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EVALUATION OF GEF SUPPORT FOR TECHNOLOGICAL INNOVATION

(Prepared by the Independent Evaluation Office)

Abbreviations

ADB	Asian Development Bank
AfDB	African Development Bank
AI	Artificial Intelligence
APR	Annual Performance Report
CAF	Development Bank of Latin America
CBIT	Capacity-building Initiative for Transparency
CI	Conservation International
CSO	Civil Society Organization
FAO	Food and Agriculture Organization
GBFF	Global Biodiversity Framework Fund
GCHP	Global Clean Hydrogen Programme
GCIP	Global Cleantech Innovation Programme
GEF	Global Environment Facility
GET	GEF Trust Fund
IEO	Independent Evaluation Office
IDB	Inter-American Development Bank
IAP	Integrated Approach Pilot
IFAD	International Fund for Agricultural Development
IoT	Internet-of-Things
IP	Integrated Program
KM	Knowledge management
LDCF	Least Developed Countries Fund
ML	Machine Learning
MTF	Multi-Trust Fund
NGI	Non-Grant Instrument
NbS	Nature-based solutions
OPS	Comprehensive Evaluation of the GEF
SCCF	Special Climate Change Fund
SME	small and medium-size enterprise
STAP	Scientific and Technical Advisory Panel
TAG	Technical Advisory Group
TNA	Technology Needs Assessments
UAV	Unmanned aerial vehicle
UN	United Nations
UNCCD	United Nations Convention to Combat Desertification
UNDP	United Nations Development Programme
UNEP	United Nations Environment Programme
UNIDO	United Nations Industrial Development Organization

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QUICK SCAN

1. Technological innovation has become increasingly critical for achieving global environmental benefits at the scale and pace required to address planetary challenges. This evaluation assessed the GEF partnership's efforts to support technological innovation across GEF-6, GEF-7, and GEF-8 replenishment periods, as a contribution to the Eighth Comprehensive Evaluation of the GEF (OPS8). Although the GEF supports multiple forms of innovation—technological, institutional and policy, and financial and business model—this evaluation focused specifically on technological innovation, reflecting its importance in the 2024 GEF risk appetite statement, the rapid pace of technological change, and its potential to deliver tangible results while attracting private sector engagement.

2. The evaluation employed a mixed-methods approach, drawing on a document and literature review, a portfolio scan of 2,016 projects from GEF-6 through GEF-8, four case studies, five targeted "snapshots" examining specific innovation initiatives, interviews with 47 stakeholders from the GEF Secretariat, STAP, GEF Agencies, and CSO Network, and field evidence from China, Indonesia, Mexico, and Viet Nam. The evaluation developed a taxonomy of 120 technological innovations categorized as advanced (emerging and cutting-edge such as Artificial Intelligence and green hydrogen), broad (including digital platforms), and other technologies.

1. Findings

3. While technology is present in majority of GEF projects, emerging and cutting-edge technologies remain relatively rare. Across GEF-6 to GEF-8, 63 percent of projects include some technological elements, 31 percent incorporate broad technological innovations, and only 10 percent feature advanced or emerging ones. The most common broad technological innovations are digital platforms (172 projects), remote sensing and geospatial technology (161 projects), and nature-based solutions, such as constructed wetlands (97 projects). Among the relatively rarer cases of advanced technological innovations, data modeling (79 projects), mobile applications (21), and sensor-based systems (20) are the most prevalent. Disruptive technologies with high environmental potential remain rare. Artificial Intelligence and machine learning (AI/ML) appear in 12 projects. Blockchain in 6 projects, and technologies such as cellular agriculture, robotics, and nanotechnology are largely absent.

4. Technological innovation in GEF projects is increasing. From GEF-6 to GEF-7, the number of projects featuring technological innovations rose by 55 percent --from 200 to 309 projects. Growth has been particularly strong in electric mobility (from 3 to 36 projects, an 1,100 percent increase), nature-based solutions (from 5 to 41 projects, a 720 percent increase), and the introduction of green hydrogen (absent in GEF-6, appearing in 3 projects in GEF-7 and expanding to a program with 10 child projects in GEF-8). This expansion is linked to GEF Secretariat initiatives

such as the Challenge Program for Adaptation Innovation, non-grant instruments, the Innovation Window, and strengthened technical expertise within Agencies and countries. The Scientific and Technical Advisory Panel (STAP) has also contributed guidance on technological innovations during this period. Although innovation is intended to be mainstreamed across the portfolio, these targeted funding windows have played a key role in explicitly encouraging new approaches and in attracting nontraditional partners — including startups, investment and microfinance institutions, and technology-oriented academic institutions.

5. The GEF places particular emphasis on innovation risk because transformational change often requires supporting solutions that are not yet proven or widely adopted. The IEO's 2024 evaluation of portfolio-level risk shows that, although higher-risk projects may at times yield lower outcomes, they can also generate exceptional benefits—especially when they involve breakthrough technologies. For instance, high-risk renewable energy initiatives that promoted solar technologies and policy reforms to reduce fossil fuel subsidies achieved the highest outcome ratings, demonstrating the payoff of targeted high-risk investments. Hence, the GEF adopted a risk appetite that assigns a high rating for innovation risk, recognizing that backing emerging technological solutions—and the uncertainties they entail—is essential for achieving transformational environmental impact (GEF IEO 2024a).

6. The overall risk profile of technological innovation in the GEF portfolio is low to moderate. The GEF's risk appetite statement postdates the design and approval of most GEF-6, GEF-7, and early GEF-8 projects. Although GEF-8 projects submitted after the approval of the risk appetite include innovation risk ratings, most still classify their innovation risks as low to moderate. Case studies also reveal inconsistencies in how projects address known risks associated with advanced technologies, such as the high energy demands of AI or the data security implications of blockchain – areas highlighted by the STAP and the broader literature.

7. GEF projects that incorporate technology have higher private sector involvement. The portfolio scan found that 67 percent of projects with technological components engaged the private sector, compared with 30 percent of projects without such elements. Stakeholder interviews confirmed that private sector actors often drive the testing, development, and deployment of technologies, which naturally increases their participation when technology is included. Previous GEF IEO evaluations have also highlighted the private sector's critical role as a source of innovation and a partner in sustainable financing and scaling, as well as the tendency for private sector–engaged projects to carry higher innovation risk ratings, including technological innovation risks.

8. Integrated programming has helped advance the adoption of technological innovation, though its full potential is still to be realized. As programming evolved from pilots to more structured modalities between GEF-6 and GEF-8, some programs made deliberate efforts to scale up transformational technologies. For instance, the Food Systems Integrated Program provides

guidance to child projects on adopting and disseminating agri-tech solutions. In the Sustainable Cities Program, 30 percent of projects incorporated broad technological innovations—such as digital platforms, remote sensing, data modeling, nature-based solutions, and smart grids—showing progress but not yet at levels that surpass the overall GEF portfolio.

9. Technological innovations can catalyze transformational change when supported by the right enabling conditions. Evidence from completed projects shows that when technological interventions are combined with policy support, institutional capacity, and innovative financing, they can drive sector-wide and system-wide shifts. Examples include Uruguay's wind energy sector transformation where early GEF support helped wind power grow to 43 percent of electricity generation by 2023, and China's adoption of automated monitoring in solid waste incinerators, which demonstrated how advanced technologies can reshape an entire sector while reducing pollution and public health risks.

10. Several key enablers support technological innovation in the GEF partnership. These include institutional capacity and an organizational culture within the GEF Secretariat and Agencies that encourage innovation; financial and operational mechanisms such as the Challenge Program for Adaptation Innovation and non-grant instruments; strong partnerships with private sector actors, research organizations, and community groups; supportive national policies and strategic frameworks; and adequate technological readiness and infrastructure in recipient countries.

11. However, several barriers continue to limit the GEF's ability to effectively support technological innovation. The most significant is strategic: although the GEF's country-driven model is essential for ensuring country ownership, the partnership currently lacks complementary system-wide approaches and tools to support countries and Agencies identify, test, deploy and scale technological innovations. As a result, opportunities are being missed, in part due to limited horizon scanning, trend monitoring, and knowledge exchange on emerging technologies at the partnership level. Additional barriers include misalignment between the GEF project cycle and the rapid pace of technological change, limited strategic partnerships with the private sector, and country-level capacity constraints—such as shortages of qualified professionals, limited technology infrastructure, low technological literacy, and institutional resource gaps.

2. Conclusions

12. The GEF's commitment to technological innovation is increasing, yet its full potential remains unrealized. The GEF partnership increasingly recognizes technological innovation as essential for transformational change, and recent efforts by the Secretariat, STAP, and Agencies have helped raise its profile in the portfolio. However, truly emerging and cutting-edge technologies remain rare, and most projects reviewed were designed before the GEF adopted its 2024 high-risk appetite for innovation. Both the 2021 innovation evaluation and this assessment

indicate that the GEF partnership must more fully operationalize its commitment to innovation in future projects and programs.

13. When aligned with local needs and enabling conditions, innovation can drive transformation. Technological innovation has contributed to meaningful environmental and socio-economic benefits across focal areas, especially when combined with institutional, policy, financial, or business model innovations. Successful pilots show that strong enabling conditions—such as local stakeholder engagement, supportive policies, and accessible, context-appropriate technologies—are essential for scalable and sustainable results.

14. Capacity gaps, fragmented partnerships, and limited foresight on emerging technologies impede uptake and scaling. Many countries face shortages of skilled professionals, weak digital readiness, and institutional gaps that hinder adoption. Partnerships with the private sector, research institutions, and technology firms are often ad hoc rather than strategic. While integrated programming has begun to foster more systematic use of technological innovation, its full potential remains to be met. The GEF lacks a structured approach to periodic horizon scanning and foresight. STAP guidance on emerging technologies has not been consistently reflected in project choices, and mechanisms for sharing Agency expertise—such as in AI/ML—across the partnership remain limited. Stronger collaboration and generating more evidence on the contribution of technological innovation to global environmental benefits are critical.

15. Rigid processes, limited risk-taking, and insufficient early-stage funding constrain bold innovation. Complex project cycles and cautious risk-taking limit the GEF's ability to support higher-risk, higher-impact technological innovations. Although mechanisms like the Challenge Program for Adaptation Innovation and non-grant instruments show promise, funding for early-stage piloting is still scarce, considering they are demand-driven. The GEF's high innovation risk appetite has yet to translate into broad, systematic support—including strategic R&D partnerships and stronger incorporation of technological innovation across projects and programs.

I. INTRODUCTION

1. The objective of this evaluation was to assess the Global Environment Facility (GEF) efforts to support technological innovation across the GEF portfolio during the GEF-6, GEF-7, and GEF-8 replenishment periods. The evaluation is a contribution to the Eighth Comprehensive Evaluation of the GEF (OPS8).

2. While the GEF partnership supports multiple types of innovation—technological, institutional and policy, and financial and business model—this evaluation focuses specifically on technological innovation. This focus reflects several factors: technological innovation's high rating in 2024 risk appetite statement of the GEF, the exponential pace of technological advancement offering unprecedented tools to address environmental degradation at scale, and technology's potential to deliver tangible outputs while attracting private sector engagement. The evaluation recognizes that the most successful GEF approaches often combine different types of innovation, and that technological solutions achieve greatest impact when aligned with supportive policies, institutional capacity, and innovative financing

3. The evaluation builds on previous GEF Independent Evaluation Office (IEO) evaluations on transformational change, innovation, and risks (GEF IEO 2018, 2021, 2024a).

4. The evaluation addresses the following key aspects:

   (a) What are the main technological innovations supported by the GEF in GEF-6, GEF-7, and GEF-8?

   (b) Are there any missed opportunities based on what has been tried and tested?

   (c) What outcomes are associated with technological innovations supported by the GEF in GEF-6 and GEF-7?

   (d) What are the enablers and barriers for the GEF to support technological innovations?

II. METHODOLOGY

5. The evaluation used a mixed-methods approach, which included a portfolio scan, four case studies (annex 1), five “snapshots” (annex 2), and interviews with stakeholders from the GEF Secretariat, GEF Agencies, the GEF Civil Society Organizations (CSO) Network, and the Science and Technical Advisory Panel (STAP). In total, 2,016 projects from GEF-6, GEF-7 and GEF-8 were

scanned[1], interviews were conducted with 18 representatives from the GEF Secretariat, CSO Network, and STAP, and 29 staff members from eight GEF Agencies, and relevant document and literature were reviewed. The evaluation also used field evidence from China, Indonesia, Mexico, and Viet Nam, enabling direct observation of technological innovations.

6. This evaluation used the STAP's definition of technological innovations as "new products and processes and significant technical changes in existing products and processes" (STAP 2018, p.7). Through a document and literature review, interviews, and expert validation, the evaluation developed a taxonomy of 120 technological innovations and other technologies and categorized them in the following sub-areas for the portfolio scan:

(a) **Advanced technological innovations:** Includes technologies explicitly mentioned in GEF strategies, STAP documents, and recent literature on technologies for the environment that are considered emerging and cutting-edge, such as Artificial Intelligence (AI) and green hydrogen.

(b) **Broad technological innovations:** This category includes advanced innovations as well as technologies with innovative elements that are not explicitly classified as emerging or cutting-edge, such as digital platforms and remote sensing or geospatial technologies (see table A3-1 for the complete list of both advanced and broad technological innovations).

(c) **Other technologies:** This category covers technologies not included in categories (a) or (b). It includes very broad technologies such as post-harvest technologies, which may incorporate some innovation but also long-standing technologies. This category also includes environmental approaches with significant technological elements that are not necessarily considered innovative.

7. The evaluation employed a portfolio scan based on the Project Component dataset from the GEF Portal, enabling systematic identification of technological innovation across the large portfolio of 2,016 projects. For each project, the portfolio scan examined project objectives, components, outputs, and outcomes. As not all innovations may be explicitly documented in this dataset, the quantitative findings should be considered a conservative estimate. To strengthen the analysis, the evaluation triangulated the scan results with stakeholder interviews and document reviews. This process identified additional instances of technological innovation, though the number of additional projects was relatively small. For example, while the scan

[1] The portfolio scan used the Project Component dataset from the GEF Portal, downloaded on July 2, 2024, to include all GEF-6-GEF-8 projects as of the end of FY2024 (excluding parents, cancelled, and dropped projects). The dataset includes information on project objectives, project components, project outputs and outcomes among other information. The team used CEO endorsement/approval data when available, otherwise PIF approval data.

identified four projects using blockchain, interviews and document reviews revealed two more, bringing the total to six. This suggests that the portfolio scan captured the majority of projects with cutting-edge technologies that were explored in greater depth.

III. BACKGROUND

8. **As global environmental challenges intensify, the ability to foster innovation while managing risk is increasingly essential for achieving meaningful and lasting impact**. For the GEF, the rationale for supporting innovation—particularly through the use of advanced technologies—has never been more compelling. These technologies offer the potential to address complex and systemic threats, such as climate change, biodiversity loss, and pollution at scale, where conventional solutions might be insufficient.

9. **The past decade has seen rapid technological advancement, offering unprecedented opportunities to address environmental challenges at scale.** These advancements blur physical, digital, and biological boundaries in what is often referred to as the Fourth Industrial Revolution (Schwab 2016). These technologies are "evolving at an exponential rather than a linear pace" and have the potential to transform entire human and environmental systems (Schwab 2016, p. 1; World Economic Forum 2017, 2020, 2021).

10. **Scientific and policy assessments recognize the importance of technological innovations in addressing global environmental challenges**. The Global Tipping Points report (Lenton et al. 2023) views technological innovations among the key enablers of positive tipping points that can trigger exponential progress towards climate, biodiversity, and sustainable development. By creating cascading effects, changes enabled by technologies in one sector can catalyze rapid transformation across multiple sectors (Lenton et al. 2023). These technological innovations include, among others, artificial intelligence (AI), big data analytics, Internet-of-Things (IoT), smart grids, renewable energy (notably green hydrogen), energy storage, blockchain, drones, and nanotechnology (Force for Good Foundation 2023, 2024).

11. **Calls for transformational change through technological innovations have increased within the GEF partnership and the broader literature**, alongside recognition of the challenges involved in achieving these goals in time to meet planetary objectives. The International Energy Agency states that reaching net zero by 2050 will require the rapid deployment of existing technologies and development of those not yet on the market, with nearly half of the needed emissions reductions relying on innovations still in demonstration or prototype stages (International Energy Agency 2020). The McKinsey Global Institute estimates that only about 10 percent of the necessary low-emissions technologies have been deployed so far (McKinsey 2025). As the GEF 2020 Vision notes, incremental strategies will not suffice given the scale of

environmental pressures, and the GEF must be equipped to promote transformational change, particularly in food, production and consumption, urban, and energy systems (GEF 2020).

12. **The STAP has provided advice and guidance on technological innovations, emphasizing their potential transformational role**. In 2018, the STAP identified novel entities or emerging technologies that were likely to be important to the GEF in the next five years. These were: technology critical elements, blockchain technology, next generation nanotechnology, gene editing, and cellular agriculture (STAP 2018b). Moreover, several recent STAP documents provide guidance to the GEF on harnessing technological innovations, including, among others, publications on Earth observation (STAP 2019a; Dean 2020), blockchain (STAP 2019b), technology critical elements (STAP 2020a & b), and agrivoltaics (STAP 2024), as well as reports on circular economy (STAP 2021a), climate mitigation (STAP 2021b), plastics (STAP 2018c), and food systems (STAP 2018a). During the TAG sessions in February 2025, the STAP highlighted the need for innovative ecosystem support to enable transformational change to meet planetary objectives.

13. **Technological innovations can also pose environmental, social, economic, and institutional risks.** The STAP has noted that technologies—if not intentionally aimed at sustainable transformation—may pose significant risks, including ecological harm from novel chemicals and biological agents, increased resource use and greenhouse gas emissions, social inequality and erosion of trust, economic disruption from job losses and data misuse. Through strategic investments, capacity building, and engagement with innovation communities, the GEF can help ensure that technological advancements align with environmental goals and catalyze transformational change (STAP 2023, 2024).

14. **GEF has a long-standing commitment to supporting innovation, including technological.** GEF was established to serve as an innovative mechanism for deploying solutions that can deliver global environmental benefits at scale. As observed by the GEF IEO, technological innovations have been an integral part of the GEF portfolio, together with policy, institutional, financial, and business model innovations (GEF IEO 2021). The GEF's role in supporting technological innovation is also important in providing seed capital to help promising technologies cross the "valley of death" – the critical interval between the proof of concept and availability of mainstream investment. STAP recommended the GEF finance technologies that need field demonstration or scaling to attract mainstream investors (STAP 2018), and a previous GEF IEO evaluation noted the value added of GEF support in bridging this critical gap for promising early-stage technologies (GEF IEO 2021).

15. **Innovation had been a defining element of the GEF partnership's comparative advantage** according to the GEF IEO's Seventh Comprehensive Evaluation of the GEF (OPS7) 2022). The OPS7 recommended the GEF to clearly articulate the level of acceptable risk to encourage innovation through a managed approach (GEF IEO 2022).

16. **To address this recommendation, the GEF has made notable institutional shifts.** The GEF-8 Strategic Positioning Framework emphasized innovation as a key driver for transformational change (GEF Secretariat 2022), supported by the establishment of an Innovation Window and reinforced by the adoption of the 2024 risk appetite statement, which assigns the GEF a high appetite for innovation risk (GEF 2024). These developments signal a clear commitment to enabling calculated risk-taking and forward-looking solutions designed to accelerate systemic change.

IV. FINDINGS

1. Technological Innovation in the GEF Portfolio

Main technological innovations supported by the GEF

17. **While technology is present in most GEF projects, emerging and cutting-edge technologies were found in 10 percent of projects.** In this regard, it is acknowledged that not all projects require cutting-edge technology to achieve their intended global environmental benefits. The portfolio scan found that, from GEF-6 to GEF-8, a wide range of technologies were supported, with most projects (63 percent of 2,016 projects) incorporating some technologies. Correspondingly, percentages for projects with broad and advanced innovations are 31 percent and 10 percent respectively (table 1). Stakeholder interviews indicated that the low presence of emerging and cutting-edge technologies in projects was mainly due to a lack of a structured approach to supporting technological innovations and external barriers such as limited capacities and infrastructure in countries to support innovations.

Table 1: Technology present in GEF projects: GEF-6, GEF-7, and GEF-8

GEF period	Any	Other	Broad	Advanced
GEF – 6	475	275	200	75
GEF – 7	574	265	309	105
GEF – 8	222	109	113	22
Total	1271	649	622	202
% of total projects (2,016)	**63%**	**32%**	**31%**	**10%**

Source: GEF Portal.

18. **The most common broad technological innovations in GEF projects were digital platforms, remote sensing and geospatial technology, and nature-based solutions**. These innovations were supported by 172, 161, and 97 projects respectively. The interviews with the GEF Secretariat and Agencies confirmed that these technologies often combine elements that are both innovative and longstanding. Among the relatively rarer cases of advanced technological

innovations, data modeling (79 projects), mobile applications (21), and sensor-based systems (20) are the most prevalent (annex 3 tables).

19. **Disruptive technologies with high environmental potential, as highlighted in scientific and policy literature, remain rare in the GEF portfolio.** Artificial Intelligence (AI) and machine learning (ML) were identified in 12 projects, often in a supportive role, but already showing early results. For example, in the project on unmanned aerial vehicles for equitable climate change adaptation in Colombia (GEF ID 10438, CAF), AI and ML supported risk analyses such as landslide prediction, feeding into early warning systems (annex 1, case study 2). Blockchain appeared in six projects, often as a supplementary rather than central feature (annex 1, case study 3). Technologies such as cellular agriculture and nanotechnology are largely absent. The role of disruptive technologies is explored further later in this section.

20. **Technological innovation in GEF projects is increasing.** From GEF-6 to GEF-7, the number of GEF projects incorporating technological innovations rose by 55 percent from 200 to 309 projects, according to the portfolio scan. For example, green hydrogen was absent in GEF-6 but grew to three projects in GEF-7, and to a full program in GEF-8 — the Global Clean Hydrogen Programme led by UNIDO, which includes 10 child projects. Figure 1 illustrates the top 10 technological innovations that experienced the strongest growth from GEF-6 to GEF-7. For instance, electric mobility projects grew from three in GEF-6 to 36 in GEF-7 — an increase of 1,100 percent. Similarly, nature-based solutions (such as constructed wetlands) grew from five to 41, representing a 720 percent increase.

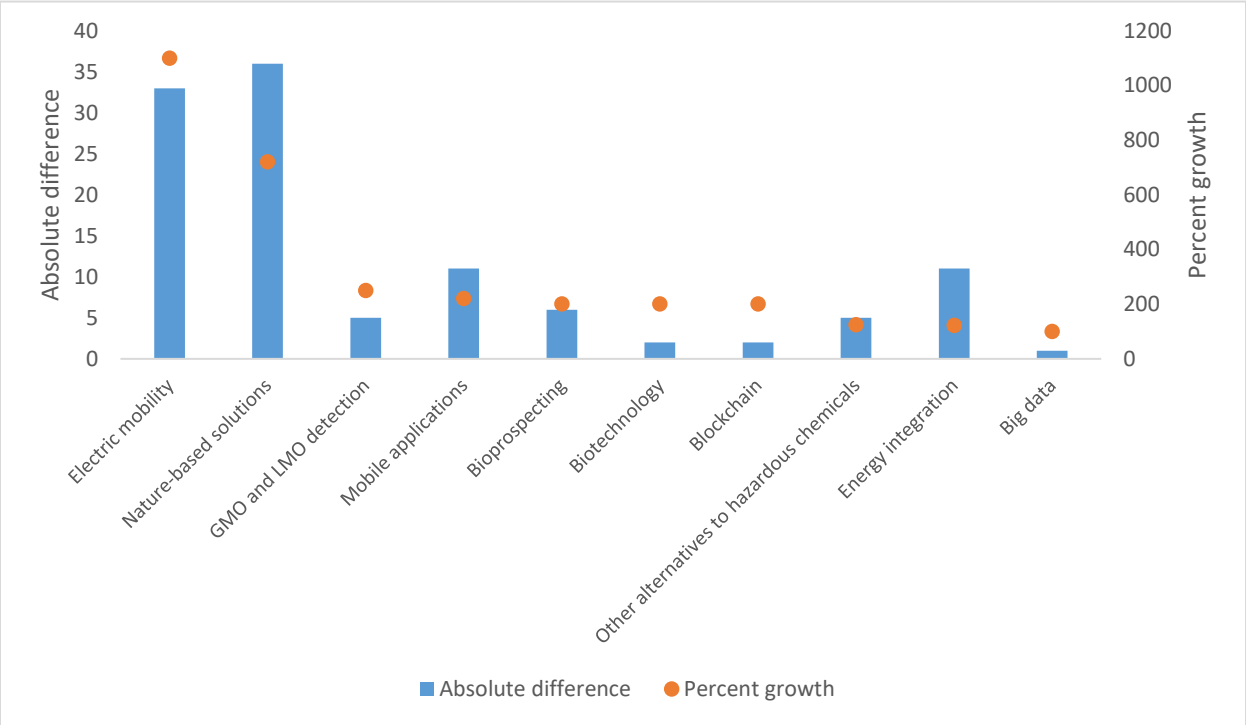
21. **Stakeholder interviews indicate that the recent focus on innovation in GEF strategies and approaches has supported the growth of technological innovations in GEF projects**. This expansion is attributed to initiatives of the GEF Secretariat such as the Challenge Program for Adaptation Innovation, non-grant instruments, the Innovation Window, and strengthened technical expertise within Agencies and countries. The STAP has also contributed guidance and advice on technological innovation during this period. Although innovation is intended to be mainstreamed across the portfolio, these targeted funding windows have played an important role in explicitly encouraging new approaches and in attracting nontraditional partners — including startups, investment and microfinance institutions, and technology-oriented academic institutions.

22. **These initiatives reflect the GEF's recognition that transformational change often requires testing unproven solutions and taking higher innovation risk.** The IEO's 2024 evaluation of Assessing Portfolio-Level Risk at the GEF found that although higher risk levels may sometimes be associated with lower outcomes, there are clear cases where high-risk projects have yielded significant benefits. For example, high-risk renewable energy projects focused on solar energy and policies to reduce fossil fuel subsidies achieved the highest possible outcome ratings (GEF

IDs 4345, 5297, 9567), demonstrating the potential rewards of targeted high-risk investments. These findings highlight the importance of balancing the GEF's generally cautious risk profile with a willingness to accept higher innovation risk in selected cases, particularly where the potential for transformational impact is high (GEF IEO 2024a).

23. **However, the overall risk profile of technological innovation in the GEF portfolio is low to moderate**. The GEF's risk appetite statement, which assigns a high appetite for innovation risks, was approved by the Council in 2024. Consequently, GEF-6, GEF-7, and early GEF-8 projects in the current portfolio were designed and approved before the risk appetite was established. While GEF-8 projects submitted after the approval of the risk appetite include relevant innovation risk ratings, the majority carry low to moderate innovation risk, including technology innovation risk. Additionally, case studies indicate that projects are not always consistent in considering energy demands of AI or data security implications of blockchain – well-documented risks identified by the STAP and broader literature.

Figure 1: Technological innovations with the highest growth in GEF projects from GEF-6 to GEF-7



Source: GEF Portal.

Note: GMO = genetically modified organism; LMO = living modified organism.

24. **The Challenge Program for Adaptation Innovation has begun to generate early results in developing and piloting specific technological innovations**. Launched in 2019 under the LDCF and SCCF, the program has awarded $40 million to a total of 32 projects in three rounds of

funding (GEF 2025). From the first two rounds, five projects included technological innovations, such as AI/ML, mobile applications, digital platforms, blockchain, and remote sensing. The GEF IEO identified early results from the first round (GEF IEO 2022a). Interviews with the GEF Agencies and the Secretariat confirmed that the program has successfully engaged new and non-traditional actors for the GEF, although it required partnering with an existing GEF Agency, and the available funding has been limited compared to the large demand (annex 2, snapshot 1).

25. **The GEF-8 Innovation Window has shown an early promise in supporting emerging and cutting-edge technologies, though it has been relatively small in size and is expected to be replaced with mainstreaming innovation across GEF projects and programs in GEF-9.** Launched in 2024, the Innovation Window selected seven projects with a total of $12.3 million in grants. Of these seven projects, three have a strong technological focus: harnessing social media and big data for wildlife use and trade indicators (GEF ID 11854, IUCN; $1.7 million); applying remote sensing and cloud computing to monitor jaguar corridors (GEF ID 11914, WWF; $1.7 million); and developing a digital compliance tool with satellite-based blockchain technology for the EU Deforestation Regulation (GEF ID 11835, IFAD; $1.7 million). Interviews with GEF Agencies' staff members reflected a positive initial assessment of the Innovation Window, while noting the limitations of its funding. The Secretariat also found it administratively heavy to manage relative to its size. As a result, the replenishment documents for GEF-9 propose mainstreaming innovation across the portfolio rather than continuing with a stand-alone window (GEF 2025a, 2025b, 2025c). This approach is consistent with OPS8 findings, which caution that expanding specialized funding windows adds to procedural complexity, and recommend streamlining and consolidating mechanisms. (annex 2, snapshot 4).

26. **GEF projects with technology components have higher private sector involvement**. The portfolio scan indicated that GEF projects with technological content had greater private sector involvement (67 percent) than those without (30 percent). As confirmed by stakeholder interviews, the use of technology in projects is largely facilitated by the private sector, which leads in its testing, development and roll-out—explaining why the private sector is often involved when technology is present. GEF IEO evaluations have also recognized the important role of the private sector as a source of innovation, and a partner for sustainable financing and scaling up; as well as the tendency of the private sector engagement projects to carry higher innovation risk ratings than the rest of the portfolio, including technological innovation risks. (GEF IEO 2021, 2025d).

27. **Non-Grant Instruments (NGIs) / blended finance have promoted technological innovation and made it easier to engage non-traditional partners such as private investors**. Between GEF-6 and GEF-8, the GEF allocated $115 million to 11 NGI projects in GEF-6, $95 million to 7 projects in GEF-7, and $194 million to 12 projects in GEF-8. While NGIs primarily target private sector engagement, project reviews show that NGI investments help de-risk and mobilize

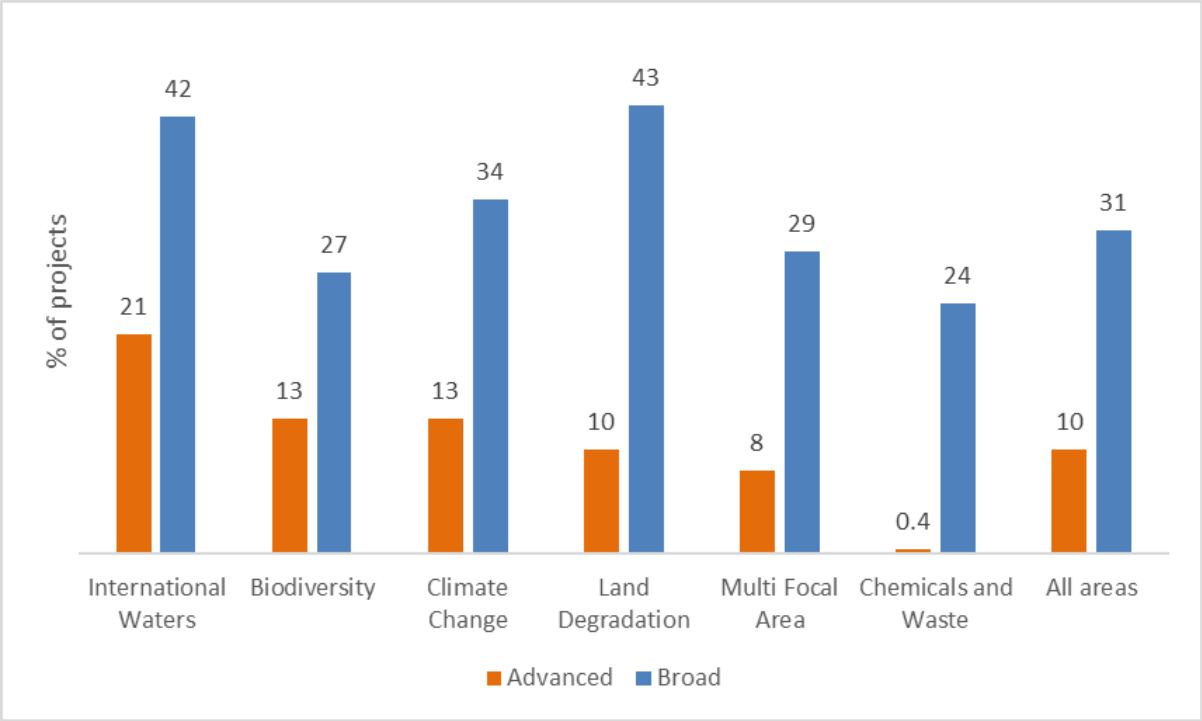
capital for emerging technologies. For example, the Decarbonization of Textile, Apparel & Footwear Suppliers (D-TAFS) fund (GEF ID 11326), an investment fund, incentivizes the adoption of cleaner production technologies, replacing traditional energy- and water-intensive processes in global supply chains. Conversely, technological innovations enable financial mechanisms to operate effectively by providing tools for monitoring, verification, and implementation. For instance, in Seychelles, the SWIOFish3 project (GEF ID 9563) integrates digital monitoring systems — including fisheries management information systems, vessel monitoring systems, and electronic logbooks — that provide the transparency and accountability needed for the Blue Bond and Blue Investment Fund to attract private investors and demonstrate environmental additionality (annex 2, snapshot 2).

28. **The strongest presence of technological innovations was in the international waters focal area.** As Figure 2 shows, 21 percent of international waters projects included emerging (advanced) technological innovations, and 42 percent included broad innovations – far above the averages of 10 and 31 percent across the portfolio. The GEF IEO evaluation of the international waters highlighted the flexibility of the focal area to test and pilot technological innovations across regions, along with its proactive and longstanding approach to knowledge management though the International Waters Learning Exchange and Resource Network (IW:LEARN) platform that promoted replication and scaling (GEF IEO 2025b).

29. Other focal areas followed: land degradation with 10 percent advanced and 52 percent broad innovations; climate change with 13 and 34 percent;[2] multifocal with 8 and 29 percent; and biodiversity with 13 and 27 percent. Chemicals and waste showed the presence of 0.4 percent advanced and 24 percent broad innovations, consistent with previous evaluation findings (GEF IEO 2021). This reflects the use of established technologies in chemicals and waste (for example, transferring technologies that are new to developing countries, such as sodium for polychlorinated biphenyl destruction), as well as emerging approaches, such as green chemistry and alternatives to hazardous chemicals. Moreover, many chemicals and waste objectives are also addressed through multi-focal area projects, where innovations are more prevalent.

[2] Including climate change mitigation (10 and 33 percent) and adaptation (21 and 39 percent).

Figure 2: Percentage of projects with narrow and broad technological innovations by GEF focal area (GEF-6-7-8)



Source: GEF Portal.

Note: These percentages are with respect to the total number of projects within focal areas. These are: international waters = 99, biodiversity = 289, climate change = 628 (including 461 climate change mitigation and 167 adaptation projects), land degradation = 88, multifocal area = 644, chemicals and waste = 268, All areas = 2016.

30. **Integrated programming [3] has evolved into a more structured and strategic programming modality from GEF-6 to GEF-8, supporting the adoption of technological innovation**. OPS8 findings confirm that integrated programming has both expanded and matured since its launch in GEF-6 (GEF IEO 2025d). Innovation is commonly included in integrated programs of GEF-6, GEF-7, and GEF-8, with designs aimed at transformational change (GEF IEO 2021, GEF IEO 2025d). Some programs have also made specific efforts to scale up transformative technologies. For example, the Food Systems Integrated Program (GEF ID 11214) provides guidance to child projects on adopting and disseminating agri-tech solutions.

31. **The full potential of integrated programming to promote a more proactive, strategic, and coordinated use of technological innovations across the GEF portfolio remains untapped**.

[3] Integrated programming refers to initiatives that tackle environmental challenges through holistic, cross-sectoral approaches. In the context of the GEF, this term encompasses both the GEF-8 integrated programs and other GEF initiatives that employ integrated strategies. In this report, the term "integrated programming" refers to the GEF-6 integrated approach pilots, the GEF-7 impact programs, and the GEF-8 integrated programs.

Progress in including technological innovations into integrated programs has not always exceeded that of the broad portfolio. For example, in the Sustainable Cities Program (GEF IDs 9077, 10391, 11287), 30 percent of projects included broad innovations such as digital platforms, remote sensing, data modeling, nature-based solutions, and smart grids — but this percentage was no higher than in other projects or programs.

32. Interviews with GEF Secretariat and Agency staff noted the absence of a more coordinated approach to technological innovation within integrated programming. This type of approach would include common methods of incorporating relevant technologies across all projects within a program, and/or frameworks such as technology/commercial readiness indices to help teams identify which innovations to support. Interviewees also noted that integrated programming knowledge platforms could play a stronger role, though challenges remain, including weak synchronization between global coordination projects and child project timelines, as well as limited resources and staff time allocated for knowledge management.

33. **IFAD, UNDP and the multilateral development banks incorporated emerging and cutting-edge technologies into their projects more frequently than other Agencies**. In GEF projects, IFAD, IDB, ADB, UNDP, CAF, and AfDB were all above the 10 percent average for advanced technological innovations, ranging between 11 and 30 percent. The analysis showed that UNDP and the multilateral development banks were statistically more strongly associated with technological innovations than other Agencies.

34. Interviews with Agency staff suggested that their ability to integrate technological innovations depended on several factors: their own institutional culture for encouraging technology adoption, the differing priorities of countries regarding innovation, and a perceived lack of flexibility in the GEF project design and approval process (see the Institutional Issues and Enabling Environment section).

35. **Geographically, technological innovations in GEF projects were widely distributed, , although they were more common in regional and global projects than in national ones**. This distribution reflects the flexibility and broader partnership networks at the regional and global levels, which facilitate the inclusion of advanced technologies and collaboration with specialized global partners.

Missed opportunities for technological innovations

36. **Several disruptive technologies with significant potential for environmental and socioeconomic benefits remain largely absent from the GEF portfolio**. Blockchain, for example, is present in six projects, while nanotechnology and cellular agriculture were not identified in any project.

37. Although it is not a widespread practice, the staff members from several GEF Agencies noted that STAP's advice directly influenced the integration of emerging technologies into proposals — for example, through the 2019 STAP workshop on harnessing blockchain for environmental benefits. These technologies hold considerable promise: blockchain can strengthen supply chain transparency and carbon credit verification; nanotechnology offers potential for water purification and pollution remediation; and cellular agriculture could reduce the environmental footprint of food production.

38. **The limited uptake of such technologies is not aligned with the pace of global technological development or the expertise already available within several GEF Agencies and multilateral organizations.** For example, UNDP has established a Blockchain Academy for United Nations (UN) personnel in over 170 countries (UNDP 2024); and the Food and Agriculture Organization of the United Nations (FAO) has developed expertise in cell-based protein, among other emerging technologies.[4] The global market for nanotechnology was projected to grow from $68.0 billion in 2023 to $183.7 billion by 2028, with applications relevant to GEF programs and focal areas already being commercialized in sectors relevant to GEF focal areas, including in African countries.[5] The example of the GEF-funded technology needs assessments (TNAs) supporting countries in identifying, prioritizing, and implementing technologies for climate change mitigation and adaptation illustrates how, as TNAs are country-driven, they may not identify technological innovations but more so prioritize technologies in sectors critical to their national economies and climate mitigation and resilience (annex 2, snapshot 3).

39. **The GEF partnership has missed opportunities for technological innovation due to several factors, including insufficient strategic guidance and monitoring, reliance on a demand-driven model, a rigid project cycle, and limited support for early-stage research**. Interviews with Secretariat and Agency staff pointed to specific barriers: the absence of a strategic approach for identifying and deploying technologies; limited capacity to monitor developments or systematically act on STAP's advice; and differences across Agencies in how strongly they promote innovation. They also noted that the GEF project cycle is often too inflexible for the fast pace of technological change, and that funding for early-stage research—critical to innovation—has been limited, while recognizing this is not the main focus of GEF funding

2. Effectiveness

Outcomes associated with technological innovations

[4] Source: FAO, Cell-based food and precision fermentation web page: https://www.fao.org/food-safety/scientific-advice/crosscutting-and-emerging-issues/cell-based-food/en/

[5] See, for example, BCC Research (2023); Campa et al. (2024); Khatoon and Velidandi (2025); Muhammad (2022); and UNECA (2020).

40. Innovation in the GEF portfolio is associated with higher outcome ratings and lower project failure. The 2021 GEF IEO evaluation on innovation found that 86 percent of reviewed completed innovative projects had outcome ratings in the satisfactory range, while 14 percent did not achieve satisfactory outcome rating at closure e (i.e., they failed). Similarly, in the portfolio scan for this evaluation, 87 percent of completed projects with broad technological innovation had outcomes ratings in the satisfactory range and 13 percent were rated unsatisfactory. This is higher than GEF's long-term average of around 80 percent satisfactory outcome ratings and 20 percent unsatisfactory ratings. However, as noted in paragraph 23, the overall innovation risk profile of technological innovation in the portfolio has been low to moderate, as most projects were designed before the 2024 high risk appetite for innovation was established.

41. **Technological innovations are associated with transformational change in the GEF portfolio**. Transformational change refers to "a deep, systemic, and sustainable change with large-scale impact in an area of a major environmental concern" (GEF IEO 2018). Previous GEF IEO evaluations have shown that technological innovations can serve as powerful catalysts that drive transformational outcomes when aligned with systemic levers such as policy, finance, and behavior change (GEF IEO 2018, 2021). Evidence from completed projects illustrates how technological interventions create the conditions necessary for sustained change at scale.

42. **Early-stage GEF support for wind energy in Uruguay demonstrates how technological innovation combined with policy support can transform an entire energy sector**. In Uruguay, the GEF supported wind energy development at an early stage through technical assistance and policy support (GEF ID 2826, UNDP). This project helped reduce perceived investment risks and paved the way for Uruguay's large-scale transition to renewable energy. By 2023, wind power accounted for more than 43 percent of the country's electricity generation, demonstrating how GEF interventions with a strong technological component can lead to sector-wide transformation (Leitzel 2025).

43. **In Kunming, China, technological innovation in solid waste management automation demonstrated how advanced monitoring systems can transform an entire sector while reducing public health risks**. The Municipal Solid Waste Management Project (GEF ID 4617, World Bank) introduced artificial intelligence to automate combustion monitoring at the Xishan and Konggang incinerators, maintaining dioxin emissions well below Stockholm Convention standards—with Xishan achieving levels as low as 0.0046 ng TEQ/m^3, far surpassing the 0.1 ng TEQ/m^3 target. The AI system has since been replicated in 22 incinerators across 13 provinces, while the pilot Integrated Emission Permit contributed to the official launch of national permitting standards and procedures for MSW incinerators. National guidelines were developed for harmonizing online monitoring systems across provincial and city levels. Since project completion, eight energy recovery companies have visited the demonstration incinerators to

learn and replicate the approach. The adoption of the advanced monitoring system across 22 facilities, coupled with national regulatory reforms, illustrates how pilot projects that use cutting-edge technology can achieve sector-wide impact through knowledge sharing and institutional change.

44. **Technological innovation has contributed to improved environmental monitoring and decision-making, enabling countries to track commitments and manage resources more effectively**. Improved monitoring has been achieved through the use of remote sensing, satellite and geo-spatial technology, drones, UAVs and AI/ML, among other technologies. For example, the Trends. Earth platform (http://trends.earth), supported through a series of Conservation International (CI) GEF projects (GEF IDs 9163, 10230, 11834) provides free global datasets for tracking changes in land degradation, aiding data harmonization and global reporting for commitments on the UN Convention to Combat Desertification (UNCCD) (Latham, Anderson 2018). Similarly Global Forest Watch (https://www.globalforestwatch.org), supported by several UN Environment Programme (UNEP)/ World Resources Institute (WRI) GEF projects since GEF-5 (GEF IDs 5356, 10050), provides free global forest monitoring to help reduce deforestation and facilitate commitments to restoration and forest biodiversity conservation. The platform is reportedly being used by thousands daily, including indigenous communities monitoring communal forests in the Amazon (GEF IEO 2022).

45. The Global Wildlife Program has deployed monitoring technologies such as the Spatial Monitoring and Reporting Tool (SMART), EarthRanger (a data visualization and analysis tool), and Low Range Wide Area Network (LoRa) technology to support conservation field personnel and strengthen protected area management effectiveness on a scale (GEF IEO 2024b). A non-grant instrument project, Piloting Innovative Investments for Sustainable Landscapes (GEF ID 9719), expanded its monitoring framework with satellite-based systems that enable daily fire detection using NASA data and detailed landscape analysis for screening investments and monitoring portfolio performance (annex 2, snapshot 2).

46. **Technological innovation has contributed to environmental benefits across GEF focal areas.** Based on the portfolio scan, GEF IEO evaluations, cases and interviews, examples were identified where technological innovation has contributed to all GEF focal areas, including:

(a) **Biodiversity**: GEF support has enhanced the protection of endangered species and habitats, while also combatting illegal wildlife trade through technologies such as GPS tracking, camera traps, drones, wildlife forensic technology (DNA analysis), and digital traceability platforms (GEF IDs 10431, 10484, 10551, 9527). The Small Grants Programme in Mexico has strengthened forest management and conservation by integrating traditional knowledge with technological tools such as drones and web-connected camera traps for forest management and conservation (GEF IEO 2025c).

(b) **Climate change**: GEF projects have reported greenhouse gas emission reductions through the adoption of electric vehicles, supporting EV infrastructure, and renewable energy integration (GEF IDs 9147, 9223). Nature-based solutions and green infrastructure have strengthened urban resilience while contributing to carbon sinks (GEF ID 10768). Grid modernization and energy-efficient appliances have further helped reduce emissions (see case study 1). Climate change adaptation projects also reported outcomes linked to technological innovations including AI and drone-based monitoring systems that achieved up to 87 percent accuracy in detecting landslide risks (GEF ID 10438), solar-powered water systems that secured access and reduced the risk of drought for nearly 10,000 vulnerable people (GEF ID 10514). Furthermore, technical assistance for adaptation SMEs has deployed innovative grain storage and water purification technologies, directly reducing post-harvest losses by 20 percent and improving community health by supplying access to clean drinking water for 620 community inhabitants (GEF ID 10296).

(c) **International waters:** GEF support has improved water quality, enhanced fisheries management, and strengthened marine ecosystem protection. In the Yellow Sea project (GEF ID 4343), integrated multi-trophic aquaculture increased productivity while reducing pollution, and the approach was shared with three Caribbean countries through IW:LEARN. Constructed wetlands in three projects (GEF ID 5353, 6962, 9121), including a Kura River Basin pilot (GEF ID 6962), naturally treated polluted water and reduced nitrogen levels by 85 percent. The Common Oceans program has advanced monitoring technologies that improved fisheries management and reduced bycatch, while better ballast water management has helped prevent the spread of invasive species in shared marine areas

(d) **Land degradation**: National capacity to monitor land cover change, degradation, and carbon stocks has improved through GEF projects, such as Trends. Earth. Further, GEF-supported land degradation satellite monitoring technologies have helped countries set and monitor voluntary land degradation neutrality targets (GEF ID 5835) (GEF IEO 2022).

(e) **Chemicals and waste**: In earlier GEF cycles (GEF-3 throughGEF-5), projects in Slovak Republic, the Philippines, and Ukraine successfully piloted non-combustion technologies for safe disposal of hazardous chemicals and persistent organic pollutants and improved efficiency in agriculture. (GEF ID 1692, 2329, 4386). Projects addressing emerging waste streams have advanced battery end-of-life management in electric mobility to reduce toxic waste risks (GEF ID 9147). A GEF-7 regional project in Asia and the Pacific is piloting the use of AI to improve monitoring of plastics pollution in river ecosystems at scale (GEF ID 10628). The GEF IEO evaluation of GEF-5 to GEF-8 found that technological innovation has played a vital

role in the chemicals and waste area, although this was a mixture of long-standing technologies, such as equipment to detect hazardous chemicals and emerging technological innovations, such as green chemistry (GEF IEO 2024c). The development and scale-up of Neem-based and bacteria-based alternatives to DDT in India have introduced new, locally produced biopesticides and related technologies (GEF ID 4612). In China, the VCM sector project has engaged in significant R&D to develop and industrially test mercury-free catalysts, including gold- and copper-based alternatives (GEF ID 6921). Other initiatives are piloting de-bromination technologies to safely treat HBCD-contaminated materials (GEF ID 10163, 10082).

47. **Technological innovation in GEF projects has generated socio-economic benefits alongside environmental outcome**s. For example, nature-based solutions have created new jobs (GEF ID 10768), while remote sensing has enabled improved property tax systems that increased local revenue (GEF ID 10768). Electric vehicle supply chains have expanded local markets (GEF IDs 9147, 9223), and advanced watershed treatment technologies have contributed to higher farm incomes (GEF IEO 2018).

48. At the program level, the Global Cleantech Innovation Programme (GCIP), a GEF-UNIDO initiative, has strengthened innovation and entrepreneurship ecosystems by helping small and medium enterprises (SMEs) turn cleantech solutions into viable businesses. Activities such as national investor forums proved effective in securing capital. Similarly, the AgTech Agventures II Fund (GEF ID 10336, IDB) is pioneering a venture capital model for novel agricultural technologies in Latin America, and has secured $58 million for 17 technology startups offering digital, biotech, and automation solutions. These innovations not only reduce emissions and land degradation, but also improve chemical management and strengthen livelihoods of small and medium-size farms (annex 2, snapshots 2 and 5).

49. **Case studies and stakeholder interviews highlight how technological innovation has been closely linked with advancing inclusion in GEF projects**. Women, youth, Indigenous Peoples, and other vulnerable groups have been actively engaged to co-create innovation, share benefits, and reduce vulnerability. For example, the Inclusive Conservation Initiative (GEF ID 10404, CI and IUCN) combined Indigenous knowledge with GPS technology to produce biocultural maps and calendars, empowering Indigenous Peoples and Local Communities (IPLC) to participate in environmental monitoring and decision-making. In Viet Nam, a green chemistry project (GEF ID 9379, UNDP) engaged youth by integrating green chemistry in university curricula and launching a student competition that resulted in innovation, such as brick alternatives from foam waste. The Global GreenChem Innovation and Network Programme (GEF ID 10353, UNIDO) encouraged inclusion by supporting women- and youth-led startups, with tailored innovation challenges in countries such as Serbia and Uganda.

50. Other projects have used blockchain and mobile platforms in agricultural and fisheries traceability to deliberately empower women and Indigenous Peoples—through targeted training with gender and transcultural elements (GEF ID 10307, UNDP), gender-sensitive digital compliance tools that ensure women farmers benefit equally (GEF ID 11835, IFAD), and mobile payments giving women direct control over income (GEF ID 10637, IUCN). These examples show that when technological innovation is coupled with explicit attention to inclusion—through capacity building, digital literacy, and accessibility—it not only delivers environmental benefits but also expands opportunities and agency for marginalized groups.

3. Institutional Issues and Enabling Environment

Enablers and Barriers to Technological Innovation

51. Based on the analysis of technological innovation across the GEF portfolio, several key factors emerge that either facilitate or hinder the effective support of technological innovation. Understanding these enablers and barriers is crucial for strengthening the GEF's capacity to support technological innovation in future programming.

52. **Several key enablers support technological innovation in the GEF partnership.**

(a) **Institutional capacity and culture** that promote innovation are reflected in the willingness of the GEF Secretariat and Agencies to encourage risk-taking, strengthen knowledge management, and leverage integrated programming and advisory support from the STAP, while also drawing on technical expertise within the Agencies and countries.

(b) **Financial and organizational mechanisms** that have shown potential to facilitate innovation include, among others, targeted initiatives such as the Challenge Program for Adaptation Innovation, NGIs / blended finance approaches designed to share and manage risks.

(c) **Effective partnerships**—particularly with private sector actors, global institutions, research organizations, social groups, and knowledge-sharing initiatives—further enhance innovation by enabling access to technical resources, infrastructure, and financing. This also included projects that considered the role of CSOs, local communities, and youth in driving technological innovation.

(d) **Supportive national policies and strategic frameworks,** including those related to electric mobility, green hydrogen, and enabling regulatory environments, create favorable conditions for adopting emerging and cutting-edge technologies.

(e) **The presence of technological readiness and infrastructure**—such as advances in AI/ML, blockchain, digital systems integration, and the availability of enabling

platforms and tools—forms the foundation for deploying and scaling technological solutions, in addition to working with open source solutions where possible and avoiding funding proprietary tools.

53. **However, some barriers continue to limit the GEF's ability to effectively support technological innovation.**

(a) **The most significant barrier is strategic**. While GEF's country-driven, demand-driven model is a core operating principle that ensures country ownership and must be maintained, the partnership currently lacks complementary system-wide approaches and tools to support countries and Agencies in identifying, testing, deploying, and scaling technological innovations. As a result, some promising opportunities with significant environmental potential may have been missed, partly due to limited partnership-level horizon scanning, trend monitoring, and knowledge exchange on emerging technologies. Although the STAP provides guidance on technological innovation, its recommendations have seen limited uptake in GEF projects and programs.

(b) **The GEF project cycle is not well aligned with the fast pace of technological advancement**. Integrating innovative technologies often requires flexibility in project design, the ability to fund research and piloting components, and mechanisms to adapt partnerships or technologies during implementation— needs that are not fully accommodated by current GEF processes. The GEF IEO has previously highlighted the need for greater encouragement of adaptive management, especially for GEF projects involving innovative interventions (GEF IEO 2021).

(c) **Limited strategic partnerships and coordination with the private sector**, that are critical for technology incubation and transfer, mostly happen at the individual project level rather than through sustained global or regional partnerships, reducing the potential for scaling and investment leverage.

(d) **Country-level capacity constraints also pose a significant barrier.** Many countries face shortages of qualified environmental technology professionals, limited access to technology infrastructure, low technological literacy, and institutional resource gaps. Gender disparities, outdated data systems, fragmented stakeholder coordination, and overreliance on external technical services further complicate efforts to scale innovation. These factors make it difficult to replicate successful innovations and limit the potential for transformational outcomes across regions and sectors.

V. CONCLUSIONS

54. **The GEF's commitment to technological innovation is increasing, yet its full potential remains unrealized.** The GEF partnership increasingly recognizes technological innovation as essential for achieving transformational change. Positively, technological innovation in GEF projects is gaining more prominence, supported by the recent approaches of the GEF Secretariat, STAP and Agencies that have encouraged innovation. While technological innovations such as electric mobility, remote sensing and digital platforms have grown exponentially in recent years, truly emerging and cutting-edge technologies such as AI/ML, blockchain, and nanotechnology are still rare in the portfolio, reflecting gaps in a proactive approach, dedicated funding, and systematic mainstreaming. The GEF risk appetite statement, which assigns a high appetite for innovation risks, was approved in 2024, and most projects reviewed in this evaluation were designed before the risk appetite was established. At the same time, the 2021 evaluation on innovation had already identified opportunities to strengthen GEF support to innovation. The 2021 and the current evaluation findings signal that the GEF partnership needs to fully embrace its commitment to innovation in future projects and programs.

55. **When aligned with local needs and enabling conditions, innovation can drive transformation.** Where technological innovation has been integrated effectively, it has contributed to environmental and socio-economic benefits across all focal areas. These successes highlight that transformational change implies matching technological solutions to local needs and capacities often combined with other types of innovation, including institutional and policy, financial and business model innovation. Involving local stakeholders and communities in project design and innovation supports scalable, open access, and sustainable technological solutions rather than proprietary tools.

56. **Capacity gaps, fragmented partnerships, and limited foresight on emerging technologies impede uptake and scaling of technological innovation.** Many countries face shortages of skilled professionals, weak digital readiness, and gaps in institutional frameworks. Partnerships with the private sector, research institutions, and technology firms remain mostly ad hoc and project-specific rather than strategic and sustained. While integrated programming has started to foster more strategic and systemwide adoption of technological innovation, its full potential still remains to be met. Furthermore, the GEF lacks a structured approach for periodic horizon scanning and foresight to systematically identify promising emerging technologies; where STAP has provided guidance on emerging technologies, it has had limited adoption in the technological choices made by Agencies and countries for GEF projects and programs. While some GEF Agencies have strong capacities to identify and apply emerging technologies—for example, several Agencies have expertise in AI/ML and other cutting-edge innovations—there are insufficient mechanisms for partnership-level sharing to leverage this expertise across the

GEF portfolio. Strengthening collaboration—both among Agencies and with the private sector—along with generating more evidence on how technologies support delivery of global environmental benefits (GEBs) is critical to ensure that innovation is leveraged effectively in line with GEF's mandate.

57. **Rigid processes, limited risk-taking, and insufficient early-stage funding constrain bold innovation.** Inflexible project cycles and complex approval processes have made it difficult to support higher-risk, higher-impact technological innovation. While instruments like Challenge Program for Adaptation Innovation, and NGIs exist and have shown some promising results, there is still little funding specifically for early-stage piloting, considering also that they are demand-driven. The high innovation risk appetite has yet to be translated into widespread support for technological innovations, such as focusing on establishing collaborations to leverage R&D and the application of technological innovation in GEF projects.

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VII. ANNEXES

ANNEX 1: CASE STUDIES

Case study 1: Sustainable Cities Integrated Programming

1. Introduction

Emerging from the GEF 2020 Strategy (GEF 2015a), the Sustainable Cities Integrated Programming responded to the growing concentration of climate change risks in urban areas—ranging from heat stress, extreme precipitation, flooding, landslides, and air pollution to water scarcity and droughts (IPCC 2014). At the same time, cities accounted for more than 70 percent of global carbon dioxide emissions (Fragkias & Seto 2013), and with urbanization levels continuing to rise, these problems are expected to intensify.

However, urban areas also offer a promising pathway toward long-term sustainability. As they accommodate over half of the world's population on less than 3 percent of the Earth's land surface (UNFPA 2007), cities present a unique opportunity to achieve both local development and global environmental goals. Recognizing this potential, the GEF launched the Sustainable Cities Integrated Approach Pilot (Sustainable Cities IAP) in 2016 under the GEF-6 funding cycle (2014–2018) to generate higher returns on investment through systemic, integrated solutions (GEF, 2015a). The pilot brought together 28 cities in 11 countries—including Brazil, China, and India—to test new models of sustainable urban development.

The Sustainable Cities IAP aimed to promote sustainable urban development through more integrated models of urban design, planning, and implementation (GEF 2015b). Conceived as a proof of concept, the program was designed to build a global network of cities that serve as champions of sustainable urban planning, generating both local and global environmental benefits. Unlike traditional, project-based approaches, the interventions under the Sustainable Cities IAP were intended to influence future resource flows and investments beyond the project's life cycle.

Building on the pilot's momentum, the GEF launched the Sustainable Cities Impact Program (SCIP) in 2019 during the GEF-7 cycle as a fully scaled Impact Program (GEF 2019). SCIP supported cities in adopting integrated urban planning approaches that deliver meaningful development outcomes alongside global environmental benefits. The most recent phase, Sustainable Cities Integrated Program (also, SCIP) launched in 2023 under GEF-8, represents a further evolution of the program (GEF 2023). Its objective is to support cities and local governments in undertaking integrated urban planning, implement policies, and invest in nature-positive, climate-resilient, and carbon-neutral urban development. The program aims to promote innovations, including technological ones, to help achieve this objective.

Across the GEF portfolio under evaluation, a total of 43 projects are part of the Sustainable Cities Integrated Programming portfolio. These are distributed as follows: 12 in GEF-6, 10 in GEF-7, and 21 in GEF-8 (figure A1-1). Regionally, the projects span Africa (15), Asia (12), Latin America and the Caribbean (12), with three global projects and one in Europe and Central Asia (ECA) (figure A1-2). As

of May 2025, of these, six have been completed, 16 are currently active, and 21 (all under GEF-8) are at the CEO endorsement stage. All projects are multifocal area and full-size (table A1-1-1).

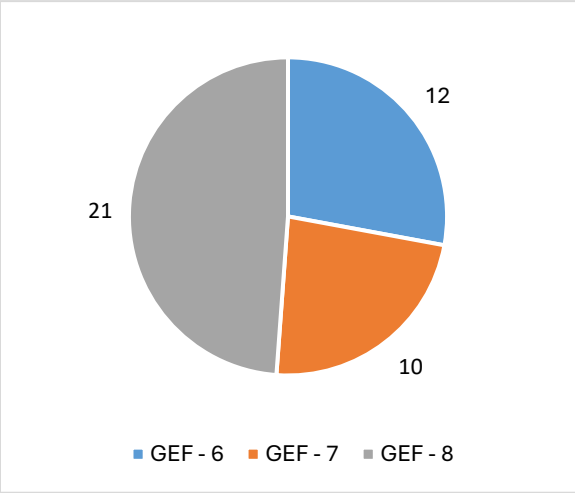

Figure A1-1. Projects by GEF period.

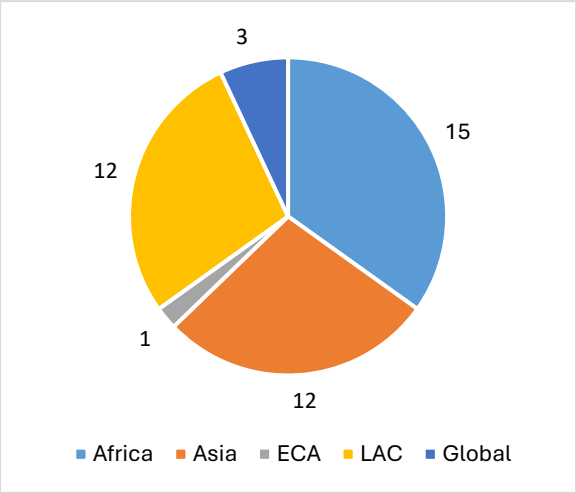

Figure A1-2. Projects by region.

2. Use of technological innovations

Recognizing that cities need a multifaceted approach to tackle their challenges and achieve sustainability, the projects under the Sustainable Cities Integrated Programming often involve the deploying multiple technologies across diverse areas, frequently through pilot initiatives that provide practical demonstrations of their effectiveness.

Within the portfolio scan of project summaries of the Sustainable Cities integrated programming projects, 30 percent of projects (13 of 43 projects) mentioned broad innovative technologies in their summaries, while 4 of these projects (9 percent) mentioned advanced innovative technologies.[6] The projects have seen technological innovations applied in support of decision-making in cities, such as digital platforms, remote sensing and geospatial technologies, data modelling, as well as to support core infrastructure interventions, such as smart grids, electric mobility, energy storage, energy integration, and nature-based solutions. Based on the portfolio scan and stakeholder interviews, five projects were selected for in-depth reviews for diversity in regions, GEF periods, and geographical areas, (Table A1-1-2).

A key technological innovation present in the reviewed projects is the application of NbS to address a variety of issues. NbS play a central role in three out of the five projects analyzed (GEF ID 10484, 10768, 11288). These include activities such as the restoration of water bodies, mangrove forests, and other natural spaces (GEF ID 10484, 10768, 11288), as well as large-scale tree planting (GEF ID 10768).

[6] Technological innovations may have been present in other projects but not identified by the portfolio scan.

Another prominent technology leveraged is remote sensing and geospatial technologies, which appear in four out of five projects (GEF ID 9223, 10484, 10768, 11288) These are key technologies to advance integrated urban planning which is the core intervention area of the Sustainable Cities program.. Geospatial data may be incorporated into databases supporting national transit-focused platforms (GEF ID 9223), high-resolution satellite imagery may be employed in storm management systems (10484), or integrated into national spatial data infrastructure systems (GEF ID 11288). Geospatial technologies supported the SISDIA platform in Brasilia, a key-decision making tool for urban planning and for promoting sustainability solutions (GEF ID 9142). Remote sensing technologies were used to develop a detailed, city-wide digital terrain model for Kigali, Rwanda, supporting urban infrastructure planning that integrates nature within and around the city (GEF ID 10530). In other instances, however, remote sensing and geospatial technology serve as key instruments for innovation—for example, transforming the Municipal Property Tax System through the use of satellite imagery to reassess all properties (GEF ID 10768).

Digital platforms are expected to be deployed in four out of five projects, although in many cases they serve primarily as instruments for hosting or conveying information, rather than being innovative on their own. For example, these platforms may function as diagnostic tools for cities to assess their transport infrastructure (GEF ID 9223), or foster citizen engagement and collaboration in ongoing interventions (GEF ID 10484, 10768). In other cases, however, they can underpin major changes, such as the creation of a carbon market digital infrastructure (GEF ID 11288).

Technologies related to sustainable transport are also noteworthy, appearing in two of the five reviewed projects. These range from the promotion and adoption of electric mobility and the development of charging infrastructure, to urban planning strategies aimed at facilitating public transit, walking, and cycling. This includes the adoption of transit-oriented development (TOD)—a design approach that supports vibrant, diverse, and livable communities through integrated transport and land use planning (Ollivier, Ghate, Bankim, & Mehta, 2021). These elements often contribute to a broader technological framework. For example, electric vehicle promotion and related infrastructure are used to support the development of smart grids or integrated transport systems (GEF ID 9147, 10484), while the TOD appears to play a more central role in structuring and delivering the projects (GEF ID 9223, 10484). For example, in Guiyang, China (GEF ID 9223), the TOD approach facilitates effective multimodal connectivity, linking rail with other transport modes as well as adjacent residential and commercial areas. Its smart ticketing system—featuring facial recognition, QR codes, and smart cards integrated with national e-payment platforms such as Alipay—facilitates seamless transfers across multiple modes of transport within a single trip.

Among the five projects, waste management technologies and renewable energy systems also feature prominently in three projects. Waste management innovations range from the construction of modern bioreactor landfills (GEF ID 10768) to the installation of composting equipment, waste bins, and related operational infrastructure (11288) and using plastic waste as an input to develop RESIN8 aggregate which is a low carbon sustainable construction material (GEF ID 10467). Regarding renewable energy, technologies include solar energy systems (GEF ID 9147) and biogas solutions (GEF ID 11288).

Finally, a variety of other technologies play varying roles across the projects. These include smart grids (GEF ID 9147), early warning systems (EWS) (GEF ID 10768), water management (GEF ID 10768), machine learning (GEF ID 10768), mobile applications (GEF ID 10768), big data (GEF ID 9223), and sustainable finance (GEF ID 11288).

3. Outcomes/added value

Projects under the Sustainable Cities Integrated Programming often set ambitious goals regarding the added value and benefits that technologies can bring. While some of the analyzed projects are still in early stages and lack outcome data (GEF ID 10484, 11288), others demonstrate positive impacts from both the programming and the technologies employed. Notably, some ongoing initiatives (GEF ID 9147, 10768) already show tangible results. Nevertheless, due to the diverse technologies being deployed, the success of implementation tends to vary across projects.

Among the achieved benefits, environmental outcomes—particularly reductions in CO_2 and broader GHG emissions—stand out. These have been realized through the adoption of electric vehicles, the development of EV infrastructure, and the deployment of renewable energy (GEF ID 9147), the implementation of nature-based solutions (GEF ID 10768), and TOD that supports regeneration, improved execution, and low-carbon transport (GEF ID 9223). These environmental benefits are expected to have both local and global impacts.

Economic benefits have also been reported, though they appear closely tied to the specific application of the technology under consideration. For example, while remote sensing has often been linked to (expected) improved monitoring capabilities, its use in enhancing property tax systems has also generated direct economic value through increased tax revenues (GEF ID 10768). In other cases, nature-based solutions, though primarily aimed at environmental outcomes, have created employment opportunities when implemented in a labor-intensive intervention (GEF ID 10768). Additional economic gains include the expansion of local markets, such as increased EV supply through local manufacturers (GEF ID 9147).

Overall, the environmental and economic benefits achieved so far are largely in line with the value-added outcomes the technologies were expected to deliver.

Other anticipated benefits, which are still in progress in some projects, include improved urban governance and planning capacity through digital and geospatial technologies. For example, remote sensing, geospatial tools, and digital platforms are expected to support better monitoring, data-driven decision-making, and more efficient implementation of urban development initiatives (GEF ID 10768, 11288). These tools are also linked to expected improvements in transparency and accountability in urban governance (GEF ID 10768). Further expected outcomes include enhanced resilience of both ecosystems and livelihoods through NbS and/or improved EWS (GEF ID 10484, 10768); improved natural resource management and biodiversity conservation through NbS (10768); enhanced public health and urban liveability through the promotion TOD and/or NbS (9223, 10484); and increased property values through TOD (GEF ID 9223). Furthermore, several projects aim to drive market transformation in specific sectors. These include the creation or promotion of green investment platforms and sustainable credit markets (GEF ID 9223, 10484, 11288), as well as the

development of new economic sectors such as ecotourism (GEF ID 10484) and a circular economy-focused waste management market (GEF ID 10768).

4. Institutional support; enablers and barriers

Projects under the Sustainable Cities Integrated Programming have supported technology deployment through policy development and technical assistance (GEF ID 9223, 10768), capacity building and networking (GEF ID 9147, 9223, 10484, 10768), and pilot initiatives and procurement (GEF ID 9223, 10768).

In designing these activities, project developers often overlook comprehensive risk assessments and corresponding mitigation strategies related to the technologies being deployed. Among the five projects analyzed, only one (GEF ID 9147) includes a relatively well-developed analysis of the potential risks associated with the technologies. The remaining projects either omit this analysis entirely or address it only marginally—typically focusing on a single technology rather than the full suite being deployed. This risk analysis covers both technical risks—such as vulnerability to climate impacts, potential technology failure, and issues arising during the technology's lifecycle like equipment disposal at decommissioning—as well as social and behavioral risks, including possible skepticism or lack of interest in adopting the new technology. Mitigation activities encompassed capacity building on areas where technological gaps are identified and need to be bridged to also promote local ownership of project activities, and the provision of support to implementing agencies during project implementation to ensure proper management and mitigation of all project risks. Despite this, additional risks emerged during implementation, such as poor uptake of the technology due to COVID-19–induced supply chain disruptions, use of defective products, shorter-than-expected product lifespan, and other functional failures that affected infrastructure maintenance. Across the reviewed projects, there is a general tendency to overlook key risk areas associated with technologies, particularly:

- Data privacy and security, and system interoperability when digital platforms are involved;
- Unmet assumptions regarding the availability of skilled personnel and local capacity for technology operation and maintenance;
- Sustainability risks, including those linked to market failure, unaffordable operating costs, and ecological factors that may compromise technology performance.

The projects also frequently identify a range of enabling factors expected to support the deployment and uptake of the technologies. Commonly cited drivers include government support, such as the adoption of enabling policies, strategies, or the integration of technology-related targets into broader development plans (GEF ID 9147, 9223, 10484, 10768, 11288). Past initiatives that offer lessons learned, as well as ongoing projects that can create synergies, are also seen as key enablers (GEF ID 9147, 10484, 10768, 11288). Local capacity, and engagement with a range of stakeholders having relevant technical expertise—such as universities and research institutions (GEF ID 9147, 10484, 10768, 11288), national utilities and state-owned enterprises (GEF ID 9147, 11288), NGOs and international organizations (GEF ID 10484, 10768, 11288), and private sector actors (GEF ID 9147, 9223, 10484), including local women- and youth-led enterprises (GEF ID 11288) or other small and medium enterprises (GEF ID 10768)—are highlighted as critical factors for the effective

implementation of technology-related activities (GEF ID 9147, 10768, 11288). In several cases, local interest and willingness to adopt the technologies under consideration are also mentioned as supportive drivers (GEF ID 10484, 10768).

Notably, one project justifies the use of NbS by referencing the economic relevance of the natural habitat under consideration (GEF ID 11288). In some instances, projects report previously unanticipated drivers—such as renewed political commitment and leadership from local partners (GEF ID 9223), the availability of local technical expertise (GEF ID 9223), and the mobilization of additional funding through tech-related activities (GEF ID 10768. Finally, enabling project activities for technology involve embedding knowledge and learning directly into interventions, utilizing digital platforms (GEF ID 9147, 9223) for information sharing and employing M&E frameworks (GEF ID 9147, 10484, 9223, 10768) to track deployment and outcomes. Scaling and replication are pursued through roadmaps, replication plans, and toolkits (GEF ID 9147, 9223, 10484, 10768, 11288), often validated by demonstration projects (GEF ID 9147, 10484, 10768, 11288).

The project reviews identify a variety of barriers that constrain the adoption and scaling of technologies, often reflecting institutional, technical, financial, and contextual limitations. Importantly, these could affect only a subset of the technologies being deployed in a project. An observed challenge is the absence of enabling policies, institutional frameworks, and/or regulatory frameworks, or siloed governance structures (GEF ID 9147, 10484). Limited technical capacity and awareness are also barriers that yield gaps in local knowledge and experience with integrated technologies, such as smart grids and NbS (GEF ID 9147, 10484). These capacity deficits often translate into low user acceptance and limited stakeholder buy-in, particularly when the perceived complexity or economic uncertainty surrounding the technology is high (GEF ID 9147, 9223, 10484). These deficiencies in capacity and buy-in can lead to unintended consequences. In one project (9147), for instance, smart meters—intended to help consumers monitor energy use—caused public dissatisfaction due to higher electricity bills from more accurate measurements and increased consumption during COVID-19 lockdowns. Financial and operational constraints further impede progress. Projects report a lack of sustainable financing, both for infrastructure (GEF ID 11288) and for the business models underpinning the technology (GEF ID 10484), particularly where private sector involvement remains limited.

Operational barriers such as outdated or damaged infrastructure and poor contract management complicate the implementation of technological innovations (GEF ID 10768, 11288). Complex interventions often face implementation and financial hurdles unrelated to the technologies themselves, hindering progress due to the need for smooth multi-stakeholder coordination. For example, a waste management technology project (GEF ID 10768) was delayed by lengthy procurement, health and political crises, and logistical issues. The COVID-19 pandemic and other socio-political disruptions have also introduced delays and contributed to reduced participation by key project actors (GEF ID 10768 and 9147). Similarly, the anticipated connection between technology deployment and systemic change may weaken, as seen with an urban development capital market (GEF ID 9223) that might not materialize as expected. Finally, context-specific challenges emerge in urban development projects, such geographical or city-level constrains (GEF ID 9223).

5. Lessons identified from the use of technological innovations in this programmatic area (optional)

Although six project has reached completion and the other four have not necessarily reached advanced stages across all technologies, some lessons can be drawn from the current implementation of the Sustainable Cities Integrated Programming projects. In addition to broader insights related to overall implementation challenges, specific lessons concerning the deployment and performance of technology-related interventions are summarized below.

1. **Risk anticipation**. A project highlighted that relying only on familiar and forecastable risks can leave it vulnerable to unforeseen events, like a pandemic, which delayed smart grid implementation (GEF ID 9147). This experience underscores the need to consider less predictable, high-impact risks—such as health crises or rare natural disasters—to build more resilient implementation plans. Moreover, as described above, it was noticed that most projects do not entail a detailed risk analysis that is strictly focused on the technologies being leveraged. Given the diverse and multiple technologies employed by Sustainable Cities Integrated Programming projects, it is of paramount importance that the project design undertake a comprehensive risk analysis of the technologies being deployed, including, but not limited to, risks on:
    a. Technical performance and lifecycle: Covering technology failure, shorter-than-expected product lifespans, and challenges with equipment disposal at decommissioning.
    b. Data and digital systems: Addressing data privacy, cybersecurity, and the interoperability of different digital platforms.
    c. Long-term sustainability: Including unaffordable operating costs, potential market failure, and the lack of local skilled personnel for operation and maintenance.
    d. Social and behavioral factors: Assessing public skepticism or lack of interest that could lead to poor technology adoption.
2. **Stakeholder engagement and coordination**. Stakeholder engagement and coordination emerged as critical for project success, particularly in digital and multi-actor settings. One project's implementation of its integrated command and control centers (ICCCs) was hindered by stakeholders' reluctance to share sensitive spatial data (GEF ID 10484), which highlighted the need for trust and appropriate data governance. Also, an experience showed that technical improvements, such as the rollout of smart meters, do not guarantee user acceptance—especially when they result in higher perceived costs to end-users (GEF ID 9147),—underlining the importance of user-centered rollout strategies. Another project encountered challenges in coordinating multiple cities under a single thematic structure, learning that streamlined design helped localize shared frameworks like TOD (GEF ID 9223). Finally, another project experienced how community opposition can force significant changes to project components, reinforcing the need for early and meaningful public consultation (GEF ID 10768).
3. **Effective design**. A project found that tech-focused interventions need results frameworks with clear indicators to measure the quality and frequency of capacity-building activities to ensure the technology is used effectively (GEF ID 9223). In another project, a practical lesson was that operational costs, such as hosting knowledge products on national learning platforms,

must be explicitly included in the project budget from the start to ensure sustainability (GEF ID 10484).

In addition to project-specific evaluations, a broader assessment of the use of NbS within the GEF portfolio (GEF IEO, 2025) highlights that, although the GEF has been a significant financier of NbS, the absence of a clear, shared definition and a consistent results framework for tracking and aggregating outcomes has limited its ability to assess and demonstrate the effectiveness of these interventions. The evaluation also identified several challenges, including limited local capacity for NbS implementation and monitoring, weak governance and enforcement, and the lack of long-term financing mechanisms.

Annexes

Table A1-1-1: All projects from the Sustainable Cities Integrated Programming.

GEF ID	Project Title	GEF period	Lead Agency	Region	PIF/CEO amount (US$ million)
9123	Cities-IAP: Sustainable Cities Initiative	GEF - 6	World Bank	Africa	8.7
9127	Cities-IAP: Asuncion Green City of the Americas – Pathways to Sustainability	GEF - 6	UNDP	LAC	7.5
9130	Cities-IAP: Abidjan Integrated Sustainable Urban Planning and Management	GEF - 6	AfDB	Africa	5.3
9142	Cities-IAP: Promoting Sustainable Cities in Brazil through Integrated Urban Planning and Innovative Technologies Investment	GEF - 6	UNEP	LAC	22.6
9145	Cities-IAP: Building a Resilient and Resource-efficient Johannesburg: Increased Access to Urban Services and Improved Quality of Life	GEF - 6	DBSA	Africa	8.1
9147	Sustainable-City Development in Malaysia	GEF - 6	UNIDO	Asia	2.8
9162	Sustainable Cities IAP - Global Platform for Sustainable Cities	GEF - 6	World Bank	Global	9.0
9223	GEF China Sustainable Cities Integrated Approach Pilot	GEF - 6	World Bank	Asia	32.7
9323	Cities-IAP: Sustainable Cities, Integrated Approach Pilot in India	GEF - 6	UNIDO	Asia	12.1
9484	Integrated Approaches for Sustainable Cities in Vietnam	GEF - 6	ADB	Asia	8.3

GEF ID	Project Title	GEF period	Lead Agency	Region	PIF/CEO amount (US$ million)
9649	Implementation of Projects Prioritized by the Sustainable and Emerging Cities Program in Three Mexican Cities	GEF - 6	IADB	LAC	13.8
9698	National Platform for Sustainable Cities and Climate Change	GEF - 6	IADB	LAC	6.4
10452	Sustainable Cities Impact Program Global Platform (SCIP-GP)	GEF - 7	UNEP	Global	16.2
10465	Promoting integrated metropolitan planning and innovative urban technology investments in Brazil	GEF - 7	UNEP	LAC	12.6
10466	Integrated low-carbon and conservation investments in Argentinian cities	GEF - 7	UNEP	LAC	23.4
10467	Transitioning to an urban green economy and delivering global environmental benefits	GEF - 7	UNDP	LAC	10.3
10484	Livable Cities in India: Demonstrating Sustainable Urban Planning and Development through Integrated Approaches	GEF - 7	UNEP	Asia	17.2
10486	Child Project Title: Strengthening Marrakech's sustainable development through innovative planning and financing	GEF - 7	UNDP	Africa	9.4
10494	Indonesia Sustainable Cities Impact Program	GEF - 7	World Bank	Asia	15.9
10530	Rwanda Urban Development Project II	GEF - 7	World Bank	Africa	8.1
10768	Resilient Urban Sierra Leone Project	GEF - 7	World Bank	Africa	6.7
10822	GEF-7: Green and Carbon Neutral Cities	GEF - 7	World Bank	Asia	26.9
11288	Belize Blue Cities and Beyond Program	GEF - 8	World Bank	LAC	3.8
11289	The Greater Nokoue Greening Program (GNGP)	GEF - 8	BOAD	Africa	7.1

GEF ID	Project Title	GEF period	Lead Agency	Region	PIF/CEO amount (US$ million)
11290	Climate Smart Sustainable Cities	GEF - 8	UNEP	Asia	4.8
11291	A Sustainable, Green, Blue, and Digital Havana	GEF - 8	UNDP	LAC	7.8
11292	Integrated governance and urban transformation for a sustainable “Grand Libreville”	GEF - 8	UNDP	Africa	8.1
11293	Towards resilient cities in Guatemala: addressing biodiversity loss and recovery through integrated urban planning and development	GEF - 8	IUCN	LAC	3.9
11294	The South African Sustainable Cities Planning and Decarbonisation Integrated Programme	GEF - 8	DBSA	Africa	7.1
11296	Supporting the shift towards Integrated, Low-Carbon and Nature-Positive Neighborhoods in Nairobi	GEF - 8	UNEP	Africa	4.6
11297	Green and Inclusive Cities in Mongolia	GEF - 8	UNDP	Asia	7.3
11298	Promoting Nature Positive, resilient and inclusive cities in Lima-Callao, Huancayo and Ica	GEF - 8	IUCN	LAC	11.9
11299	Green and Resilient Cities	GEF - 8	UNDP	Asia	11.9
11300	Global Program - Sustainable Cities Integrated Program	GEF - 8	World Bank	Global	17.9
11301	Green cities transformation – smart, sustainable and low-carbon urban solutions in triangular metropolitan area	GEF - 8	UNDP	ECA	7.1
11307	Strengthening Urban Resilience and Electricity Services	GEF - 8	World Bank	Africa	6.5
11339	Enhancing Nature-based Solutions and Green Infrastructure networks to promote biodiversity conservation and climate change mitigation and adaptation in urban and peri-urban areas in Chile	GEF - 8	FAO	LAC	4.7
11340	Integrated urban development in Bamako	GEF - 8	UNDP	Africa	4.7

GEF ID	Project Title	GEF period	Lead Agency	Region	PIF/CEO amount (US$ million)
11341	Establishing the basis for clean, healthy and resilient cities through an integrated and smart approach in Madagascar	GEF - 8	UNIDO	Africa	10.3
11342	The Sustainable City Project for Coordinated Development of the Beijing-Tianjin-Hebei Region	GEF - 8	UNIDO	Asia	11.4
11343	Decarbonisation and sustainable cities for a net-zero future in Malaysia	GEF - 8	UNIDO	Asia	4.4
11344	UPRISE Zimbabwe: Urban and Peri-urban Resilience through Investment for Sustainable Ecosystems in Zimbabwe	GEF - 8	FAO	Africa	3.5
11345	Reshaping Algeria's Cities for a Clean and Healthy Environment Today and Tomorrow (REACT)	GEF - 8	FAO	Africa	3.0

Source: GEF Portal as of May 30, 2025

Table A1-1-2. Reviewed projects.

GEF ID	Project Title	Technologies
9147	Sustainable-City Development in Malaysia	Smart grid; Solar; Energy integration; Energy storage; Electric mobility (Digital platforms; Smart meters)
9223	GEF China Sustainable Cities Integrated Approach Pilot	Mass transit; (Sustainable transport/TOD; Digital platforms; Big data; Remote sensing and geospatial technology)
10484	Livable Cities in India: Demonstrating Sustainable Urban Planning and Development through Integrated Approaches	NbS (Sustainable transport/TOD; Electric mobility; Digital platforms; Remote sensing and geospatial technology)
10768	Resilient Urban Sierra Leone Project	Remote sensing and geospatial technology; Waste management; Supply and value chains (Digital platforms; Remote sensing and geospatial technology; EWS; machine learning; drones)
11288	Belize Blue Cities and Beyond Program (Applies biotechnology to enhance the Belize City Wastewater Treatment Plant	(Digital platforms; Remote sensing and geospatial technology; Fintech/sustainable finance; Water management; NbS; Waste management/circular economy)

GEF ID	Project Title	Technologies
	(WWTP), improving its design and operations to boost treatment efficiency)	

Source: GEF IEO analysis

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Case study 2: Artificial Intelligence (AI) and Machine Learning (ML)

1. Introduction

Artificial Intelligence (AI) involves technology that allows computers and machines to mimic human learning, comprehension, problem-solving, decision-making, creativity, and autonomy. Machine learning (ML) is a subset of AI that develops algorithms that enable computers to learn from data and make predictions or decisions without explicit programming (Boppana, 2022).

Both AI and ML have been predicted to provide significant benefits for the environment. These technologies can enhance real-time monitoring, improve forecasting, optimize resource management, and accelerate scientific discovery, leading to more effective solutions for a range of environmental challenges (Environmental Innovations Initiative, 2025).

However, AI/ML also pose risks to the environment. The STAP identified five potential risks of these technologies in their application across the GEF portfolio: (a) ecological risks, such as the proliferation of novel chemicals and biological agents with unknown effects; (b) increased energy and resource use needed to fuel AI-powered technologies; (c) social risks related to the erosion of shared norms, trust, and social cohesion; (d) economic concerns due to potential job losses; and (e) institutional risks, such as those affecting processes of public deliberation over societal goals (STAP, 2024).

The potential application of AI/ML has not been mentioned in the programming directions for GEF-6 and GEF-7. In the GEF-8 programming directions, under Private sector engagement, AI/ML are cited as an opportunity to generate wide-reaching environmental benefits, specifically mentioning baseline setting, prioritization, monitoring, evaluation, and modelling for Integrated Programs (GEF, 2022, p. 240). GEF's IEO in their report of GEF Support to Innovation (2021) mentioned that AI was creating new means of tracking and communicating environmentally critical information, in addition to predictive modeling and large-scale forecasting, that would enable both better project design and more informed M&E.

2. Use of AI and ML in GEF projects

The portfolio scan and interviews identified 12 projects with AI and/or ML present: 1 in GEF-6, 9 in GEF-7 and 2 in GEF-8. Ten of these projects were under implementation, one was closed and two were in the pipeline[7]. These projects were all stand-along projects with the exception of one project (GEF ID 9658), which was a child project of the Global Wildlife Program. Three of the projects of GEF-7 (GEF ID 10927, 10933, 10965) were selected through the Challenge Program for Adaptation Innovation. The two projects of GEF-8 (GEF ID 11854, 11914) were selected through the GEF-8 Innovations Window. Six of the projects supported the biodiversity focal area, four supported climate change adaptation, one supported international waters and one supported multifocal area (international waters and chemical and waste). The GEF allocations for

[7] It is possible that other projects do have AI/ML present and were not found during the project scan.

the projects ranged from USD $0.5 million to 7 million (for further details, see the table at the end of the case).

In GEF-8 programming directions, the GEF Secretariat set out possible uses for AI and ML for key IPs; Circular Solutions to Plastic Pollution IP; Ecosystem Restoration IP, Wildlife Conservation for Development IP, in addition to the International Waters focal areas. These potential uses involved improving environmental monitoring and resource management, though they remain aspirational and were not yet implemented.

As reported by STAP and in interviews, GEF agencies, such as Conservation International, WWF, UNIDO, World Bank and the Asian Development Bank have adopted a wide range of AI and related technology across their environment-focused activities, in addition to improve operations effectiveness in general, although not necessarily yet for their GEF portfolio (STAP, 2024).

Across these projects, AI/ML was primarily foreseen to be used to enhance environmental monitoring, wildlife tracking, biodiversity assessment, climate adaptation planning, and digital agriculture services such as data analysis, predictive tools, and integrated digital platforms.

3. Expected outcomes and added value in relation to AI/ML

Given that most GEF projects identified with AI/ML element are currently being implemented, outcomes described below are those expected rather than achieved. The only completed project (GEF ID 9658) used AI/ML to analyze images on social media to detect instances of illegal wildlife trade. According to the agency, ADB, the use of AI/ML was not successful beyond initial trials due to legal barriers to access private data through social media. The Terminal Evaluation also reported that the project did not have sufficient time to test fully the contributions of these technological innovations (Pedragosa, 2022). Another project (GEF ID 10438) had already reported early results with data sets using AI/ML to predict risks analyzed and feeding into early warning systems, such as for landslide prediction.

As described in the following table, expected outcomes included improved environmental monitoring and early warning systems, enhanced wildlife tracking and trade monitoring, higher-quality biodiversity assessments, better climate adaptation planning, and more efficient digital agriculture services with stronger stakeholder engagement.

Table A-1-2-1: Expected outcomes

Expected Outcomes	Roles and Approaches for AI / ML	Projects (GEF IDs)
Improved environmental monitoring and early warning systems	AI/ML used for risk prediction, early warning systems, and detecting environmental changes (e.g., disasters, presence of plastics in rivers, coral bleaching).	10438 10575 10628
Enhanced wildlife tracking and monitoring of illegal trade	AI/ML applied to track wildlife, analyze social media for illegal trade, and develop data indicators using big data and standardized algorithms.	9568, 10701 11854
Higher-quality biodiversity assessments and ecosystem monitoring	AI/ML, sometimes combined with remote sensing, to produce more accurate, frequent biodiversity assessments and actional plans and monitor habitat conditions.	10897 11036 11914
Better climate planning and integration of adaptation in land-use strategies	AI embedded in tools/platforms to identify climate adaptation opportunities in net-zero projects; supports dynamic monitoring and scenario planning.	10933 11914
More efficient digital agriculture services and improved stakeholder engagement	AI/ML used for digital farming services, customer interaction (e.g., chatbots), and data integration from multiple sources (farm-level, satellite, weather).	10927 10965

Source: GEF IEO analysis

These expected outcomes are anticipated to contribute to a range of global environmental benefits including reductions in greenhouse gas emissions, biodiversity conservation, strengthening marine/coastal ecosystems, climate change mitigation and resilience, and improved chemicals and waste management. Socio-economic benefits identified include reduced poverty and vulnerability and increased resilience to the impacts of climate change and improved incomes and livelihoods.

Previous GEF IEO studies have found that innovation, including technological innovation is associated with higher additionality or value added, such as contributions to quality, scale, and efficiency in achievement of environmental and related socio-economic benefits (IEO, 2021). In addition to the environmental and related socio-economic benefits described above, the projects aimed to improve efficiency mainly through reducing costs and increasing the efficiency, frequency and accuracy of data management, services and analyses.

Most of the projects emphasize replication, scaling up, and additionality with the support of the AI/ML elements. This includes making available the algorithms, tools or platforms developed (GEF ID 10438, 10965, 11854, 11914), the development of “replicability toolkits” (GEF ID 10438, 10701) and knowledge dissemination to the global level and across countries (China for GEF ID 10701) (GEF ID 10701, 10575).

Two projects (GEF ID 10438, 11854) had AI/ML as a central element, whereas for the other projects, AI/ML were in a supportive technological role for tracking, data management, analyses and assessments.

4. Risks related to AI and ML

identified risks related to AL/ML were in relation to data security and safety concerns, such as inadvertently collecting private images/information and the difficulties in protecting personal data (GEF ID 10701, 11854), in addition to data security in general (GEF ID 10575, 11914), challenges of interoperability (GEF ID 11914), insufficient data (GEF ID 11854) and resistance of stakeholders towards new systems, tools and technology (GEF ID 10933, 10965, 11914). However, the other risks identified by STAP, such as ecological, economic, institutional and social risks, in addition to excessive power use, were not mentioned (STAP, 2024).

5. Enablers for and barriers to the use of AI and ML

A number of enablers for AI/ML were identified by the projects; the availability, advances and proliferation of AI/ML technology (GEF ID 10701, 10897, 10965, 11854), successful application of AI/ML in similar projects (GEF ID 107014) or supportive existing platforms (GEF ID 11914), the increasing ability of systems to integrate AI/ML (GEF ID 10438, 10578) and the interest in funders and governments in modern systems and platforms (GEF ID 10438, 10965, 11914).

Several barriers were also identified, including the availability of qualified IT professionals to work in the environmental field (GEF ID 10701, 10897, 10575, 11854), technological literacy of users (GEF ID 10927, 10965), poor internet coverage (GEF ID 10927,10965) and the evolving nature of the AI/ML technology (GEF ID 10438, 10575). The large amount of data generated for analysis was also identified as a challenge (GEF ID 10701), requiring collaboration with a technological provider (Lenovo) to apply AI for species monitoring and analysis.

6. Lessons identified from the use of AI and ML in GEF projects

1. AI and ML integration Is emerging but limited: Despite their potential, AI/ML has been integrated into a small number of GEF projects, primarily in GEF-7, and often in a supporting rather than central role. As expanded upon by academia, STAP and the GEF Secretariat the potential of AI/ML in supporting project outcomes and eventual environmental benefits is considerable.

2. AI and ML enhance efficiency and data quality: These technologies are expected to improve environmental monitoring, data management and analysis, digital services and decision-making, contributing to more accurate, cost-effective, and scalable solutions; the examples of GEF projects featured in this case illustrate this potential.

3. **Replication and scalability show promise:** Projects emphasize the importance of replicability and knowledge sharing, providing examples of the potential of AI/ML technology to support broader adoption and scaling.

4. **Risks are under-addressed**: While some projects acknowledge data security concerns and user resistance, broader risks identified by STAP—such as ecological, social, and institutional risks—are largely unaddressed by the projects to date, indicating an area for future focus.

5. Growing expertise in GEF Agencies underutilized: A number of GEF agencies, including ADB, Conservation International, UNIDO, WWF and World Bank have developed expertise on AI/ML, often beyond the GEF portfolio. The GEF partnership could further learn from this expertise through exchanges and integration within GEF projects.

6. Enablers and barriers are finely balanced: Key enablers including technological advances and funder/government interest are finely balanced against the shortage of qualified IT professionals in the environmental sector, technological literacy and the rapidly evolving nature of AI/ML technologies.

Table A1-2-2: Twelve GEF projects identified with AI and/or ML present (GEF-6, GEF-77, GEF-8)

GEF ID	***Project Title***	***GEF period***	***Lead Agency***	***Region***	***Focal Area***	***Project Type***	***CEO Amount***
9658	Combating Environmental Organized Crime in the Philippines	GEF-6	ADB	Asia	BD	MSP	1.8 M
10438	UAVs/drones for Equitable Climate Change Adaptation: Participatory Risk Management through Landslide and Debris Flow Monitoring in Mocoa, Colombia	GEF–7	CAF	Latin America and Caribbean	CC	MSP	0.5 M
10575	Coral Reef Rescue: Resilient Coral Reefs, Resilient Communities	GEF–7	WWF-US	Global	IW	FSP	7 M
10628	Promoting Resource Efficiency and Circularity to Reduce Plastic Pollution for Asia and the Pacific	GEF-7	ADB	Asia	MFA (IW & CW)	MSP	2 M
10701	Transformational wildlife conservation management in China	GEF-7	UNDP	Global	BD	FSP	5.7 M
10897	Knowledge-4-Nature: Provisioning the biodiversity data behind global goals for nature	GEF-7	IUCN	Global	BD	MSP	1.8 M
10933	Net-Zero Adaptation Finance (NZAF)	GEF-7	FAO	Global	CC	MSP	0.8 M
10927	Acceleration of financial technology-enabled climate resilience solutions	GEF-7	UNIDO	Africa	CC	MSP	0.86 M
10965	SMARTFARM - A data and digital technology driven and farm management solution for climate resilience.	GEF-7	IFAD	Africa	CC	MSP	0.8 M

GEF ID	*Project Title*	*GEF period*	*Lead Agency*	*Region*	*Focal Area*	*Project Type*	*CEO Amount*
11036	Technical Support for the Global Biodiversity Framework Early Action Support project	GEF-7	UNDP	Global	BD	MSP	1.5 M
11854	Revolutionising indicators of (un)sustainable wildlife use and trade by harnessing social media and big data	GEF-8	IUCN	Global	BD	MSP	1.7 M
11914	Jaguar Corridors in the Face of Rapid Environmental Change: A dynamic monitoring and assessment system for prioritizing conservation investments	GEF-8	WWF-US	Latin America and Caribbean	BD	MSP	1.7 M

Source: GEF Portal as of May 30, 2025

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Case study 3: Blockchain

1. Introduction

Blockchain is a digital ledger that decentralizes data and eliminates intermediaries typically required to validate transactions. It uses a distributed database to store information securely, transparently, and efficiently, thereby improving processes that require secure sending, storing, accessing, or verification of information (STAP, 2018).

Already by 2017, researchers began to propose how blockchain could 'save the environment', arguing that it provided potential solutions for a wide range of challenges from biodiversity to climate change and could support sustainability endeavors by providing ways to build trust and create greater transparency among stakeholders (Hutson, 2017).

Blockchain was one of the six technological innovations highlighted by STAP in 2018 for their potential benefits (and problems) in delivering global environmental benefits. Specifically concerning blockchain, potential benefits identified by STAP included improved environmental monitoring, sustainable resource management, transparent supply chains, and innovative financing models. However, the STAP also expressed concerns about blockchain's excessive energy consumption as the underlying technology for Bitcoin virtual currency (STAP, 2018, 2019).

The STAP stressed that "*the GEF should not wait for blockchain technology to become well established before getting involved as it may miss the opportunity to help shape blockchain applications and prevent negative consequences*" (Environmental Law Institute, 2018, p. 16). In 2019, the STAP mapped over 80 blockchain use cases (many already in use) onto GEF focal areas and programs, including: biodiversity, climate change mitigation and adaption, land degradation, international waters, chemicals and waste, and food systems. Similarly in 2018, the World Economic Forum mapped 65 existing and emerging block chain use cases for the environment (World Economic Forum, 2018).

The potential application of blockchain has not been mentioned in the programming directions for GEF 6 and GEF 7. Blockchain is mentioned specifically in the programming direction for GEF 8, in relation to private sector engagement and for its potential application in support of climate, water and biodiversity fintech (GEF, 2022, p. 237)

2. Use of blockchain in GEF projects

The portfolio scan indicated that blockchain was present in a small number of projects in GEF-6, GEF-7 and GEF-8; 6 projects in total were identified. Of these six projects, one is in the pipeline; four are under implementation and one has been closed[8]. These projects supported the following focal areas: one in multifocal area (areas of biodiversity and land degradation); two in land degradation, and one each in climate change, chemicals and waste and international waters. The

[8] It is possible that other projects have blockchain and were not found during the project scan.

projects were at all levels: global (2), regional (2) and national (2). The GEF allocations for these projects ranged from USD $1.7 million to 13.6 million (for further details, see the table at the end of the case). In terms of programming affiliation, four are standalone projects, and two are parts of programs: one of them is part of GEF-7 FOLUR IP (Food Systems, Land use and Restoration Impact Program), and one is part of a GEF-7 chemicals and waste program (Financing Agrochemical Reduction and Management (FARM)). As for financing windows and mechanisms, one project has been selected through the GEF-8 Innovations Window.

Across these projects, blockchain technology was primarily foreseen to be used to support the storing, tracking, traceability and monitoring of data in support of real-time data flows and decision-making. For example, this included improving compliance and/or supply chain traceability in agriculture (GEF ID 11835, 10307), for pesticides (GEF ID 10902) and fishing (GEF ID 10394); and underpinning digital tools and platforms for estimating climate mitigation targets (10014) or mobilizing crowdfunding investments (GEF ID 10637).

3. Expected outcomes and added value in relation to blockchain

Given that most GEF projects identified with a blockchain element are currently being implemented, outcomes described below are those expected rather than achieved. The only completed project (GEF ID 10014) did not deliver the blockchain element of the project as anticipated, therefore no related outcomes were seen (Voordouw, 2024).

As described in the following table, the expected outcomes, such as increased sustainable production, reduced illegal fishing, and improved land and chemical management will be supported through processes and systems based on blockchain technologies. Efficiency will be enhanced through blockchain technologies to streamline verification, scale-up investments, reduce administrative burdens, enable data-driven decision-making, and build trust among stakeholders. Empowering smallholders and female workers will further strengthen local implementation and compliance.

Table A-1-3-1: Expected outcomes

Expected Outcomes	Blockchain Role	Projects (GEF IDs)
Increased sustainable production of coffee, cacao, and palm oil through responsible and traceable value chains	Tracing sustainable commodities & verifying practices	10307
Establishment of verification systems system and inventory tracking	Real-time data tracking, emissions reporting	10014, 10637
Reduced illegal, unreported, and unregulated fishing and enhanced port compliance through improved monitoring	Tracking catch origin, documentation enforcement	10394
Empowerment of smallholder farmers and female port workers through access to transparent digital monitoring and compliance tools	Tools for compliance and monitoring	10394, 10637, 11835
Scaled-up investment in landscape restoration efforts and transparent, trusted payment systems	Supporting trusted payment system and restoration tracking	10637
Improved management of pesticides and containers with verified health and environmental benefits	Tracking pesticide use and container recycling	10902

Source: GEF IEO analysis

These expected outcomes are anticipated to contribute to a range of global environmental benefits including reduced deforestation, biodiversity conservation, sustainable land management, climate change mitigation and resilience, and improved chemicals and waste management.

Previous GEF IEO studies have found that innovation, including technological innovation is associated with higher additionality or value added, such as contributions to quality, scale, and efficiency in achievement of environmental and related socio-economic benefits (IEO, 2021).

Within the GEF projects identified with blockchain present, such additionality or added value was not yet evident. The Terminal Evaluation of the only closed project (GEF ID 10014) concluded "*No catalytic or replication effects of the project were recorded*" (Voordouw, 2024, p.7). However, in their documentation, the ongoing projects have identified potential for replication and scalability. Several projects indicated that replication and scalability will be pursued across other countries and regions, with such expansion partially contingent on the successful integration of technological elements such as blockchain (GEF ID 10637, 11835, 10902). Further, some projects also foresaw the sharing of best practices and lessons to encourage replication in other countries and/or regions, although blockchain was not always specifically mentioned (GEF ID 10307, 11835).

Nevertheless, the centrality of blockchain to the projects' success was evident in a minority of projects. For example, where the projects aimed to develop a digital compliance tool (GEF ID 11835) or traceability mechanism (GEF ID `10902), blockchain was crucial to their successful

implementation. For the remaining projects (GEF ID 10014, 10307, 10394, 10637), blockchain technology appears to have a relatively minor role in activities and outputs. Further, the project documentation implied that blockchain elements would be developed, rather than adapted from existing solutions. For some projects, such as the project on fishery management and seafood tracking (GEF ID 10394), several blockchain solutions exist already in this area[9] but do not seem to have been taken into consideration for the project to date.

4. Risks related to blockchain

The GEF projects identified several risks related to the implementation and adoption of blockchain technology. These include technical risks such as failure to develop the blockchain supported platform in time or within budget and its potential underperformance as a crowdfunding tool (GEF ID 10637). Capacity-related risks included insufficient technical expertise (GEF ID 10014, 11835), lack of harmonization across government IT systems (GEF ID 10014), and potential stakeholder disagreement or slow policy alignment on blockchain adoption (GEF ID 10307, 11835). While some projects did not specify blockchain-related risks, they highlighted broader institutional or technological vulnerabilities that could impact implementation (GEF ID 10394), such as insufficient demand for sustainable products undermining blockchain-based traceability efforts and lack of financing for long-term technology investments (GEF ID 10307). Further, none of the projects in their documentation identified other well-recognized potential risks of blockchain technology, including data security, legal and regulatory challenges, scalability, digital access and literacy in developing countries, and the substantial energy consumption and resulting carbon emissions (Alzoubi & Mishra, 2023, STAP, 2019, World Economic Forum, 2018). The GEF Secretariat advised that cost was an obstacle encountered in using blockchain; for example, using blockchain for the planetGOLD program was found to require propriety technology at significant costs.

5. Enablers for and barriers to the use of blockchain

Enablers for the use of blockchains in GEF projects and programs identified have included strong collaboration with existing initiatives and institutions (GEF ID 11835), shared infrastructure and staffing to support blockchain-supported platforms (GEF ID 11835), and lessons learned from prior blockchain pilots (GEF ID 10394, 10902). Further highlighted was stakeholder engagement including local governments and agribusinesses to support the adoption of the tools within

[9] IBM blockchain Food Trust: https://seafood4blockchain.com/; Bumblebee seafood blockchain: https://thebumblebeecompany.com/bumble-bee-foods-and-sap-create-blockchain-to-track-fresh-fish-from-ocean-to-table/; Fishcoin, seafood traceability: https://fishcoin.co/; TraceX, blockchain traceability for seafood value chain: https://fishcoin.co/.

national frameworks and supply chains (GEF ID 11835), in addition to existing technological infrastructure (e.g. mobile phone penetration and mobile money mechanisms) that was necessary for the implementation of the blockchain elements (GEF ID 10637). Some projects also benefited from positive visibility and partner interest in innovative technology (GEF ID 10637).

Barriers identified included limited local capacity, financial constraints, and misalignment with institutional frameworks (GEF ID 11835), delays in blockchain component setup due to technical and bureaucratic challenges (GEF ID 10637), Gender-based barriers to technology access and decision-making (GEF ID 10307) were also cited. In the closed project (GEF ID 10014), some of the reasons for the project's unsatisfactory performance were related to limited local technical capacities and expertise, including on blockchain.

For some projects, enablers or barriers specific to blockchain were not explicitly detailed (GEF ID 10307, 10902, 10394).

6. Lessons identified from the use of blockchain in GEF projects

1. Blockchain holds promise but remains marginal in GEF's portfolio: Despite blockchain's recognized potential to improve transparency, traceability, and efficiency in environmental projects, its actual use within the GEF portfolio remains very limited—just 0.3% of all projects. Moreover, blockchain is mentioned in GEF-8 programming directions for the first time and in a narrow context, suggesting that blockchain's potential is still at its very early stages rather than central in GEF's technological innovation approach.

2. Blockchain's added value for GEF's projects is unproven to date: Most projects with blockchain elements are still in early or mid-implementation, and demonstrable outcomes or additionality (e.g., replication, scale, catalytic effects) are not yet evident. The only identified closed project (GEF ID 10014) failed to deliver the blockchain component, offering no results to evaluate its contribution. It should also be recognized that other organizations have experience with the blockchain technology for the environment (STAP, 2019, World Economic Forum, 2018) and could provide further insights on Blockchain's added value.

3**. Blockchain Is often supplementary and not central within GEF projects:** In the majority of identified projects, blockchain is a minor component, often one of several technological tools rather than the critical element for project success. Only a few projects (GEF ID 11835, 10902) feature blockchain as a critical element for success. This indicates that blockchain has not yet been widely adopted and used in GEF projects as STAP envisaged in 2018.

4. Implementation Is hindered by capacity, technical, and institutional barriers: The integration of blockchain in GEF projects has encountered a variety of obstacles including insufficient local technical expertise, which hampers the ability to develop, adapt, or maintain blockchain platforms (as seen in projects like GEF ID 10014 and 11835). Additionally, bureaucratic and logistical delays in configuring blockchain systems and negotiating with local service providers have slowed implementation, in the examples to date. Some projects also faced broader institutional misalignment and unclear policy environments (GEF ID 10307, 11835).

5. Successful use of blockchain depends on strong partnerships and existing Infrastructure: Where blockchain shows promise for GEF projects, it has been in projects that leverage strong partnerships, existing infrastructure and have a clear added value and critical role for the projects. Collaboration with ongoing initiatives, shared technical platforms, and lessons from prior pilots (e.g. GEF ID 11835 and 10394) have helped lower the entry barrier for blockchain adoption. Local government involvement and private sector engagement also play a crucial role in integrating blockchain tools into national frameworks and supply chains. These enablers highlight the need for ecosystem readiness and stakeholder alignment for blockchain elements to succeed and potentially scale up further. Where further focus would still be needed is in considering the use of existing blockchain solutions for the environment rather than creating new solutions.

Table A1-3-2: Six GEF projects identified with blockchain present (GEF-6, GEF- 7, GEF-8)

GEF ID	Project Title	GEF period	Lead Agency	Region	Focal Area	Project Type	CEO Amount
10014	Strengthening Jamaica´s Capacity to Meet Transparency Requirements under the Paris Agreement	GEF - 6	IADB	LAC	CC	MSP	$ 1.3 M
10307	Deforestation Free Commodity Supply Chains in the Peruvian Amazon	GEF - 7	UNDP	LAC	MFA	FSP	$ 13.6 M
10394	Mainstreaming climate change and ecosystem-based approaches into the sustainable management of the living marine resources of the WCPFC	GEF - 7	UNDP	Asia	IW	FSP	$ 10 M
10637	Restoration Challenge Grant Platform for Smallholders and Communities, with Blockchain-Enabled Crowdfunding	GEF - 7	IUCN	Africa	LD	MSP	$ 2 M
10902	FARM: Strengthening investment for adoption of alternatives and sustainable management of agrochemicals and agriplastics in Africa and Latin America through pilots in Kenya and Uruguay	GEF-7	UNEP / FAO	Global	CW	FSP	$7.4 M
11835	AgroWeb3 Powered by LACChain: Market Access Window Project	GEF - 8	IFAD	Global	LD	MSP	$ 1.7 M

Source: GEF Portal as of May 30, 2025

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Case study 4: Green Hydrogen

1. Introduction

Hydrogen can be used to power fuel cells for vehicles, serve as an energy carrier for electricity storage, and is widely used in industry, such as in refining petroleum, producing fertilizers and making steel. Traditionally produced hydrogen (called "grey", "brown" or "black" hydrogen) has been labeled as a "climate killer" due to its significant amounts of climate emissions in production (Reda et al, 2024; World Economic Forum, 2021).

Green hydrogen is hydrogen produced using renewable energy sources—such as wind, solar, or hydropower—to power the electrolysis of water, splitting it into hydrogen and oxygen without emitting carbon dioxide (Reda et al, 2024).

Since twenty years, there have been increasing efforts to develop green hydrogen technologies, given it is considered as one of the most suitable choices for future clean energy markets. To date, some of the limitations of green hydrogen identified include the high cost of hydrogen production, safety, lack of appropriate infrastructure and its production requirement for large amounts of purified water (Reda et al, 2024, Squadrito et al, 2023).

The European Commission has set out binding targets for the uptake of renewable hydrogen in industry and transport; by 2050, renewable hydrogen must cover some 10% of the energy needs of the European Union countries (European Commission, 2020). Other countries, such as Australia, Japan, Canada, United Kingdom and South Korea have set out policy targets and timelines for low-carbon and green hydrogen development, although they are more voluntary and aspirational rather than being binding.

STAP has not proactively promoted green hydrogen as it has other technological innovations (STAP, 2018). However, it has cited green hydrogen in its report on blended finance (STAP, 2024), specifically citing the Green Hydrogen Facility project (11065) as an example of a GEF blended financial instrument, although this project was consequently cancelled.

The potential application of green hydrogen has not been mentioned in the programming directions for GEF-6 and GEF-7. However, green hydrogen is mentioned specifically in the programming directions for GEF-8 in two areas: for the Net-Zero Nature-Positive Accelerator Integrated Program (NZNP Accelerator IP) and in the Climate Change focal area. In these area, green hydrogen is profiled of a potential technological solution for a shift to a cleaner and more resilient electrification and energy storage for various sectors including manufacturing and transportation (GEF, 2022, p.85, 86, 145, 148, 153).

2. Use of green hydrogen in GEF projects

The portfolio scan indicates that green hydrogen was not present in GEF-6 and present in a small number of projects in GEF-7 and GEF-8; four stand-alone projects, one child project (in a Net-Zero Nature-Positive Accelerator IP) and a programme comprised of 10 child projects. In GEF-8, the Global Clean Hydrogen Programme (GCHP) was approved, led by UNIDO and comprised of a

global and nine national child projects.. As of May 30, 2025, Five of these projects were active (under implementation), while the GCHP projects were in the CEO endorsement stage[10].

The ten projects of the GCHP and the other five projects all support the climate change focal area, with one project (GEF ID 11095) being a multifocal area project (areas of climate change, biodiversity and land degradation). Including the child projects of the GCHP, they were either global (2) or national (13); with China accounting for three of these 13 national projects.

The GEF allocations for the projects (outside of the GCHP) ranged from USD $1 million to 17.4 million; the total allocation for the GCHP was $13.1 million (for further details, see the tables at the end of the case). Aside from the GCHP in terms of programming affiliation, four were standalone projects, and one (GEF ID 11095) was part of the GEF-8 NZNP Accelerator IP.

Across these projects, green hydrogen was primarily foreseen to be used to support decarbonization in key sectors such as transport, heavy industry, power, agriculture, and construction by overcoming regulatory, financial, and technical barriers, enabling value chain development, piloting zero-emission technologies, and fostering policy innovation, knowledge sharing, and public-private investment mobilization.

3. Expected outcomes and added value in relation to green hydrogen

Given that all GEF projects identified with a green hydrogen element recently became active or are still waiting for CEO endorsement, outcomes described below are those expected rather than achieved.

As described in the following table, the sum of the expected outcomes range from improved policy frameworks and enabling environments for green hydrogen to technical readiness, implementation of pilot projects, improved knowledge sharing to industrial transition and investment mobilization.

[10] It is possible that other projects have green hydrogen present and were not found during the project scan.

Table A1-4-1: Expected Outcomes

Expected Outcomes	Roles and Approaches for Green Hydrogen	Projects (GEF IDs)
Improved policy frameworks, regulatory standards, and enabling environments for green hydrogen development	Support for strategic planning, governance, and institutional frameworks that enable green hydrogen scale-up	10918 11271 11445 11095 GCHP
Enhanced technical readiness for production, application, and integration of green hydrogen technologies	Deployment and technical validation of green hydrogen technologies in transport, industry, and infrastructure	10918 11271 11445 GCHP
Demonstration and implementation of green hydrogen pilot projects across sectors	Pilot-scale application in transport, ports, industry, and energy systems to validate feasibility and scalability	10790 10918 11095 GCHP
Improved knowledge sharing, capacity building, and stakeholder engagement on green hydrogen	Awareness raising, training, and establishment of knowledge platforms for public-private cooperation and adoption	10918 11271 11445 11095 GCHP
Industrial transition and value chain development in green hydrogen	Development of industrial clusters, value chains, and supply networks for green hydrogen in hard-to-abate sectors	11271 11095 GCHP
Mobilization of investments and establishment of financial mechanisms for green hydrogen	Design and operationalization of innovative financing tools to attract private sector investment in green hydrogen	10790 10918 11445 11095 GCHP

These expected outcomes are anticipated to contribute to a range of global environmental benefits including large-scale reductions in greenhouse gas emissions, improved air quality, increased energy efficiency, and greater energy security, particularly in hard-to-abate sectors like transport and industry. Socio-economic benefits identified include job creation, inclusive

economic growth, industrial innovation, and the promotion of gender equity and workforce diversity in emerging green hydrogen markets.

Previous GEF IEO studies have found that innovation, including technological innovation is associated with higher additionality or value added, such as contributions to quality, scale, and efficiency in achievement of environmental and related socio-economic benefits (IEO, 2021).

Within the GEF projects (including GCHP) identified with green hydrogen present, this added value was present in the environmental and related socio-economic benefits as described above. The projects aim to improve efficiency by lowering costs, enhancing technological readiness, and creating supportive financial and policy frameworks. This includes piloting cost-effective models, reducing investment risks, and enabling faster, more viable deployment.

The projects (including GCHP) emphasize replication, scaling up, and additionality as central strategies for accelerating green hydrogen adoption. They aim to develop replicable models such as UNIDO's industrial clusters (GCHP) that can guide other countries, while pilot projects are designed to generate scalable lessons, reduce risk perceptions, and attract larger follow-on investments (GCHP, GEF ID 10918, 11095,11271). Projects also include explicit outputs for developing and financing scale-up plans particularly in transport and industrial applications and producing knowledge products to promote uptake nationally and globally. Additionally, activities such as capacity building, policy support, and financial mechanism design are intended to create the enabling environments necessary for long-term replication and scaling (GCHP, GEF ID 10790, 11095, 11271).

4. Risks related to green hydrogen

The main risks related to green hydrogen identified across the projects include technological uncertainties, such as limited infrastructure, safety concerns, and high production costs; financial and business model risks, including insufficient funding, unclear revenue models, and market misalignment; and policy and institutional challenges, such as weak regulatory frameworks and shifting political priorities. Additional concerns include environmental and social risks (e.g., land use, water stress, occupational safety), climate sensitivity affecting performance and reliability of green hydrogen, and limited stakeholder acceptance or awareness, particularly in emerging markets. The risks identified by the projects largely correlate with those identified in the literature, such as excessive water consumption, high production costs, safety and investment risks (Reda et al, 2024, Squadrito et al, 2023).

5. Enablers for and barriers to the use of green hydrogen

Green hydrogen projects are supported by a range of enablers across the participating countries. Many have established supportive policy frameworks, national hydrogen strategies, and roadmaps—such as in China, Indonesia, Ecuador, and Morocco—demonstrating strong political will and planning foundations (GCHP, GEF ID 10790, 10918, 11095, 11271). Technological progress, including falling costs of electrolyzers and renewable energy, improved system efficiency, and increasing private sector interest, has enhanced economic viability. Several projects benefit from pre-existing pilot programs, government-led research and development

efforts, and public-private partnerships that offer expertise and infrastructure (GHPC, GEF ID 10790, 10918, 11095, 11271). The international momentum behind green hydrogen—driven by climate goals and net-zero targets—has boosted knowledge-sharing initiatives, regional cooperation, and interest from global institutions.

However, green hydrogen deployment faces significant barriers. High production, storage, and transportation costs—along with uncertain market demand and limited offtake agreements—undermine economic competitiveness against grey hydrogen (all projects). Many countries lack adequate policy frameworks, harmonized safety standards, and certification systems, which creates regulatory uncertainty and could deter private investment (GHPC, GEF ID 11095, 11271). Technical challenges persist, including renewable energy intermittency, insufficient infrastructure (like refueling stations and pipelines), and gaps in technology performance (e.g., electrolyzer durability). A shortage of skilled professionals, limited institutional capacity, and underfunded research and development hinder implementation and innovation. Fragmented coordination, lack of publicly available data, and low awareness among stakeholders could further weaken project planning and investor confidence (GHPC, GEF ID 10790, 10918, 11271).

6. Lessons identified from the use of green hydrogen in GEF projects

1. Green hydrogen is emerging but still nascent in the GEF portfolio: Green hydrogen has only recently been seen in GEF programming, in GEF-7 and GEF-8, representing a very small share (0.7%) of the total portfolio. Its inclusion and adoption of a comprehensive programme in GEF-8 (GHPC) reflects growing international interest and the progressive development of green hydrogen as a viable and clean alternative to traditional hydrogen production.

2. Projects are aligned with high-impact sectors and GEF priorities: Green hydrogen within GEF projects is often a central technology and primarily targeted at hard-to-abate sectors like transport, industry, power, and construction. This alignment supports GEF priorities such as climate change mitigation and contributes to net-zero pathways and nature-positive strategies.

3. Projects show strong potential for environmental and socio-economic benefits: Expected outcomes of the projects identified include reduced greenhouse gas emissions, improved air quality, and increased energy efficiency, alongside job creation, industrial innovation, and inclusive economic growth.

4. Replication and scaling are core strategies: Projects are designed to be replicable and scalable, with models like UNIDO's green hydrogen industrial clusters of the GHPC serving as blueprints for broader adoption. Knowledge sharing, capacity building, and policy support are also emphasized to foster enabling environments for scale-up. GHPC and other projects (GEF ID 11095) are designed as a pathway for scaling up green hydrogen; combining upstream policy and regulatory work with downstream pilot investments in renewable-powered hydrogen production and industrial decarbonization.

5. Significant risks remain across technical, financial, and institutional domains: Challenges include high production costs, weak infrastructure, regulatory gaps, limited technical expertise,

and market uncertainty. These risks potentially put at risk the anticipated outcomes and environmental and socio-economic benefits of green hydrogen.

Table A1-4-2: Five GEF projects identified with green hydrogen present (GEF- 6, GEF-7, GEF-8)

GEF ID	***Project Title***	***GEF period***	***Lead Agency***	***Region***	***Focal Area***	***Project Type***	***CEO Amount***
10770	China Energy Transition Towards Carbon Neutrality Project	GEF - 7	World Bank	Asia	CC	FSP	17.4 M
10790	Pathways for Decarbonizing Transport towards Carbon Neutrality in China	GEF - 7	World Bank	Asia	CC	FSP	10 M
10918	Green Hydrogen Support in Developing Countries	GEF - 7	World Bank	Global	CC	MSP	1.7 M
11095	Indonesia's NZNP Acceleration through Integrated Actions in the Energy and Industrial Sectors	GEF - 8	UNDP	Asia	MFA	FSP	15.7 M
11271	China Green Hydrogen: from Production to Hard-to-Abate End Uses	GEF - 8	UNIDO	Asia	CC	FSP	16 M

Source: GEF Portal as of May 30, 2025.

Table A1-4-3: UNIDO Global Clean Hydrogen Programme – 10 child projects (GEF- 8)

GEF ID	***Project Title***	***Region***	***Focal Area***	***Project Type***	***CEO Amount***
11487	Child Project of the Global Clean Hydrogen Programme of Ecuador	Latin America and Caribbean	CC	MSP	0.87 M
11445	Global Child Project of the Global Clean Hydrogen Programme	Global	CC	FSP	2.6 M
11444	Child project of the Global Clean Hydrogen Programme of Egypt	Africa	CC	FSP	3.5 M
11443	Child Project of the Global Clean Hydrogen Program of Malaysia	Asia	CC	MSP	1.3 M
11442	Child Project of the Global Clean Hydrogen Programme of Namibia	Africa	CC	MSP	0.5 M
11441	Child Project of the Global Clean Hydrogen Program of South Africa	Africa	CC	MSP	0.86 M
11440	Child project of the Global clean hydrogen programme of Philippines	Asia	CC	MSP	1 M
11439	Child project of the Global clean hydrogen programme for Nigeria	Africa	CC	MSP	1.8 M

GEF ID	*Project Title*	*Region*	*Focal Area*	*Project Type*	*CEO Amount*
11438	Child Project of the Global Clean Hydrogen Programme of Algeria	Africa	CC	MSP	0.63 M
11724	Decarbonization through innovative clean hydrogen technology in Pakistan (Child Project of the Global Clean Hydrogen Programme for Pakistan)	Asia	CC	MSP	N/A

Source: GEF Portal as of May 30, 2025.

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ANNEX 2: SNAPSHOTS

Snapshot 1: Challenge Program for Adaptation Innovation

In 2019, the GEF launched the Challenge Program for Adaptation Innovation under the Least Developed Countries Fund (LDCF) and the Special Climate Change Fund (SCCF). The program specifically sought applications from the private sector, nongovernmental organizations (NGOs), and academia in partnership with GEF Agencies. To date, three rounds of funding have awarded $40 million to a total of 32 projects (GEF, 2025). The program has been very popular; the first round attracted 388 applications of which nine were funded, less than 3 percent of applications (GEF IEO, 2022).

In the first two rounds, five out of 19 projects were identified as including technological innovations. These five projects included a range of technological innovations including AI, machine learning, mobile applications, digital platforms, and remote sensing to support climate adaptation, agricultural transformation and resource management (GEF ID 10431, 10438, 10927, 10933, 10965). Specific innovations included AI chatbots (GEF ID 10927), landslide monitoring with drones and unmanned aerial vehicles (GEF ID 10438), blockchain smart contracts (GEF ID 10927), integrated digital agriculture services (GEF ID 10965), and a semi-automated screening tool for incorporating climate change into net-zero projects (GEF ID 10933).

In 2022, the GEF IEO found that the projects from the first round had produced some early results, such as progress in developing and piloting specific technological innovations. This was despite the limited funding available, about $1 million in funding per project. The projects also have ambitions to scale-up and replicate the technological innovations or technological enabled solutions they include, such as making publicly available the AI/ML algorithms developed (GEF ID 10438) or scaling up of technical platforms to other regions (GEF ID 10965). There is also a project focused solely on learning and KM to amplify the impact of the program (GEF ID 11303).

Interviews with the GEF Agencies and the Secretariat confirmed that the program has been successful in engaging with new and non-traditional actors for GEF, such as start-ups, investment and micro-finance funds, and technological-focused academia, although it required partnering with an existing GEF agency and had limited funding available to meet the large demand. The program was seen as a potential model for the future engagement of the GEF partnership with new and non-traditional actors.

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Snapshot 2: Non-Grant Instruments / Blended Finance

Non-grant instruments (NGIs) and blended finance are among the mechanisms used by the GEF to support innovation, including technological. Blended finance combines public and private finance to accelerate private sector engagement in projects where actual or perceived risks are too high for private finance alone (GEF 2020). A non-grant instrument (NGI) in the GEF is an instrument which provides financing in a form that has the potential to generate financial returns, regardless of whether such returns accrue to the GEF (GEF 2023). Over the years, the GEF's rationale for using blended finance and NGIs has been to attract private sector investment and deliver global environmental benefits beyond business as usual (GEF 2025). Between GEF-6 and GEF-8, GEF allocated $115 million to 11 NGI projects in GEF-6, $95 million to 7 projects in GEF-7, and $194 million for 12 projects in GEF-8 (GEF IEO 2025).

While the primary focus at the design stage of NGI projects appears to be on private sector engagement, the portfolio scan and interviews identified NGI projects supporting technological innovation. Based on review of six NGI projects spanning GEF-6- GEF-8 periods, NGI investments and technological innovations demonstrate complementary relationships. NGI investments in venture capital and investment funds help de-risk and mobilize capital for emerging technologies, while technological innovations provide monitoring, verification, and implementation tools that enhance the credibility and effectiveness of these financial mechanisms.

For example, the Agtech Agventures II Fund (GEF ID 10336, GEF-7, IDB) aims to create a shift in the Latin America regional investment landscape for agricultural technology. The project is establishing the venture capital (VC) fund to prove the investment case for Agtech, and attract other VCs to specialize and invest in the sector. By financing startups that offer digital, biotech, and automation solutions, the project intends to change the agricultural practices in the region towards lower GHG emissions, reduced land degradation, better management of chemicals, and improved livelihoods for Small and Medium Sized Farms (SMSFs). Similarly, the Decarbonization of Textile, Apparel & Footwear Suppliers (D-TAFS) fund (GEF ID 11326, GEF-8, World Bank), an investment fund, supports the adoption of cleaner production technologies and replace traditional energy and water intensive processes in global supply chains.

In turn, technological innovations provide credibility, transparency, and verification mechanisms that enable these financial mechanisms to function and attract private capital. The Seychelles SWIOFish3 (GEF ID 9563, GEF-6, World Bank) integrates digital monitoring systems (Fisheries Information Management Systems, Vessel Monitoring Systems, electronic logbooks) that provide the data transparency and accountability required for the Blue Bond and Blue Investment Fund to attract private investors and demonstrate environmental additionality. The &Green Fund project (GEF ID 9719, GEF-6, UNEP) relies on satellite-based monitoring technology to screen prospective investments and continuously monitor the environmental performance of agro-commodities projects, providing the verification for its "Production-Protection-Inclusion" de-risking finance approach. In the Indonesia Coral Bond project (GEF ID 11323, GEF-8, World Bank), the outcome-based financing instrument depends on digital platforms (MERMAID and SMART) to monitor and verify coral reef health outcomes that trigger Conservation Success Payments - without this technological infrastructure, the innovative bond structure could not function.

The expected outcomes related to technological innovations in the reviewed NGI projects demonstrate ambitious goals for systems transformation, though actual achievements remain limited due to the early stage of most projects. The most concrete progress appears in the &Green Fund (GEF ID 9719), which successfully expanded its monitoring framework with satellite-based systems enabling daily fire detection using NASA data and detailed landscape analysis for both screening investments and monitoring portfolio performance. The Agtech fund (GEF ID 10336) has made progress in building its investment portfolio by committing $58 million of investment in 17 technology startups, though actual environmental and socioeconomic benefits have not yet been reported. Several projects face implementation delays, such as the SWIOFish3 (GEF ID 9563) with the Fisheries Information Management Systems development potentially exceeding project life.

Discussions at the GEF Technical Advisory Group meetings, interviews with GEF Secretariat, and Agencies revealed both significant potential and operational challenges for expanding NGI support for technological innovation. The discussions confirmed that NGIs and blended finance attract new actors and private capital, including through mechanisms , such as the proposed ADB's Chemicals and Waste Financing Partnership Facility (GEF ID 11681, GEF-8) targeting PFAS alternatives and other chemical substitutions, and the World Bank's conservation bonds including the upcoming Madagascar Lemur Bond (GEF ID 11694, GEF-8) that combines multiple trust funds (GEF Trust Fund, LDCF) and Non-Grant Instrument financing with private capital markets. However, key barriers limit the program's effectiveness and scale, including the lack of direct access to private sector actors (requiring partnerships with GEF Agencies), complex approval processes misaligned with private sector timelines, and limited understanding of financial instruments and insufficient capacity for blended finance operations in countries.

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Snapshot 3: Technology Needs Assessments

Technology Needs Assessments (TNAs) are enabling initiatives under the UNFCCC process that support developing countries in identifying, prioritizing, and implementing technologies for climate change mitigation and adaptation through a country-driven, participatory, and action-oriented approach (GEF, 2024, p. 85, 100). While GEF's support for TNAs began in 2001, more structured assistance for LDCs and SIDS started in 2009 with the Poznan Strategic Programme on Technology Transfer (PSP), launching the TNA Global Project Phase I (GEF, 2024, p. 100–101. Subsequent phases expanded the initiative's scope and depth:

- Phase II (2014–2021) supported 28 countries in completing TNAs or, for two returning countries, deepening efforts via Technology Action Plans (TAPs) (GEF, 2024, p. 101).
- Phase III (2018–2023) involved 23 countries and enhanced the process by not only producing TNAs and TAPs, but also introducing barrier analysis and enabling frameworks (BAEFs) for mitigation and adaptation, policy briefs, and concept notes. Methodologies were refined, the TNA guide was updated to align with Nationally Determined Contributions (NDCs), and new guidance was provided on gender and financing TAPs (GEF, 2024, p. 101–102).
- Phase IV (2020–2024) engaged 17 countries and introduced new thematic components, including guidebooks on transformational change and the integration of Indigenous Peoples' perspectives into climate technology planning. Capacity-building was emphasized through regional workshops in Africa, Asia-Pacific, and the Caribbean, as well as through online trainings and bilateral technical support meetings. (GEF, 2024, p. 102, 103)
- Phase V (submitted in 2024) will support 17 new or returning countries (GEF, 2024, p. 104). This phase will strengthen TNA and TAP methodologies by incorporating human rights, and social and environmental risk considerations—areas previously under-addressed. Moreover, the updated guidebook and reporting templates will reflect these additions, and regional trainings will cover them to ensure they are considered for each prioritized technology (UNEP, 2024b, p. 10, 29).

The TNAs have achieved mixed results in identifying technology needs and solutions that are viable, potentially impactful, and likely to lead to actual investments. While the reviews do not assess technological innovativeness, they report strong alignment with national priorities. This is largely because the TNAs are country-driven, leading countries to prioritize technologies in sectors critical to their economies and climate resilience. This alignment enhances the potential viability and impact of the selected technologies, as evidenced by stakeholder feedback in the Terminal Review of Phase III, which noted that TNA III was well-integrated with countries' climate change priorities, policy frameworks, and broader development and sectoral strategies, with many countries directly linking their TNAs to their NDCs (UNEP, 2024a, p. 42–43). National stakeholders also highlighted the appreciation for the methodologies and support provided,

which helped in identifying technologies (UNEP, 2024a, p. 12). Nevertheless, the Terminal Review of Phase III concluded that the influence of TNAs on climate change, development, and sector planning was only moderate, as reported by national stakeholders (UNEP, 2024a, p. 76).

In terms of investment mobilization, the 2024 Terminal Review of Phase III notes that financing strategies for identified technologies were developed to some extent. Two countries—Liberia and São Tomé and Príncipe—successfully mobilized GCF readiness funding for sustainable energy projects directly linked to their TNAs. Additionally, the review mentions that Fiji secured funding from its domestic Rural Electrification Trust Fund and the Adaptation Fund for technologies prioritized in its TNA. Moreover, the 2024 Terminal Review also reports that countries from TNA phases I and II have also achieved significant financial mobilization. Pakistan, for example, mobilized USD 583 million from the Asian Development Bank and the GCF for urban public transportation projects based on its TAPs, while Thailand secured USD 33.9 million from the GCF and UNDP for ecosystem-based agricultural water management (UNEP, 2024a, p. 53). On the other hand, there is currently no evidence that projects from TNA Phase IV have translated into actual investments. Review reports note that several countries have yet to complete their TNA and BAEF reports, and none of the 17 countries has begun drafting their TAPs (UNEP, 2023a, p. 7; UNEP, 2023b, p. 6).

Four key lessons emerged from implementing the TNA projects:

1. Continuity and a long-term perspective enable better support and thus better results. (UNEP, 2024a, p. 13)
2. Integrating project implementation and outputs in existing processes and structures enhances results and buy-in and thus adds value. (UNEP, 2024a, p. 13)
3. Country-driven processes and emphasis on stakeholder participation does not always ensure full government buy-in. (UNEP, 2024a, p. 13)
4. Moving from planning to implementation is still constrained by limited access to finance, highlighting the need for sustained support and partnerships. (UNEP, 2024a, p. 64)

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Snapshot 4: The Innovation Window

The Innovation Window was established in the GEF-8 Programming Directions (2022-2026) to strengthen the GEF as an innovative institution in the global environmental finance space. Operating through Medium-Sized Projects (MPSs), the window was envisioned to invest in testing and piloting new solutions to global environmental problems and for generating knowledge aimed at improving the quality, effectiveness, and impact of GEF programming (GEF 2022). The call for proposals for the window was announced in May 2024. While any institution could serve as the lead and executing entity for projects, all selected proposals had to be prepared and submitted through GEF Agencies to meet GEF funding requirements (GEF 2024a). By December 2024, 7 proposals were selected from 128 applications (5.5 percent of applications) to receive $12.3 million in grants (GEF 2024b). As of June 2025, all selected projects are still in the development phase awaiting CEO approval.

Of the seven projects selected, three have a clear focus on technological innovation based on the initial information available.[11] The AgroWeb3 project (GEF ID 11835, IFAD, $1.7 million) combines blockchain with satellite monitoring and drone technology to develop a digital compliance tool for the EU Deforestation Regulation; a wildlife project (GEF ID 11854, IUCN, $1.7 million) plans to harness social media, big data, Artificial Intelligence and Machine Learning for wildlife use and trade indicators; and the Jaguar Corridors project (GEF ID 11914, WWF, $1.7 million) intends to use Machine Learning, cloud computing, and geospatial technology for monitoring in jaguar corridors.

These projects expect measurable outcomes supported by technological innovations: the AgroWeb3 (GEF ID 11835) anticipates enabling 5,000 smallholder farmers, including 2,500 women, to achieve EU Deforestation Regulation compliance across 10,000 hectares and generate $10 million in agricultural exports; the IUCN wildlife project (GEF ID 11854) expects to provide real-time wildlife trade tracking through automated algorithms and a public Application Programme Interface (API); and the Jaguar Corridors (GEF ID 11914) aims to analyze 110 million hectares with annually updated data while building capacity among stakeholders for data-driven conservation decisions.

The projects are expected to partner with specialized organizations including academia, research institutions, space agencies, and networks, while employing scaling strategies that emphasize open-access design and knowledge sharing for broader technology adoption. Each project includes knowledge and learning activities, but there is no dedicated knowledge management project for the Innovation Window portfolio as a whole, which contrasts with the Challenge Program for Adaptation Innovation's approach.

Interviews with GEF Agencies' staff reflected a positive initial assessment of the Innovation Window, while noting funding size limitations. The Secretariat also found it administratively

[11] The remaining projects focus on other types of innovation, such as policy and institutional, financial and business model.

heavy to manage relative to its size. As a result, the replenishment documents for GEF-9 propose mainstreaming innovation across the portfolio rather than continuing with a stand-alone window (GEF 2025a, 2025b, 2025c). This approach is consistent with OPS8 findings, which caution that expanding specialized funding windows adds to procedural complexity, and recommend streamlining and consolidating mechanisms (GEF IEO 2025).

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Annexes

Table A2-4-1: All projects selected through GEF-8 Innovation Window

GEF ID	Project Title	GEF period	Lead Agency	Region	Focal Area	Project Type	CEO Amount ($ Million)
11925	Private Finance and Investments for Nature-Positive: Developing a Framework and Guidance for Financial Institutions	GEF - 8	WWF-US	Global	BD	MSP	0.8
11914	Jaguar Corridors in the Face of Rapid Environmental Change: A dynamic monitoring and assessment system for prioritizing conservation investments	GEF - 8	WWF-US	Latin America and Caribbean	BD	MSP	1.7
11855	Accelerating Rapid Transition of Subsidies and Incentives (ARTSI) Grant Mechanism	GEF - 8	CI	Global	MFA	MSP	1.8*
11854	Revolutionizing indicators of (un)sustainable wildlife use and trade by harnessing social media big data	GEF - 8	IUCN	Global	BD	MSP	1.7
11843	Accelerating Integration, Policy Coherence, and Food Systems Investment with the TCC – Learning from Africa's Food Systems Vanguard Countries	GEF - 8	World Bank	Africa	CC	MSP	1.7

GEF ID	Project Title	GEF period	Lead Agency	Region	Focal Area	Project Type	CEO Amount ($ Million)
11840	Collaboration for Complex Challenges: addressing the food-biodiversity-climate nexus	GEF - 8	UNDP	Global	MFA	MSP	1.7
11835	AgroWeb3 Powered by LACChain: Market Access Window Project	GEF - 8	IFAD	Global	LD	MSP	1.7

*PIF amount, since CEO amount is not available yet. Source: GEF Portal, June 2025

Source: GEF Portal as of May 30, 2025.

Table A2-4-2: Innovation Window projects with explicit focus on technological innovation

GEF ID	Project Title	GEF period	Lead Agency	Region	Focal Area	Project Type	CEO Amount ($ Million)
11914	Jaguar Corridors in the Face of Rapid Environmental Change: A dynamic monitoring and assessment system for prioritizing conservation investments	GEF - 8	WWF-US	Latin America and Caribbean	BD	MSP	1.7
11854	Revolutionizing indicators of (un)sustainable wildlife use and trade by harnessing social media big data	GEF - 8	IUCN	Global	BD	MSP	1.7
11835	AgroWeb3 Powered by LACChain: Market Access Window Project	GEF - 8	IFAD	Global	LD	MSP	1.7

Source: GEF Portal as of May 30, 2025.

Snapshot 5: Global Cleantech Innovation Programme

The Global Cleantech Innovation Programme (GCIP), a joint GEF-UNIDO initiative born from the GEF-5 Revised Private Sector Strategy, traces its roots to the pilot Cleantech Innovation Competition for SMEs in South Africa in 2011. (GEF, 2020, p. 6, 56)

Under the GEF 5 and GEF 6 cycles, the GCIP was developed and implemented as nine separate, independent national-level projects with the primary objective of strengthening innovation and entrepreneurship ecosystems to help SMEs transform their cleantech innovations into viable, investment-ready businesses. (GEF, 2019, p. 28) The program's approach, focused on climate change mitigation, supported innovations primarily energy efficiency, renewable energy, and waste-to-energy, to name a few, (GEF, 2020, p. 11) through four types of interventions:

- *Business acceleration*. Equipping participating entrepreneurs with critical skills through structured training and one-on-one mentorship. The core objective was to help them overcome critical commercial barriers and accelerate the development of their technology and solutions toward market readiness. (GEF, 2020, p. 6)
- *Investment facilitation*. De-risking new technologies for the private sector through demonstration and pilot projects to prove a technology's viability for the private sector. Furthermore, in specific cases where the market failed to provide capital, the program itself stepped in with direct funding. (GEF, 2020, p. 40, 49)
- *Ecosystem and policy development*. Building the capacity of national institutions to strengthen their reputation as innovation conveners and improving the policy framework for cleantech. (GEF, 2020, p. 7)
- *Networking and market access*. Connecting entrepreneurs to markets and partners through national and international forums like the Young Enterprise Development Program in France, the Grassroots Innovation Program in India, and the Swiss Start-up Program, among others, that would allow them to showcase their technology. (GEF, 2020, p. 10)

An in-depth 2018 evaluation of this initial phase provided several key lessons. Participants highly appreciated the networking opportunities to display their work at national and global competitions, which was ranked as a top-three benefit by 47% of those surveyed. National investor forums, in particular, proved especially effective for securing capital. The customized mentorship program was also an important element, rated as a top-three benefit by 56% of survey respondents. Finally, the hands-on business training was the most highly-rated component, as start-ups found great value in its specific focus on developing business models, validating customer bases, and refining financial plans. (GEF, 2020, p. 22, 27)

However, the evaluation also revealed significant challenges. First, Some of the services offered were below expectations. For instance, mentors sometimes lacked familiarity with an entrepreneur's specific technology. (GEF, 2020, p. 23) This was compounded by the fact that

early-stage start-ups noted that they would have benefited from more support for the technical feasibility of their ideas, as the accelerator focused mainly on the business model. (GEF, 2020, p. 26) Moreover, the lack of a formal, cross-country coordination mechanism limited knowledge sharing and the ability to aggregate results. (GEF, 2020, p. 50) Also, the program often failed to strengthen national policy frameworks to foster the growth of cleantech innovation, a component that was often underfunded and initiated too late. (GEF, 2020, p. 30) Similarly, projects frequently lacked clearly defined exit strategies, which endangered their sustainability after GEF funding concluded. Successful handovers, however, were achieved through collaboration with national technology and scientific institutions, such as the Technology Innovation Agency (TIA) in South Africa and the Scientific and Technological Research Council (TÜBITAK) in Turkey. (GEF, 2020, p. 50, 51)

Following this evaluation, a new GEF-7 phase was designed—which is ongoing in GEF-8—sharpening the objective to more explicitly foster private sector engagement and investment at scale. (GEF, 2019, p. 5) The program expanded its thematic alignment to include the Chemical and Waste and Land Degradation focal areas and expanded its geographic scope to include three new countries. (GEF, 2019, p. 29) The new phase prioritizes innovations in areas such as electric mobility, decentralized renewable energy with storage, energy efficiency, and cleantech innovations related sustainable cities and sustainable food systems. (GEF, 2019, p. 50) Its design directly addresses the lessons learned by shifting from standalone projects to a globally coordinated program (GEF, 2019, p. 49). Moreover, to address the identified gap in technical support, the new phase introduced dedicated post-accelerator support for later-stage companies, which explicitly includes assistance with validating the technology, creating prototypes, advancing product development, and securing intellectual property rights. (GEF, 2019, p. 44, 57) One of the emerging lessons from the stakeholder interviews about the Cleantech approach incubation/acceleration of technological innovation, is that due greater focus of the GEF on integrated programming, there is a space for stronger integration of the GCIP approach with other focal areas and programs in the GEF, such as Sustainable Cities and Food Systems.

References

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ANNEX 3: ADDITIONAL PORTFOLIO SCAN ANALYSIS

The values in the "Total number of projects in this category" column may differ from the numbers mentioned in the text. This discrepancy occurs because the portfolio scan took technology terms from the Project Component dataset from the GEF Portal, downloaded on July 2, 2024 and does not include additional projects with technological innovations identified through interviews and document reviews. For example, while the portfolio scan found four projects using blockchain, interviews and document review revealed two more, so the text refers to a total of six.

Table A3-1: Broad and Advanced technological innovations present in GEF projects: GEF-6-7-8

Area	Broad Technological Innovation	Total number of projects in this category	Percent of total number of projects	Advanced Technological Innovation
Advanced digital technologies	***Sub-total***	***244***	***12.1***	
	Blockchain	4	0.2	TRUE
	Extended reality	0	0	TRUE
	Big data	3	0.15	TRUE
	AI and machine learning	3	0.15	TRUE
	Other digital applications	3	0.15	TRUE
	Mobile applications	21	1.04	TRUE
	Digital platforms	172	8.53	
	Cloud computing	0	0	TRUE
	Edge computing	0	0	TRUE
	Green data	0	0	TRUE
	Real-time systems	18	0.89	TRUE
	Data modeling	79	3.92	TRUE
	Fintech	6	0.3	TRUE
Advanced technological solutions (combine digital and other technology types)	***Sub-total***	***42***	***2.08***	
	3D printing	0	0	TRUE
	Drones	10	0.5	TRUE
	Robotics	0	0	TRUE
	Automated system	13	0.64	TRUE
	Sensors (advanced sensors and sensor-based systems)	20	0.99	TRUE
	Internet of things	2	0.1	TRUE
	Advanced tracking technology	4	0.2	TRUE
	Precision agriculture	2	0.1	TRUE
	Precision conservation	0	0	TRUE
	Smart irrigation	0	0	TRUE
	Smart fencing; virtual fencing; geofencing	0	0	TRUE
	Smart grid*	3	0.15	TRUE
	Smart meter	3	0.15	TRUE

Area	Broad Technological Innovation	Total number of projects in this category	Percent of total number of projects	Advanced Technological Innovation
	Smart lighting	1	0.05	TRUE
	Smart packaging	0	0	TRUE
	Intelligent transport*	1	0.05	TRUE
	Smart waste management	0	0	TRUE
	Smart building	0	0	TRUE
	Smart fishing gear	0	0	TRUE
	Sonar	0	0	TRUE
Earth observation	***Sub-total***	***161***	***7.99***	
	Remote sensing and geospatial technology	161	7.99	
Nanotechnology	***Sub-total***	***0***	***0***	
	Nanotechnology	0	0	TRUE
Biotechnology	***Sub-total***	***28***	***1.39***	
	Biotechnology	4	0.2	TRUE
	GMO and LMO detection	9	0.45	TRUE
	Bioprospecting	12	0.6	TRUE
	Genetic monitoring	10	0.5	TRUE
	Engineered bio-based materials and food	3	0.15	TRUE
	Engineered bioremediation	0	0	TRUE
Technologies related to agriculture	***Sub-total***	***48***	***2.38***	
	Soilless cultivation	2	0.1	
	Aquaculture	48	2.38	
Power systems and energy storage	***Sub-total***	***35***	***1.74***	
	Smart grid*	3	0.15	TRUE
	Demand-side management technologies	5	0.25	
	Energy integration	30	1.49	
	Energy storage	13	0.64	
	Green hydrogen	5	0.25	TRUE
Sustainable transport	***Sub-total***	***46***	***2.28***	
	Electric mobility	45	2.23	
	Intelligent transport*	1	0.05	TRUE
	Decarbonization of shipping and aviation	0	0	TRUE
Technologies related to sustainable management and reduction of hazardous chemicals and waste	***Sub-total***	***50***	***2.48***	
	Non-combustion technologies	6	0.3	
	Mercury-free technologies	35	1.74	
	Other alternatives to hazardous chemicals	13	0.64	
Circular economy	***Sub-total***	***25***	***1.24***	
	Plastic circularity	6	0.3	

Area	Broad Technological Innovation	Total number of projects in this category	Percent of total number of projects	Advanced Technological Innovation
	Batteries circularity	6	0.3	
	Sustainable building materials	4	0.2	
	Green chemistry	9	0.45	
Nature-based solutions	***Sub-total***	***97***	***4.81***	
	Nature-based solutions	97	4.81	
	Total	**622**	**31**	

*Some technological innovations (e.g., smart grid, intelligent transport) are categorized under multiple technology areas; however, projects are counted only once in the total, regardless of how many technology areas their innovations span.

Table A3-2: Geographical breakdown of top 5 broad technological innovations.

Digital platforms		Remote sensing and geospatial technology		Nature-based solutions		Data modelling		Aquaculture	
Country	Pjt. No.	Country	Pjt. No.	Country	Pjt. No.	Country	Pjt. No.	Country	Pjt. No.
Global	36	Global	14	Regional (LAC)	4	Regional (Africa)	9	Regional (Africa)	3
China	9	Regional (LAC)	10	Global	3	Regional (Asia)	4	Regional (LAC)	3
Regional (LAC)	7	Regional (Africa)	9	Regional (Asia)	3	Regional (LAC)	3	Palau	3
Regional (Africa)	6	Palau	4	Cabo Verde	3	Türkiye	3	Viet Nam	2
Argentina	5	Argentina	4	Cambodia	3	Comoros	3	Regional (ECA)	2
Senegal	5	Viet Nam	3	Thailand	2	Malaysia	3	Global	2
Peru	4	Tajikistan	3	Guinea	2	Senegal	2	Regional (Asia)	2
Regional (not stated)	4	South Africa	3	Nepal	2	Tanzania	2	Chile	2
Brazil	3	Somalia	3	Regional (ECA)	2	Rwanda	2	Malawi	2
Benin	3	Regional (Asia)	3	Mexico	2	Argentina	2	Cuba	2

Table A3-3: Geographical breakdown of top 5 advanced technological innovations.

Data modeling		Mobile applications		Sensors (advanced sensors and sensor-based systems)		Real-time systems		Automated system	
Country	Pjt. No.	Country	Pjt. No.	Country	Pjt. No.	Country	Pjt. No.	Country	Pjt. No.
Regional (Africa)	9	Regional (Africa)	2	Regional (Africa)	2	Regional (Africa)	3	Global	2
Regional (Asia)	4	Angola	2	Guinea	2	Global	2	Philippines	1
Malaysia	3	Global	2	Chad	2	Mali	2	Regional (Asia)	1
Regional (LAC)	3	Lao PDR	1	Belize	2	Malaysia	1	Lesotho	1
Comoros	3	Nicaragua	1	Regional (Asia)	1	Burundi	1	Guinea	1
Türkiye	3	Namibia	1	Colombia	1	Peru	1	Guinea-Bissau	1
Senegal	2	Micronesia	1	Solomon Islands	1	Serbia	1	Ethiopia	1
Tanzania	2	Jamaica	1	Lesotho	1	Regional (ECA)	1	Vanuatu	1
Rwanda	2	Niue	1	Malaysia	1	Regional (LAC)	1	Burkina Faso	1
Montenegro	2	Ethiopia	1	Kyrgyz Republic	1	Benin	1	Costa Rica	1

Table A3-4: Broad and advanced technological innovations by GEF agencies (GEF-6, 7, 8)

Lead Agency	Total broad projects	Total projects	Broad projects as % of total projects	Total advanced projects	Total projects	Advanced projects as % of total projects
AfDB	12	27	44%	8	27	30%
IUCN	25	63	40%	5	63	8%
CAF	7	19	37%	2	19	11%
UNDP	236	673	35%	93	673	14%
ADB	8	25	32%	3	25	12%
UNIDO	51	163	31%	10	163	6%
FAO	80	268	30%	20	268	7%
World Bank	36	126	29%	11	126	9%
UNEP	126	457	28%	35	457	8%
CI	14	59	24%	4	59	7%
IADB	5	21	24%	3	21	14%
IFAD	11	45	24%	5	45	11%
WWF-US	7	41	17%	3	41	7%

Note: Agencies with less than 10 projects in the portfolio scan were excluded from this analysis.

Table A3-5: Project counts for focal areas across technology "sub-areas"

Program	None		Any		Advanced		Broad		Other		Total	
	Count	%	Count	%	Count	%	Count	%	Count	%	Count	%
Biodiversity	138	48	151	52	39	13.5	78	27.0	73	25.3	289	100
Chemicals and Waste	125	47	143	53	1	0.4	65	24.3	78	29.1	268	100
Climate Change	260	41	368	59	79	12.6	215	34.2	153	24.4	628	100
International Waters	25	25	74	75	21	21.2	42	42.4	32	32.3	99	100
Land Degradation	7	8	81	92	9	10.2	38	43.2	43	48.9	88	100
Multifocal Area	190	30	454	70	53	8.2	184	28.6	270	41.9	644	100
Total	745	37	1271	63	202	10.0	622	30.9	649	32.2	2016	100.00

Table A3-6: Project counts for selected programmatic areas across technology "sub-areas"

Program	None		Any		Advanced		Broad		Other		Total	
	Count	%	Count	%	Count	%	Count	%	Count	%	Count	%
Food Systems	33	42	46	58	3	4	11	14	35	44	79	100
Sustainable Cities	22	51	21	49	4	9	13	30	8	19	43	100
Wildlife	33	65	18	35	6	12	8	16	10	20	51	100

Table A3-7. Technology "sub-areas" across trust funds.

Technology Type	GET	GET (%)	LDCF	LDCF (%)	SCCF	SCCF (%)	MTF	MTF (%)	CBIT	CBIT (%)	GBFF	GBFF (%)
None	665	19.6	22	6.6	6	16.2	10	13.7	32	51.6	10	28.6
Any	1093	32.3	116	34.6	13	35.1	25	34.2	12	19.4	12	34.3
Advanced	159	4.7	32	9.6	2	5.4	5	6.8	4	6.5	0	0
Broad	534	15.8	57	17	5	13.5	12	16.4	11	17.7	3	8.6
Other	559	16.5	59	17.6	8	21.6	13	17.8	1	1.7	9	25.7

Table A3-8. Private sector involvement in GEF projects across technology sub-areas.

Private sector involvement	None		Any		Advanced		Broad		Other		Total	
	Count	%	Count	%	Count	%	Count	%	Count	%	Count	%
No	524	70.4	420	33.3	81	40.1	209	33.8	211	32.8	944	47
Yes	220	29.6	843	66.7	121	59.9	410	66.2	433	67.2	1063	53
Total	744	100	1263	100	202	100	619	100	644	100	2007	100

ANNEX 4 METHODOLOGY

The evaluation used a mixed-methods approach based on a non-experimental design. The evaluation methods selected aimed to respond to the evaluation questions as detailed in the evaluation matrix below. The main methods used were as follows:

Document review: All documents located that were found to be relevant to technological innovation were reviewed, including internal GEF guidance, strategies and policies, STAP guidance and advisory documents, GEF IEO evaluation reports, and external studies and reports by development organizations, research and policy institutions. In total 52 documents were reviewed, in addition to project and program level documents that were reviewed as part of the portfolio scan (see below).

Case studies and "snapshots": Four case studies and five "snapshots" were created. Based on information and data collected through other methods, such as the portfolio scan and key informant interviews, the case studies and snapshots were drafted and guided by a common structure and content for each format. The case study topics were selected to focus on key advanced technologies; blockchain, AI/ML and green hydrogen, in addition to an integrated program (Sustainable Cities). The snapshot topics were selected to focus on key initiatives of the GEF partnership that were identified as promoting technological innovations; Challenge Program for Adaptation Innovation, Non-Grant Instruments / Blended Finance, Technology Needs Assessments, the Innovation Window, Global Cleantech Innovation Programme.

Key informant interviews (KIIs): KIIs were held with 47 stakeholders: 16 staff of GEF Secretariat, 29 staff of eight GEF Agencies, one representative of STAP; and one representative of the GEF CSO Network. All KIIs were semi-structured and followed an interview guide based on the evaluation questions.

Field validation: The evaluation also used evidence from field visits to China, Indonesia, Mexico, and Viet Nam, enabling direct observation of technological innovations. A GEF IEO mission to China visited three projects: the China Sustainable Cities Integrated Approach Pilot (GEF ID 9223), the Municipal Solid Waste Management Project (GEF ID 4617), and the Transformational Wildlife Conservation Management project (GEF ID 10701). Additional field-based inputs were received from GEF IEO colleagues who conducted missions to Viet Nam and Indonesia for green chemistry projects (GEF IDs 9379 and 10353), and to Mexico for the Small Grants Programme. The field verification approach included site visits, focus group discussions with project beneficiaries, interviews with project management staff and implementing partners, observation, and review of monitoring data and documentation.

Portfolio scan: Through a document and literature review, interviews, and expert validation, the evaluation developed a taxonomy of 120 technological innovations and other technologies and categorized them in the following sub-areas for the portfolio scan:

a. **Advanced technological innovations:** Included technologies explicitly mentioned in GEF strategies, STAP documents, and recent literature on technologies for the

environment that are considered emerging and cutting-edge, such as Artificial Intelligence and machine learning: 42 technologies in total.

b. **Broader technological innovations:** This category included the above advanced innovations as well as technologies with innovative elements that are not explicitly classified as emerging or cutting-edge, such as remote sensing: 58 technologies in total including the 42 included in (a).
c. **Other technologies:** This category covers technologies not included in categories (a) or (b). It included very broad technologies such as post-harvest technologies, which may incorporate some innovation but also long-standing technologies. This category also includes environmental approaches with technological elements that are not necessarily considered innovative. 62 technologies were included in category (c), distinct from (a) and (b).

A total of 2,016 projects were scanned from GEF-6, GEF-7 and GEF-8. The portfolio scan used the Project Component dataset from the GEF Portal, downloaded on July 2, 2024, to include all GEF-6, GEF-7 and GEF-8 projects as of the end of FY2024 (excluding parents, cancelled, and dropped projects). The dataset included information on project objectives, project components, project outputs and outcomes among other information. The team used CEO endorsement/approval data when available, otherwise PIF approval data. Project objectives, components, outputs, and outcomes were systematically reviewed to identify the presence of technological innovations and technologies from the taxonomy. Once the portfolio was established, it was analyzed using descriptive statistics, logistic regression, and machine learning methods (Random Forests and Gradient-Boosted Trees).

A limitation of the analysis was that not all technological innovations were explicitly documented in this dataset. Therefore, the quantitative findings should be considered a conservative estimate. To strengthen the analysis, the evaluation triangulated the scan results with stakeholder interviews and document reviews. This process identified additional instances of technological innovation, though the number of additional projects was relatively small.

Evaluation matrix - Evaluation of the GEF Support for Technological Innovations

Evaluation questions	Indicators	Methods/tools	Sources
1. What are the main technological innovations supported by the GEF in GEF-6, GEF-7, and GEF-8? 1.1. Are there any missed opportunities based on what has been tried and tested?	1. Identification and evidence of the main technological innovations supported by the GEF; cross-referenced by GEF 6-8. 1.1. Identification of missed opportunities (technological innovations).	Portfolio scan Interviews Case studies	GEF 6-8 programme/project documentation Document review Central-level stakeholders (GEF Secretariat, STAP, Agencies, CSO Network)
2. What outcomes are associated with technological innovations supported by the GEF in GEF-6 and GEF-7?	2. Evidence of the outcomes associated with identified technological innovations; cross-referenced by GEF 6-7.	Interviews Case studies Field validation	Document review Central-level stakeholders (GEF Secretariat, STAP, Agencies, CSO Network) Site visits, focus group discussions, direct observation
3.What are the enablers and barriers for the GEF to support for technological innovations	3. Identification of 1) enablers and 2) barriers to support technological innovations within the GEF.	Interviews Case studies Field validation	Document review Central-level stakeholders (GEF Secretariat, STAP, Agencies, CSO Network) Site visits, focus group discussions, direct observation