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Mobilising Private Investment for Adaptation to Climate Change in India

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Executive summary

This Working Paper explores the scale and nature of commercial opportunities from adaptation to climate change, while stressing that adaptation to climate change is also a public good. It is one of the first efforts in India to sample some enterprises in the real economy that produce adaptation goods and non-financial services, such as flood forecasting and drought resistant seeds. The aim is to understand the diversity, size, and potential of these markets and to discuss the regulatory and policy, financial and other types of barriers that these enterprises face.

The paper is intended to support policymakers, practitioners, and development funders to understand what is meant by private sector investment in adaptation, and how it could be mobilised. It uses information obtained from literature, but also from market data, as well as research and information provided by market players in confidential interviews. The paper uses this analysis to make some recommendations targeted at the Government of India, development finance institutes, and other interested stakeholders. This includes designing new innovative financing instruments to de-risk investments, advancing how adaptation is defined in green taxonomies, and encouraging national policy reform to break down barriers to private investment in adaptation.

The paper is organised across the following sections.

Section 1 presents the available macro-level data and analysis from literature on the overall adaptation financing gap in India and the contribution of the private sector. This highlights the lack of a common definition for adaptation financing in India and the need for a taxonomy that will support the tracking of private investment.

Section 2 summarises a rapid review of 77 adaptation solutions that were identified from the literature as being viable for increased private investment in India. It also presents a broad analysis on the key barriers facing these solutions. It then gives a more in-depth analysis of seven specific investment opportunities in adaptation solutions (Section 2.2). This is based on a detailed review of market analysis and research, as well as consultations with market players. Annex A presents the details that have informed the estimates on market size and immediate investment opportunities.

Section 3 reflects on the findings of the review of the sample solutions to consider the opportunities to mobilise increased private investment. It considers global experience in investment funds and instruments that specifically target adaptation, as well as learning from the Action on Climate Today (ACT) programme in India that provided technical assistance to support both public and private funding in adaptation.

Section 4 concludes, summarising some of the recommendations that emerged from this review.

There has been much less global work on private investment in adaptation compared to mitigation, although over the last year this has begun to change. The authors hope this paper will contribute to this discussion and expand the debate on the role of private investment in adaptation in India. Please do contact them with feedback and comments at elizabeth.gogoi@opml.co.uk.

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List of abbreviations

ACT	Action on Climate Today
CaaS	Cooling as a Service
CAGR	Compound Annual Growth Rate
CIF	Climate Investment Funds
CPI	Climate Policy Initiative
CRAFT	Climate Resilience and Adaptation Finance and Technology Transfer Facility
DEFRA	Department for Environment, Food and Rural Affairs
DSS	Dust Suppression System
EPC	Engineering, Procurement, and Construction
FPC	Farmer Producer Company
FPO	Farmer Producer Organisation
GCA	Global Commission on Adaptation
GCF	Green Climate Fund
GGEF	Green Growth Equity Fund
GPP	Green Ports Policy
IPCC	Intergovernmental Panel on Climate Change
IRR	Internal Rate of Return
MLD	Million Litres per Day
MT	Megatonne
PPP	Public–Private Partnership
RHS	Rainwater Harvesting Systems
SME	Small and Medium-Sized Enterprises
STP	Sewage Treatment Plant
WWTP	Waste Water Treatment Plant

1 The adaptation financing gap in India

This section outlines the requirement for increased private sector financing of adaptation in India and brings up the global challenge of defining adaptation investment and tracking such financing.

1.1 Defining adaptation investment

India is one of the most vulnerable countries in the world to climate change. An estimated 800 million people are currently experiencing significant increases in temperature, and more than 80% of India's population lives in districts highly vulnerable to extreme hydro-met disasters (Garg *et al*., 2015; Mohanty and Wadhawan, 2021). Future climate impacts will be profound, given that 650 million Indians are dependent on rain-fed agriculture for their livelihoods, 250 million live along 7,500 km of coastline with waters that are rising, many of the 10,000-odd Indian glaciers are rapidly receding, and deforestation is happening at an alarming rate (Garg *et al*., 2015; Mohanty and Wadhawan, 2021).

India therefore urgently needs to adapt to the current and future impacts of climate change. In India's updated Nationally Determined Contribution in August 2022, the Government of India recommitted to '*better adapt to climate change by enhancing investments in development programmes in sectors vulnerable to climate change, particularly agriculture, water resources, Himalayan region, coastal regions, health and disaster management*'.

Adaptation can take many forms, and adaptation 'solutions' are not a well-defined set of activities. The Intergovernmental Panel on Climate Change (IPCC) defines adaptation as '*Adjustment[s] in natural or human systems in response to actual or expected climate stimuli or their effects, which moderates harm or exploits beneficial opportunities*', and a financial activity can be classified as adaptation if it helps adjust *'to actual or expected climate and its effects'* (IPPC, 2022) These definitions are very broad, leaving much room for debate.

To unpack the definition of private investment in adaptation, it is useful to distinguish between three key characteristics:

1. protection against avoided losses in the future (the adaptation 'benefit');
2. an offer a profitable revenue stream (this is what make them attractive to private sector operators); and
3. bringing public good benefit (they help reduce climate risks to the public or wider economy).

Some adaptation investments meet the first two criteria, but not the third. These investments are designed purely to protect the operations of the company in question ('adapted activities' according to a green taxonomy: see Box 1). This is important, but the government's role is likely to be limited to raising awareness of the private sector on the necessity of making these investments.

This paper focuses on investments that meet all three criteria and bring significant benefits to the public or wider economy. The Global Commission on Adaptation (GCA) describes this as a 'triple dividend' of avoided losses, economic benefits, and social and environmental benefits (GCA, 2019):

> *'The public sector needs to shift its focus to include both generating finance and creating incentives to scale up private sector engagement in adaptation investments'* (GCA, 2019).

Adaptation investments can be categorised as *defensive solutions* (protecting existing operations or infrastructure); *innovative solutions* (new methods, practices, or technologies that can spawn new social or value chain relationships); and *transformative solutions* (changing the nature of the company or sector, disrupting business as usual, or finding new applications for existing tools or practices) (NDF and IDB, 2020).

These investments will support adaptation solutions across sectors, ranging from traditional infrastructure projects (e.g. schools, roads, bridges) that need to be made resilient to climate change to standalone adaptation projects, such as protecting the coast from erosion due to sea rise. Thus, it is difficult to 'label' or 'itemise' an activity as purely adaptation.

Box 1: Definition of adaptation within green taxonomies

Around 30 countries and regions around the world have developed or are designing a taxonomy for sustainable or 'green' investment. These define what activity can be classified as sustainable for that location. It helps investors identify opportunities that provide assured sustainability benefits, and helps avoid 'greenwashing' where a project is misrepresented as 'green' without delivering the expected sustainability benefits. It also provides a consistent framework for tracking green investment in a particular country or region.

A taskforce has been established by the Ministry of Finance of the Government of India to develop a sustainable investment taxonomy, but at the time of drafting this Working Paper the scope and detail of any definition for adaptation investment under this taxonomy was not available.

The EU Taxonomy for Sustainable Activities is one of the most comprehensive classification systems. It does not provide a specific list of adaptation solutions that can be categorised as 'sustainable', as it does for mitigation solutions, such as renewable energy and energy efficient boilers. This is due to the location- and context-specific nature of climate adaptation. For example, flood-resistant road construction will only provide adaptation benefits in areas at risk of flooding.

Instead, it sets out criteria that must be met for an activity to be classified as making a 'significant contribution to adaptation'. There are two types of adaptation activity.

- Adapted activities: These directly reduce the effect of climate change on an economic activity itself—for example, a water utility purchasing and installing early warning systems to reduce the risk of flooding in its facilities. For these activities, capital/operating expenditure linked to implementing the adaptation is covered, e.g. the cost to the utility for purchasing and installing the early warning system.
- Adaptation enabling activities: These include activities that facilitate adaptation, meaning activities that reduce the effect of climate change on other people, nature, or assets—for example, a company developing and installing early warning systems for flooding. For these activities, equity or debt financing of the turnover and expenditure in providing these activities is covered, e.g. the turnover of the company is linked to developing the early warning system.

For both types of activity, certain qualitative selection criteria need to be met, including 'Do No Significant Harm Criteria' such as avoiding pollution and environmental and ecosystem damage.

There have been other useful initiatives to develop classification systems and tools specifically for adaptation solutions, including the Adaptation SME Accelerator Program (ASAP) Adaptation Solutions Taxonomy, which builds on the EU taxonomy with a categorisation of adaptation solutions typically offered by small and medium-sized enterprises (SME) (Trabacchi *et al*., 2020).

1.2 The scale of the financing challenge for adaptation

Finance for adaptation (both public and private) is not flowing at a pace commensurate with the impacts of climate change already being felt in India and across the globe. At the global level, adaptation finance increased 53% between 2017 and 2020, reaching US$46 billion, but this still falls short of the estimated costs of adaptation (Climate Policy Initiative (CPI), 2021). International adaptation finance flows to low- and middle-income countries are 10–18 times below estimated requirements, and the gap is widening. Estimated annual adaptation requirements are US$215 billion to US$387 billion for this decade, at least 50% higher than previously estimated (UNEP, 2023).

In India, in 2020, the government estimated that US$4 trillion would be needed for the required adaptation investments (DEA, 2020). For infrastructure alone, an estimated US$178 billion would be required to build resilience to climate impacts (Garg *et al.*, 2015). There is no comprehensive tracking of either public or private adaptation finance in India, but in 2019–20, CPI estimated that financing on three adaptation solutions (disaster monitoring and emergency response; flood mitigation; and drought management) reached US$5 billion, of which 94% came from central and state government budgets (CPI, 2021).

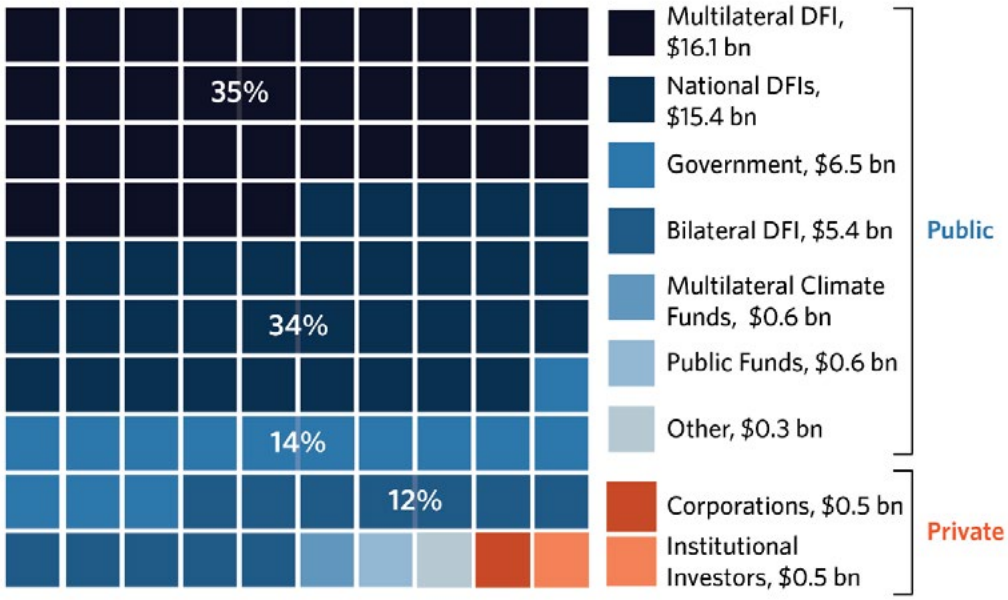
There are significant methodological challenges to tracking private sector financing of adaptation (Richmond *et al.*, 2020). Investment in adaptation or resilience solutions tend to be part of much wider development investment, and it is difficult to disaggregate the two. For example, a building contractor may install a rainwater harvesting system (RHS) within a new house, but the cost of this will be incorporated within the total cost of the build.

The private sector is also not homogeneous and is composed of millions of potential investors. The investment made by any individual private sector entity, including farmers and small and micro enterprises, to ensure their own businesses are resilient—for example, by purchasing more water efficient irrigation technology—is, in principle, private investment in adaptation, but is unlikely to be captured by standard data collection methods.

Therefore, the data and analysis available on private sector investment in adaptation should be treated with caution.

- At the global level, of the US$46 billion in adaptation finance identified in 2019/20, only 2% was sourced to the private sector (Figure 1) (CPI, 2021).
- In India, while there are ongoing efforts to estimate private sector financing flows for low-carbon technology and mitigation solutions (US$22 billion by domestic private sector actors and US$1.2 billion of foreign direct investment in 2020), little is known about private financing flows into adaptation solutions (CPI, 2021).
- One study (Singh *et al.*, 2021) has estimated that less than 0.1% of the finance mobilised for adaptation in India comes from the private sector, while in contrast 53% of mitigation financing comes from the private sector.

Figure 1: Sources of global adaptation finance



Source: CPI (2021)

Despite this serious evidence gap, we can be confident that private investments in adaptation lag far behind those in mitigation. Therefore, there is still a clear economic and development case for India to focus on mobilising private investment in adaptation. The adaptation financing gap cannot be filled by the public sector alone, and private sector investment can result not just in company profits, but also in wider societal benefits. For example, in low- and middle-income countries, the extra cost of building resilience into infrastructure is expected to cost only ~3% of overall investment needs, and every US$1 invested in resilient infrastructure in low- and middle-income countries yields US$4 in net benefits (Hallegatte, 2019). Making infrastructure more resilient avoids costly repairs, but also minimises the economic damage and social consequences of natural disasters.

2 The untapped opportunity for private investment in adaptation in India

This section presents the findings of a macro-level market scan of the scale and size of investment opportunities in adaptation solutions in India, including the barriers that exist to mobilising this finance.

2.1 The market size for adaptation solutions in India

There are three different ways for private investment in adaptation to flow.

1. **Provision of finance for adaptation solutions:** This includes commercial banks, microfinance institutions, and institutional investors offering financial products for others to implement or enable adaptation solutions.
2. **Provision of adaptation solutions:** This involves enterprises in the real economy that produce adaptation goods and non-financial services, such as flood forecasting, drought resistant seeds, etc. Such activities are categorised as 'adaptation enabling activities' under the EU sustainable financing taxonomy (Box 1).
3. **Adapting companies' own operations to be more resilient:** This involves implementing adaptation solutions to make their own operations and supply chains more resilient and to avoid disruptions and loss of profits from climate risks, such as building flood protection around a factory. Such activities are categorised as 'adapted activities' under the EU sustainable financing taxonomy (Box 1).

This section focuses on the second vehicle for private investment in adaptation, as well as on opportunities to increase the volume and scale of private companies offering adaptation solutions that will in turn build the resilience of other companies and the wider society. There is a long list of adaptation solutions that could be offered by the private sector in nearly every segment of the economy, and which includes a range of investment types. See box below for an example.

Box 2: An example of an adaptation investment opportunity: Geosynthesis

Geosynthesis is a durable biodegradable material that stabilises structures to prevent coastal and soil erosion. An example is membranes or grids used to reduce the movement of ballast carrying rail tracks. It has wide potential application across a range of sectors, including railways, oil and gas infrastructure, agriculture, etc. The manufacture and use of geosynthesis is at nascent stage in India, but is reportedly poised for rapid growth.[1] Fifty percent of the total geographic area of India is at high risk of erosion (although 91% is at potential risk) (Sharda *et al*., 2013). There is huge potential for the use of geosynthesis to build the resilience of the US$1.3 trillion worth of infrastructure included in the National Infrastructure Pipeline. The World Bank has made geosynthesis mandatory for all their infrastructure funded projects, and the Indian Railways is piloting its use.

However, there are a number of barriers to realising the investment opportunity from geosynthesis. In particular, it is a higher-cost material and therefore relies on the consumer recognising and valuing the resilience benefits it provides. There is also reportedly some concern about the durability and damage caused by degradation of the material. It has received some policy attention (e.g. the National Technical Textiles Mission includes an objective to promote its use), but this

[1] This is based on market research, such as: https://indianinfrastructure.com/2021/02/18/upward-trend/.

needs to be enhanced. Indian standards would also help regulate the increasing number of domestic manufacturing units.

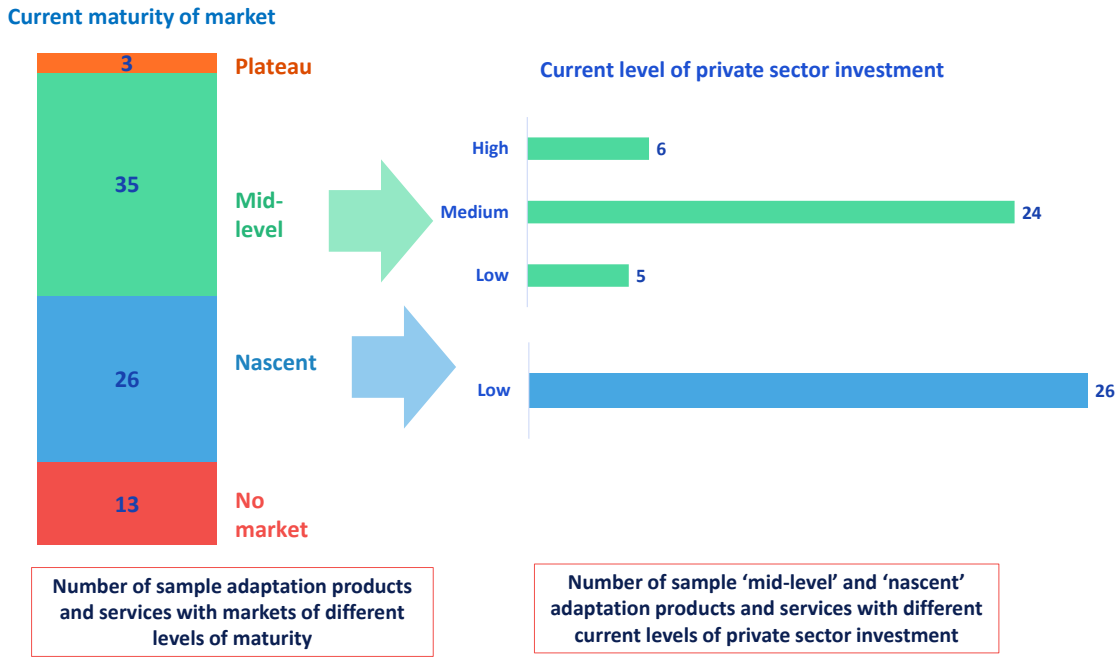
From a rapid review of literature and market research, a sample of 77 adaptation goods and services were identified as having potential for increased private investment (Table 1). Of these, over 40% are infrastructure opportunities, 27% are manufacturing opportunities, 24% are for services, and 6% involve the provision of resources. However, many cut across multiple investment categories—for example, for permeable pavements there is both a manufacturing opportunity (of the technology) and an infrastructure opportunity (in the construction of the pavements).

Table 1: Adaptation products and services that are viable for private investment

Segment	Adaptation products and services viable for private investment
Infrastructure	All-weather road technology; motor graders for blading of gravel roads; floating dry docks; raised/new embankments; port dredging; sustainable breakwaters; raising docks; river information services; geosynthesis on railway slopes; corrosion resistant railway stock; wind fences on railway track; pervious concrete; sediment monitoring for hydropower; air cooled condensers for thermal power; stainless steel electricity distribution infra; aerial bundled conductors; underground cabling; geosynthesis for coastal erosion; drainage for oil and gas facilities; preventative maintenance of oil/gas pipeline; low-power wireless telecommunications network; back-up power at cell towers; underground telecommunications cables; reflective surfaces; green rooftops; green buildings
Agriculture	Rapid soil testing devices; soil testing labs; urea deep placement technique; green seeker; micro irrigation; reinforced HDPE geomembrane lining for farm pond; laser land leveller; climate resilient crops; systematic rice intensification; hydroponics; automated data collection and sensors; cold storage; drones for precision farming
Water and sanitation	Desalination plants; rainwater harvesting for infiltration; solar RO water purification; managed aquifer recharge system; sustainable water purification; smart water meters; water recycling and reuse; solar water pump; rainwater harvesting for storage; sand dams; flood-proof wells; perforated dams; silt management; flood resilient latrines; resizing urban storm water drains
Disaster management	Household weather insurance; weather-based crop insurance; social protection from extreme weather for low-income groups; cyclone shelters; slope stabilisation; artificial reef construction; groynes; individual flood protection barriers; closure dams; dykes; island raising; seawalls
Nature-based solutions	Urban forests; mangrove restoration; forest conservation; beach nourishment; seagrass beds restoration; biosales; sand dune stabilisation
Climate services	Aerial LIDAR remote sensing; weather forecasting; meteorological equipment; real-time flood monitoring

This sample indicates that there is a strong business rationale for investing in adaptation goods and services. Demand for such solutions is already high and will almost certainly increase further. However, there is very limited information available on the exact market size and growth potential across these adaptation solutions. A rapid assessment of the level of maturity of the markets for the 77 sample adaptation solutions is shown in Figure 2. An estimated 80% of the markets are considered nascent or mid-level (meaning high growth is expected), and current private investment in these adaptation solutions markets is mostly low or medium.

Figure 2: Rating of level of maturity, and current level of private investment of sample adaptation markets



2.2 Market assessment of seven adaptation investment opportunities

This section presents the findings from a deep dive assessment of a set of adaptation solutions, which provides a more nuanced understanding of the scale and diversity of the actual investment opportunities.

Following a review of the adaptation solutions and after collecting relevant data and information from existing market analysis and expert interviews, seven specific investment opportunities were identified (two different investment options were explored for solar water treatment solutions). The adaptation solutions (of which many also provide significant mitigation benefits) were selected to provide insight on a range of nascent and mid-level adaptation markets and across sectors and investment categories.

The investment opportunities are briefly described below, with further detail (including references and market size calculations) being provided in Annex A. They are summarised in

Table 2. The next section explores opportunities to mobilise finance for these adaptation solutions.

Construction of solar-powered utility-scale desalination and waste water treatment plants (WWTPs): Utility-scale desalination and WWTPs is a mid-level mature market in India, but the use of solar power at treatment plants is still at the pilot stage. For example, in Tamil Nadu, a desalination plant was established by IIT Madras and the Ministry of Earth Sciences costing US$175,000 and with a capacity of 10,000 litres per day.

The desalination and WWTP market is expected to grow significantly, given the huge need for water efficiency. Assuming that around one-third of the expected investment opportunities will be solar-powered, the market size by 2026 is estimated at US$500 million for solar-powered desalination and US$1.55 billion for solar-powered WWTP. The approximate ticket size of a utility-scale project is US$130 million, with return expectations of 9–11%. There are currently only a few domestic market players in solar water treatment plants, but many infrastructure companies are engaged in the water sector in general and could enter the solar-powered segment.

Manufacture of decentralised solar-enabled desalination and WWTPs: Decentralised solar-enabled desalination and WWTP is less energy intensive and more sustainable than utility-scale systems. However, the technology has not yet been demonstrated in India beyond small-scale pilots. The market for this technology is expected to be industrial clusters, governments in rural/remote areas, large residential welfare associations, etc.

By 2026 there were approximately just eight commercially viable installations will be feasible for both solar-enabled desalination and WWTP, valued between US$2 million and US$4 million. Each unit is assumed to cost US$262,000 based on pilots done for a throughput of 10,000 litres per day. In the future, if each technology provides 1% of the freshwater demand projected for 2030, the total market size will be US$7–8 billion. The manufacturing opportunity will involve seed funding for the further development and demonstration of the new technology. Currently only a couple of companies produce small-scale desalination plants.

Installation of green technology at ports: ‘Green ports’ use a number of viable technologies to reduce energy use and emissions, increase water and resource efficiency, and reduce the environmental effect of the port. The Government of India is promoting this technology through the national Green Ports Policy (GPP), which requires 100% of consumed water to be reused/recycled by 2030. There is a clear revenue stream from the installation of the technology by developers or through engineering, procurement, and construction (EPC) contracts, with various cost recovery mechanisms possible such as adjustments to the revenue share with the port operator.

The immediate market size for each individual green port technology varies significantly. For example, one technology that delivers clear adaptation benefits is on-port STPs and WWTPs, with an estimated market size in 2026 of US$67 million. If a range of other mitigation and adaptation technologies are also considered, including installing renewable energy plants, battery storage, electrification of cranes, and other processes, the estimated market size could reach US$273 million in 2026.

Few of India’s current 13 major ports and 205 non-major ports have the green technology installed, and there is therefore an immediate market to service. The individual ticket size for each green port technology varies, but the technologies can also be packaged together. For example, the average cost of installing a sewage treatment plant (STP) is US$3.4 million

(major port)/US$181,800 (non-major port) and a dust suppression system (DSS) is US$1.4 million (major port)/ US$54,000 (non-major port). The return expectations also differ but is approximately 14–16% for STPs and DSS, and a range of companies are ready to install this technology.

Manufacturing and installation of RHS: RHS technology ranges from simple low-cost to large-scale, and can be installed in residential homes (which is 55% of the market), large buildings, and infrastructure. It collects and stores rainwater for agriculture, domestic, or other uses, and helps protect against water scarcity during drought, manage stormwater, and prevent flooding and soil erosion. The Government of India and various state and city authorities have been promoting RHS as part of wider efforts to encourage 'smart cities' and 'green buildings'.

There is a clear revenue stream based on the market demand for the manufacture, installation, and maintenance of RHS. The residential segment has seen a compound annual growth rate (CAGR) of around 7% in recent years, and is estimated to reach US$0.8–1 billion by 2026. Only 8% of rainwater is currently being harvested, and only 18% of rural households have a tap connection. RHS technology ranges considerably in cost, depending on size and site location. Model projects marketed by Central Ground Water Authorities and private manufacturers for residential complexes range between US$850–9,600.

The market is currently dominated by small, local turnkey providers who produce and install RHS within a locality. The current market for the residential segment is very fragmented and there is the possibility of consolidating with large-scale manufacturing of off-the-shelf solutions.

Service providers for a variety of climate and weather data, analytics, and tools: Climate services is a broad term covering a wide variety of applications, users, and markets, such as weather forecasts, climate analytics, risk modelling, and remote sensing. Private and public sector customers use this weather and climate data and analysis to make decisions that carefully consider the immediate and longer-term risks of climate change. One specific example of commercial climate services are the private providers of weather forecasting. They provide tailored weather information to both public and private clients to supplement what is provided by the government.

The overall market size for climate services is difficult to estimate given its diverse scope. The private weather forecasting service was reportedly valued at US$100 million in 2019, which if it follows global market trends of CAGR of 9.9% is estimated to reach US$160–170 million by 2026. A related market, the private sector geospatial market, was valued at US$280 million in 2020.

The long-term market is expected to grow considerably as public and private clients want specific analysis and information on the climate risks they are facing, including through the global movement towards climate-related financial disclosures.

This is a nascent market in India today. Only three companies are providing private weather forecasting services, with an annual revenue range of US$680,000–5.3 million. These have received funding in the range of Series A funding of around US$1.78 million to Series C funding of US$6.27 million.

Manufacture of decentralised solar-powered cold storage systems and/or solar Cooling as a Service (CaaS) providers: Decentralised solar-powered cold storage is a

nascent technology in India, with an estimated 3,000 units (of 5–100 megatonne (MT) capacity each) installed. The units are off-grid with a thermal (ice) battery, but can connect to the grid for back-up power. Manufacturers are currently targeting farmer producer organisations (FPOs), traders, and collectives rather than individual farmers. There are also pilots underway offering CaaS that rent or lease space within the system to individual small-scale farmers.

Cold storage in India is a high-growth market, and there is an opportunity for solar-powered systems to fill the US$20 billion opportunity across all chilling segments. India produces more than 400 million MT of perishables (horticulture produce, dairy, meat, fish, etc.) every year, and there is an estimated total cold storage capacity (solar/non-solar) in India of just 32 million MT. The decentralised cold storage market in general was valued at US$9 million in 2022, and is projected to be US$13 million in 2026, of which 33% is estimated to be solar-powered (US$4.3 million).

There are only three known companies producing solar-panelled cold storage, including a start-up, Inficold, with an annual revenue of US$480,000, and a larger company, Ecozen, with an annual revenue of US$9.11 million. They have seen average investments of between US$0.73 million (Series A) and US$7.5 million (Series B). There is only one known CaaS provider, which reports an equity internal rate of return (IRR) of 31–43% for a 15MT system. The big 'farm to fork' corporates are not currently offering cold storage at the farm gate.

Establishment and operation of large-scale solar-powered hydroponics farms: Hydroponics is a method of growing crops in a controlled environment, without soil, in a nutrition-rich water solution. This uses up to 90% less water than traditional agriculture practices and is therefore more resilient to temperature and rainfall changes. It requires less land and can be used in urban settings. Hydroponics can provide health benefits by not requiring as much pesticide use compared to traditional agricultural practices.

The hydroponics market is nascent in India: in 2019, the market size was estimated to be 3,100MT and valued at US$4.5 million. However, it is expected to grow by 26% annually to reach 10,500MT by 2023, and then by 13% until 2028. Therefore, the 2026 market is estimated to be US$15–20 million. This is still a small portion of the overall fruit and vegetables market. Future growth is expected to be driven by increasing demand for exotic vegetables (currently India imports 85% of exotic vegetables), as well as by investments in hydroponics by pharmaceutical and traditional medicine companies.

A small number of hydroponic companies are currently in operation, with a relatively small annual turnover. For example, in 2018, the turnover of Barton Breeze and Urban Kisaan was US$231,000 and US$27,000 respectively, but they saw their top line grow at a CAGR of 300–400% in 2019. Hydroponic start-ups in India have received seed funding of US$125,000 and Series A funding of US$5.5 million.

Table 2: Summary of seven investment opportunities for adaptation solutions (in order of market size)

Solution	Funding opportunity	Maturity	Estimated market potential (2026/27)	Revenue model
Solar water treatment (1)	Infrastructure: Solar-powered utility-scale desalination and WWTPs	Mid-level	Medium: US$1.55 billion for solar-powered waste water treatment/US$0.5 billion for solar-powered desalination	Driven by long-term contracts
Green ports	Infrastructure: Installation of green technology (e.g. sewage and waste water treatment) in port	Nascent	Medium: US$0.27 billion (for range of green technologies)	Revenue sharing model
Rainwater harvesting	Manufacture: Manufacture (and installation) of RHS	Mid-level	Medium: US$0.8–1 billion	Based on market (supply/ demand)
Climate services	Services: Services providers for range of climate and weather data, analytics, and tools	Mid-level	Medium (across range of specific service/ products) (e.g. for weather forecasting alone, US$0.16–0.17 billion)	Based on market (supply/ demand)
Solar-powered hydroponics	Infrastructure: Establishment and operation of large-scale hydroponic farms	Nascent	Small: US$15–20 million	Based on market (supply/ demand)
Solar water treatment (2)	Manufacture: Manufacture (and/or operation) of decentralised solar-enabled desalination and waste water treatment systems	Nascent	Very small: US$2–4 million	Based on market (supply/ demand)
Solar-powered cold storage	Manufacture/services: Manufacture of decentralised solar-powered cold storage systems and/or CaaS providers	Nascent	Very small: US$4–5 million	Based on market (supply/ demand)

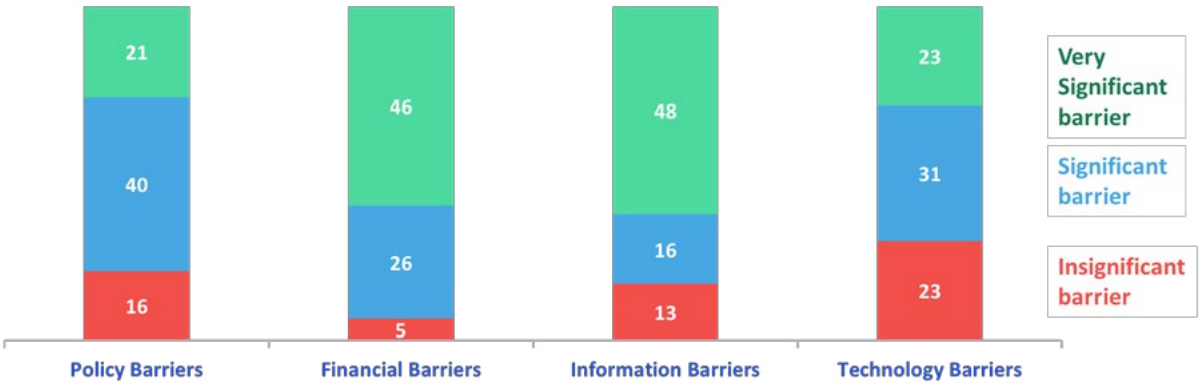
3 Strengthening the market for adaptation solutions in India

This section explores how finance can be mobilised towards the wide range of types and sizes of investment opportunities in adaptation in India. This includes an initial analysis of the main barriers to private sector investment that need to be addressed.

3.1 Barriers to private sector investment in adaptation solutions in India

An analysis of the barriers to mobilising increased investment in adaptation solutions reveals some of the critical problems the Government of India needs to consider. A rapid review of each of the 77 sample adaptation solutions categorised the type of barrier they face (policy, financial, information and technology) and how significant this barrier is (high significance, medium significance and low significance). Figure 3 illustrates the number of solutions facing these categories of barrier, and at different levels of significance.

Figure 3: Number of the sample adaptation products and services with barriers at different significance levels



Policy and regulatory barriers are fundamental for those markets where the adaptation solution is currently being provided by the public sector and the private sector is dependent on government contracts or public–private partnerships (PPPs). For example, the revenue model for underground electricity cables is public procurement for converting overhead to underground cables and for constructing new cable lines.

The wider regulatory environment is still important for markets in which one company is producing or providing a service to another company or to private citizens—for example, the manufacturing of geosynthesis to prevent coastal erosion in infrastructure projects. This includes designing consumer incentives, setting standards, and removing barriers such as in land acquisition. For example, the Government of India is providing various fiscal incentives to promote cold storage facilities.

Access to finance is one of the main challenges faced by both buyers and providers of adaptation solutions. These markets require access to capital flows to scale up promising technologies and services. Forty-six percent of the adaptation solutions sampled showed

'financial barriers' as a key reason for delayed market entry. Finance problems should be temporary for viable markets offering reliable returns. However, in the short term, financial markets may be slow to respond to new opportunities, overestimating risk in new technologies or services. The diversity of adaptation solutions therefore makes finance barriers harder to address than for renewable energy, where fewer technologies are at play. There are also some particular climate challenges where imperfect financial markets can limit adaptation in many ways. For example, climate risks often materialise across longer time-horizons.

Incomplete or asymmetric information occurs as actors—whether investors, farmers, or businesses—are unaware of the scale of risks and impacts that climate change exacerbates, as well as the measures available to mitigate these risks (Fayolle *et al.*, 2019). This is a fundamental demand-side challenge for half the adaptation goods and services sampled in India. For example, solutions targeted at small-scale farmers (e.g. urea deep placement technology) face a highly fragmented consumer base that may not yet be aware of the risks from current agricultural practices and the potential benefits of this new technology.

Technological or skill limitations arise when a technology remains nascent or unproven. For example, geosynthesis—and its application in India in different sectors and local conditions—is still developing, and the relevant technical manufacturing and engineering expertise is limited. In some cases, the technology is not easily available at low cost in India—for example, rapid soil testing devices.

Box 3: An example of an adaptation investment opportunity: Underground electricity cables

Electricity cables are placed underground for a number of reasons, including to protect electricity infrastructure from storms, floods, and landslides. For example, Cyclone Fani damaged 200,000 electricity poles in Odisha in 2019, affecting 2,500,000 families (Nayak, 2019). The Supreme Court in 2021 also passed an order directing the Rajasthan and Gujarat governments to put underground existing overhead cables to protect a rare bird species in a biodiversity hotspot (Arora and Kotoky, 2021).

The investment opportunity includes converting overhead to underground cables and installing new underground cables for public and private clients. Many state governments are commissioning such projects: Maharashtra completed 4,364 km of underground cabling project, worth INR 2,300 crore, benefiting 1.2 crore urban consumers (Wire Cable, 2021). There is also an opportunity to manufacture underground cables and accessories, and the electric wiring and cable market as a whole is projected to grow by US$1.65 billion during 2021–25, progressing at a CAGR of almost 4%.[2]

The main barrier is cost, in particular the higher cost of installing the cables underground and the much higher cost in the case of their needing repair. In addition, like any government contracted work, there are risks for the supplier across the procurement, contracting, and payment process, particularly in the case of work being contracted by the cash-strapped electricity distributors (Dash, 2019).

[2] This is based on market research: www.globenewswire.com/en/news-release/2022/02/25/2392079/0/en/Electric-Wire-And-Cable-Market-In-India-2022-2025-Growth-Drivers-Developments-Demand-Status-Size-Share-Trends-Regional-Segments-Report-by-Absolute-Reports.html.

3.2 Approaches to mobilising private investment in adaptation solutions in India

India's experience of successfully mobilising private investment in low-carbon technology, particularly solar power and more recently electric vehicles, presents some useful lessons for building markets for adaptation solutions. This includes the value of ambitious policy targets and getting the economics right. For example, the commercial returns expected from renewable energy are now higher than for coal-fired power production (Garg, 2022), as a result of successfully crowding in private investments.

However, there are also important differences between adaptation and mitigation solutions. In particular, this review of adaptation solutions has highlighted that their market size tends to be smaller than low-carbon solutions. For example, the largest adaptation investment opportunity (which also provides mitigation benefits) identified in this sample is solar-powered utility-scale WWTP, which has an estimated projected market size of US$1.55 billion in 2026. In contrast, the equivalent estimated market size for electrolysers required to produce green hydrogen is US$32 billion.[3]

The ticket size for adaptation investment opportunities, particularly non-infrastructure ones, also tends to be smaller. This is partly because the adaptation solution has to be tightly defined and clearly separated from the 'development' investment they are making more resilient (to avoid 'green washing' and to accord with the EU sustainable investment taxonomy). This makes mobilising finance harder and more costly.

As a result, the approach to mobilising private investment in adaptation solutions in India needs to be carefully considered, depending on the maturity of the market, the potential for growth, and the ticket size of potential investments.

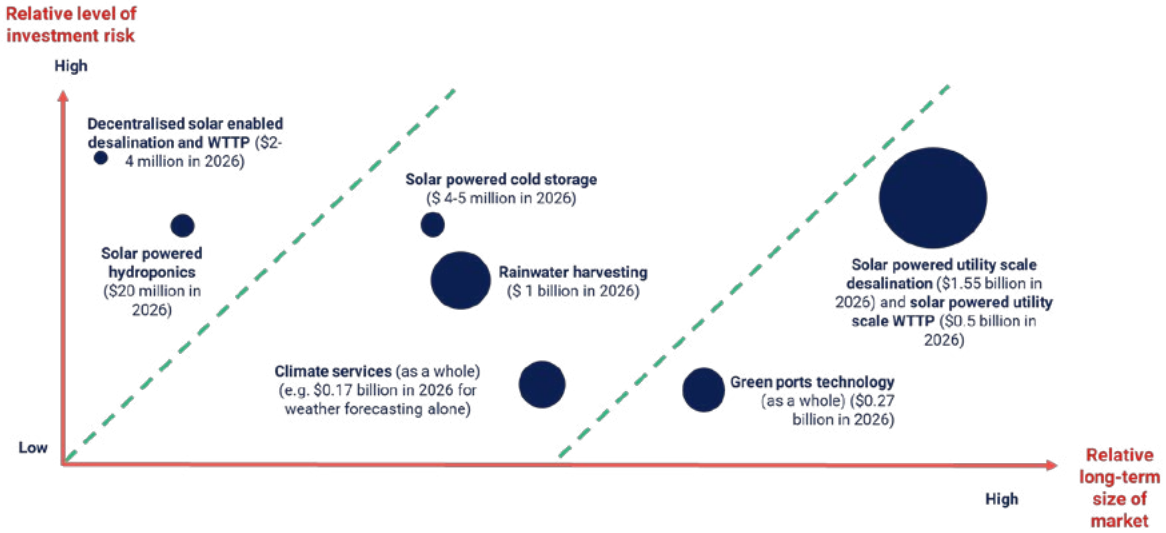
Figure 4 maps the seven adaptation investment opportunities in India against three dimensions: the relative estimated market size in 2026 (indicated by bubble size); the long-term market size (up to 2050); and the level of investment risk.[4] The solutions can be divided into three groups:

- ***ready for (relatively) large sums of investment (right side)***: In adaptation solutions with a large market potential, investment risk is low and provides for a relatively large individual ticket size for investments;
- ***ready for limited sums of investment (middle)***: For adaptation solutions with a medium market size potential, the individual ticket size and the level of investment risk matter; and
- ***requires pro-market support (left side)***: For adaptation solutions with a small market potential, the individual ticket size and the level of investment risk become important.

[3] This assumes that 20% of the projected 9.6 MMT demand for H2 in India by 2026 comes from Green H2 (with demand for 2026 extrapolated from estimates for 2021 and 2030), and also that 10 MW electrolyser (cost ~US$21.7 million per unit) will produce 1,300 tpa of H2 equating to a demand for 1,500 electrolysers of 10 MW capacity by 2026. This does not assume a reduction in the costs of electrolyser units due to scale and/or improved technology.

[4] The investment risk is an approximate rating given the maturity of the market, technology penetration, the policy enabling environment, etc.

Figure 4: Adaptation investment opportunities versus market size and level of investment risk



The Government of India and development partners must identify and support innovative methods of de-risking private investment in such adaptation solutions. Table 3 summarises some examples of how to do this for each category of adaptation investment opportunity.

Table 3: Examples of support to catalyse increased private investment

Category of adaptation investment opportunity	Support required to de-risk private investment
Adaptation solutions ready for (relatively) large sums of investment	New/expanded fund with dedicated focus on adaptation solutions; could include a platform approach, with co-ownership of some assets
Adaptation solutions ready for limited sums of investment	New/expanded fund that combines different financing mechanisms to provide risk-appropriate capital, such as blended private equity with concessional commercial layers
Adaptation solutions requiring market enabling support	Grants for pilots/scaling and policy reform to address regulatory and other barriers to private investment

There are good practices in India and beyond across these types of financing instruments and support mechanisms. The following are examples that can be learned from, adapted, and applied to channel private financing into these and other adaptation investment opportunities.

3.2.1 Examples of adaptation focused climate funds

A small but growing number of funds are experimenting with different models and financing instruments for mobilising private investment in adaptation. Some examples include the following.

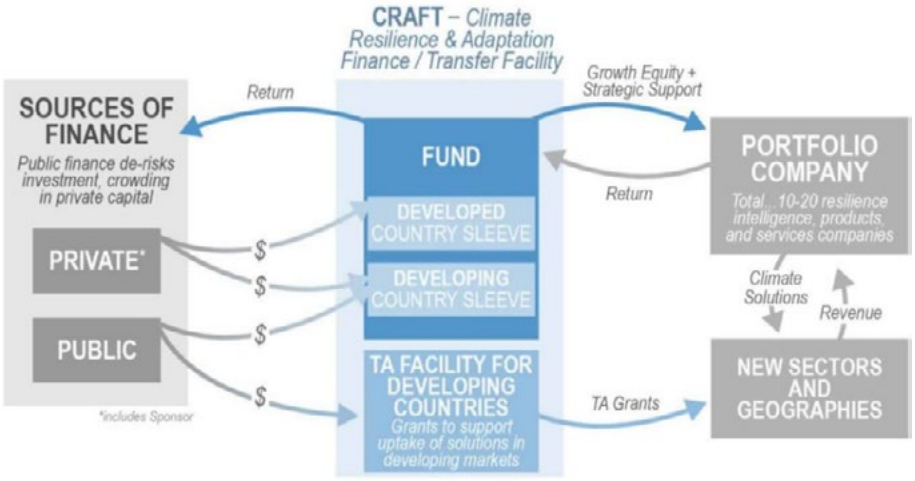
Climate Resilience and Adaptation Finance and Technology Transfer Facility (CRAFT) is the first global growth equity fund on adaptation developed by global sustainable private equity firm the Lightsmith Group. They have brought together investors, including the PNC Insurance Group, the Rockefeller Foundation, the Kinneret Group, and Caprock Impact Partners, as well as the Green Climate Fund (GCF), the European Investment Bank, the

Asian Infrastructure Investment Bank, KfW, the Nordic Development Fund, and the Government of Luxembourg.

CRAFT is focusing on six initial technology areas: water efficiency and smart water management, resilient food systems, agricultural analytics, geospatial intelligence, supply chain analytics, and catastrophe risk modelling and risk transfer. These represent an estimated total addressable market of over US$170 billion today.

Two-thirds of the fund is to be invested in developing countries. It is a blended private equity fund, with a concessional equity layer (US$250 million) and a commercial equity layer (US$250 million), as well as a complementary technical assistance facility (see Box 4 for an example of an investment in India). For every US$1 of concessional financing and technical assistance grants, it is expected to leverage US$3.3 of direct commercial investment (Lightsmith Group, 2022; The Lab, 2022).

Figure 5: Overview of the CRAFT strategy



Source: Lightsmith Group (2022)

Box 4: CRAFT investment in WayCool Foods in India

In January 2022, CRAFT announced US$186 million of commitments including an investment in WayCool Foods, an India-based agriculture and food supply chain services company applying physical automation and digital technology to reduce food wastage and improve farm output. The company reported that they would use this funding to deepen and widen its technology and automation, as well as to further develop its next-gen technology centre in Bengaluru, which will have a tech platform with layers of Artificial Intelligence and analytics. WayCool also plans to add up to 50 more distribution points over the next 18 months.

The Climate Investment Funds (CIF) on climate resilience use private sector set-asides to allocate concessional financing (US$25 million in 2019) on a competitive basis to climate resilience projects. They provide risk-appropriate capital to drive private investment in challenging markets. However, this represents only 10% of the otherwise grant-based US$1.2 billion resilience spending of the CIF.

The UK's Department for Environment, Food and Rural Affairs (DEFRA)'s Big Nature Impact Fund is a public–private, blended finance vehicle that is currently in the start-up phase, with fund managers Federated Hermes and Finance Earth appointed in late 2022. DEFRA will invest £30 million to capitalise the fund and de-risk private investments in projects in the UK

capable of generating revenue from ecosystem services, such as tree planting, woodland creation, and peatland restoration.

WaterEquity is the first asset manager focusing exclusively on the global water and climate crisis. It invests across the water value chain from bulk water via distribution to waste water treatment and reuse. Investments can fund both municipal and industrial needs, with a focus on impacting low-income communities, integrated water resource management, and climate resilience. It invests in both small/mid-size infrastructure projects (PPPs or investment platforms) and growth companies in the water value chain (see Box 5 for an example). Since 2016 it has raised more than US$200 million in capital, made 47 debt investments, and reached 2.7 million people with safe water and sanitation, including through 430,000 micro-loans to low-income consumers (WaterEquity, 2021).

Box 5: WaterEquity investment in Banka Bio in India

Banka Bio is a company in Telangana that develops products and services in the water, sanitation, and hygiene sector. WaterEquity invested US$1 million in the company to expand the innovation and rehabilitation of STPs in urban areas. With the financing, Bank Bio began the renovation of a large STP for a residential apartment complex providing high-quality water for reuse—such as water for toilet flushing and gardening—and properly treated discharge into stormwater drains. Since early 2022, the plant has treated nearly 57 million litres (57 megalitres) of waste water and 56 million litres (56 megalitres) of water for reuse. Looking ahead, Banka will fully operate and maintain the STP over the next seven years, ensuring residents receive continuous access to these services.

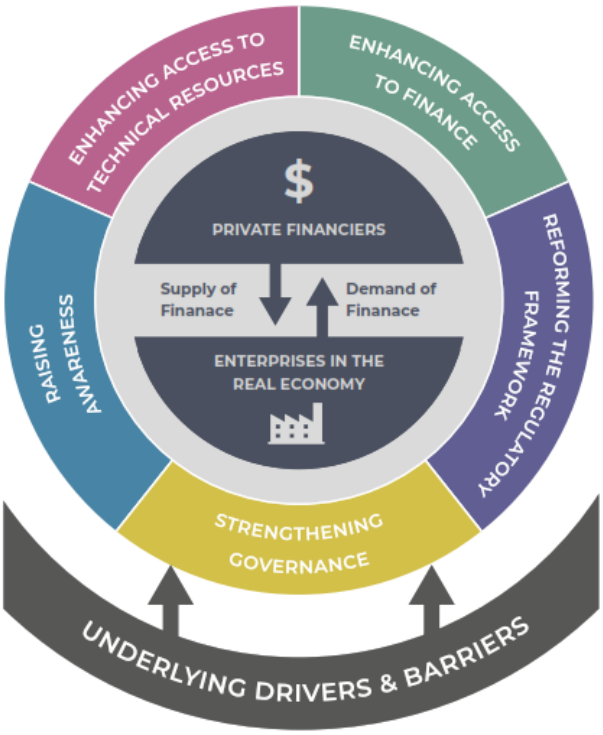
Source: WaterEquity (2021)

The GCF Private Sector Facility funds and mobilises private sector actors, including institutional investors, to de-risk the delivery of private capital. By the end of 2019, it had approved 25 projects with US$2.2 billion of GCF investments (loans: 67%; guarantees: <1%; grants:11%; equity: 22%). However, it has struggled to fund adaptation projects, citing the challenge of showing they can be profitable and generate a revenue stream (IEU, 2021).

3.2.2 Examples of technical assistance to support private investment in adaptation

There is learning and experience of building markets for adaptation solutions in India and beyond. This section is primarily extracted from OPM's learning from the ACT programme 2014–19 working across six states in India and across South Asia (Fayolle *et al.*, 2019). This learning identified five 'enablers' for mobilising private investment in adaptation, which can address the underlying drivers and barriers to both the supply and demand for private financing (Figure 6).

Figure 6: Framework for private sector engagement in adaptation



Source: Fayolle (2019)

Raising awareness of the business opportunities in adaptation: This includes providing market analysis on adaptation solutions with growth potential, as well as information on costs and benefits of corporates investing in adaptation of their own business (see Box 6 for an example).

Box 6: Raising awareness of the business opportunity from silt

Ravaging floods have become a constant feature over the past decade in Bihar, increasing siltation in the River Kosi and its floodplain and leading to poorly drained land and forced migration. This cycle of flooding and sediment deposition adversely affects agricultural yields and the livelihood and social development of the local population. Year after year, the silt is removed by the state and then comes back into the river by the next monsoon. This leads to substantial public spending on the same activity, with no real benefit, in the face of a recurrent disaster.

Under the ACT programme, OPM conducted a technical feasibility analysis of the commercial use of silt for the ceramic, brick-making, and construction industries, along with agriculture, turning a waste product into a commercial resource. Based on this feasibility analysis, the team developed an investment portfolio and a road map for a sediment management framework with clear entry points for private sector investment.

Enhancing access to finance: This involves improving the risk-reward profile of adaptation investments, such as through public sector incentives and subsidies, public or private sector financing instruments, insurance or financial risk products, etc.

Reforming the regulatory framework: This includes policies and regulations that allow, encourage, or require particular adaptation solutions—for example, land use and construction permitting rules that promote the use of climate resilient building methods.

Enhancing access to technical resources: This includes providing technical support to the suppliers of adaptation solutions to grow their business and access the required investment (see Box 7 for an example).

Box 7: OPM's technical support to farmer producer companies (FPCs) in Maharashtra

Under the ACT programme (2014–19), OPM worked with the Department of Agriculture to support FPCs to access finance to invest in climate resilient agricultural practices. An assessment of a sample of FPCs found there were capacity and information gaps both with the FPCs and the institutional financial lenders, particularly in terms of the FPCs' ability to develop bankable projects and a lack of understanding about, and trust of, FPCs by bank managers. Both sides also lacked awareness of the commercial opportunities from climate resilient crops and other practices.

OPM worked to address some of these barriers. For example, the team developed an FPC rating tool that was used by the institutional lenders, as well as by the World Bank under their agriculture programme, to allow for the systematic evaluation of factors that support or restrict FPC business growth, including a specific focus on climate resilient practices. OPM worked with both FPCs and lenders to bridge the trust gap, develop business planning skills, and strengthen awareness of the benefits of climate resilient crops.

Strengthening governance mechanisms: This includes partnerships between the public and private sector, and engaging the private sector when designing regulation to ensure they support private investment in adaptation.

4 Conclusion

There is a clear need to build and grow markets for adaptation goods and services in India. This review of the investment opportunities offered by a sample of adaptation solutions suggests that the following steps could be considered.

First, India requires a green taxonomy with a clear approach to defining adaptation. The taxonomy is crucial to help firms understand and value the adaptation investments they are making, and also to help the government and others track investment in adaptation across the country. This should ideally include a specific list of at least some adaptation solutions, as is done for mitigation solutions. The Government of India and international organisations should encourage jurisdictions pursuing a taxonomy-based approach to consider comparability and interoperability. Further technical analysis is required to enhance the usability of all existing taxonomies for adaptation investments, including preparing further guidance to simplify the application of the criteria in practice.

Second, potential investors need to be made aware of the opportunities presented by adaptation solutions in India. This includes carrying out similar deep dive assessments to highlight the market growth potential and key players across a range of adaptation solutions. The 'Invest India' platform could also be used to facilitate new investments in adaptation.

Third, market enabling activities will help encourage and de-risk investments in nascent markets. This includes providing seed funding to start-ups and business development support to existing and new market players. Multilateral development banks need to expand de-risking facilities for crowding in private investments. In many cases, the policy and regulatory regime could be enhanced to support adaptation solutions, including through fiscal and other incentives.

Fourth, a new investment fund focused on adaptation could help mobilise investment in these markets. However, this cannot replicate the platform-oriented approach used by funds such as the UK–India Green Growth Equity Fund (GGEF) to catalyse investment into low-carbon infrastructure projects. Given the smaller profile of most adaptation investment opportunities, alternative financing mechanisms will be required, such as private equity, blended finance, fund of funds, etc.

Mobilising increased private sector investment in adaptation in India presents an opportunity to deliver not just commercial returns, but also significant direct impact on the lives and livelihoods of vulnerable communities across the country.

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Annex A Further details on seven adaptation investment opportunities

A.1 Investment Opportunity 1: Solar-powered utility-scale desalination and WWTPs—*infrastructure opportunity*

What is the commercial opportunity? Utility-scale desalination and WWTP is a mid-level mature market in India, but the use of solar power at treatment plants is still at the pilot stage. Solar-powered systems have been deployed globally—for example, Ultrik Atoll in the US Marshall Islands has been deriving drinking water from solar desalination since 2014.[5] In India, some pilot projects have been developed by both the government and private sector, including the following.

- In Tamil Nadu, a desalination plant established by IIT Madras and the Ministry of Earth Sciences with an investment of US$175,000 has a capacity of 10,000 litres per day.
- In West Bengal, the Carlsberg Group has backed a 20,000 litres per day solar-powered desalination plant in Sundarbans, as part of its plan to halve water usage at its breweries by 2030.

The desalination and WWTP market in general is expected to grow significantly, given the huge need for water efficiency. India holds only 4% of the world's freshwater resources, to serve 16% of the global population. In addition, groundwater in India is rapidly depleting: 36% of districts are classified as over-exploiting groundwater. There is untapped potential to reuse water: 72% of municipal waste water in India is currently untreated.

The government has demonstrated its intention to invest in desalination and WWTP infrastructure, albeit not yet with added solar power. For example, the Jal Jeevan Mission is a US$46.5 billion programme aimed at strengthening existing water sources and setting up treatment and desalination plants. The central and state governments are developing desalination plants, for example a 150 million litres per day (MLD) plant in Tamil Nadu to be connected to the grid in 2023; a 6 MLD plant in Prakasam district in Andhra Pradesh; and a 100 MLD plant in Dahej in Gujarat to supply local industries.

As an infrastructure opportunity, there is a clear revenue stream, with long-term contracts with utilities, municipalities, or industrial units (EPC/PPP mode).

Does it meet the EU taxonomy for sustainable investment? Water treatment is aligned with the EU taxonomy for adaptation ('activity enabling adaptation') as it manages the impact of freshwater scarcity. However, water treatment is energy intensive, so a clean energy source is required. Also, any infrastructure investment in this sector needs to manage the project risks of disposing of brine/waste water.

[5] www.waterworld.com/home/article/16214928/desalination-system-helps-thwart-drought-in-marshall-islands

What is the market size? The immediate market size is estimated to be US$500 million by 2026 for solar-powered desalination (this assumes 33% of the expected desalination market is solar-powered)[6] and US$1.55 billion for solar-powered WWTP (this assumes a 30% market share of overall WWTP market is solar-powered).[7] In the longer term, this market is expected to grow significantly. By 2030, demand for fresh water will be 1.5 billion m^3, while supply will only be 750 m^3, and this technology will need to be scaled up.[8]

What is the specific investment opportunity today? The individual ticket size for an infrastructure project (60 MLD solar-powered desalination plant) is US$130 million.[9] The return expectations for such an investment, benchmarked against similar water projects using conventional energy, is 9–11%. While there are currently only a few domestic market players in solar water treatment plants, many infrastructure companies are engaged in the water sector in general (e.g. Wabag, Veolia, etc.) and could enter the solar-powered market.

What are the investment risks? Such infrastructure projects usually involve contracts with the government as the customer and hence run revenue risk. Alternative customer profiles (for example industrial estates, manufacturers) and alternative revenue models could be explored to mitigate this risk. In addition, solar power would be seasonal in some areas and does not work at night. Hence, to have a similar output to a plant working 24/7 on conventional power, the solar-powered plant either has to store power generated during the day or has to have a higher throughput during daylight hours.

A.2 Investment Opportunity 2: Manufacture of decentralised solar-enabled desalination and WWTPs

What is the commercial opportunity? Decentralised solar-enabled desalination and WWTP is less energy intensive and more sustainable than utility-scale systems. However, the technology has not yet been demonstrated in India beyond small-scale pilots. The market for this technology is expected to be industrial clusters, governments in rural/remote areas, large residential welfare associations, etc.

Does it meet the EU taxonomy for sustainable investment? Water treatment is aligned with the EU taxonomy for adaptation ('activity enabling adaptation'), as it manages the impact of freshwater scarcity. However, water treatment is energy intensive, so a clean energy source is required. Also, any infrastructure investment in this sector will need to manage the project risks of disposing of brine/waste water.

What is the market size? By 2026, it is estimated that just eight commercially viable installations will be feasible for both solar-enabled desalination and WWTP, with a total value of US$2–4 million. Each unit is assumed to cost US$262,000 based on pilots done for a throughput of 10,000 litres per day.

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[6] The market size for desalination markets is estimated from third-party analysis, and assumes that the 2024 market size of US$1.4 billion will grow 5% per annum to reach US$1.55 billion by 2026: www.businesswire.com/news/home/20190801005939/en/Indias-1.4Bn-Desalination-Plant-Market-by-End-Use-Sector-Technology-and-Competition---Forecast-to-2024---ResearchAndMarkets.com.

[7] The market size for the WWTP market is estimated from third-party analysis, and assumes that the 2025 market size of US$4.3 billion will grow 5% per annum to reach US$4.52 billion in 2026: https://beta.ficci.in/pressrelease-page.asp?nid=4080 .

[8] www.indiawaterportal.org/articles/indias-deepening-water-crisis.

[9] The project cost has been benchmarked against desalination projects in Saudi Arabia, which has an advanced and competitive market for desalination infrastructure: www.water-technology.net/projects/al-khafji-solar-saline-water-reverse-osmosis-solar-swro-desalination-plant/.

In the longer term, if each technology were to provide 1% of the freshwater demand projected for 2030, the total market size would be US$7–8 billion.[10]

What is the specific investment opportunity today? The manufacturing opportunity will involve seed funding for the further development and demonstration of the new technology. Only a couple of companies are currently producing small-scale desalination plants.

What are the investment risks? The technology still needs to be demonstrated and customer demand validated.

A.3 Investment Opportunity 3: Installation of green technology at ports—*Infrastructure opportunity*

What is the commercial opportunity? 'Green ports' use a range of viable technologies to reduce energy use and emissions, increase water and resource efficiency, and reduce the environmental impact of the port. They therefore encompass both mitigation and adaptation benefits. The installation of each of these technologies can be considered a separate commercial opportunity, or they can be bundled together as an investment in green ports in general.

The Government of India's current push for promoting this technology provides an immediate market to be serviced. The upcoming national GPP will require the use of many of these technologies to achieve green port status (e.g. the GPP is expected to require 50% of water to be reused/recycled by 2025). An expansion of ports is also expected in India, to handle a projected 75–100% increase in trans-shipment cargo.

There is a clear revenue stream involving the installation of the technology by developers or through EPC, with various cost recovery mechanisms possible, such as adjustments to the revenue share with the port operator. The GPP is also proposing viability gap funding via tax discounts.

Does it meet the EU taxonomy for sustainable investment? The alignment with the EU taxonomy will depend on the specific green port technology being considered. It will also cover only the additional cost of installing the green technology, and not the overall cost for constructing a port. Some technologies have project risks that need to be managed, such as the impact on marine ecosystems from STPs.

What is the market size? The immediate market size for each individual green port technology varies significantly. For example, one technology that delivers clear adaptation benefits is on-port STPs and WWTPs, with an estimated market size in 2026 of US$67 million.[11] If a range of other mitigation and adaptation technologies are also considered, including installing renewable energy plants, battery storage, electrification of cranes, and

[10] This assumes the average throughput of the desalination plant is 1 MLD, which points to a demand for 100,000 of such units (costing US$262,000 each) and assumes an average capacity for solar-enabled WWTP of 0.1 MLD, which gives a demand for 250,000 units (costing US$262,000 each).
[11] This assumes that a total of 101 MLD potential capacity of WWTPs is viable (with an estimated cost of INR 5 crore per MLD of capacity).

other processes, the estimated market size will be much greater. An estimate of the market size for green port technology in general in 2026 is US$273 million.[12]

What is the specific investment opportunity today? Few of India's current 13 major ports and 205 non-major ports have green technology installed, and there is therefore an immediate market to service. The individual ticket size for each green port technology varies, but the technologies can also be packaged together. For example, the average cost of installing an STP is US$3.4 million (major port)/US$181,800 (non-major port) and a DSS is US$1.4 million (major port)/US$54,000 (non-major port). The return expectations also differ, but is approximately 14–16% for STPs and DSS,[13] and a range of companies are ready to install this technology.

What are the investment risks? Ports in India are in general underperforming, making it a challenge to mobilise fresh capital. In addition, concession agreements between major ports and private operators already define the necessary infrastructure. The private operators may avoid investing in additional infrastructure because their financial costs are already covered.

A.4 Investment Opportunity 4: Manufacturing and installation of RHS—*Manufacturing opportunity*

What is the commercial opportunity? RHS technology ranges from simple low-cost to large-scale, and can be installed in residential homes (which is 55% of the market), large buildings, and infrastructure. It collects and stores rainwater for agriculture, domestic, or other uses, and helps protect against water scarcity during periods of drought, manage stormwater, and prevent flooding and soil erosion.

The Government of India and various state and city authorities have been promoting RHS as part of wider efforts to promote 'smart cities' and 'green buildings'. The Smart Cities Mission requires smart buildings in the smart city to include rainwater harvesting, among other eco-friendly facilities. This is directly linked to tax benefits for builders. In addition, as part of the National Water Mission, a masterplan for aquifer recharge for the country has been developed. There is a clear revenue stream based on the market demand for the manufacture, installation, and/or maintenance of RHS. The current market for the residential segment is very fragmented and localised, and there is the possibility of consolidating off-the-shelf large-scale manufacturing.

Does it meet the EU taxonomy for sustainable investment? RHS is aligned with the EU taxonomy for adaptation ('activity enabling adaptation'), although infrastructure projects for large-scale RHS would require an assessment of any local risks.

What is the market size? The residential segment (the largest chunk of the market) has seen a CAGR of around 7% in recent years,[14] and is estimated to reach US$0.8–1 billion by

[12] This incorporates six different green port technologies: solar plants, battery storage, electric vehicle charging stations and CNG stations, crane electrification, STPs and WWTPs, and DSS. For each technology there are different assumptions about the viable capacity and costs across existing ports.
[13] This is estimated based on market consultations.
[14] This is based on market research: www.technavio.com/report/rainwater-harvesting-market-in-india.

2026. There is huge growth potential beyond this. Only 8% of rainwater is currently being harvested, and only 18% of rural households have a tap connection.[15]

What is the specific investment opportunity today? RHS technology ranges considerably in cost, depending on size and site location (for example whether there is an existing well or tank). Model projects marketed by Central Ground Water Authorities and private manufacturers for residential complexes range between US$850 and US$9,600. The market is currently dominated by small, local turnkey providers who produce and install RHS within a locality. The manufacturers of the required parts (which have a wider application than just RHS) also tend to be small companies (with an annual turnover below US$120,000) and have seen growth rates of 5–32%.[16] Consolidation of the market can be expected, as well as large-scale off-the-shelf manufacturing of RHS units.

What are the investment risks? There is still limited demand from consumers for RHS. Although a growing number of states and cities are mandating it in new builds, compliance remains a challenge. The upfront cost of installing RHS remains prohibitive for the majority of consumers, although some states/cities are providing a tax rebate. The fragmented and local nature of the market also limits large-scale investment opportunities.

A.5 Investment Opportunity 5: Service providers for a range of climate and weather data, analytics, and tools—*Services opportunity*

What is the commercial opportunity? Climate services is a broad term covering a wide range of applications, users, and markets, such as weather forecasts, climate analytics, risk modelling, remote sensing, etc. Private and public sector customers use this weather and climate data and analysis to make decisions that carefully consider the immediate and longer-term risks of climate change. As weather, extreme events, and long-term trends become more uncertain and erratic, this information becomes even more important and valuable.

Some, but not all, climate service providers are companies that charge for this information, while other services are provided by the public sector, such as early warning systems provided by state governments using data from the Indian Meteorological Department. One specific example of commercial climate services are the private providers of weather forecasting. They provide tailored weather information to both public and private clients to supplement what is provided by the government.

Does it meet the EU taxonomy for sustainable investment? Climate services are aligned with the EU taxonomy for adaptation ('activity enabling adaptation'), as the information provided enables the customer to adopt appropriate and relevant risk mitigation strategies.

What is the market size? The overall market size for climate services is difficult to estimate given its diverse scope. The private weather forecasting service segment specifically was reportedly valued at US$100 million in 2019. If it follows global market trends of a CAGR of

[15] This is according to data reported by the Times of India: https://timesofindia.indiatimes.com/readersblog/lookingatthehorizon/an-investment-of-rs-2-3-lakh-crore-from-private-sector-for-water-storage-and-supply-of-tapped-water-to-every-household-just-assure-water-procurement-11447/.

[16] This is based on market data for leading RHS companies in India D&D Ecotech Services, KRG India, N.S.& Associates, Osmosis India, and Water Field Technology.

9.9%, it is estimated to reach US$160–170 million by 2026.[17] A related market—the private sector geospatial market—was valued at US$280 million in 2020.[18]

The long-term market is expected to grow considerably, as public and private clients want specific analysis and information on the climate risks they are facing, including through the global movement towards climate-related financial disclosures.

What is the specific investment opportunity today? This is a nascent market in India today. Only three companies provide private weather forecasting services, with an annual revenue in the range of US$680,000–5.3 million. These have received funding in the range of Series A funding of around US$1.78 million to Series C funding of US$6.27 million.[19]

What are the investment risks? The regulatory regime is still evolving, particularly in terms of the use of drone technology and data storage rules. There is also some concern within the Indian Meteorological Department about private providers of weather forecasts, which might trigger further regulation, although state governments are already purchasing this service.

A.6 Investment Opportunity 6: Manufacture of decentralised solar-powered cold storage systems and/or solar CaaS providers

What is the commercial opportunity? Decentralised solar-powered cold storage is a nascent technology in India, with estimates that only around 3,000 units (of 5–100MT capacity each) have been installed.[20] India produces more than 400 million MT of perishables (horticulture produce, dairy, meat, fish, etc.) every year, and there is an estimated total cold storage capacity (solar/non-solar) in India of just 32 million MT. Currently, 60% of cold storage capacity is concentrated in two states (Uttar Pradesh and West Bengal), and the majority is for a single crop (potato).[21] The units are off-grid with a thermal (ice) battery, but can connect to the grid for back-up power. Manufacturers are currently targeting FPOs, traders, and collectives rather than individual farmers. There are also pilots underway offering CaaS that rent or lease space within the system to individual small-scale farmers.

Does it meet the EU taxonomy for sustainable investment? Cold storage is aligned with the EU taxonomy for adaptation ('activity enabling adaptation'), as it builds the resilience of farmers and food systems to variable weather and climate change. However, given cooling is energy intensive, a clean energy source is required. It also provides mitigation co-benefits

[17] As per a market analysis reported by the Economic Times: https://economictimes.indiatimes.com/news/politics-and-nation/private-forecasters-smell-big-bucks-in-indian-weather/articleshow/70543648.cms?from=mdr.
[18] This is based on market research: https://analyticsindiamag.com/indian-geospatial-market-to-grow-to-inr-36300-crore-by-2025/.
[19] This is based on available market data on companies in India. Series A funding—Average: US$1.78 million. (SkyMet): US$998,000; (WeatherRisk): US$600,000; US$1.5 million; (Agrivi—UK): US$1.1million and US$4.74 million. Series B funding—Average: US$4.5million. (SkyMet): US$4.5 million. Series C funding—Average: US$6.27 million. (SkyMet): US$6.27 million. Annual revenue—SkyMet (US$5.3 million in 2019); Weather Risk Management Services (US$2.71 million); BKC Weathersys (US$679,000); NCML (weather stations form one segment of the company) (US$637 million).
[20] This is based on interviews with market players.
[21] This is based on market information from the Government of India: www.mofpi.gov.in/sites/default/files/OpportunitiesinColdChainSectorinIndia.pdf.

in reducing food waste, given that 2–16% of India's 400MT of perishable products is wasted.[22]

What is the market size? The decentralised cold storage market in general was valued at US$9 million in 2022, and projected to be US$13 million in 2026, of which 33% is solar (US$4.3 million).[23] Cold storage in India is considered a high-growth market, and there is an opportunity for solar-powered systems to fill the US$20 billion opportunity across all chilling segments.[24] Looking into the longer term, the total immediately serviceable market for 5MT solar-based farm gate cold storage systems is currently estimated to be US$3 billion.[25]

What is the specific investment opportunity today? There are only three known companies producing solar-panelled cold storage, while approximately 10 are manufacturing cold storage in general. These three companies include a start-up, Inficold, with an annual revenue of US$480,000, and a larger company, Ecozen, with an annual revenue of US$9.11 million. They have seen average investments of between US$0.73 million (Series A) and US$7.5 million (Series B).[26]

There is only one known CaaS provider, which reports an equity IRR of 31–43% for a 15MT system.[27] The big 'farm to fork' corporates (e.g. ITC, Amazon) are not currently offering cold storage at the farm gate.

What are the investment risks? Solar-powered cold storage systems cost more than grid-connected systems. While there are policy enablers promoting cold storage in general, this is not specifically geared towards solar-powered systems. The technology for solar-powered systems still needs to develop, particularly in terms of maintenance.

A.7 Investment Opportunity 7: Establishment and operation of large-scale solar-powered hydroponics farms

What is the commercial opportunity? Hydroponics is a method of growing crops in a controlled environment, without soil, in a nutrition-rich water solution. While there are approximately 40 hydroponics farms in India, mostly growing leafy vegetables and other exotic fruit/vegetables and flowers, these are mostly/all grid-connected rather than powered by their own source of renewable energy.

Does it meet the EU taxonomy for sustainable investment? Hydroponics is aligned with the EU taxonomy for adaptation ('activity enabling adaptation'), as it uses up to 90% less water than traditional agriculture practices and is therefore more resilient to temperature/rainfall changes.[28] It also requires less land and can be used in urban settings.

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[22] This is based on market information from the Government of India: www.mofpi.gov.in/sites/default/files/OpportunitiesinColdChainSectorinIndia.pdf.
[23] This is based on market research: www.techsciresearch.com/report/india-decentralized-cold-storage-market/4923.html.
[24] This is based on various market research reports, for example: www.researchandmarkets.com/reports/5578080/indian-cold-chain-market-industry-trends-share#:~:text=The%20Indian%20Cold%20Chain%20Market%20was%20estimated%20to%20be,INR%201585.1%20Billion%20in%202021.
[25] This is based on market analysis, shared in confidence.
[26] This is based on available market data on companies in India. Series B funding: Average: US$7.5 million. (Ecozen): US$9.11 million and US$6 million. Series A funding: Average US$0.73 million. (Inficold): US$250,000; and US$497,000 and US$900,000. (Ecozen): US$782,000 and US$154,000 and US$1.84 million.
[27] This is based on interviews with the company.
[28] This is based on market research: Hydroponic Farming for India (investindia.gov.in).

Hydroponics provides health benefits by not requiring pesticide use, but it can require large amounts of energy for cooling, and as such a renewable energy source of power is required.

What is the market size? The hydroponics market is at a nascent stage in India. In 2019, the market size was estimated to be 3,100MT and valued at US$4.5 million. However, it is expected to grow by 26% annually to reach 10,500MT by 2023, and then to grow by 13% until 2028. Therefore, the 2026 market size is estimated at US$15–20 million.[29]

This is still a small portion of the overall fruit and vegetables market. Future growth is expected to be driven by increasing demand for exotic vegetables (currently India imports 85% of exotic vegetables), as well as by investments in hydroponics by pharmaceutical and traditional medicine companies.

What is the specific investment opportunity today? A small number of hydroponic companies are currently in operation, with a relatively small annual turnover (for example, in 2018, the turnover of Barton Breeze and Urban Kisaan was US$231,000 and US$27,000 respectively, but they saw their top line grow at a CAGR of 300–400% in FY2019). Hydroponic start-ups in India have received seed funding of US$125,000 and Series A funding of US$5.5 million.

What are the investment risks? Hydroponics involves significant upfront costs. For a 500 square foot farm, the initial start-up costs are estimated to be US$20,000, with an expected profit margin of just US$830 per month.[30] The food produce segment relies on a consumer base willing to pay a premium for the sustainability and health benefits.

[29] This is based on estimates in market research, such as: www.datamintelligence.com/research-report/india-hydroponics-market#:~:text=India%20Hydroponics%20Market%3F-,India%20Hydroponics%20Market%20is%20expected%20to%20grow%20at%20a%20CAGR,the%20forecasting%20period%202022%2D2029.

[30] This is based on costs reported here: www.thefarminghouse.com/2021/08/hydroponic-farming-setup-cost.html.