114.203539; Moyo, Thinah, and Charles L. Machethe. "The Relationship between Smallholder Irrigation and Household Food Availability and Dietary Diversity in Greater Tzaneen Municipality of Limpopo Province, South Africa." Journal of Sustainable Development 9, no. 4 (July 30, 2016): 165. https://doi.org/10.5539/jsd.v9n4p165; Upton, Joanna B., Jennifer Denno Cissé, and Christopher B. Barrett. "Food Security as Resilience: Reconciling Definition and Measurement." Agricultural Economics 47, no. S1 (November 2016): 135–47. https://doi.org/10.1111/agec.12305;

Processing of products also makes it possible to preserve their nutritional value over a longer period of time. For instance, milled flours and oils tend to have a longer lifespan compared to the unprocessed raw materials from which they are derived. Similarly, cold storage and refrigerated transport increase the usable lifespan of foods.[74] Ultimately, increased food security and nutritional diversity provide adaptation benefits by increasing nutritional intake, resulting in better health during childhood—which improves both physical and mental aptitude later in life—and during adulthood.[75] These are long term processes that enhance adaptive capacity, but the extent to which they are realized as a consequence of different intervention strategies needs to be clarified and analyzed carefully.

In addition, part of these food security benefits can be linked to climate change. As ambient temperatures increase, food will spoil faster when left exposed to environmental conditions; cold storage thus becomes more valuable in a warmer world. Also, superior nutritional diversity helps individuals and communities be healthier and better-fed, which can increase resilience to changing climatic conditions. However, part of the benefits would occur independent of climate change.

Improved air quality. Diesel-powered equipment and diesel backup generators are often significant contributors to local pollutant emissions. IFC (2019) found that backup diesel generators (in all sectors, not just agriculture) account for 15% of total emissions of nitrogen oxides (NOx) in sub-Saharan Africa.[76] NOx can trigger and exacerbate asthma among children and adults, and some studies suggest long-term exposure may lead to the development of asthma. NOx has also been implicated in the onset of heart disease and diabetes, as well as adverse birth outcomes, and premature death. Diesel generators also emit other pollutants known to damage human health, including fine particulate matter (PM2.5), black carbon, volatile organic compounds (VOCs), and carbon monoxide (CO). The combination of VOC and NOx emissions also make generators a potentially important contributor to the formation of ground-level ozone, which has been implicated in respiratory disease (IFC 2019).[77] Burning fossil fuels, especially coal, for grid-based electricity generation results in similar types of pollutant emissions and associated adverse impacts on local air quality. Furthermore, some evidence suggests there is a synergistic effect between heat stress and polluting emissions, such that the adverse effects of pollution are worse for human health when temperatures are higher.[78]

The relative contribution of diesel generators, and fossil-fuel-powered grid-connected assets, to local air pollution varies considerably depending on geographic and temporal context. Other emissions sources such as solid-fuel cookstoves, motorized vehicles, brick kilns, and other local manufacturing plants can also be important contributors, including in rural and agricultural communities.[79] Nevertheless, diesel generators do constitute a measurable portion of local air pollution in many settings: for instance, several studies of pollutant source contributions in cities in India found generators account for as much as 28% of local PM2.5 pollution.[80]

Ecosystem services. Agricultural systems rely on ecosystem services such as pollination, biological pest control, soil structure and fertility, and nutrient cycling. The value of these ecosystem services to agriculture is enormous, and often underappreciated. Depending on management practices, agriculture can also be the source of numerous disservices, including loss of habitat, nutrient runoff, sedimentation of waterways, and pesticide poisoning of humans and nontarget species; or it can produce a variety of ecosystem services, such as regulating soil and water quality, maintenance of soil structure and fertility, and support for biodiversity.[81] As a result, agricultural practices can have a significant impact both on the provision of ecosystem services and future yields over the medium and long term, which in turn relate in complex ways to climate risk vulnerability and adaptive capacity.

AgTech innovations can contribute to ecosystem service provision. For instance, as part of an integrated management plan, irrigation can contribute to improved soil quality by making it possible to have active plant growth throughout the year, thus reducing the risk of wind erosion or surface sediment runoff.[82]

74 Winkworth-Smith, "The Impact of Reducing Food Loss
75 Behrman, Jere R., and Mark R. Rosenzweig. "Returns to Birthweight." The Review of Economics and Statistics 86, no. 2 (May 1, 2004): 586–601. https://doi.org/10.1162/003465304323031139.Pitt, Mark M., Mark R. Rosenzweig, and Mohammad Nazmul Hassan. "Human Capital Investment and the Gender Division of Labor in a Brawn-Based Economy." American Economic Review 102, no. 7 (December 2012): 3531–60. https://doi.org/10.1257/aer.102.7.3531.
76 IFC, "The Dirty Footprint."
77 IFC, "The Dirty Footprint.
78 Pascal, Mathilde, Vérène Wagner, Anna Alari, Magali Corso, and Alain Le Tertre. "Extreme Heat and Acute Air Pollution Episodes: A Need for Joint Public Health Warnings?" Atmospheric Environment 249 (March 15, 2021): 118249. https://doi.org/10.1016/j.atmosenv.2021.118249.
79 E. Somanathan, Marc Jeuland, Eshita Gupta, Utkarsh Kumar, T. V. Ninan, Rachit Kamdar, Vidisha Chowdhury, Suvir Chandna, Michael H. Bergin, Karoline Barkjohn, Christina Norris, T. Robert Fetter, Subhrendu K. Pattanayak. "Electric stoves as a solution for household air pollution: Evidence from rural India." Unpublished manuscript.
80 IFC, "The Dirty Footprint."
81 Power, Alison G. "Ecosystem Services and Agriculture: Tradeoffs and Synergies." Philosophical Transactions of the Royal Society B: Biological Sciences 365, no. 1554 (September 27, 2010): 2959–71. https://doi.org/10.1098/rstb.2010.0143.
82 Idowu, John and Kulbhusan Grover. "Principles of Cover Cropping for Arid and Semi-Arid Farming Systems." NM State University, 2014. https://aces.nmsu.edu/pubs/_a/A150.pdf.

Certain kinds of irrigation systems that allow water to permeate into soils near gravity irrigation channels can also enhance biodiversity around farm fields, which can contribute to biodiversity and pollination services among other benefits.[83] When overused, however, irrigation can accelerate mineral weathering and nutrient leaching.[84]

Education. Education and human capital development improve individuals' and households' ability to understand risks as well as access information that helps to mitigate them.[85] Moreover, education is a critical building block for the development of rural areas. Insufficient time for studying is among the factors inhibiting academic progress especially in rural areas. Services provided by AgTech can enable better education for members of rural and agricultural communities, due in large part to the time savings that such services afford for members of farming households. Minimizing the time spent on hauling water throughout the growing season, transporting products to nearby villages for processing or cold storage, manually processing produce, and other activities, frees up time for studying, reading, or listening to the radio or watching television, which also can be educational.[86] In turn, the education of community members can contribute to increasing the productivity of agricultural activities. Improved education and learning can also help rural community members to eventually diversify their income sources, which can help individuals and communities be more resilient to climate change. However, this benefit is difficult to measure and quantify, since many complementary conditions (e.g., high quality schools and teaching) must be in place, and the process of rural economic development and transformation unfolds over years or even decades. Moreover, the extent to which energy-ag interventions contribute to improved educational outcomes and climate adaptation is not well explored in the literature.

In conclusion, evidence from around the world demonstrates that the services that AgTech SMEs offer provide numerous benefits for adaptation and resilience to climate change. Even so, the link between climate change and these benefits is not always clear, and in some cases, careful analysis would be necessary to distinguish how much of a particular type of benefit should be "creditable" for the purposes of receiving climate adaptation finance.

3.2 Contributions of AgTech to Climate Mitigation

While the contribution of AgTech SMEs to GHG mitigation is limited currently, scaling these value chains could generate significant carbon reductions compared to incumbent technologies. As noted above, AgTech has the potential to reduce GHG emissions in all three value chains: by displacing diesel-powered irrigation pumps, diesel generators used for primary or backup power for processing and refrigeration units, and grid-powered electrical connections. In the case of grid displacement, GHG reductions are especially large when electricity generation sources include coal, gas, and oil.

To estimate the GHG reduction potential from a given magnitude of investment in AgTech SMEs, we use Kenya and India as demonstration markets. These countries may be indicative of other national or regional markets in sub-Saharan Africa and South Asia as those other markets develop more over time. Nevertheless, even in these relatively well-developed and well-studied markets, data to estimate potential GHG reductions are somewhat limited.

3.2.1 Carbon mitigation potential of solar irrigation

In both Kenya and India, solar irrigation pumps have a higher upfront cost than diesel pumps, even as solar pump prices have declined dramatically in recent years. However, the cost to operate and maintain solar pumps is vastly lower, and they tend to have longer useful lives, so the total cost for farmers is much lower for a solar pump than a diesel pump (Mercy Corps 2020, CEEW 2018, IEEFA 2018, ICID 2019).[87]

In Kenya, currently 3% of arable land is irrigated—about 165,000 hectares—which is well below the average for sub-Saharan Africa of 7%. Under the National Water Master Plan 2030, the Government of Kenya aims to irrigate an additional 803,000 hectares by 203.[88] Thus, an investment in SMEs providing renewables-powered irrigation equipment and services would provide for a massive boost to productivity as well as reduced GHG emissions, since the alternative to renewables-powered irrigation would be primarily diesel-powered irrigation pumps. Mercy Corps (2020) suggests that developing the market for solar irrigation pumps would require a combination of four interventions: a targeted subsidy for smallholder farmers to purchase solar pumps; an awareness campaign to convey the benefits of solar irrigation; financial support to increase access to water sources; and extending risk sharing agreements to enable better financing options for customers.[89] Evaluating administrative

83 Boyce, James, and Barry Shelley. Natural Assets. Island Press, 2003.
84 Murray, RS, and CD Grant. "The Impact of Irrigation on Soil Structure." Land & Water Australia, 2007. https://library.dbca.wa.gov.au/static/FullTextFiles/070521.pdf.
85 Lee, Tien Ming, Ezra M. Markowitz, Peter D. Howe, Chia-Ying Ko, and Anthony A. Leiserowitz. "Predictors of Public Climate Change Awareness and Risk Perception around the World." Nature Climate Change 5, no. 11 (November 2015): 1014–20. https://doi.org/10.1038/nclimate2728.
86 Ministry of Foreign Affairs of the Netherlands Policy and Operations Evaluation Department (IOB). "IOB Study – Renewable Energy: Access and Impact. A systematic literature review of the impact of livelihoods of interventions providing access to renewable energy in developing countries." Jan 2013. https://www.government.nl/ministries/ministry-of-foreign-affairs/documents/reports/2013/03/01/iob-study-renewable-energy-access-and-impact
87 Mercy Corps, "Policy Brief" ; Raymond, "Solar for Irrigation ; Garg, "India: Vast Potential"; International Commission on Irrigation and Drainage (ICID). "Solar Powered Irrigation Systems in India: Lessons for Africa Through a FA Study Tour." ICID, 2019. https://www.icid.org/FAO-SPIS-Report.pdf.
88 Mercy Corps, "Policy Brief."
89 Mercy Corps, "Policy Brief."

data, custom survey data, and the market landscape for irrigation solutions, Mercy Corps (2020) indicates that this package of interventions would support sufficient market development to deploy 1.3 million solar water pumps, increasing Kenya's irrigated land area to 1,265,000 hectares (22% of arable land).[90]

In general, these interventions would be most efficient to deploy through providing finance to SMEs. The package of market development interventions, along with the capital necessary for SMEs to deploy irrigation pumps in the marketplace, would cost approximately $206 million. Diesel use (and resulting GHG emissions) for a given pump varies depending on the crops grown, crop water needs and watering cycles, groundwater depth, and other factors, but using a representative nationwide average of 2,000 liters per year this investment would result in savings of 2.6 billion liters of diesel fuel annually and avoid emissions of 6.7 million tons of CO_2 per year.[91] (Appendix A provides additional details on these calculations.)

In India, where nearly half of arable land is irrigated[92], the market for irrigation pumps is much better developed—but is currently dominated by grid electricity, which powers 70.1% of current irrigation pumps, and diesel, which powers about 29.4%. Solar water pumps account for the remaining 0.5%.[93] Market landscape surveys and experimental field deployment studies suggest that even though solar pumps save farmers money over time, capital constraints prevent widespread uptake and make diesel pumps relatively more attractive in many cases. Most farmers face capital constraints, and for many farmers (as many as 50% of farmers in Uttar Pradesh, according to one large survey), these capital constraints already force them to rent pumps or buy water, even though buying a pump would reduce total costs .[94], [95] The upfront cost of solar pumps is on the order of three times that of comparable diesel pumps, which means that already capital-constrained farmers are even less likely to be able to afford solar pumps.[96]

In this context, investments into AgTech would ease the capital constraints that farmers face by allowing firms that sell solar pumps to sell their pumps with affordable interest rates and generous lease-to-own terms (assuming the investments have sufficiently generous terms). An investment of $100 million into the market in India would allow SMEs to deploy about 67,000 3-horsepower solar water pumps, which would in turn save about 133 million liters of diesel fuel and avert the emissions of nearly 350,000 tons of CO_2 per year. Replacing grid-connected pumps with solar pumps may be unrealistic given that grid power is typically available to farmers at highly subsidized rates—although such a replacement could result in substantial fiscal benefits for the government entities that must ultimately pay out those subsidies. However, replacing just one-quarter of India's 8.8 million diesel pumps with solar pumps—which would require an investment of approximately $3.3 billion—would result in savings of 4.4 billion liters of diesel, based on the national average of 2,000 liters of diesel fuel consumed per pump per year.[97] This, in turn, would result in avoided emissions of 11.4 million tons of CO_2 per year. (See Appendix A for detailed calculations.)

3.2.2 Carbon mitigation potential for processing

As noted above, the agricultural processing value chain encompasses many different activities, such as milling, threshing, pressing, drying, and canning. Unlike irrigation, there is very little published analysis on the GHG mitigation potential from expanding access to these services, or from displacing current power sources (grid electricity and/or diesel generators that provide primary or backup power) with renewables.[98] Also, despite a comprehensive review of published literature we did not identify a source of information on electricity or diesel fuel use from agricultural processing activities as a whole.

To provide insight on potential emissions reduction from an investment into SMEs that provide equipment and services for processing agricultural products, we used data from one of the SMEs we interviewed, S4S Technologies. Based in India, with a global reach that also includes other countries in South Asia as well as in East Africa, S4S manufactures and sells high-capacity solar conduction dryers. Each dryer has the potential to dry 100 kg of agricultural products per day, although actual use depends on factors such as crop type(s), season, yields, and availability of labor. According to S4S data, when the solar dryers displace grid-powered dryers, each kg of food treated saves 0.8 kg of CO_2 emissions, based on the carbon intensity of grid-based electricity. When the solar dryers are a "greenfield" technology (providing drying services where they were not available before), each kg of food treated can save up to 7.9 kg of CO_2 emissions.

90 Mercy Corps, "Policy Brief."
91 IRENA , "Renewable Energy Benefits."
92 Jitendra. "Growing Gap in Irrigation Potential and Usage Major Challenge." DownToEarth, September 6, 2019. https://www.downtoearth.org.in/news/agriculture/growing-gap-in-irrigation-potential-and-usage-major-challenge-66580.
93 Garg, Vibhuti. "India: Vast Potential in Solar-Powered Irrigation." IEEFA, 2018. https://ieefa.org/wp-content/uploads/2018/08/Indias-Vast-Potential-in-Solar-Powered-Irrigation-.pdf
94 Raymond, "Solar Irrigation"
95 Jain, Abhishek and Tauseef Shahidi. "Adopting Solar for Irrigation: Farmers' Perspectives from Uttar Pradesh." CEEW, 2018. https://www.ceew.in/publications/adopting-solar-irrigation-0
96 CEEW (2018) states that the upfront cost of a 3hp solar pump is ten times that of a 3 hp diesel pump. Renjini et al. (2021) report on a survey of 2019 field prices in Andhra Pradesh that found the upfront cost for a solar pump is eight times more than diesel. However, solar pump prices have fallen dramatically in recent years; we searched online catalogs (e.g., IndiaMart.com) and found that the upfront cost for a 3 hp submersible solar pump in 2021 is about three times that of a comparable diesel pump.
97 IRENA. "Solar Pumping for Irrigation: Improving livelihoods and sustainability." IRENA, 2016. https://www.irena.org/publications/2016/Jun/Solar-Pumping-for-Irrigation-Improving-livelihoods-and-sustainability
98 A few university-based applied engineering labs provide data from the lab-based performance of individual units, but carefully controlled studies using strict protocols in idealized conditions are not a good guide for field performance (Wathore et al. 2017 [https://pubs.acs.org/doi/abs/10.1021/acs.est.6b05557], Grieshop et al. 2017 [https://agupubs.onlinelibrary.wiley.com/doi/full/10.1002/2017GH000066]).

This higher CO_2 savings from "greenfield" development arises from a combination of reduced in GHG emissions associated with transport and logistics—since dried produce has less mass and volume, more can be transported for a given quantity of fuel—and reduced post-harvest food loss. Less food spoilage means that more useful food can be grown with a given quantity of inputs, and it also reduces the decomposition of organic waste, which generates methane—a potent GHG.

Assuming that the actual throughput for a solar conduction dryer is about 10% of its nameplate capacity, and assuming that about 70% of dryers are deployed in villages where mechanized (grid-based) drying is currently available, each dryer unit would save about 10,700 kg of CO_2 per year.[99] Furthermore, S4S's financial calculations suggest that an investment of $1 million would allow them to deploy about 15,000 dryer units. Thus, scaling up solar conduction dryers with a $1 million investment would result in saving about 161,000 tons of CO_2 per year.

3.2.3 Carbon mitigation potential for cold storage

As with mechanized processing, there is relatively little published data on the GHG mitigation potential from expanding access to cold storage. To provide insight on potential GHG emissions reductions from expanding such access, we used data from an SME we interviewed that provides cold storage solutions in India, which suggested that an investment of approximately $750 million would permit SMEs to deploy 50,000 cold storage units across the country. This, in turn, would be sufficient to provide cold storage solutions for the current addressable market, based on a 2017 report from the Associated Chambers of Commerce and Industry of India (ASSOCHAM), which noted that India's 6,300 cold storage units provide cooling for 11% of its perishable produce.[100] Assuming that these solar cold storage units displace diesel-powered units (that would otherwise be deployed, in the absence of solar-powered units), this would avert the emissions of approximately 975,000 tons of CO_2 per year.[101] It is important to note that these estimated reductions are limited to the displacement of diesel-powered cold storage units with solar-powered units—although preventing food waste would also reduce methane emissions from decomposition of spoiled agricultural products.

3.3 Steps to better measure, quantify, and value impact

Well-established approaches exist for measuring benefits from climate adaptation and carbon mitigation, but their deployment requires evidence generated by relevant impact evaluation methods. Environmental economists and others have developed a considerable body of knowledge about how to rigorously measure benefits and costs of various types of interventions, including the deployment of agricultural services and technologies in rural areas in LMICs. But realistically, applying the most rigorous standards of evidence for academic studies is not possible for most SMEs, who are appropriately concerned about near-term profitability, scaling-up, and other financial and logistical challenges. Few SMEs have intimate familiarity with state-of-the-art impact evaluation methods, or the resources to develop certain data items that would be necessary to apply the most rigorous methods. Nonetheless, it is instructive to consider the steps involved in rigorous measurement of impacts, since this overview provides some insight on what might be feasible, especially if additional tools can be developed.

A framework for rigorously quantifying impacts would follow these steps (see Figure 9):

1. Identify the benchmark or baseline scenario (e.g., consisting of fossil-fuel-powered or inefficient technologies)
2. Describe the physical changes or outputs that arises from a given amount of new financing
3. Identify relevant categories of adaptation and mitigation benefits (and costs) that flow from those output
4. Quantify the adaptation and mitigation benefits (and costs) in physical terms
5. Estimate the monetary value of the benefits and costs
6. Aggregate the monetary values to estimate a total net benefit from the investment.

99 The 70% figure is based on the proportion of irrigation pumps in India that are connected to the grid (CEEW 2018, IEEFA 2018). That is, the assumption is that villages with grid-connected irrigation pumps also have access to grid-connected produce drying facilities.

100 Chauhan, Monika. "Up to 50pc of milk, fruit, veggies, produced go waste India." The Tribune, 25 October 2017. https://www.tribuneindia.com/news/archive/science-technology/up-to-50pc-of-milk-fruits-veggies-produced-go-waste-in-india-486989

101 Goel, Nitin. "World's 1st Retrofittable Thermal Energy Storage for Refrigeration & Air-Conditioning." InfiCold. https://old.viennaenergyforum.org/sites/default/files/documents/Goel-%20Inficold.pdf.

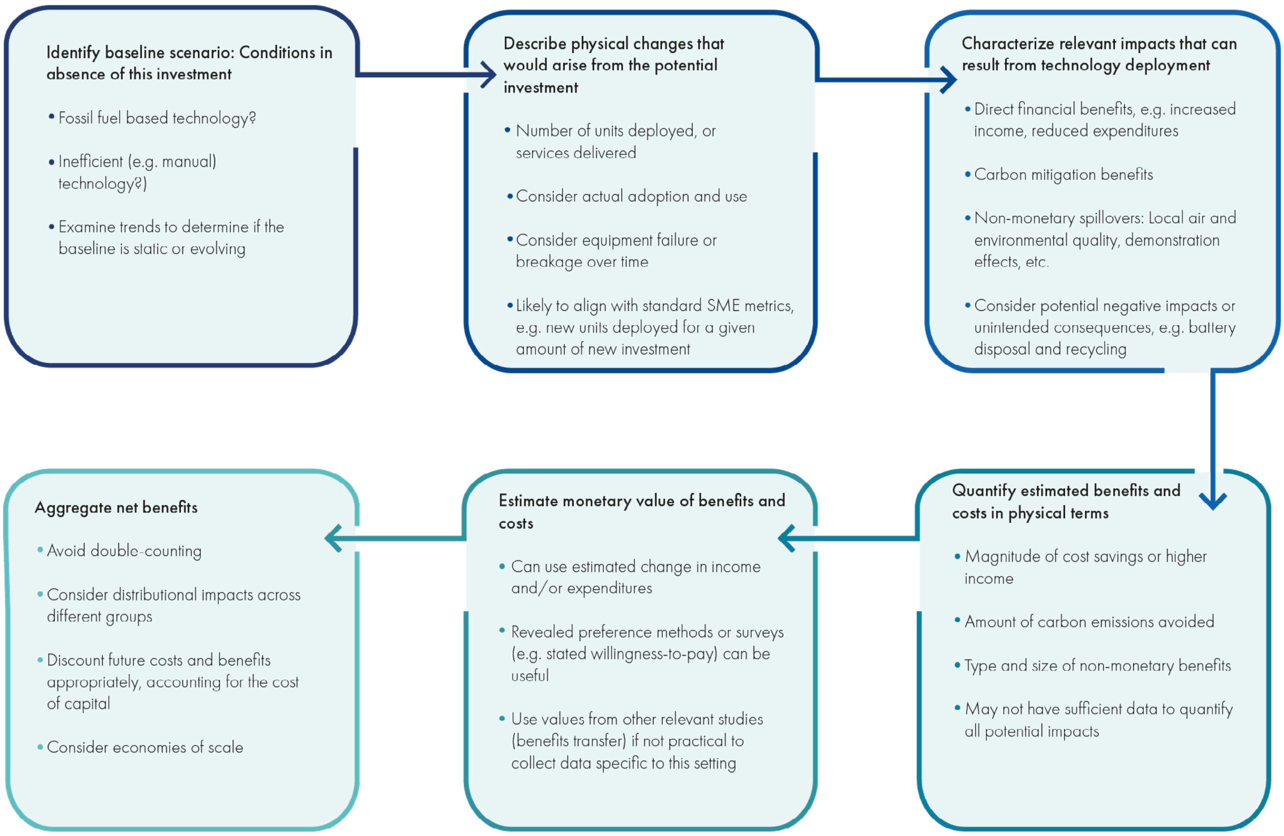


Figure 9. Steps for rigorous impact evaluation

Step 1: Identify the baseline or benchmark scenario. The first step is to consider the baseline of the current technology that is being used to provide the service. This will typically consist of a fossil-fuel-powered technology or an inefficient technology, such as manual processing or hand-carrying water in buckets. Benchmarking the current condition is important because the economic, environmental, and health impacts of a new intervention should be measured against what is being displaced. For instance, if solar irrigation pumps are providing consistent water inputs to a field that previously had no access to irrigation, the economic benefits from higher-quality produce and higher yields may be substantial but the immediate net benefit in terms of GHG reductions may be negligible. Conversely, if a solar-powered grain mill displaces a grid-connected grain mill with a backup diesel generator, the adaptation benefits related to higher revenue may be negligible (assuming that the capacity and quality of milling is identical). But the solar-powered mill may offer operational cost savings by reducing the need to purchase diesel fuel. Displacing diesel-powered technologies with solar-powered technologies would also provide air quality benefits and climate change mitigation benefits by reducing emissions of carbon dioxide and other pollutants.

Critically, it is also important to consider whether the baseline condition against which the comparison is made is static, that is, unchanging irrigation or milling technology in the example above, or is naturally evolving on its own over time, for example if some farmers or processors are already undergoing a transition (albeit a slow one) to new and improved technology. This type of information can be obtained by examining trends in technology use in a given location over time, or by conducting surveys with potential beneficiaries that include retrospective questions about technology use. Establishing whether the baseline is static or dynamic is essential for addressing cause-and-effect questions, which are fundamental for rigorous impact evaluation. Impact evaluation seeks to compare what actually happened (or would happen) with an intervention, and what would have happened in the absence of the intervention. This requires identifying changes in outcomes that are directly attributable to a program, which in turn requires a "counterfactual" scenario. In short, impact evaluation seeks to compare conditions "with and without" an intervention and not just "before and after."

Step 2: Describe the physical changes or outputs that would arise from a specific increment in financing. Physical change in this case refers to the quantity of uptake by agricultural operations, households, communities, or other customers. Depending on the goods and services provided by the SME, it may refer to a number of units, a quantity of services delivered, or some other metric. This step may align closely with metrics that SMEs produce as part of their business plans, monitoring efforts, and strategic communications. For instance, the technical or financial experts in the SME may be well used to answering the question of how much equipment or services they could deliver if they had access to a given amount of investment.

It is important to consider actual adoption by customers: for instance, the number of units that can be produced for a given amount of investment is not necessarily the same as the number that will be purchased and ultimately used by customers. The frequency and intensity of utilization may also differ from theoretical capacity. For instance, consider a grain milling machine that has the capacity to process 100 kg of grain per day. If the machine is actually used only during a four-week harvest season that occurs twice per year, the physical impact of the machine should be considered in light of the fact that its actual use is on the order of one-sixth of its theoretical capacity. In addition, there may be some equipment failure or breakage over time that should be included in the determination of outputs.

Step 3: Characterize relevant impacts that can arise from the investment. The third step is to identify the relevant categories of positive (and, potentially, negative) impacts that arise from access to AgTech equipment and services. This provides a qualitative conception of the benefits (and costs) that arise from such access. The analysis in Section 3.1 may provide a useful guide for adaptation-related benefits. For instance, solar-powered irrigation pumps help to reduce the risk of crop failure or low yield due to changing rainfall patterns or infrequent rainfall. In so doing, solar irrigation pumps provide for better food security and dietary diversity for both the smallholder family and nearby populations who depend on food production from nearby farm operations. Solar irrigation pumps also have lower operating costs compared to diesel-powered pumps and offer particularly large financial savings in areas where diesel fuel is difficult or costly to obtain. Displacement of diesel-powered pumps also results in improved local air quality, with subsequent reductions in childhood asthma and adult respiratory diseases, as well as reduced carbon emissions. On the other hand, in locations where solar-powered pumps displace hand-carried water (e.g., carrying buckets to fields), these air quality improvements may be nonexistent or immaterial. In this case, however, solar irrigation pumps would generally result in substantial labor savings, such as the time spent carrying water from rivers or ponds to the field. If this labor is paid a wage, this implies a reduced operating cost to the farm operation. If the labor is unpaid (e.g., unpaid household members carrying buckets), the time savings also represent a category of benefit to be considered.

Regarding costs specifically, some beneficial investments may nonetheless have negative consequences that must also be quantified. For example, a solar irrigation pump system with a battery must account for the potential costs of battery disposal and recycling, in terms of environmental or other costs. Assessors should also carefully think about what types of unintended consequences may result from investments, for example, if loss of employment in previously labor-intensive systems cannot be easily absorbed otherwise by the local economy.

Step 4: Quantify the estimated impacts in physical terms. The next step is to consider the physical outputs identified in Step 2 and determine how they translate into physical quantities of benefit (or cost) categories identified in Step 3. Like the work in Step 2, this element has some natural alignment with activities that SMEs already engage in, especially those that draw financing from impact investors. For instance, an SME providing solar irrigation pumps, and reporting on avoided GHG emissions that arise from this technology, would likely be able to quantify the amount of avoided GHG emissions that would result from a given magnitude of investment. In some cases, the "physical terms" may be one and the same with monetary or financial terms, as in the case of reduced expenditures that result from avoiding the need to buy diesel fuel to power a diesel-powered grain mill, once the grain mill is displaced with a solar-powered mill. Other impacts may be difficult to quantify without custom-designed surveys, however. For instance, while an SME may have anecdotal evidence that their goods and services result in time savings for farmers or farm household members, being able to rigorously quantify the amount of time saved for the average customer would require a time use survey applied to a large group of customers.

Furthermore, to provide rigorous evidence, any survey (whether it asks questions about reduced expenditure, higher revenue, time savings, or any other outcome) would have to be conducted on a random sample of customers, not a "convenience sample" (e.g., customers who volunteer such information on their own, or customers who are most forthcoming when approached by SME sales staff). This is because customers who mention a particular impact—say, time savings—of their own accord are not likely to be representative of the whole population, and those most eager to provide feedback via surveys are often those who have benefitted most. Identifying a representative sample of customers for measurement purposes requires careful application of scientific sampling methods.

Most impact analyses tend to be deterministic in their approach, using a single value for each category of physical impacts that is based on the average value observed in a representative sample. For impacts that are inherently uncertain, such as the reduced risk of crop failure, it may be more appropriate to conduct a scenario analysis or a probabilistic simulation analysis. Scenario analysis involves analyzing and evaluating possible "states of nature" or scenarios that could take place in the future and predicting possible outcomes of an intervention. The number of scenarios is usually relatively small, typically three to five at most. Probabilistic simulation analysis typically involves a procedure known as Monte Carlo simulation, which involves building models of possible results by substituting a range of values (i.e., a probability distribution) for factors that are inherently uncertain, such as the date of monsoon onset, the amount of rainfall in a growing season, or other weather or climate conditions. It then calculates results over and over, each time using a different set of random values from the probability functions. Depending upon the number of uncertainties and the ranges specified for them, a Monte Carlo simulation could involve thousands of calculations before it is complete. Monte Carlo simulation produces distributions of possible outcome values, which can be quite helpful for a variety of purposes: identifying the full range of outcomes, identifying the most probable range of outcomes, and analyzing which assumptions or parameters are most influential in determining outcomes.[102]

Step 5: Estimate the monetary values of benefits and costs. The fifth step is to quantify impacts in monetary or financial terms. For increased revenues or expenditure savings, the process of translating physical terms to financial terms is straightforward and is based on average (measured or estimated) increases in revenues or reductions in expenditures. This information can be measured from a representative sample of prior customers, and often with relatively straightforward questions about financial matters—although some care is needed to ensure that values provided are accurate. For instance, researchers have repeatedly found that most individuals cannot accurately recall average revenues or expenditures over long periods of time, so it is more informative to ask questions about revenues and expenditures that occurred within the last few weeks or the last month.

As Section 3.2 highlights, another benefit that many AgTech SMEs provide—reduced GHG emissions—could be substantial. Because the social cost of carbon has been extensively studied, and carbon markets are relatively well-developed, if SMEs can quantify emissions reductions in physical terms, then it is relatively straightforward to convert these benefits into monetary or financial terms. Still, certifying the carbon emissions reductions to the standards of Verra or Gold Standard takes considerable effort and cost, and only a handful of the SMEs we spoke to have undertaken that step.

For other types of benefits, translating the physical outcome measure into a financial metric can be more challenging. For instance, the amount of time savings resulting from mechanized processing replacing manual processing can be measured from time diaries for a representative sample of individuals, but translating that into a monetary value requires determining the value of time. One way to do this is to use the average wage that individuals can earn from off-farm work, but if labor markets are not well-developed, this average wage may not be available or reliable. Asking individuals directly to estimate the value of their time is also unreliable, since many people in rural LMIC settings may not customarily think of their time in monetary terms. Whittington and Cook (2018) offer recommendations for analyses in these settings to estimate the value of time.[103]

A potentially useful approach to measure many kinds of benefits is the contingent valuation method, which in its simplest form involves asking people how much they would pay in exchange for a certain good or service. In principle, the responses should encapsulate both financial benefits (e.g., reduced expenditures on diesel fuels) and nonfinancial benefits (e.g., time savings, improved local air quality, improved nutritional diversity, and so on). In practice, there are challenges with using this method. Some of these may arise from people's lack of familiarity with certain kinds of benefits that arise from AgTech, or uncertainty about the extent to which they will actually experience advertised benefits. Other concerns relate to a well-established tendency to report a stated willingness-to-pay that exceeds actual willingness-to-pay, which arises in part from the simple fact of the hypothetical nature of the question.[104] Nevertheless, economists have developed a large toolkit of other methods to measure benefits, including various forms of "revealed preference" methods that leverage people's actual behavior to discern how much they value various kinds of services or amenities. Revealed preference methods are generally viewed as more reliable than stated preference methods.[105]

Thus, in some cases, measuring benefits from such investment will require making a logical connection—and considerable targeted data collection—to support how the service provided generates economic returns. However, some SMEs have made progress in such efforts. For instance, one company is in the process of obtaining Gold Standard certification for the production of both averted disability-adjusted life years (ADALYs)[106] and women's time savings. Under the Gold Standard for the Global Goals program, these certificates will allow AgTech SMEs (and others) who generate such benefits to receive funding from specific funders on the Gold Standard public registry.

102 For examples of simulation analysis to measure impacts see: Whittington, D., W.M. Hanemann, C. Sadoff, and M. Jeuland (2009). "The Challenge of Improving Water and Sanitation Services in Less Developed Countries", Foundations and Trends in Microeconomics: Vol. 4: No. 6–7, pp 469–609; and also Jeuland, M., and S. Pattanayak (2012). "Benefits and costs of improved cookstoves: Assessing the implications of variability in health, forest and climate impacts." PLOS One 7(2): e30338. doi:10.1371/journal.pone.0030338. For a brief overview of simulation analysis see Palisade Economics, 2021, "Monte Carlo Simulation: What Is It and How Does It Work?".
103 Whittington, Dale, and Joseph Cook. "Valuing Changes in Time Use in Low- and Middle-Income Countries." Journal of Benefit-Cost Analysis 10, no. S1 (ed 2019): 51–72. https://doi.org/10.1017/bca.2018.21.
104 For further detail on this and other critiques, see Jerry Hausman (2012), "Contingent Valuation: From Dubious to Hopeless," Journal of Economic Perspectives 26(4):43–56. But for a countervailing opinion, see Catherine L. Kling, Daniel J. Phaneuf, and Jinhua Zhao (2012), "From Exxon to BP: Has Some Number Become Better than No Number?," Journal of Economic Perspectives 26(4):3–26.
105 Vermeulen, Frederic. "FOUNDATIONS OF REVEALED PREFERENCE: INTRODUCTION." The Economic Journal 122, no. 560 (2012): 287–94. https://www.jstor.org/stable/41494436.
106 Gold Standard. "Health Impacts: Averted Disability-Adjusted Life Years (ADALYs)." Gold Standard. https://www.goldstandard.org/articles/health-impacts-averted-disability-adjusted-life-years-adalys

Step 6: Aggregate net benefits. The final step in the contributions of investment in AgTech is to aggregate benefits across all categories. In so doing, it is important to consider potential negative impacts, such as overuse of water resources that may affect the functioning of ecosystems, downstream water users, or water use by future generations. These costs should also be quantified, and subtracted from benefits, to calculate the net social benefits of AgTech investments. It is also important not to double-count benefits. Depending on the methods used to convert physical outcomes into financial terms, some measures of value will include several categories of benefits, while others may not.

For example, suppose a solar pump reduces the time required to access water for irrigation, which then translates into time savings. But in addition to this, people also start using more water for irrigation, which delivers benefits of higher crop yields. A survey reveals the average willingness-to-pay for the irrigation pump is, say, $100, and time diaries demonstrate that the average time savings is 10 hours per household per month. The value of the time savings should not be added to the willingness-to-pay, because the latter should include all financial and nonfinancial benefits (as perceived by the household). In other words, the household's value of time saved is naturally included in the willingness-to-pay measure. On the other hand, if the irrigation pump reduces the water available to another farmer—one who draws water from a point downstream, or if withdrawals from a reservoir deep below ground limit water available to future generations—and this reduction has adverse impacts on productivity, this cost should be subtracted from the benefit to calculate social net benefits.

The aggregation step should also determine the scope of the impacts: that is, how many beneficiaries are affected. It is also often helpful to track, as far as possible, the distribution of impacts. That is, to consider how benefits flow to different groups, and whether this distribution reveals important information that can be used to optimize certain aspects of investments. In a distributional analysis, it is also important to consider not just net benefits but how both benefits and costs are distributed. For instance, in the case of an irrigation pump that has net benefits upstream farmers but net costs for downstream farmers, it is important to document this distributional impact and attempt to achieve a more equitable distribution of benefits.

Finally, because some benefits (and costs) manifest later in time, analysis should discount future costs and benefits using a discount rate that corresponds to consumers' rate of time preference. The concept is that most people tend to prioritize benefits received today (or in the near future) and deprioritize benefits or costs that are received or incurred later in the future. Furthermore, studies of time preference among consumers in LMICs suggests that discount rates in LMIC communities are relatively high compared to consumers in industrialized countries. For instance, although discount rates of 7% to 10% are commonly reported in household studies in the USA, household studies in Ethiopia, Zambia, Indonesia, and India support a range of rates between 30% to 104%.[107] However, social discount rates (which are more relevant for government investments) are generally thought to be more like 3% to 5%, and there is some belief that even those are too high when considering long term climate change issues with intergenerational implications.[108]

107 Holden, Stein T., Bekele Shiferaw, and Mette Wik. "Poverty, Market Imperfections and Time Preferences: Of Relevance for Environmental Policy?" Environment and Development Economics 3, no. 1 (February 1998): 105–30. https://doi.org/10.1017/S1355770X98000060.; Pender, J.L. and T.S. Walker. "Experimental measurement of time preference in rural India." Progress Report No. 97, 1990, Andhra Pradesh: ICRISAT.
108 Mercatus Center. "The Social Discount Rate: A Primer for Policymakers," June 30, 2020. https://www.mercatus.org/publications/regulation/social-discount-rate-primer-policymakers.

3.4. Challenges and solutions for practical use

SMEs lack the technical capability, resources, and staff time to rigorously evaluate the entirety of the mitigation and adaptation benefits that result from the goods and services that they provide. However, measuring some of these benefits—such as reduced expenditures on diesel fuel, increased yields, or increased revenues—often aligns well with the information that SMEs present when marketing to prospective customers or investors. It is also straightforward to quantify certain benefits in monetary terms, either because they are inherently financial in nature (e.g., reduced expenditures) or because they are closely tied to existing markets for goods and services (e.g., increased yields of agricultural products).

For SMEs that seek and receive climate mitigation finance, estimating GHG emissions reductions may also align with information they assemble for that purpose. Translating GHG emissions reductions into financial terms (and leveraging those for climate financing) may also be relatively straightforward, since markets for carbon credits—and verification programs such as Gold Standard and the Verified Carbon Standard—already exist. But certifying GHG emissions reductions requires costly and time-consuming auditing and verification, so an SME's decision to certify will depend in part on the magnitude of the impact.For carbon mitigation benefits specifically, platforms such as the FAO's Ex-Ante Carbon-balance Tool (EX-ACT) and the "Carbon Reduction Assessment of New Enterprises" (CRANE) tool, developed by Prime Coalition, have been developed that can assist with measuring carbon accounting. These tools help to fill a critical gap for investors in early-stage ventures, including SMEs. Whereas most climate impact assessment tools and services are designed to retrospectively assess the climate impact of business operations, early-stage businesses with small operations and limited or no product deployment face a very different set of challenges. Both CRANE and EX-ACT offer carbon accounting and appraisal methods for a range of businesses, including agricultural ventures. Indeed, in the case of EX-ACT, one specialized tool focuses exclusively on agriculture and forestry development projects and programs, and another focuses on identifying off-farm sources of GHG emissions in agricultural value chains. Yet even these tools require a significant amount of data, and some form of training or prior expertise with GHG emissions estimation, to generate reliable estimates.

Although the adaptation benefits that SMEs provide are real, quantifying adaptation benefits that arise from improved health conditions or better quality of life in monetary terms is a challenge. As documented in Section 3.3, rigorous impact evaluation methods require surveys to collect data not just on the population that benefited from an investment or received an intervention, but also on a comparison population to provide insight on the counterfactual scenario—that is, what would have happened in the absence of the investment or intervention. Rigorous measurement requires a careful approach to sample selection to ensure that measurements are taken across a representative sample of customers, and in many cases, surveys must be customized to the specific application of interest. Surveys are likely most reliable and objective when conducted by a third party, rather than SME staff responsible for implementing the intervention being evaluated. Even after taking caution to measure the outputs and outcomes of an investment, converting physical outcomes into monetary terms is far from straightforward.

However, SMEs can benefit by reflecting on their theory of change. Even if they cannot rigorously quantify all the benefits they provide in financial or even physical terms, the exercise of articulating what they think will happen as a result of their work can help clarify goals and strategies and provide essential data with which to better manage and allocate limited resources. This will help in explaining the theory of change to a prospective funder, even if impacts in a particular context are hard to quantify. And, as our interviews demonstrate, some SMEs have found that undertaking rigorous measurement can and does unlock climate adaptation financing.

Section 4: Challenges & Recommendations for channeling climate finance to scale enterprises

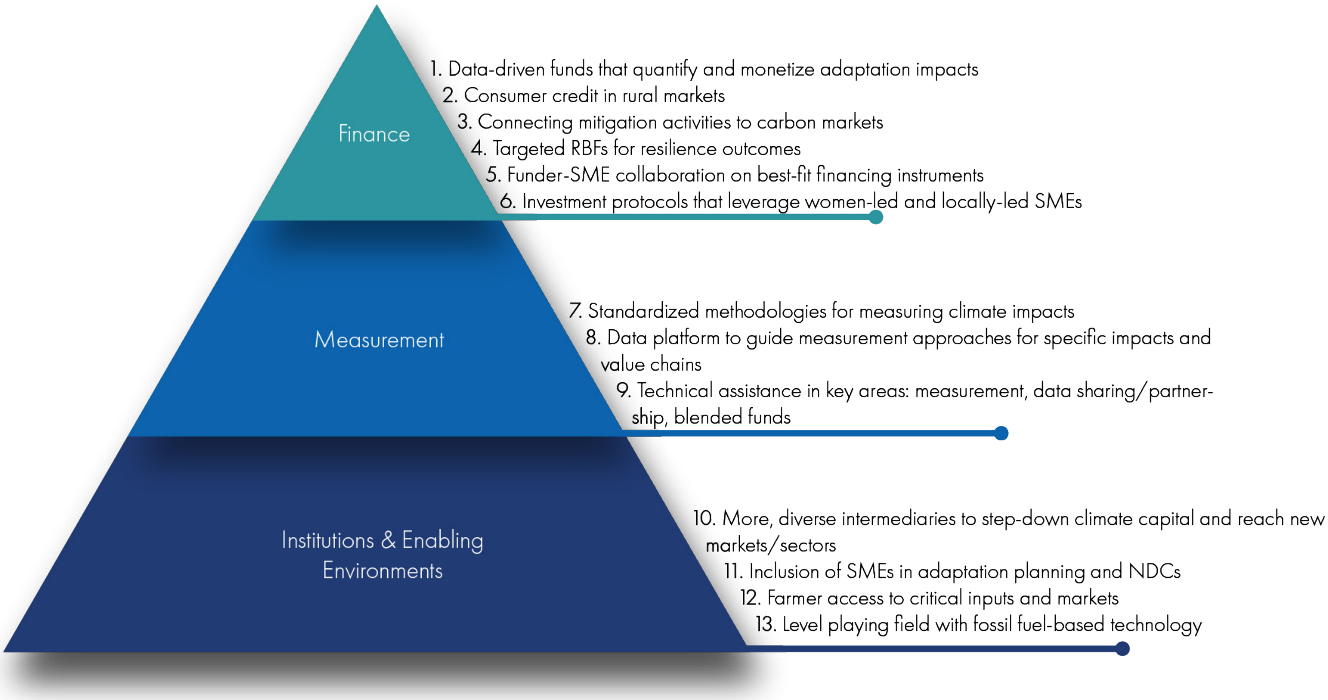


Figure 10. Categories of challenges and recommendations

There are several areas of challenges related to climate financing that must be addressed in parallel to unlock the potential of AgTech enterprises, including a misalignment of available finance with what enterprises need, difficulties in measuring climate impacts accurately and affordably, and high-level institutional and enabling environment barriers. Based on insights from discussions with investors and SMEs, this section offers potential solutions to address these challenges.

4.1 Finance

Enterprises and investors almost unanimously identified two major financing challenges, early-stage growth equity and short-term debt to meet working capital needs. While these financing gaps are not unique to AgTech SMEs, it is notable that this important sector for delivering climate benefits has not been able to overcome these persistent financing bottlenecks. How these gaps are addressed will be critical to unlocking low carbon development and ensuring limited public climate investments are more catalytic and transformative.

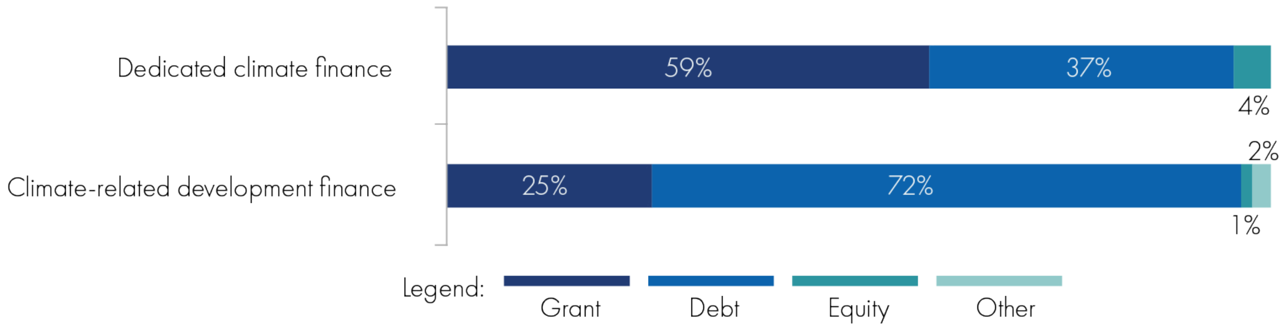
	Recommendation	Multilateral Climate Funds, Development Banks and DFIs	Fund Managers and Other Intermediaries	Impact Investors	LMIC Governments	AgTech Enterprises	Research Partners	Donors and Philanthropy	Commercial Investors	Corporates (including ESG)
Finance	1. Data-driven financial mechanisms that quantify and monetize adaptation impacts are needed to mobilize climate finance and prioritize its deployment for greatest impact.	●	●	●			●	●		●
Finance	2. Investments are needed to supply rural markets with credit and other critical inputs to ready them for AgTech uptake and sector transformation.	●			●			●	●	
Finance	3. LMIC carbon mitigation funds/platforms for SMEs are needed to mobilize premium carbon reductions.	●	●	●				●		●
Finance	4. Target results-based financing on resilience outcomes.	●			●			●		
Finance	5. To accelerate deployment of climate finance with a low-carbon AgTech focus, groups of funders and companies should collaborate to identify best-fit financing instruments, with an eye to demonstration.	●	●	●		●		●	●	●
Finance	6. Investing in women-led and locally-led SMEs may require updating internal processes, more flexible finance terms, and additional technical support.	●	●	●				●	●	●

Relevant Actors

Figure 11. Summary of finance recommendations and relevant actors

The type of climate finance available is poorly aligned with what low carbon AgTech SMEs need to grow and deliver impact. In 2017, of the $57 billion in climate financing from major international public sources to developing countries—the bulk of climate financing available in those countries—grants made up 26.7% of investment, or $15.3 billion. The vast majority of these grants are to governments and government-led projects.[109] Different start-up grants, competitions, and incubators are successfully seeding the field with innovative companies with transformational potential. To highlight an example, EEP Africa, managed by the Nordic Development Fund, has invested over EUR 50 million in 274 projects since 2010. The fund provides early-stage grant financing to innovative clean energy projects and businesses across Southern and East Africa.[110]

However, it is not a lack of grant funding holding back scale for low-carbon AgTech. Viable companies that build on grants and other seed investments get stuck in the "missing middle," starved for growth capital.[111] DFIs await far in the future once a company can demonstrate profitability, a pathway to scale, and an ability to absorb at least $3–5 million in debt, or preferably more for many DFIs to provide financing directly. Most of the roughly $40 billion in annual climate finance in the form of debt—which represents 70% of the climate finance available in developing countries—is inaccessible for small companies.[112]



Notes: Based on cumulative climate finance flow data from 2014 to 2017
Source: CPI & Vivid Economics, based on CPI and OECD (2019a) data

Figure 12. Shares of climate finance flows by instrument[113]

Note: Dedicated climate finance is provided by specific climate institutions or funds specifically set aside for climate action. Climate-related development finance is finance with climate co-benefits provided through DFIs, which are primarily supporting economic or social development.

109 Vivid Economics. "Transformative Climate Finance: A Framework to Enhance International Climate Finance Flows for Transformative Climate Action." Vivid Economics, June 2020. https://www.vivideconomics.com/wp-content/uploads/2020/06/Vivid-Economics-2020-Transformative-Climate-Finance.pdf .
110 EEP Africa. "EEP Africa New Portfolio 2021." EEP Africa, 2021. https://eepafrica.org/wp-content/uploads/2021/09/EEPAfrica_PortfolioBooklet2021_rev.pdf.
111 Wood, David, Cameron Pratt, and Belinda Hoff. "Investing in the Backbone of Emerging Markets." Boston College Center for Corporate Citizenship's Institute for Responsible Investment, n.d. https://iri.hks.harvard.edu/files/iri/files/iri_-_sustainable_sme_investment_-_investing_in_the_backbone_of_emerging_markets.pdf.
112 Vivid Economics, " Transformative Climate Finance."
113 Vivid Economics, " Transformative Climate Finance."

AgTech SME financing gap: early-stage growth equity and short-/medium-term working capital debt. Just $0.7 billion (1%) of public climate finance to LMICs is in the form of equity.[114] This is a glaring hole, as equity investments may be particularly valuable for early-stage enterprises to support the development of longer-term growth strategies and harness opportunities that require additional time and effort to capture. Equity can also help to facilitate lenders to provide debt capital, as their position is better protected by the presence of the equity investor.[115]

There are very few early-stage equity investors able to provide AgTech SMEs the $1–5 million capital infusion needed to achieve key viability milestones and support enterprise growth to a Series B investment round. The impact investors—that is, patient investors seeking social returns in exchange for some amount of purely financial returns—with non-dilutive capital serving the sector are very well known among enterprises. However, the numbers of them and their available capital does not appear to be growing, despite the growing interest in climate investment.

There is also a need for working capital debt since most AgTech enterprises sell hardware requiring inventory, and unmet working capital demands translate into small, frequent batch procurements and high-transaction costs. For both SMEs and their customers, the cost of capital can reach 30–40% annually or more, with the term of debt limited to 1–3 years in many markets in Africa and South Asia. As early-stage companies, they struggle to access debt because of small equity bases, high risks associated with agricultural SMEs, and banks lacking of lending experience in the sector. To address this need, some SMEs are increasingly tapping crowd-funding platforms, like Kiva or Lend A Hand, for small tranches of short- and medium-term debt.

The lack of equity and short- to medium-term working capital debt in the incumbent climate finance capital mix is stifling innovation and preventing ag-energy SMEs from scaling. There are very few short- and medium-term debt facilities that can support working capital needs. SMEs in this phase often need longer repayment terms (at least 2–3 years), longer grace periods to account for supply chain challenges and common delays that come with working in challenging markets, and more flexible repayment schedules. Filling both gaps is likely to be addressed, in part, with the implementation of some of the other steps outlined in this chapter that have direct impacts on the profitability of enterprises. For example, as companies are better able to monetize positive climate impacts generated through their operations and channel results-based financing to increase sales, the sector becomes more attractive for early-stage investment.

In the meantime, "blended" capital arrangements are essential for mobilizing new capital in the near-term. Blended structures introduce concessional funding—grants and below-market financing from private and public entities—that can help reduce risks or increase returns to attract private investment at scale. In situations where private investments are not viable due to high risks or low returns, blending concessional money into an investment vehicle in the form of performance guarantees or first-loss investments can be effectively used to align the risk-return profiles of different investor categories. These arrangements are most effectively used where SMEs are expected to reach commercial viability in the medium term.[116]

On the equity side, one example of several emerging funds built on this blending strategy is the Acumen Resilient Agriculture Fund (ARAF), which closed $58 million in initial investment in June 2021, from a range of investor types including DFIs, multilateral climate funds, foundations, and private investors.[117] ARAF aims to scale climate adaptation-focused agribusinesses in Africa, using a first-loss investment from the GCF and IKEA Foundation, to leverage DFIs and other investors with higher return requirements.

A notable example on the working capital debt side is the Food Securities Fund managed by Clarmondial, which closed an initial investment round in March 2021. While not targeting AgTech SMEs specifically, the fund does illustrate a blended approach for addressing the gap of local agricultural companies in LMICs lacking access to credit from local banks, funds, and other lenders by providing working capital loans. An innovative feature of this fund is that it enters into risk-sharing arrangements with SMEs' corporate customers so that loans are provided based on the quality and nature of their supply chain relationships with corporates. Instead of solely relying on collateral that many smaller companies lack, this approach unlocks debt based on sustainability practices that key corporate off-takers value. This is another blended structure that leverages concessional funding from private and public entities to attract private investment, bringing together investors with interests and risk appetites as diverse as Good Energies Foundation, USAID, US DFC, Conservation International, WWF USA, and the Global Environment Facility.[118]

114 Climate finance that is provided by specific climate institutions or from clearly delineated funding set aside for climate action, as opposed to more general development finance that has climate co-benefits.
115 Vivid Economics, "Transformative Climate Finance."
116 World Bank Group, "Transformative Climate Finance"
117 Acumen, "Acumen Closes $58 Million Impact Fund."
118 Clarmondial. "Food Securities Fund Starts Operations, Makes First Investment," March 9, 2021. https://www.clarmondial.com/fsf_launch_first_investment/.

These types of funds can be effective vehicles for increasing investor learning and lowering perceived risks of the private sector-led adaptation space. For example, many bilateral DFIs facing increasing climate finance mandates struggle to move beyond utility-scale renewable projects and into new areas of low-carbon development. Blended investment vehicles provide opportunities for DFIs—key sources of catalytic capital generally—to move further down the risk spectrum and into more frontier sectors and geographies in need of their de-risking and demonstration capital. Another added benefit is a consortium of diverse investors can often-times leverage unique tools and authorities. For example, certain fund participants may be able to offer currency risk coverage to an investment vehicle, helping to clear a major investment hurdle in many countries where currency fluctuations can leave SMEs unable to repay foreign currency-denominated loans.

A handful of more mature AgTech SMEs are mobilizing finance from voluntary carbon markets. Carbon markets and M&E protocols for tracking and verifying carbon reductions have become standardized over the last decade, and, as discussed in Section 3, the mitigation potential of AgTech value chains is significant. Familiarity with carbon markets and carbon credit schemes was high among interviewed AgTech SMEs. Two SMEs interviewed were certified to sell carbon credits, both primarily energy enterprises offsetting diesel generation, and many others are considering it. SMEs noted that carbon quantification methods were relatively primitive and undercounted the potential GHG reduction capabilities of firms in the sector. For example, one entrepreneur pointed out that soil carbon practices like silvopasture, or other carbon sequestration opportunities, could also be monetized in the future. They described the process of getting carbon validation as extremely expensive, around $200,000–$250,000, an expense that keeps most SMEs away.

Improving access to credit for SME customers will boost sales, scale climate impacts, and allow SMEs to focus on core competencies. In many markets, conservative banking practices and high perceived risks associated with the agricultural sector undercut the credit access SME customers need.[119] Financing facilities and organizations—banks, NBFCs, MFIs, or other groups—dedicated to increasing consumer credit for climate-related technologies and businesses are needed to scale AgTech value chains, especially in African markets. Among the SMEs we spoke with, nearly 60% either became consumer finance organizations directly or invested in third-party relationships to solve for a lack of consumer credit access. Almost all of them struggle to access the debt to support these credit programs and are forced to hire additional skilled capacity if they wish to develop this aspect of their business.

119 Green Climate Fund. "GCF Agreement with CABEI to Unlock Finance for Climate Adaptation in Central America." Text. Green Climate Fund, June 21, 2019. https://www.greenclimate.fund/news/gcf-agreement-cabei-unlock-finance-climate-adaptation-central-america.

Spotlight on Gender: Finance Challenges

Women-led companies are not sufficiently included in climate finance. Women are more likely to work in adaptation-relevant sectors, such as agriculture, than traditional mitigation-related sectors like energy. Women make up 43% of the agricultural labor force and only 22% of global energy jobs.[120] The under investment in adaptation risks leaving women and women-led businesses out of the climate change solution.

The SME finance gap for female entrepreneurs in developing countries is estimated at $1.48 trillion.[121] This gap represents the difference between the current supply of finance and potential demand which could be addressed by financial institutions. Although female-owned businesses represent 28% of SMEs, they represent 32% of the finance gap. In East Asia, women-owned businesses account for a staggering 59% ($1.2 trillion) of the SME finance gap, followed by sub-Saharan Africa where women-owned businesses account for 17% ($42 billion) of the finance gap.[122]

Female-owned SMEs account for roughly a third of formal SMEs in emerging markets, and our sample within AgTech was well below that.[123] While women produce an estimated 70% of the food in Africa and make up nearly half of small holders in developing countries, women-owned SMEs tend to be far more capital constrained than their male counterparts. In many countries, outdated laws and cultural customs keep female land ownership—and loan collateral—low. With less access to male-dominated business networks and shorter track records, women-owned SMEs have less growth capital and tend to be smaller.[124] Women also work within different networks than men, which can mean that many viable businesses fly below the radar of male-dominated investment firms. Because of these challenges in accessing formal finance, women's businesses often rely on personal or family funds. Notably, these are also challenges that locally-owned companies face.[125] In many countries, outdated laws and cultural customs keep female land ownership—and loan collateral—low. With less access to male-dominated business networks and shorter track records, women-owned SMEs have less growth capital and tend to be smaller.[126, 127] Notably, these are also challenges that locally owned companies face.[128]

120 "Women in Agriculture | Reduce Rural Poverty | Food and Agriculture Organization of the United Nations." Accessed November 22, 2021. https://www.fao.org/reduce-rural-poverty/our-work/women-in-agriculture/en/.; "Renewable Energy: A Gender Perspective." IRENA, 2019. https://www.irena.org/publications/2019/Jan/Renewable-Energy-A-Gender-Perspective.
121 IFC. "MSME Finance Gap." International Finance Corporation, 2017. https://www.smefinanceforum.org/sites/default/files/Data%20Sites%20downloads/MSME%20Report.pdf.
122 IFC,"Entrepreneurship.» https://www.ifc.org/wps/wcm/connect/Topics_Ext_Content/IFC_External_Corporate_Site/Gender+at+IFC/Priorities/Entrepreneurship/.
123 Energia. "Scaling up energy access through women-led business." Energia, 2017. https://energia.org/assets/2017/03/WE-brochure_webversion.pdf.
124 112 – IFC, "MSME Finance Gap"
125 113- Schiff, "Beyond the Threshold"
126 Abass, Jamila. "Women Grow 70% of Africa's Food. But Have Few Rights over the Land They Tend." World Economic Forum, March 21, 2018. https://www.weforum.org/agenda/2018/03/women-farmers-food-production-land-rights/.IFC,"MSME Finance Gap";
127 Schiff, H., Fries, R., & Chambers, T. (2013) "Beyond the Threshold: Investing in Women-led Small & Growing Businesses," https://www.aspeninstitute.org/wp-content/uploads/files/content/upload/VFW%20Report%20Brochure.pdf.
128 Schiff, "Beyond the Threshold."

Spotlight on Gender: The Investor Perspective

Women-led businesses may be underrepresented in climate finance or impact portfolios. While many climate investors cite gender diversity in the portfolio as a morally good—and oftentimes profitable—goal, over a third of investors interviewed did not report on the gender diversity of portfolio companies, as seen in Figure 11. For those that did report—and who also professed efforts to target women-led companies—the share of investment flowing to female-owned companies roughly tracked the underlying gender split in SME ownership in emerging markets, in which women-owned companies account for 31 to 38% (8 to 10 million) of formal SMEs.

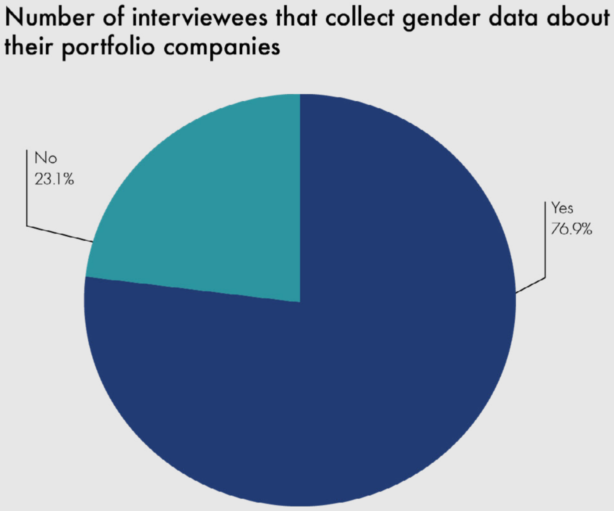


Figure 13. Number of interviewees that collect gender data about their portfolio companies

There is a narrative that requiring investment in women-owned businesses makes investment harder. One investor said that adding gender diversity as another investment criteria—on top of geographic, sector, and other requirements—would make it difficult to disperse funds. Another investor said that they do not use "affirmative action" with women-led organizations, because they believe that giving a preference to women-led businesses may distort the investment decision-making process. A third investor said that they would like to see more women-led businesses in their portfolio but followed up with a clarification that they would not like to sacrifice quality. And yet, an increasing amount of evidence suggests that women in leadership are good for a business's bottom line, increasing net profits and improving share price performance.[129,130] These attitudes also ignore the gendered manner in which "merit" is evaluated.[131]

Funds found success in reaching women-led SMEs and maintaining quality through changes to internal procedures and new marketing approaches. First and foremost, all investors should be tracking and reporting on the gender breakdown of ownership in their portfolio, as well as making efforts to track and report on investee employee gender breakdown. Beyond that, several investors had success with slightly adjusting internal procedures for evaluating potential investments. Since women-owned businesses may be a level removed from Western investor networks, one investor specifically marketed their call for applications through women's professional energy networks, like GWNET and ENERGIA. This led to a huge boost in applications from women. In order to overcome internal bias about idealized business approaches, they implemented a 50% women-led and 50% locally-led company quota (those shares could overlap) for the initial shortlist screening of companies. In the final tally, nearly 40% of investees were women-led, and the organization concluded that taking an extended look at many of the women-led companies led to new realizations of the business's value.

129 Shell Foundation. "A Business-First Approach to Gender Inclusion: How to Think About Gender Inclusion: How to Think About Gender Inclusion in Small and Medium Enterprise Operations." Shell Foundation, 2018. https://shellfoundation.org/app/uploads/2018/10/A-business-first-approach.pdf.
130 Shell Foundation. "Lessons Learned: Gender Inclusion Strategies for SMEs in the Off-Grid Energy Sector." Shell Foundation, 2017. https://shellfoundation.org/app/uploads/2018/10/Gender-Programme-Learnings.pdf.
131 Chief Executive Women. "In the Eye of the Beholder: Avoiding the Merit Trap." Chief Executive Women, 2016. https://cew.org.au/wp-content/uploads/2016/08/MCC-CEW-Merit-Paper-FINAL.pdf.

Recommendation 1: Data-driven financial mechanisms that quantify and monetize adaptation impacts are needed to mobilize climate finance and prioritize its deployment for greatest impact.

Monetization of AgTech enterprises' adaptation benefits is critical to attracting private capital, which currently makes up just 1% of the $30 billion in annual adaptationinvestment.[132] Innovative funds and outcome-oriented financing facilities are emerging business approaches, they implemented a 50% women-led and 50% locally-led company quota (those shares could overlap) for the initial shortlist screening of companies. In the final tally, nearly 40% of investees were women-led, and the organization concluded that taking an extended look at many of the women-led companies led to new realizations of the business's value. that lean heavily on data and impact metrics to understand how private models deliver adaptation benefits and how capital seeking those types of gains can be effectively allocated. Investor confidence in such facilities will increase with the progress on the Measurement Recommendations #7–9, outlined in the following section.

Such financing mechanisms can take a range of forms and target different outcomes, but key design elements include verifying benefits of specific adaptation activities, putting reputable methodologies and organizations behind the effort, and incorporating a rigorous stakeholder and government engagement process to build credibility and political will. One program now getting off the ground built around such a template is the African Development Bank's Adaptation Benefit Mechanism (ABM). ABM aims to de-risk and incentivize investments by certifying the social, economic, and environmental benefits of adaptation activities and facilitating payments for the delivery of those benefits. The value of adaptation action captured in these certificates, including the incremental costs of generating the benefits, will be estimated and put to interested investors and lenders. The current pilot phase aims to test low carbon AgTech value chains and other smaller-scale interventions that are replicable or scalable in rural African markets.[133]

Another new data-focused platform for channeling adaptation investment to SMEs is South Pole's Landscape Resilience Fund. The fund focuses on translating categories of adaptation impacts relevant to SME operations into tailored metrics and then invests in establishing quality baselines to establish certainty around progress. In blending public, philanthropic, and private capital interested in nonfinancial adaptation benefits, it can more directly target adaptation impacts SMEs are positioned to deliver.

Recommendation 2: Investments are needed to supply rural markets with credit and other critical inputs to ready them for AgTech uptake and sector transformation.

Even with access to growth capital internally, AgTech enterprises cannot scale in a vacuum. For these enterprises to grow to their potential, their customers need access to credit. SMEs across agriculture value chains are hitting this same roadblock. Their products routinely offer customers paybacks of 6–24 months, but that makes little difference to customers facing borrowing costs of 30–40% annually. Of SMEs interviewed, nearly 60% either became consumer finance organizations directly or invested in third-party relationships to solve for a lack of consumer credit access. Improving access to credit—through banks, micro-finance institutions (MFIs), cooperatives, and other nonbank financial institutions—directly benefits farmers and allows SMEs to focus on core competencies.

Climate finance can help overcome these challenges in various contexts. One option is support to MFIs in markets where they are positioned to serve AgTech customers. One successful model is the German-funded Microfinance for Ecosystem-Based Adaptation program implemented across Latin America by United Nations Environment Program Panama. The program focused on integrating a better understanding of climate risk into credit methodologies with local MFIs, which, unlike commercial banks, tend to serve more vulnerable groups without collateral and handle a high volume of transactions in small amounts.[134] Private financing models have scaled this challenge in other markets—like India's tractor market for example—where tractor companies themselves spun off organizations to help farmers access the credit needed to buy tractors.[135] In these cases where a financing institution aims to target a specific sector of climate relevance, credit guarantees and other forms of support from governments and climate finance institutions can help unlock credit.

132 Macquarie et al, "Updated View."
133 African Development Bank. "Adaptation Benefit Mechanism (ABM)." Text. African Development Bank - Building today, a better Africa tomorrow, April 16, 2019. https://www.afdb.org/en/topics-and-sectors/initiatives-partnerships/adaptation-benefit-mechanism-abm.
134 ICI. "Microfinance for Ecosystem-Based Adaptation(MEbA)." International Climate Initiative, 2021. https://www.international-climate-initiative.com/en/details/project/microfinance-for-ecosystembased-adaptation-meba-11_II+_002-257.
135 Bhattarai, Madhusudan, Gajendra Singh, Hiroyuki Takeshima, and Ravindra Shekhawat. "Farm Machinery Use and Agricultural Industries in India: Status, Evolution, Implications and Lessons Learned." International Food Policy Research Institute, 2018. https://doi.org/10.2499/1032568654.

Aceli Africa is a facility aiming to meet agriculture SME borrowing needs more directly, with a target to drive $700 million in new bank lending to the sector in East Africa by 2025. Aceli offers portfolio first-loss coverage to banks to incentivize lending to agriculture SMEs that meets impact criteria. They also offer origination incentives to compensate lenders for making smaller, higher-cost loans to SMEs, as well as "impact bonuses" that reward gender inclusivity and other practices.[136]

Recommendation 3: LMIC carbon mitigation funds/platforms for SMEs are needed to mobilize premium carbon reductions.

A carbon revenue stream has the potential to buoy SMEs if it were more accessible. A lack of scale and high transaction costs are the primary reasons companies are not generating financial returns from their carbon benefits. The project certification process for carbon credits can be lengthy and create a long-term monitoring burden that lean organizations have little appetite for. The scale of the emissions reductions—and the value they could generate through carbon markets—are relatively small in isolation.

However, a targeted fund or an investor with an appetite for aggregating verifiable emissions reductions across a portfolio could conceivably realize the value of these carbon reductions more efficiently. They might also be in a position to better connect this carbon to markets willing to pay a premium based on the geography where the mitigation occurred, the catalytic nature of those investments on a potentially transformative sector, or other co-benefits. One potential approach is the Carbon Value Exchange that 4R Digital is developing that would pool and aggregate emissions data from remotely monitored equipment (like AgTech) to centralize and lower the cost of verification.[137] These and other emerging approaches could make it easier for smaller projects and companies to engage in carbon markets.

Recommendation 4: Target results-based financing on resilience outcomes.

Consumers of low-carbon AgTech are extremely price sensitive and small price drops can bring large increases in addressable market size. Demand-side subsidies, which directly lower the cost of good or service to consumers, along with results-based financing (RBF)—essentially paying companies after agreed-upon results are achieved—are underutilized tools for targeting resilience outcomes generally. They could be deployed effectively to lower affordability barriers for consumers and scale AgTech into new markets. RBF programs are highly customizable and can be used to address other barriers to adoption by introducing quality standards or incorporating maintenance contracts.

RBFs alone may not address the fact that many people may be unaware of product benefits or how to use the product. Awareness of AgTech is increasing in places like Kenya, where 68% of farmers in a recent survey had heard of solar water pumps.[138] However, among a recent sample of 400 farmers in Tanzania not a single farmer owned a solar pump, with many of these farmers citing their lack of awareness of other pumping technologies as a major decision driver.[139] Where there is low customer awareness of low-carbon AgTech products, programs like Lighting Africa's new 'Ngaa na Sola - Ndo Mpango Mzima" campaign, should be implemented alongside RBFs in order to unlock consumer demand for these products.[140]

RBFs in the agriculture sector would create incentive structures for SMEs to budget targeted adaptation outcomes appropriately, deliver them within a specific time period and ensure verification by independent third parties. The approach is, by many accounts, a well-suited tool for supporting adaptation interventions and garnered the endorsement of 81% of interviewed parties as a key lever for mobilizing additional climate finance to the sector. One example of this approach is Root Capital's Social Impact Incentives (SIINC) program, developed with Roots of Impact and supported by the Inter-American Development Bank and the Swiss Agency for Development and Cooperation, which encourages lending to agricultural enterprises in Latin America through a "pay-for-impact" funding mechanism that incentivizes Root Capital to lend to 40 early-stage and higher-risk agriculture enterprises that no other social lender or commercial lender is willing to make.[141]

The GCF's Independent Evaluation Unit, in giving its support recently for the Fund to utilize RBF to a greater extent within its adaptation portfolio, is indicative of the growing support behind the tool. The report found a robust base of evidence pointing to effective results-based modalities—including vouchers, pay-for-performance models, payments for environmental services, and conditional cash transfers.[142]

136 ACELI Africa. "Bridging the Financing Gap: Unlocking Impact Potential of Agricultural SMEs in Africa." ACELI Africa, 2020. https://aceliafrica.ams3.digitaloceanspaces.com/wp-content/uploads/2020/09/08173725/Aceli-Africa_Full-Benchmarking-Report.pdf.
137 Ganie, Zeenat. "New Platform to Increase Access to Carbon Markets." ESI-Africa.Com (blog), October 13, 2021. https://www.esi-africa.com/industry-sectors/smart-technologies/new-platform-to-increase-access-to-carbon-markets-currently-in-development/.
138 ABI, PLEASE SEE THE ATTACHMENT I JUST SENT YOU!
139 CLASP "Solar Water Pumping Immersion Report, Machakos County July '21"; https://storage.googleapis.com/e4a-website-assets/SWP_MarketSnapshot_Tanzania.pdf
140 https://pressroom.ifc.org/all/pages/PressDetail.aspx?ID=18261
141 https://rootcapital.org/about-us/press-room/press/root-capital-launches-its-first-pay-for-impact-partnership/
142 Binet, Silvia, Matthijs De Bruijn, Daisuke Horikoshi, Rene Kim, Byungsuk Lee, Max Markrich, Peter Mwandri, Kulthoum Omari-Motsumi, Martin Prowse and Galyna Uvarova. "Independent evaluation of the adaptation portfolio and approach of the Green Climate Fund." Evaluation Report No. 9, February 2021. Independent Evaluation Unit, Green Climate Fund. https://www.greenclimate.fund/sites/default/files/document/gcf-b28-17.pdf.

Recommendation 5: To accelerate deployment of climate finance with a low-carbon AgTech focus, funders and companies should collaborate to identify best-fit financing instruments, with an eye to demonstration.

As lean organizations, SMEs often have limited visibility into and understanding of the emerging climate financing products and platforms. For obvious reasons, they are very interested in monitoring these potential funding facilities but pursuing new mechanisms has generally yielded a very low hit rate for the SMEs interviewed, and consumed valuable time. Interviewees voiced support for collaborative groups of SMEs and funders that could come together to understand respective needs and identify overlap, especially when actual funding may be available if and when workable financing solutions are identified. Far less popular among interviewees were platforms aiming to facilitate matchmaking between investors and SMEs, as these tend to lead to fewer transactions unless there is a clear understanding that new funding is coming to the table.

Recommendation 6: Investing in women-led and locally-led SMEs may require updating internal processes, more flexible finance terms, and additional technical support.

Women-led firms appear to be significantly underrepresented in the AgTech sector. To overcome internal biases and fully leverage the potential of the sector, investors should consider process reforms like leveraging women's professional energy networks for pipeline development and quotas in assembling investment "short lists." Investors may need to consider non-asset-based lending—as is the case with the Africa Trust Group's Empress Fund—or other forms of security like future cash flows, purchase order contracts or accounts receivables.[143]

With social norms also limiting women's ability to use formal finance, investors may want to consider sensitivities to the **way** in which women want to scale—possibly slower or with a different emphasis on scale. For example, one investor noted that women are sometimes hesitant to scale their business quickly, afraid that juggling domestic and childcare roles with a larger enterprise would be overwhelming.

143 The Empress Fund website, https://empress.fund/; Schiff, "Beyond the Threshold."

4.2 Measurement

	Recommendation	Multilateral Climate Funds, Development Banks and DFIs	Fund Managers and Other Intermediaries	Impact Investors	LMIC Governments	AgTech Enterprises	Research Partners	Donors and Philanthropy	Commercial Investors	Corporates (including ESG)
		Relevant Actors								
Measurement	7. Standardized methodologies for measuring climate impacts are needed to help companies quantify climate benefits in monetary terms and establish markets.	●		●		●	●	●		●
	8. Develop a publicly-available database of evaluations that provide a range of credible values corresponding to specific impacts of targeted value chains, giving SMEs a starting point for more specific impact measurement.	●					●	●		
	9. Moving towards more impact-driven adaptation investment models will require targeted technical assistance in key areas, including support to SMEs for impact measurement and investment readiness (especially for women-led and locally-led SMEs); support to facilitate partnership and data sharing between weather index insurers and SMEs; and support to investment fund managers for development of innovative blended instruments.	●	●	●				●		●

Figure 15. Summary of measurement recommendations and relevant actors

Adaptation impacts are difficult to define, measure, and verify, making adaptation benefits hard to benchmark or monetize. Unlike climate mitigation finance, which relies on CO_2 emissions or GHG emissions avoided, there is no single, standard set of metrics for adaptation impacts. Adaptation is a multifaceted concept that includes impacts to social, economic, and environmental resilience, which will vary widely by intervention and geography. Adaptation impacts need to be measured over a longer time horizon and with proper baseline measurements, which is expensive and time-consuming for lean SMEs. While the majority of SMEs collect data around livelihoods—primarily jobs created and income increased—few other potential adaptation metrics are regularly collected. There is a chicken-and-egg problem here: as there is currently no way to monetize these benefits, unlike carbon markets for mitigation, there is no incentive to measure them, and because there is no common understanding on measurement, there is no "adaptation impacts" market.

Articulating a theory of change and measuring the impacts of interventions plays a number of important roles. SMEs most regularly collect metrics on their operations because investors are interested in their reach and economic impact. SMEs also collected impact data to ensure that they were delivering the impacts that they thought they were—to test their theory of change and improve their product and service. Adaptation metrics could also provide an input for investment decisions or form the basis of an innovative finance mechanism, such as an adaptation-oriented RBF mechanism or a certified adaptation credit, like a carbon credit.[144]

144 Ngoasong, Michael, Rob Paton, and Alex Korda. "Impact Investing and Inclusive Business Development in Africa: A research agenda." The Open University, 2015. http://oro.open.ac.uk/42157/1/ikd-working-paper-76.pdf.

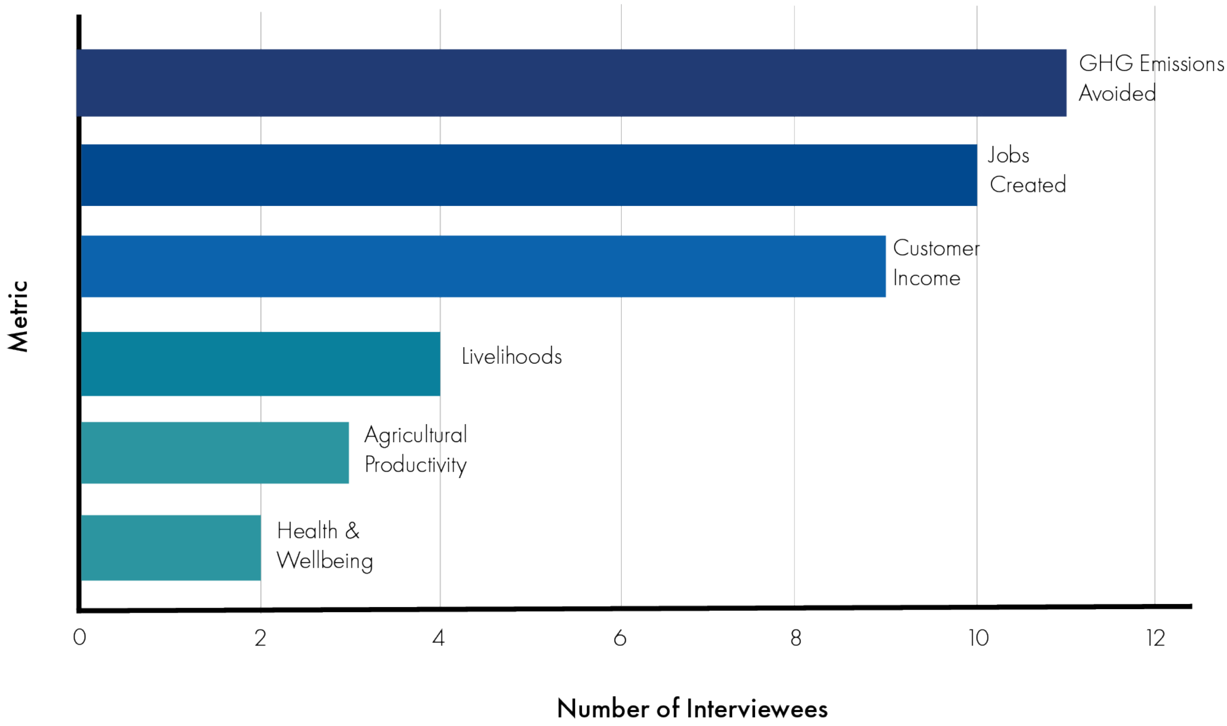
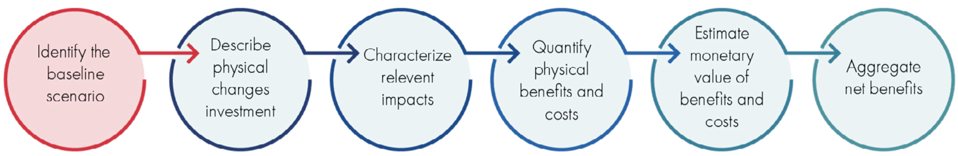


Figure 16. Most common impact metrics collected (Source: Interviews)

But the metrics that SMEs currently collect are a poor reflection of their true adaptation impact. The impacts that SMEs can have on adaptive capacity is varied: irrigation can improve food productivity during droughts, cold storage can provide greater food security, and agricultural processing can increase community resilience through improving incomes. However, SMEs rarely collect metrics that could speak to these impacts. While a few SMEs use standardized impact metrics such as IRIS or GIIN,[145] the overwhelming majority collect data on a small handful of impact indicators, often as few as one or two. Figure 16 illustrates the most common metrics collected: essentially all SMEs and investors collect (or ask investees to collect) output metrics, including products sold and people employed in the business; 82% collect data on longer term economic impacts, usually in the form of income or employment rates; 62% collect information on environmental impacts, which is almost exclusively measured in GHG emissions avoided; and 29% collect data on short term economic impacts like productivity and food loss avoided. Only 14% of SMEs and investors collect data on health impacts.

Given financial pressures, companies typically conduct brief customized phone surveys to measure outcomes such as revenues or satisfaction. In these approaches, companies rarely study a comparison group—that is, look at impacts that occur in the same time period for a community or group that is comparable on observable characteristics, but that was not exposed to the intervention or investment. Omitting a comparison group makes it impossible to measure anything beyond simple project outputs.

This has been sufficient for at least some investors, but more rigorous evaluation could have the potential to unlock additional investment, and especially now as investors are becoming more familiar with climate impacts and impact evaluation. The key challenges of defining and measuring adaptation impacts are outlined below.



Measurement Challenge #1: The probabilistic and uncertain nature of climate change makes it difficult to define the Theory of Change, and thus the rationale for adaptation finance.Adaptation to climate change requires knowledge of what the impacts of climate change are likely to be and to what extent potential solutions could mitigate those negative impacts. However, extreme weather events caused by climate change are probabilistic in nature and require access to granular climate impact models or datasets collected over time and space.

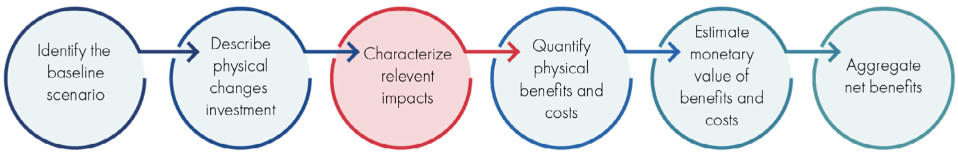
145 Ngoasong, Michael et al. "Impact Investing."

Marrying high-level climate data with local solutions is a real barrier to creating projects, but also to measuring their success. Without knowledge of what the climate impacts have been and are likely to be, it is impossible to measure how effective interventions have been at mitigating those impacts.

Access to localized climate forecasting and defining a climate project's rationale is a barrier:

> "The availability of data, lack of guidance on the concept of climate rationale at AE [accredited entity] and Secretariat level, and the complexity of adaptation projects are key reasons for delays. Adaptation projects require more specific and local high-resolution data to analyze climate risks, have less standardized business models and have complex execution structures. **Forty percent of all registered CNs for adaptation projects are withdrawn during the review process.** Survey respondents identified **climate rationale as the single most difficult hurdle** for project development in both adaptation and cross-cutting projects. "[146]

Because climate change will have different impacts on different regions, both the impacts of climate change and potential solutions are highly localized and vary widely from country to country, and within countries. Climate-first investors with small origination teams are not equipped to match highly localized adaptation opportunities with SMEs serving the needs of affected communities. From a planning perspective, most NAPs acknowledge the need to create more specific regional plans for adaptation, with those local plans being the responsibility of county or province level governments.[147] While the high geographic variation in climate impacts and adaptation needs can be an opportunity for SMEs with deep understanding of local markets, this variation makes evaluation and benchmarking—and ultimately financing—more challenging.



Measurement Challenge #2: SMEs need support to articulate the connection between the work that they do and adaptation impacts. Despite the many connections between AgTech and climate resilience, most SMEs interviewed limited their theory of change to potential carbon mitigation benefits, with only a handful collecting data on agricultural productivity and health benefits. This arises in part from the factors highlighted in Section 3: data collection is time-consuming and expensive, so SMEs are reluctant to add new metrics. Multilateral climate funds and development banks allocate additional budget to monitoring and evaluation, which allows them to require a long list of output, outcome and impact metrics. Another issue, which emerged multiple times during the interviews, was a lack of knowledge or understanding about climate adaptation benefits. AgTech companies found it challenging to articulate their impacts in terms of climate adaptation.

Multilateral climate funds often focus their metrics on outputs and outcomes (see Figure 17), but are increasingly expanding their suite of relevant adaptation impact indicators.[148] GCF's Adaptation performance measurement framework includes adaptation impact indicators, but of these 17 indicators only one attempts to measure impact: "1.1 Change in expected losses of lives and economic assets (US$) due to the impact of extreme climate-related disasters in the geographic area of the GCF intervention."[149] GCF's own internal audit acknowledges that the "depth of impact for adaptation interventions cannot be monitored with the current set of indicators" and that "[t]he GCF currently has no systematic approach to assess the depth of adaptation impacts."[150] However, recent work led by The Lightsmith Group in partnership with GEF—under the rubric of the Adaptation SME Accelerator Program—aims to create an Adaptation Solutions Taxonomy aimed at connecting SMEs' work with adaptation impacts, including metrics like water saved, energy reliability, and agricultural yield. This work also involves creating a directory of SMEs providing adaptation solutions, presently containing over 150 emerging market SMEs, with another 250 under review. The Adaptation Solutions Taxonomy emphasizes that metrics and measurement approaches are context-specific, though it also identifies the need for at least conceptual harmonization.[151]

146 Binet et al, "Independent Evaluation of the Adaptation Portfolio."
147 Morchain, "Progress and Challenges."
148 "Mitigation and adaptation performance measurement framework" Green Climate Fund. https://www.greenclimate.fund/sites/default/files/document/mitigation-adaptation-performance-measurement.pdf; "Updated Results Architecture for Adaptation to Climate Change Under the Least Developed Countries Fund and the Special Climate Change Fund (2018-2022)" Global Environment Facility, 2018. https://www.thegef.org/sites/default/files/council-meeting-documents/EN_GEF.LDCF_.SCCF_.25.Inf_.05_Updated_Results_Architecture_for_Adaptation_to_CC_under_LDCF_SCCF-LDCF_0.pdf.
149 GCF, "Mitigation and adaptation performance measurement frameworks,"
150 GEF, "Updated Results Architecture."
151 Trabachi, Chiara, Jay Koh, Serena Shi, and Tara Guelig. "Adaptation Solutions Taxonomy." The Lightsmith Group. 2020. https://lightsmithgp.com/wp-content/uploads/2020/09/asap-adaptation-solutions-taxonomy_july-28-2020_final.pdf; "Global Directory and Accelerator Initiative Launched to Support Private Sector Solutions That Boost Climate Adaptation and Resilience—The Lightsmith Group." Accessed November 22, 2021. https://lightsmithgp.com/news-posts/global-directory-and-accelerator-initiative-launched/.

Likewise, the World Bank is trying to embed climate adaptation more fully into its projects. Currently, project metrics focus on outcomes and outputs, with a few exceptions, such as agricultural productivity.[152] However, the World Bank recently released its first ever Resilience Rating System, which rates projects both in terms of their resilience to climate change and also how resilience is created through the actions of the project.[153] For the latter, achieving an A rating requires the project to monitor resilience-building activities through at least one climate or disaster (resilience) indicator. It is possible that these attempts to clarify the relationship between AgTech and climate smart agriculture and climate resilience will support SMEs in identifying climate impact metrics

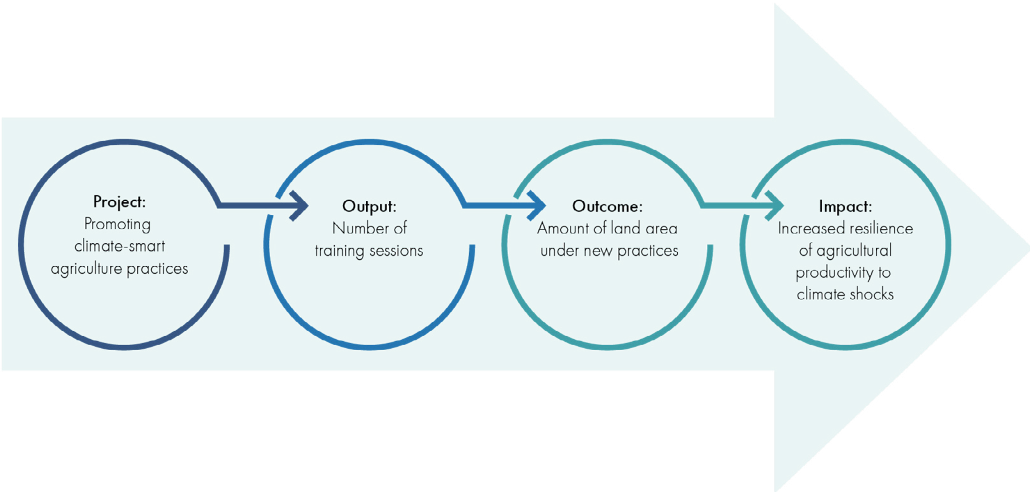
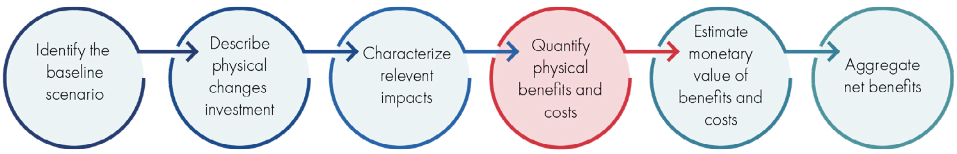


Figure 17. Example output, outcome and impact based on a hypothetical climate-smart agriculture project.



Measurement Challenge #3: Unclear how to treat additionality. The term "additionality" has become a key part of the climate finance lexicon in various contexts.[154] One is in the context of developed countries' commitments under the UNFCCC to deliver "new and additional" resources to developing countries for measures taken to address climate change. Another is in the context of mitigation and adaptation actions themselves. In the mitigation context, additionality refers to net GHG emissions savings or sequestration benefits in excess of those that would have arisen anyway in the absence of a given activity or project. Along with issues of permanence, leakage, and displacement, additionality is widely considered a core aspect of quality assurance of climate change mitigation activities. When a mitigation project lacks additionality that means that there are no GHG abatement benefits over and above those that would have arisen anyway. Credits issued for benefits which are not additional, if used as carbon mitigation offsets, result in an overall increase in GHG emissions.[155] A similar principle applies in the context of climate adaptation: development that would have occurred in the absence of adaptation financing should not be considered additional.

Another element to consider in discussing "additionality" is effectiveness. Directing financial resources toward technologies and business models where the private sector is already investing at the necessary scale is not effective. Public financing should be invested in initiatives that have the potential to deploy new technologies, reach new markets, and leverage additional private investment where the market on its own is not efficient.[156] In other words, public finance should address market failures, not compete with existing and robust private markets.

152 World Bank Group. "Kenya Climate Smart Agriculture Project." World Bank Group, 2021. https://documents1.worldbank.org/curated/en/384161617128040766/pdf/Disclosable-Version-of-the-ISR-Kenya-Climate-Smart-Agriculture-Project-P154784-Sequence-No-09.pdf.
153 World Bank Group. (2021) "Resilience Rating System : A Methodology for Building and Tracking Resilience to Climate Change." World Bank Group, 2021. https://openknowledge.worldbank.org/handle/10986/35039.
154 Escalante, Donovan, Dario Abramskiehn, Karoline Hallmeyer, and Jessica Brown. "Approaches to assess the additionality of climate investments: Findings from the evaluation of the Climate Public Private Partnership Programme (CP3)." Climate Policy Initiative, 2018. https://www.climatepolicyinitiative.org/wp-content/uploads/2018/03/Approaches-to-assess-the-additionality-of-climate-investments-_-Findings-from-the-evaluation-of-the-Climate-Public-Private-Partnership-Programme-CP3-2.pdf.
155 Valatin, Gregory. "Additionality and Climate Change Mitigation by the UK Forest Sector." Forestry: An International Journal of Forest Research 85, no. 4 (August 13, 2012): 445–62. https://doi.org/https://doi.org/10.1093/forestry/cps056.
156 Escalante et a, "Approaches to assess the additionality."

Operationally, much of the work to establish additionality of adaptation finance must rely on MDB's and other public finance providers. For private sector actors in emerging markets this means gaining access to financing or innovative financing structures and instruments that the local capital markets or financial sector would not otherwise provide, such as local currency or extended tenor financing.[157] In 2018 a group of MDBs published the Harmonized Framework for Additionality in Private Sector Operations, which provides concrete guidance on the application of the additionality principle, including examples of types of evidence that help demonstrate the presence of additionality.[158] For their part, SMEs and project developers seeking to establish additionality should be prepared to address whether the project outcomes are likely to be achieved without MDB financing. For instance, documenting limited or nonexistent options for financing in commercial markets could support this objective. To the extent that financing is conditional on measuring outcomes as well as outputs, it is also helpful to use decision support tools in advance of an investment to identify and characterize adaptation benefits—and, ideally, to follow up with impact assessments to confirm the impacts that were anticipated.[159]

Measurement Challenge #4: Adaptation benefits are best measured over long time frames. Unlike GHG emissions avoided, climate adaptation must be measured over time to assess its impacts. Impacts to food productivity, for instance, cannot be determined at the point of intervention, but instead must be measured over longer periods of time. In part, this is because impacts are not instantaneous, and productivity increases manifest over multiple seasons.[160] However, the resilience benefits that are required to generate a positive return on adaptation investments are typically measured on longer timeframes than that for which impact and commercial investors have appetite. This also points to a market failure: although investors do not account for benefits that accrue beyond their time horizon, individuals and communities (including some individuals who may not be born yet) would nonetheless receive these benefits. Where such externalities exist, there is particularly strong justification for public investment—in this case, for projects that deliver longer term benefit streams.

Another key reason for longer-term measurement is that adaptation impacts often take the form of resilience to shocks, which are unpredictable and probabilistic in nature. Droughts may be a 1-in-5-year event or a 1-in-15-year event, and climate change will shift that likelihood over time. Resilience to such shocks cannot be measured at the time of intervention. In addition to requiring baseline measurements and regular measurements on an annual or semi-annual basis, measurements may be required even after the project activities have completed to understand the impact of the intervention on resilience to external shocks.[161] While ex-post impact measurement cannot inform the activities within the program that has been completed, it is critical for understanding whether such a program was effective, and to inform improved **ex ante** analysis of future similar investments.

Because rigorously measuring adaptation impact is hard, most investors treat these benefits as a "bonus"—collecting limited relevant metrics, but rarely weighing them heavily in investment decisions. The implication of these challenges is that the non-financial benefits of adaptation investments may be difficult to quantify, not credible or verifiable, or lack sufficient market interest. Unlike mitigation investments, fund managers may be unable to identify or evaluate adaptation investments or face unclear mandates from their own investors on adaptation impact metrics. As a result, the adaptation components of SME operations are mostly treated as a bonus or secondary investment criteria.

Without technical assistance, improving the measurement of adaptation impacts will actually prevent many SMEs from engaging with climate investors. AgTech SMEs are lean operations that lack the resources required for extensive metrics reporting. If investors do require rigorous impact assessment reporting, as outlined in the challenges above, SMEs are likely to be unable to dedicate resources to meet such requirements. Currently, SMEs are ill-equipped to engage bureaucratic international financing institutions or climate finance funds. The needs of these climate investors, their investment timelines, and the impact metrics/reporting create high transaction costs and expertise requirements that represent a large barrier to resource-constrained SMEs. For SMEs working with UNFCCC funds, external consultants assisted with surveying and reporting requirements. Improving impact evaluation will increase such costs unless technical assistance is made available.[162,163]

157 Azevedo, Viviane. "Why Is Additionality Key for Private Sector Development Finance?" IsDB Invest. IsDB Invest, October 26, 2018. https://IsDBinvest.org/en/blog/development-impact/why-additionality-key-private-sector-development-finance.

158 "Multilateral Development Banks' Harmonized Framework for Additionality in Private Sector Operations." IFC, 2018. https://www.ifc.org/wps/wcm/connect/topics_ext_content/ifc_external_corporate_site/development+impact/resources/201809-mdbs-additionality-framework.

159 Narayan, Tulika and Anu Rangarajan. "Using Climate Finance Effectively: Five Recommendations." Mathematica, 2020. https://www.mathematica.org/-/media/publications/pdfs/international/2020/using-climate-finance-effectively.pdf.

160 Agrawal, Anirudh, and Kai Hockerts. "Impact Investing: Review and Research Agenda." Journal of Small Business & Entrepreneurship 33, no. 2 (March 4, 2021): 153–81. https://doi.org/10.1080/08276331.2018.1551457.

161 Narayan, T. & Rangarajan, A. (2020) "Using Climate Finance Effectively: Five Recommendations", https://www.mathematica.org/-/media/publications/pdfs/international/2020/using-climate-finance-effectively.pdf.

162 Dominice, R. & Minci, J. (2013) "Small Enterprise Impact Investing: Exploring the "Missing Middle" beyond Microfinance", https://www.smefinanceforum.org/sites/default/files/post/files/457628_symbiotics-small-enterprise-impact-investing.pdf.

163 Dominice, Roland and Julia Minci. "Small Enterprise Impact Investing: Exploring the 'Missing Middle' beyond Microfinance." Symbiotics, 2013. https://www.smefinanceforum.org/sites/default/files/post/files/457628_symbiotics-small-enterprise-impact-investing.pdf.

There is still a lot of room to move from "minimal impact measurement" to "fit for purpose impact measurement." To address several of the challenges above, the International Development Finance Club and MDBs created the Common Principles for Climate Change Adaptation Finance Tracking, which states that an adaptation project must 1) explain the climate change vulnerability to be addressed, 2) state the intention to address it, and 3) articulate a clear link between the project activities and that climate vulnerability.[164] On the other hand, most SME investors are currently measuring resilience by a very limited suite of indicators, usually "jobs created" or "income." In many cases, SMEs do not collect income over time, but only the baseline income of a farmer, in order to better understand customer dynamics. There is significant room for improvement here, from selecting a wider range of adaptation impacts to measuring such impacts over time.

Spotlight on Gender: Measurement Challenges

MCFs place a high premium on gender-sensitive approaches. Recognizing gender equality as a good in and of itself, as well as recognizing that gender-sensitive project design improves project outcomes, the GCF, GEF, and AF—and many of the organizations that implement those projects, including the World Bank and AfDB—have created gender policies that aim to mainstream gender concerns.[165] Gender mainstreaming includes conducting gender analyses of projects, incorporating gender-specific activities into project plans, and collecting gender-disaggregated indicators.

Collecting gender-disaggregated data has become the standard throughout the climate finance ecosystem. The impact of the strong push for gender-disaggregated data can be felt from the large multilaterals to fund managers and impact investors to SMEs. This has translated into action, with nearly 80% of the organizations consulted in this study collecting gender-disaggregated data. However, there is still some way to go: even the GCF acknowledges that only 78% of its approved projects provide sex-disaggregated indicators, and only 63% of DFIs disaggregate data by gender.[166,167]

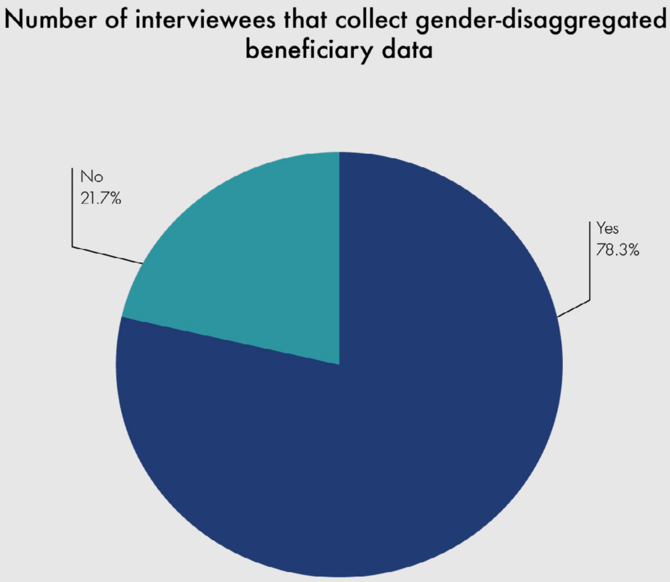


Figure 18. Number of interviewees that collect gender-disaggregated beneficiary data

Some investors (61% of those we spoke to) are also collecting gender data about their portfolio companies, usually in the form of number of women-led businesses or the gender make-up of leadership positions in a company. However, multiple investors acknowledged that the focus on gender metrics continues to be on "women as beneficiaries" with less progress on "women as leaders."

164 Micale, Valerio, Bella Tonkonogy, and Federico Mazza. "Understanding and Increasing Finance for Climate Adaptation in Developing Countries." Climate Policy Initiative, 2018. https://www.international-climate-initiative.com/fileadmin/Dokumente/2019/20190225_Understanding-and-Increasing-Finance-for-Climate-Adaptation-in-Developing-Countries.pdf.

165 GEF. "Mainstreaming Gender at the GEF." GEF, 2013. https://www.thegef.org/sites/default/files/publications/Mainstreaming_Gender_Eng_3.pdf; GEF. "Policy on Gender Equality." GEF, 2017. https://www.thegef.org/sites/default/files/council-meeting-documents/EN_GEF.C.53.04Gender_Policy.pdf;GCF. "Gender Policy." GCF, 2019. https://www.greenclimate.fund/document/gender-policy; https://www.adaptation-fund.org/document/updated-gender-policy-and-gender-action-plan/

166 GCF. "Updated Gender Policy and Gender Action Plan 2020-2023." GCF, 2019. https://www.greenclimate.fund/sites/default/files/document/gcf-b24-15.pdf.

167 Lee, Nancy, Megan O'Donnell, and Kelsey Ross. "Gender Equity in Development Finance Survey." Center for Global Development, September 10, 2020. https://www.cgdev.org/publication/gender-equity-development-finance-survey.

But women's voices are still often hard to hear in AgTech value chains. Although most SMEs collect gender-disaggregated data, because they typically collect only 1 or 2 indicators of economic impact, the gender data tends

to manifest as a single indicator on the number of women employed or the number of women who have purchased the product. Across the value chains studied, SMEs acknowledged that collecting data on customers was insufficient to understanding the impact of their technologies on women. For solar irrigation, for example, men are usually the owner of pumps, because purchasing a pump usually requires a loan and assets are in the man's name. However, these devices can have significant ramifications in terms of intra-household bargaining power. One survey in East Africa found that a family's ownership of a pump saves women an average of 7 hours per week.[168] Other studies have shown that access to a solar irrigation system causes a statistically significant increase in women's empowerment indexes, especially on the economic independence factor. Women with access to irrigation increase their yields and sell surplus produce, whether farming as part of a women's group or on their own plots. [169]

Collecting data only on customers may miss out on the impact of technology on other members of the household. In India, for example, men are often the primary customer for cold storage for milk, even though women are the major producers of dairy in the country, simply because men will take the milk to market. In this way, disaggregating data collected from customers is a poor reflection of the impact these technologies have on households. As cited above, intrahousehold impact surveys could peel back an additional layer of impact, but they can be resource-intensive.

There was a sense among SMEs that gender was a "box checking exercise" for many investors. SMEs believed that investors were interested in gender, but it often took the form of a single KPI or activity that the SME was already doing or could do with minimal burden. SMEs reported that returns, unit economics and deployment numbers mattered much more to their investors. Incorporating gender into the narrative without providing technical assistance or guidance on how to address gender better was often described as a kind of "social greenwashing." For investors looking for a more accurate accounting of gender impacts in SME operations, one solution would be supporting gender inclusive programming and tracking through technical assistance facilities, which were cited frequently in interviews. It's worth noting that this type of support may be most effective once the business model and key processes are stabilized, so may not be appropriate for seed-stage companies.[170]

Recommendation 7: Standardized methodologies for measuring climate impacts are needed to help companies quantify climate benefits in monetary terms and establish markets.

Measuring climate impacts generally, and adaptation impacts specifically, is challenging because more rigorous methods are needed to prove impact, and those rigorous methods are often onerous for SMEs. SMEs and investors need a set of rules and criteria that permit third-party verification of methodologies or frameworks to rigorously measure specific adaptation benefits. Credible measurement of impacts relies on good quality, transparent, and verifiable climate impact data. Therefore, solutions to this measurement problem need to balance the need for rigor with SMEs' resource limitations.

In terms of climate mitigation, some tools already exist that try to balance those needs, such as the CRANE tool; for climate adaptation, there are many more potential adaptation outcomes to measure (see Figure 8). Third-party-certified methodologies already exist for other benefits and project types: for instance, the Gold Standard has developed methodologies for quantifying and monetizing several types of adaptation benefits. Through the Gold Standard for the Global Goals program, Gold Standard certified projects can receive funding for providing ADALYs, which represent the number of years of healthy life made possible by a given intervention; sustainable water management, including water conservation, purification, and provision; and reductions in black carbon and other short-lived climate pollutants.[171]

Similarly, Verra's Sustainable Development Verified Impact Standard (SD VISta) sets out rules and criteria for rigorous evaluation of how projects contribute to advancing the SDGs.[172] C-Quest Capital has developed a methodology for SD-VISta for quantifying and valuing women's time savings.[173]

168 Efficiency for Access."Use and Benefits of Solar Water Pumps: Kenya, Tanzania, and Uganda Consumer Research." Energy for Access, June 2019. https://www.clasp.ngo/wp-content/uploads/2021/01/Use-and-Benefits-of-Solar-Water-Pumps.pdf

169 Burney, Jennifer, Halimatou Alaofè, Rosamond Naylor, and Douglas Taren. "Impact of a Rural Solar Electrification Project on the Level and Structure of Women's Empowerment." Environmental Research Letters 12, no. 9 (September 2017): 095007. https://doi.org/10.1088/1748-9326/aa7f38.

170 Shell Foundation, "Lessons Learned."

171 The Gold Standard (2021), "Gold Standard for the Global Goals", https://www.goldstandard.org/articles/faq-gold-standard-global-goals

172 Verra (2019) "Verra Launches Sustainable Development Verified Impact Standard", https://verra.org/verra-launches-sustainable-development-verified-impact-standard/

173 https://verra.org/sdvista_method/time-savings-from-improved-cookstoves-ics/ Verra "Methodology for Time Savings from Improved Cookstoves (ICS)", https://verra.org/sdvista_method/time-savings-from-improved-cookstoves-ics/

This is specific to improved cookstove projects but the methodology may be adaptable to other types of projects too. In the conservation space, Quantified Ventures and the Iowa Soybean Association are scaling a financing vehicle to provide farmers with financial incentives to implement conservation practices that generate verifiable environmental outcomes including water quality improvement, biodiversity and habitat protection, and flood mitigation.[174]

The market for SDG co-benefits remains nascent, however. Measurement approaches are not standardized across different certifiers, so it is not clear whether the metrics and approaches that would satisfy one system (e.g., the Gold Standard for the Global Goals) would also satisfy another (e.g., SD VISta). Also, approaches to quantify and monetize many co-benefits have yet to be developed. The end goal is to build out approaches to measure additional adaptation benefits, and standardize existing methodologies, so that adaptation benefits can become as investible as carbon emissions reductions.

Recommendation 8: Develop a publicly available database of evaluations that provide a range of credible values corresponding to specific impacts of targeted value chains, giving SMEs a starting point for more specific impact measurement.

This database could also identify portfolios of projects that lie roughly within a value chain but would critically include rigorous counterfactual estimation strategies. These evaluations would be set in different contexts but using similar methods and approaches. These would be **nimble**, in the sense that the evaluations should allow for design tweaks during the evaluation process, and these tweaks should not invalidate the entire evaluation strategy. And they would be **modest**, in the sense that such evaluations need not be fully powered (i.e., have sufficiently large sample sizes) or have failsafe (RCT-type) identification of impacts on their own, but they should be credible for pointing to options that appear promising, based on clear and transparent metrics. This will allow for the initial identification of those value chains and investments that appear most promising for generating real benefits to both rural households and rural societies as a whole, and that are worthy of further investment and, possibly, more rigorous evaluation at larger scale. It would also shed light on design features that are most important for improving success. Furthermore, it would allow for integration with local datasets that provide information on locally specific risks, such as the data developed by weather index insurance providers (see Recommendation 9 for details).

The aim in developing those evaluations would be to build up a library or database, with accompanying documentation, that provides both a range of values corresponding to certain specific impacts in these value chains, and guidance on options for how to quantify impacts in a way that is rigorous and credible but also manageable for SMEs. Then, with that in hand, SMEs could undertake lighter-touch methods with more pragmatic data approaches, to help to approximate the impact of interventions in specific places, at a lower cost. There will still be some drivers of variation, but the evidence base will help provide some guidance as to which are most important and how much variation they actually drive.

Modest and nimble evaluations would appropriately account for specific projects or portfolios, according to the relevant scale of investment. They would allow for learning and tweaking of the intervention, product, or service provided, but would not rely solely on a single approach (e.g., an RCT), instead leveraging the best aspects of attention to context, cost, and practical aspects relating to targeting. It would be critical to target the intervention at important intermediate points in the theory of change to assess where logic does or does not hold. Finally, such an evaluation would leverage a mix of qualitative and quantitative methods for surveying and data collection, as far as possible. This will also help to identify points in the theory of change to assess where the logic does or does not hold.

174 Quantified Ventures (2021). "Soil and Water Outcomes Fund", https://www.quantifiedventures.com/soil-and-water-outcomes-fund

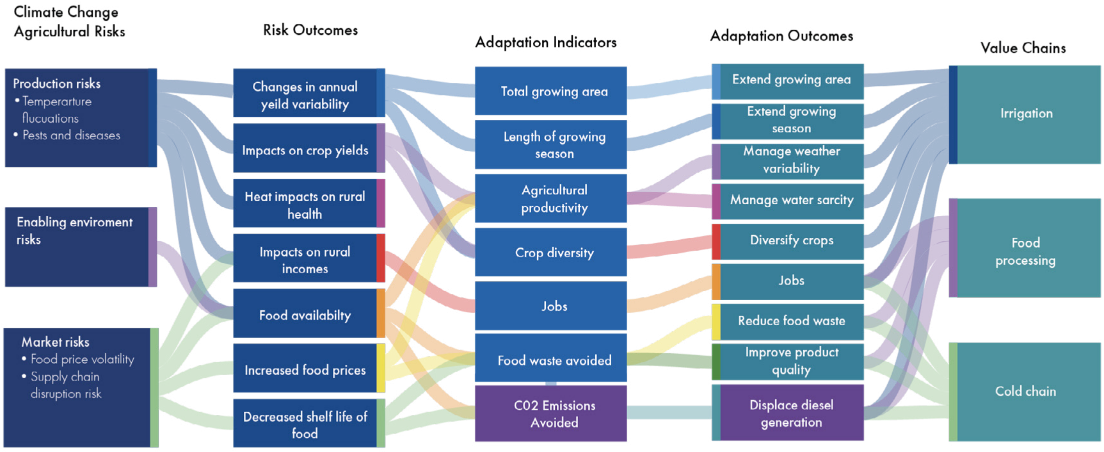


Figure 19. Connecting climate risks for agriculture to value chains

Recommendation 9: Moving towards more impact-driven adaptation investment models will require targeted technical assistance in key areas, including support to SMEs for impact measurement and investment readiness (especially for women-led and locally-led SMEs); support to facilitate partnership and data sharing between weather index insurers and SMEs; and support to investment fund managers for development of innovative blended instruments.

SMEs of various sizes and stages of maturity were consulted in preparing this report, and all reported that impact measurement was a costly and time-consuming activity, in which they felt limited by their internal capacity and financial resources. Some SMEs and investors that were surveyed acknowledged this challenge and put funds aside to support the hiring of third parties like 60 Decibels for metrics collection and analytics. Intermediaries channeling MCF investment often set aside dedicated funds to support their companies in meeting more rigorous reporting requirements. As climate-interested investors work towards more rigorous climate impact evaluation, technical assistance will be necessary to meet those data collection expectations.

Investment readiness TA for SMEs can be particularly important for locally led and women-led AgTech SMEs that know their market well, but which may be less familiar with international investors and practices. This assistance can take various forms, but in all cases targets the problem that viable business models may fail to attract investment because of relatively small barriers—language and culture, financial modeling skills, and awareness of international financing sources and processes. Well-designed programs that can properly identify SME gaps and facilitate solutions were identified by 84% of interviews as positive levers for helping scale additional climate finance to the sector.

Measuring how AgTech solutions help communities to avoid, reduce, or be more resilient to extreme weather events requires understanding the probability distribution of potential outcomes. Providers of weather index insurance are ideally positioned to offer useful insights about local risks. For instance, the agriculture and livestock insurer Pula is providing coverage to more than 5 million smallholder farmers in Africa against losses from drought, floods, pests and diseases.[175] These and other weather index insurers build and maintain probabilistic simulation models of weather patterns and extreme events, paying out benefits on the basis of loss of assets, investments, and/or reduced yields resulting from deviations from predetermined indexes (e.g., rainfall level). Because index insurance typically does not require in-person inspection from an insurance claim assessor, it reduces transaction costs and allows for a quicker and more objective claims settlement process.[176] The outcomes of these simulation models (i.e., probability distributions indicating the frequency and severity of weather effects) can be paired with impact assessment tools to help measure the effects of AgTech solutions. Technical assistance focused on building partnerships and data-sharing arrangements between these insurers and SMEs would support the application of these tools for better understanding the localized resilience impacts of SMEs.

With lower return profiles or greater investment risk—realities facing many AgTech enterprises—comes a greater need for investment funds to incorporate grant and other risk-tolerant capital into them. Mobilizing diverse investor groups with a range of objectives, risk tolerances, and return requirements can take years, during which time management fees are not collected.

175 https://www.pula-advisors.com/
176 Kramer, Berber. 2019. "Can weather index insurance help farmers adapt to climate change?" International Food Policy Research Institute (IFPRI) Blog, December 13. Online at https://www.ifpri.org/blog/can-weather-index-insurance-help-farmers-adapt-climate-change.

Targeted assistance can help blended funds overcome structuring challenges, long lead-times, and meet investors that are new to innovative vehicles on their terms and timeframes. Design funding grants from the blended capital advisory and network building firm Convergence have been instrumental in getting several climate funds successfully launched. Similarly, the Global Innovation Lab for Climate Finance accelerates financial instruments that aim to unlock investment across a range of sustainability sectors, including renewable energy and climate-smart agriculture.[177]

Improved impact measurement is an essential ingredient to monetizing positive climate impacts for SMEs and may prove to be a gateway to greater private sector participation in adaptation finance in the future, as illustrated in the roadmap in Figure 14.

177 The Global Innovation Lab for Climate Finance. "The Global Innovation Lab for Climate Finance." Accessed September 12, 2021. https://www.climatefinancelab.org/.

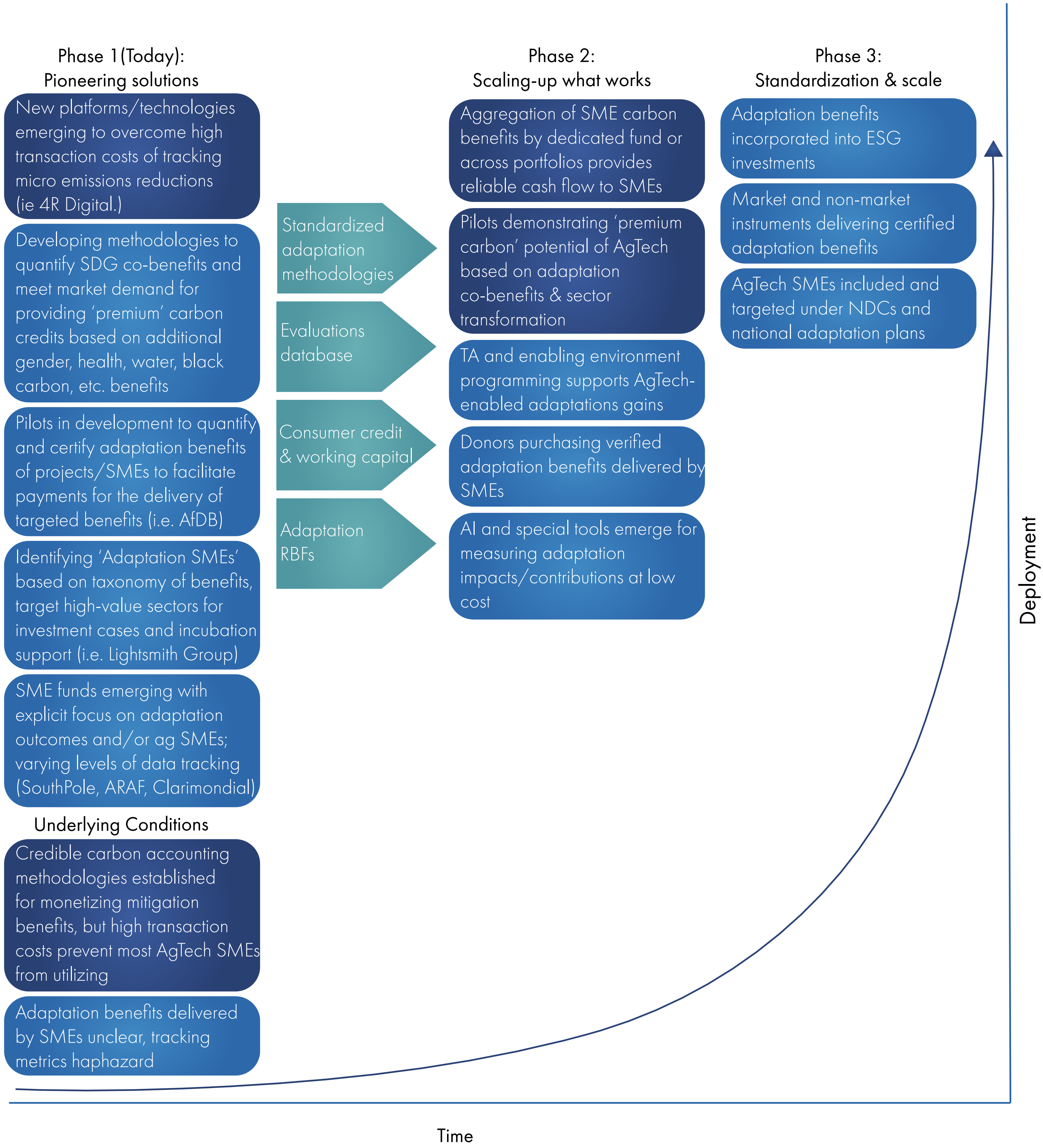


Figure 14. Roadmap for monetizing climate benefits

4.3 Institutional & Enabling Environment

	Recommendation	Multilateral Climate Funds, Development Banks and DFIs	Fund Managers and Other Intermediaries	Impact Investors	LMIC Governments	AgTech Enterprises	Research Partners	Donors and Philanthropy	Commercial Investors	Corporates (including ESG)
Institutions & Enabling Environment	10. Build-out a diverse infrastructure of financial intermediaries to more quickly move large pools of climate capital to small enterprises, and activate frontier markets and sectors.	●	●	●	●			●		
	11. Encourage inclusion of SMEs in the development of country-level adaptation planning and connectivity to Nationally Determined Contributions.	●			●			●		
	12. Complementary policy and financing must focus on ensuring farmers and rural businesses have access to critical inputs and markets so that AgTech deployment will maximize productivity and resilience gains.	●	●	●	●			●		
	13. Low-carbon AgTech should be competing on a level playing field, with emissions-heavy investment bearing the costs of damages it imposes.	●			●					

Relevant Actors

Figure 20. Summary of institutional and enabling environment recommendations and relevant actors

Large public climate finance institutions (DFIs, MDBs, MCFs)—the source of the vast majority of climate finance to LMICs—are not designed to work with SMEs. Funded projects tend to be large and government-led, with long lead times, and ticket sizes are typically too large for SMEs absorb. To give a sense of portfolio make-up and project characteristics:

- Typical ticket sizes for private sector investments across all these institutions are in the tens of millions to hundreds of millions of dollars.
- Most GCF projects go to public sector implementers, but even private sector projects are larger on average, with nearly 75% of private sector projects topping $100 million, compared to just over 50% of public sector projects.
- Procurement opportunities coming from such projects, while rare for AgTech, are usually too large for these companies that may have a few thousand units in the field or less.
- MDBs and MCFs dispense funding through projects that often require 3–4 years of lead time before initiation and typically implement over 4–6 years. In one example, GCF's project in Kenya called "Towards Ending Drought Emergencies: Ecosystem Based Adaptation in Kenya's Arid and Semi-Arid Rangelands (TWENDE)" reaches 775,000 people, costs $34.5 million and will take at least nine years from entering the pipeline to completion.[178]

These are obviously not useful transaction templates for thinly capitalized SMEs that are severely resource-constrained.

DFIs do focus on financing private sector approaches, but generally at a scale much larger than what SMEs can handle. SMEs engage with these funders primarily through fund managers and other intermediaries, who provide the due diligence, evaluation against KPIs and other investment criteria, and monitoring services needed to effectively administer a portfolio of targeted investments. Small enterprises seeking $500,000–$5 million or more can work through these intermediaries, although funds with the capital instruments to serve AgTech SMEs are in very short supply.

178 Green Climate Fund. "FP113: TWENDE: Towards Ending Drought Emergencies: Ecosystem Based Adaptation in Kenya's Arid and Semi-Arid Rangelands." Text. Green Climate Fund, July 8, 2019. https://www.greenclimate.fund/project/fp113.

The layering of different intermediaries can get complicated and expensive to administer. A GEF investment to an SME, for example, must flow through one of 18 project agencies then to an investment fund, and finally to an enterprise. Rigorous donor-mandated oversight, strict policy and sectoral adherence, and aggregation of different institutional reporting obligations can have major implications on efficiency and timelines, as well as the ability of fund managers to identify eligible investments.

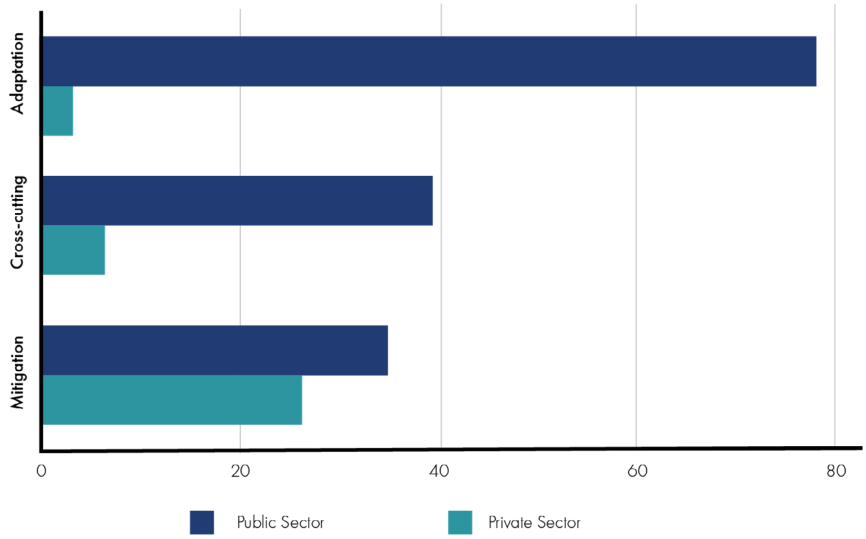


Figure 21. GCF projects by category and number of projects

MCFs are also connected to country-backed national adaptation plans (NAPs) and NDCs, which largely ignore SMEs. The NAPs were initiated in 2010 as countries increasingly recognized that climate adaptation would be closely linked to development strategy, and these plans generally aim to link between adaptation and development funding more explicit by identifying medium- and long-term adaptation needs.[179] Through UNFCCC policy, the MFCs are intended to be funding sources for implementation of these country-led plans.

NAPs are government-led policy plans documents that tend to focus on national and government stakeholders, placing less emphasis on local stakeholders like civil society organizations and SMEs, despite guidelines suggesting processes that engage with a wide range of stakeholders, including business and industry.[180], [181] Adaptation plans generally see SMEs as being impacted by adaptation, rather than as a partner in any serious adaptation work.[182] The specifics of this rarely go beyond "raise awareness within the sector" of climate adaptation risks and encourage planning for opportunities.[183] Kiribati's adaption plan is a notable exception, with an extensive strategy for strengthening and greening the private sector that includes networking and supporting dialogues with private investors in green, local SMEs.[184] However, most plans talk about the private sector principally as a funding source for adaptation, but with few specifics on how this private capital will be sourced or deployed.

A small minority of countries refer to SMEs in the context of innovation, but don't necessarily acknowledge the current work of SMEs to do climate resilience work. For example, Kenya's NAP includes prototype and innovation testing by the Kenya Climate Innovation Centre and African Enterprise Challenge Fund, UNDP Low Emissions, and the Climate Resilient Development Project, acknowledging that "small and medium sized enterprises in Kenya operated by the youth are at the forefront of innovation in technology and require adequate support to upscale and increase uptake of these innovations in order to enhance resilience."[185] Ethiopia's NAP also sees developing adaptation technologies as an objective, but does not link this to supporting technology SMEs.[186] Meanwhile, these NAPs do not acknowledge that in many cases, existing SMEs doing "development" work are already supporting climate adaptation, albeit at insufficient scale.

179 UNFCC. "What do adaptation to climate change and climate resilience mean?." UNFCCC. https://unfccc.int/topics/adaptation-and-resilience/the-big-picture/what-do-adaptation-to-climate-change-and-climate-resilience-mean#eq-2.
180 UNFCC LDC Expert Group. "National Adaptation Plans: Technical guidelines for the national adaptation plan process." UNFCCC, 2012. https://unfccc.int/files/adaptation/cancun_adaptation_framework/application/pdf/naptechguidelines_eng_high__res.pdf.
181 "NAP Progress in Participation and Transparency." Southern Voices on Adaptation. https://www.southernvoices.net/en/documents/key-documents/69-southern-voices-report-on-participation-and-transparency-in-national-adaptation-plans-2018/file.html.
182 "Republic of Fiji National Adaptation Plan: A pathway towards climate resilience." Government of the Republic of Fiji, 2018. https://www4.unfccc.int/sites/NAPC/Documents/Parties/National Adaptation Plan_Fiji.pdf.
183 "National Adaptation Plan to Climate Change." Brazil Ministry of Environment, 2016. https://www4.unfccc.int/sites/NAPC/Documents/Parties/Brazil NAP English.pdf.
184 "Kiribati Joint Implementation Plan for Climate Change and Disaster Risk Management." Government of Kiribati, 2019. https://napglobalnetwork.org/wp-content/uploads/2019/09/Kiribati-Joint-Implementation-Plan-for-Climate-Change-and-Disaster-Risk-Management-2019-2028.pdf.
185 "Kenya National Adaptation Plan 2015-2030." Government of Kenya, 2016. https://www4.unfccc.int/sites/NAPC/Documents%20NAP/Kenya_NAP_Final.pdf.
186 Government of the Federal Republic of Ethiopia. "Ethiopia's Climate Resilient Green Economy." Government of the Federal Republic of Ethiopia, 2019. Final Ethiopia-national-adaptation-plan (1).pdf (unfccc.int).

The result is that SMEs and many impact investors believe that the world of climate finance is not for them. Impact investors not affiliated with MCFs have limited awareness of the latter's associated programs. Climate-interested investors are generally aware of accreditation processes to gain access to MCF funds but consider them too onerous. Awareness of large climate funds is even lower among SMEs, except among those who have previously received funding through a MCF intermediary. SMEs know that their investors are interested in climate outcomes, but rarely know what climate finance is available or how to market themselves in a way that enables them to access it.

Broadly adopted and standardized sustainability investment criteria across the corporate ecosystem is raising the awareness of AgTech enterprises for partnership and investment. While not necessarily related to their own internal environmental, social, and corporate governance (ESG) approaches, 35% of those interviewed saw an increased focus on corporate sustainability as potentially driving support to ag-energy SMEs delivering climate benefits. Some stated that policies focusing companies on generating long-term competitive financial returns and positive societal impact were likely drivers for investment they had already received.

Opinions diverge on whether climate-related financial disclosure regulations and mainstreaming of climate related risk are likely to be helpful or harmful to AgTech investment in LMICs. Climate-related disclosure requirements have been recommended by a growing number of bodies and are being adopted legally in Europe and other jurisdictions, requiring greater transparency around organizational financial exposure to climate risk. The aim is to address the significant climate blind spots in corporate adaptation strategies, which underestimate the scale of climate impacts, the costs of mitigation and adaptation, as well as the increasing speed at which these costs will manifest.[187] While these may seem like far-off debates for those operating in LMICs, 65% of those interviewed see disclosure requirements and mainstreaming of climate risk into investment decisions driving capital towards their sectors and drawing greater awareness to low-carbon solutions that serve the most vulnerable.

This perspective holds that the financial sector will reward climate resilient models with preferential financing conditions. For instance, when fragrance manufacturer Givaudan considered the long-term climate impacts on the materials they relied on, they invested in more sustainable agriculture practices.[188] Others see these measures drawing investment away from the regions most vulnerable to climate change impacts, highlighting high climate risk and making them less attractive to investors.[189] The concern is that mainstreaming climate risk will make investments into climate vulnerable sectors and regions unattractive and, perversely, lead to less investment.

Recommendation 10: Build-out a diverse infrastructure of financial intermediaries to more quickly move large pools of climate capital to small enterprises, and activate frontier markets and sectors.

Over the near- and medium-term, top-line climate finance flows to agriculture sectors in LMICs are likely to grow. Governments and donors increasing their climate commitments, MDBs and DFIs prioritizing climate—especially adaptation—in their portfolios, corporate sustainability efforts and Net-Zero implementation could all be powerful drivers for delivering badly needed capital to the sector. However, the infrastructure has not been adequately developed to deliver large pools of climate capital into smaller denominations and workable instruments that can be absorbed by AgTech enterprises. Very few investment funds are targeting SMEs along these value chains. Over 85% of investors and SMEs interviewed identified the need for additional intermediaries to provide the step-down function of evaluating enterprises and delivering finance efficiently.

More innovative intermediaries are also needed to test sector strategies, activate new geographic markets, demonstrate funding models, and scale the most effective approaches. This is especially critical for low-carbon AgTech, where climate vulnerability and the need for adaptation responses may vary radically by geography. Decentralizing investment decision-making to local fund managers is the best way to leverage local expertise, align climate-related investment objectives with SME business models, and mobilize private sector co-financing.

The accreditation process to become an approved intermediary to administer different MCF funds is widely perceived as too lengthy, expensive, and cumbersome for many private sector entities, which has led to a very limited pool of private sector intermediaries accessing MCFs directly.[190]

187 Goldstein, Allie, Will R. Turner, Jillian Gladstone, and David G. Hole. "The Private Sector's Climate Change Risk and Adaptation Blind Spots." Nature Climate Change 9, no. 1 (January 2019): 18–25. https://doi.org/10.1038/s41558-018-0340-5.

188 Goldstein et al, "The Private Sector's Climate Change Risk."

189 United Nations Environment Programme. "Adaptation Gap Report 2020." UNEP, 2021. https://www.unep.org/resources/adaptation-gap-report-2020.

190 Based on interviews as well as independent evaluations, for example: Independent Evaluation Unit (2021). Independent evaluation of the Green Climate Fund's approach to the private sector. Evaluation Report No. 10, (September). Songdo, South Korea: Independent Evaluation Unit, Green Climate Fund. https://ieu.greenclimate.fund/sites/default/files/document/priv2021-final-report-vol-i.pdf

For example, of GCF's 74 adaptation projects only five specifically fund the private sector. Two of these—the Acumen Resilient Adaptation Fund (ARAF) and Productive Investment Initiative for Adaptation to Climate Change (CAMBio II)—provide loans, equity investments, and/or technical assistance for agriculture SMEs and could be important templates for scaling MCF finance to AgTech enterprises.

ARAF is designed to build the climate resilience of smallholder farmers by investing in early- and growth-stage agribusinesses. Initiated in 2019, the fund operates in four countries (Uganda, Nigeria, Ghana, and Kenya) with invests directly in low-carbon AgTech value chains. The aim of the fund, in part, is to shift investments in adaptation from grants to longer-term equity and debt capital, which can be a more sustainable use of investment resources.[191] ARAF is one of three GCF accredited funds that Acumen manages—along with the Energy Access Relief Fund and the KawiSafi Ventures—highlighting efficiency gains that can come once an intermediary is accredited. Another similar intermediary fund is Southpole's Landscape Resilience Fund, which was co-developed with WWF and is funded by GEF, along with a commitment from Chanel. The fund aims to mobilize $100 million by 2025 for climate adaptation projects, with a focus on forestry and agriculture, through blending public, philanthropic, and private funding.

Increasing the number of certified investment funds eligible to administer institutional capital is needed, especially within certain sectors and regions. While some markets like Kenya and India may have a critical mass of seasoned fund managers networked into agriculture enterprises, most markets in sub-Saharan Africa and South Asia do not. Building that local capacity, especially among women, is necessary to access the private sector in these markets and increase the scalability of SMEs across new geographies. This will likely require policy changes and experimentation from climate finance institutions, including consideration of diversity, development of first-time fund managers, increased risk tolerance for funds operating in particularly challenging markets or unproven value chains.

Increasing the number of certified investment funds will have to balance the need for proper oversight and targeting of donor funds while addressing the criticisms leveled at the intermediary certification process, namely that it is too expensive and time consuming.

Recommendation 11: Encourage inclusion of SMEs in the development of country-level adaptation planning and connectivity to Nationally Determined Contributions.

As implementing agencies of the UNFCCC, MCFs are positioned to deliver funding for country-led initiatives that support adaptation and mitigation efforts in line with a country's NDCs. However, adaptation plans rarely include activities or policies that support SMEs doing the work of adaptation on the ground. None of the SMEs interviewed were engaged in the adaptation planning process or aware of the content of country plans where they operate. In most cases, there is little or no official role for SMEs to engage in the development of these plans.

LMIC governments should promote alignment between national climate strategies and opportunities for SME involvement, including defining the types of private sector projects that will be supported through country-driven MCF financing. SMEs should be included in multi-sectoral planning related to financing and implementation of NDCs, national adaptation plans, and other climate policies. Support should be made available to ensure broad engagement in national adaptation plans and consideration of SME-delivered interventions, as appropriate. These recommendations are consistent with those of the GCF's Independent Evaluation Unit, which has also identified the lack of private sector engagement in national climate policies to be an impediment to GCF investment in private sector-led adaptation initiatives.[192]

Targeted roles for SMEs in adaptation plans could also help increase the viability for attracting private investment to these initiatives. Globally, only about $500 million—just 1.6%--of adaptation finance is coming from private sources.[193] Integrating private sector-led adaptation approaches into national climate plans and policies will help shift MCF, MDB, and DFI financing to the types of products that de-risk and facilitate private investment—be it through blended finance, credit enhancement, currency coverage, demonstration projects, or other measures.

191 ARAF. "Portfolio—ARAF." Accessed October 15, 2021. https://arafund.com/portfolio/. ; Green Climate Fund. "FP078: Acumen Resilient Agriculture Fund (ARAF)." Text. Green Climate Fund, March 1, 2018. https://www.greenclimate.fund/project/fp078.

192 Independent Evaluation Unit (2021). Independent evaluation of the Green Climate Fund's approach to the private sector. Evaluation Report No. 10, (September). Songdo, South Korea: Independent Evaluation Unit, Green Climate Fund. https://ieu.greenclimate.fund/sites/default/files/document/priv2021-final-report-vol-i.pdf

193 World Bank Group. "Enabling Private Investment in Climate Adaptation & Resilience: Current Status, Barriers to Investment and Blueprint for Action." 2021. https://www.worldbank.org/en/news/feature/2021/03/04/unlocking-private-investment-in-climate-adaptation-and-resilience

Recommendation 12: Complementary policy and financing must focus on ensuring farmers and rural businesses have access to critical inputs and markets so that AgTech deployment will maximize productivity gains.

Across the value chains examined, AgTech SME sales generally cluster around geographic areas where there is a critical threshold of other key sector participants, markets, infrastructure, information, and inputs to maximize farm yield (seed, fertilizer, and agro-chemicals). Further, AgTech frequently does not make economic sense unless purchased by a group of small holders, a cooperative, or a business that can drive higher utilization rates for the equipment. Improving market ecosystems in agriculture communities will ensure AgTech SMEs have fertile markets to expand into—and that their interventions deliver greater economic and environmental benefits.

A range of market building efforts and agriculture extension services can help assemble this infrastructure of inputs and critical mass of participation. The Agriculture Transformation Agency in Ethiopia (ATA) is an example of an institution providing key services meant to ripen the broader agriculture ecosystem, including increasing investment in rural infrastructure; coordinating geographic clusters of smallholders to strengthen value-chains, optimize cropping, connect commodities to markets, and scale-up best practices; and promoting the adoption of improved technologies by smallholder farmers.[194] Working with the Ethiopian Ministry of Water, Irrigation, and Energy under the new Distributed Renewable Energy Agriculture Modalities (DREAM) program, ATA is demonstrating the case for distributed solar resources to power rural irrigation, cold storage, and processing, and helping to mobilize large-scale financing for scale-up.[195]

Conversely, this implies a particular need to address challenges existing in especially remote and poor locations. The regions where markets and inputs are not aggregated, where commercial AgTech does not represent a near-term solution, and where climate impacts may be disproportionately felt demand attention and public investment of a different variety, likely supported by a rationale based around redistribution.

Recommendation 13: Low-carbon AgTech should be competing on a level playing field, with emissions-heavy investment bearing the costs of damages it imposes.

While advanced economies dominate the estimated $1–5 trillion in global fossil fuel subsidies, as a share of GDP fossil fuel subsidies are higher in all developing country groups than among advanced economies.[196] Organizations interviewed made clear that rural farmers and business customers are highly attuned to AgTech costs vis-a-vis incumbent diesel-powered options and purchase decisions are made on the margin. Climate mitigation and air quality benefits of cleaner technologies are not considerations of these buyers. In many markets where fossil fuels are artificially cheap—especially diesel—leveling the playing field in the form of either reduced fossil subsidies, or tax exemptions or subsidies that lower the cost of AgTech to consumers may be needed to allow low-carbon AgTech to compete.[197]

194 Agricultural Transformation Agency website. Accessed November 23, 2021. https://www.ata.gov.et/.
195 Tafesse, Yifru. AGRF 2021 Summit presentation. September 6, 2021. https://www.youtube.com/watch?v=hi899zplxoE
196 Vivid Economics, "Transformative Climate Finance."
197 World Bank Group, "Tranformative Climate Finance: A new approach."

CONCLUSION

In summary, low-carbon AgTech value chains represent a win-win for improving both climate adaptation and mitigation outcomes in sub-Saharan African and South Asian markets facing some of the most severe consequences of climate change. The rural agriculture-dependent populations served through these value chains are among the poorest in the world and least equipped to deal with deteriorating land productivity and increasingly hostile weather events. Even so, small enterprises that are well-positioned to meet their needs and provide critical benefits to support adaptation and resilience are failing to attract the growing flows of climate finance and are instead hitting the same obstacles to scale that other SMEs in these regions encounter. The climate contributions of these enterprises are generally not being monetized in a way that generates cash flows or that attracts growth capital from climate investors.

The report provides deeper analysis into the specific challenges facing these enterprises and offers 13 recommendations to specific ecosystem actors, focused on improving financing tools, impact measurement, and enabling environment factors. Taken together, these recommendations aim to help clarify the climate contributions the AgTech sector provides, integrate these enterprises into country-level climate and development strategies, and provide a high-level roadmap for leveraging the sector's positive climate impacts to bolster its investment case in the coming years.

We invite investors, SMEs, policymakers, research partners, and donors to engage with the findings, provide feedback, and identify new approaches for mobilizing climate finance to improve people's lives and livelihoods and transform rural economies through low-carbon, resilient development.

Appendix A: Detailed Assumptions to Calculate Carbon Emission Reductions for Solar Irrigation

This appendix provides additional assumptions and details of calculations for carbon emission reductions associated with AgTech investments in solar-powered irrigation. Detailed calculations for the other two value chains are provided in Section 3.2.2 (Carbon mitigation potential for processing) and 3.2.3 (Carbon mitigation potential for cold storage).

Solar-powered irrigation in Kenya

The estimated investment to deploy 1.3 million solar water pumps in Kenya includes the capital required for SMEs to purchase solar pumps, as well as costs for related activities such as increasing farmers' access to water sources (e.g., by digging wells or building dams). A market landscape analysis of irrigation providers and buyers in Kenya by Mercy Corps concluded that the addressable market for solar water pumps comprised 1.3 million new pumps.[198] This analysis also determined that a combination of four interventions—targeted subsidies for smallholder farmers to purchase solar pumps, an awareness campaign to convey the benefits of solar irrigation, financial support to increase access to water sources, and extending risk-sharing to enable better financing options for customers—would support addressing the entire market. The package of interventions analyzed would cost $119 million; providing the necessary capital for SMEs to purchase solar pumps would represent an additional $87 million, for a total of $206 million.

In the absence of solar water pumps, we assumed that diesel water pumps would be used instead, and thus calculated GHG emissions based on avoided use of diesel fuel. The amount of diesel used by one irrigation pump is highly variable. It depends on factors such as the specific crop or crops being grown, duration of the growing season, rainfall patterns, duration of water stress or periodicity of watering cycles, and the distance that water must be pumped (either depth to groundwater or distance from surface water to crop field). We identified a wide range of estimates for average diesel fuel per pump per year—ranging from 600 liters to 9,000 liters—and used an average value of 2,000 liters per pump.[199] Using a standard factor of 2.6 kg of CO2 emissions per liter of diesel[200] leads to the conclusion that displacing 1.3 million diesel pumps would save 2.6 billion liters of diesel per year, and CO2 savings would amount to 6.8 million tons per year.

Solar-powered irrigation in India

India has about 21 million grid-connected irrigation pumps, 8.8 million diesel-powered pumps, and 130,000 solar irrigation pumps.[201] Prior field studies note that the upfront capital cost of solar pumps is the most significant barrier to their adoption; one study found that the upfront cost for a solar pump is on the order of ten times the cost for a diesel pump, and that capital cost subsidies of at least 30% would be required to encourage widespread adoption.[202] In addition, SMEs would also require working capital to deploy solar pumps on a wide scale.

We assumed that displacement of existing diesel-powered pumps would require capital investments to pay the upfront costs of solar pumps, and to provide a capital subsidy for farmers, but would not require new development of water sources, since diesel pumps already draw from surface or groundwater. Because of the rapid price declines of solar technology, we estimated the cost for solar pumps based on searching web-based catalogs of agricultural equipment providers in India. We found the average cost for a 3hp solar pump is about $2,250, and assumed that investment would need to cover about two-thirds of the capital cost (partly to provide a capital cost subsidy, and partly to cover upfront costs for AgTech SMEs).[203] This results in an estimated $1,500 of investment needed per pump, or $3.3 billion to displace one-quarter of the 8.8 million diesel pumps present in India today.

The quantity of diesel fuel used per irrigation pump is variable and depends on factors related to crop water requirements, rainfall patterns, and pumping depth or distance. We used an average value of 2,000 liters per pump, which appears to be a nationwide average as reported by IRENA and the India-based Council on Energy, Environment and Water.[204] Based on a standard factor of 2.6 kg of CO2 emissions per liter of diesel,[205] displacing 2.2 million diesel pumps would save 11.4 million tons of CO2 emissions per year.

198 Mercy Corps (2020), "Policy Brief: Achieving Food Security in Kenya Through Smart Solar Irrigation", https://www.mercycorpsagrifin.org/project/policy-brief-achieving-food-security-in-kenya-through-smart-solar-irrigation/.
199 Kiptum, K. 2018. Water and Petrol Use Efficiencies of Cabbages and Kales Under Supplemental Irrigation in Kimumu Farm in Uasin Gishu County, Kenya. University of Eldoret. Also see IRENA (2015). Solar Pumping for Irrigation: Improving Livelihoods and Sustainability. IRENA, Abu Dhabi, United Arab Emirates. For other estimates, see IRENA (2016), "Decentralised Solutions in the Agri-Food Chain", https://www.irena.org/-/media/Files/IRENA/Agency/Publication/2016/IRENA_Decentralised_solutions_for_agrifood_chain_2016.pdf.
200 IRENA (2016), "Decentralised Solutions in the Agri-Food Chain".
201 CEEW, 2018, "Solar for Irrigation: A Comparative Assessment of Deployment Strategies", Anne Raymond and Abhishek Jain. https://www.ceew.in/sites/default/files/CEEW-Solar-for-Irrigation-Deployment-Report-17Jan18_0.pdf. Also see IEEFA, 2018, "India: Vast Potential in Solar-Powered Irrigation", Vibhuti Garg, https://ieefa.org/wp-content/uploads/2018/08/Indias-Vast-Potential-in-Solar-Powered-Irrigation-.pdf.
202 CEEW (2018), "Solar for Irrigation: A Comparative Assessment of Deployment Strategies".
203 CEEW (2018), "Solar for Irrigation: A Comparative Assessment of Deployment Strategies".
204 IRENA (2016), "Solar pumping for irrigation: Improving livelihoods and sustainability", https://www.irena.org/-/media/Files/IRENA/Agency/Publication/2016/IRENA_Solar_Pumping_for_Irrigation_2016.pdf.
205 IRENA (2016), "Decentralised Solutions in the Agri-Food Chain".