



November 2024

# Annual Report 2024





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# PROLOGUE

The Green Powered Future Mission (GPFM) has been instrumental in driving innovation to accelerate the renewable energy transition, a crucial step toward achieving a power system aligned with the Paris Agreement. As a core member, IRENA is proud to witness GPFM's success in pioneering diverse innovation streams through their three workstream pillars: affordable and reliable variable renewable energies, system flexibility and market design and digitalization for system integration. Those are essential for overcoming the challenges of decarbonization. This partnership reflects the shared commitment of IRENA and GPFM to not only advance technology but also to explore innovative market designs, regulatory frameworks, and resilient business models that support global renewable energy goals.

COP28 marked a pivotal moment for the energy sector, underscoring the urgent need to move away from fossil fuels and embrace a path that will triple renewable power capacity and double energy efficiency by 2030. Yet, despite this progress, the world remains behind on the trajectory needed to meet a 1.5°C climate goal. IRENA's latest data highlights that just under 480 GW of new renewable capacity was deployed in 2023, compared to the 1,000 GW required. This shortfall pushes annual targets even higher, emphasizing the need for immediate and scaled innovation efforts.

Through GPFM's collaboration with Mission Innovation member countries and leading experts, these challenges are being tackled head-on. The Mission's emphasis on global knowledge sharing has brought critical insights to stakeholders worldwide. Looking ahead, IRENA and GPFM remain committed to advancing innovation that supports the deployment of 11 TW of renewable power by 2030. Together, we are making significant strides in transforming the energy landscape and creating a future powered by renewables.

**Ann-Kathrin Lipponer**, *International Renewable Energy Agency - IRENA*

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## THE YEAR IN WORDS



**LUCIANO MARTINI**

***Green Powered Future Mission Director***

I strongly believe that the GPFM has made remarkable progress over the past 12 months. In line with its Action Plan, GPFM delivered all planned outputs, namely technical factsheets, the GPFM Toolbox, new strategic funding calls, very informative webinars, groundbreaking pilot projects, and significant contributions to international fora and events. By these outputs the Mission has significantly advanced towards its goals of accelerating clean energy innovation and

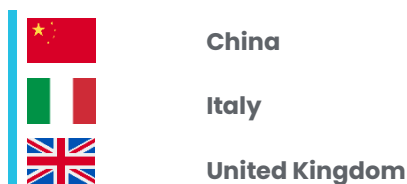
deployment, while strengthening collaboration among coalition members and with external partners and has clearly marked its central role in the power sector innovation landscape.

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# GPFM COALITION MEMBERS

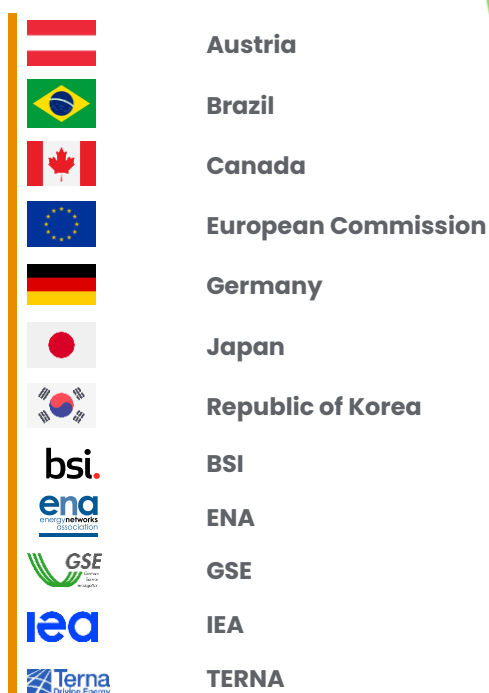
## Co-Leads



## Core Team



## Support Team



# 1. INTRODUCTION

## 1.1 About the GPFM

The Green Powered Future Mission (GPFM), launched as part of Mission Innovation 2.0 in June 2021, champions the vital role of innovation in combating climate change and driving decarbonization at pace to limit global warming to 1.5°C and attain net zero targets.

The GPFM is a global initiative that drives Research and Innovation (R&I) to achieve its ambitious target of demonstrating that, by 2030, power systems in different geographies and climates are able to effectively integrate up to 100% Variable Renewable Energy (VRE) in their generation mix while maintaining a cost-efficient, secure and resilient system.

In its first 2 years, the GPFM built a strong coalition of international members to come together and collaborate on R&I. The [Joint Roadmap of Global Innovation Priorities](#), published at COP26, outlined 100 green power Innovation Priorities (IPs) categorised under 3 R&I pillars:

**Pillar 1 – Affordable and Reliable VRE:** reduce cost and increase efficiency, resilience, and reliability of VRE technologies in various climates and system configurations.

**Pillar 2 – System Flexibility and Market Design:** develop flexible solutions to meet network infrastructure needs, to be supported by regulation and innovative markets design.

**Pillar 3 – Data and Digitalisation for System Integration:** accelerate the digitalisation of energy systems through the development of interoperable data exchange and effective system integration to unlock the full value of VRE.

The Roadmap was succeeded in 2022 by the Mission's first "[Action Plan 2022–2024](#)", which narrowed the focus to the 50 most urgent IPs that need to be addressed by 2024. This plan detailed the establishment of the Mission's two flagship projects (FPs):

- ❖ FP1 – 5 Demos in Five Continents
- ❖ FP2 – Multilateral Research programme

The goal of the 5 Demos in Five Continents project is to demonstrate large scale innovation activities across the continents of Asia, Australia, Europe, North America, and South America. These demonstrations are made up of 80 National Pilots that are tackling one or more of the 50 most urgent IPs. This culminated in the publication of the Mission's first [National Pilots Report](#) in 2023.

Meanwhile, the goal of the Multilateral Research programme is to address 20 of the 50 most urgent IPs, while promoting collaboration across the membership and engagement with other international initiatives. The first iteration of this project was a joint funding call in collaboration with the Clean Energy Transition Partnership.

Through these flagship projects, the Mission is sprinting towards achieving its ambitious 2030 goals.



## 2.PROGRESS TOWARDS THE MISSION GOALS

Progress towards the Green Powered Future Mission's goals is updated and assessed every year. To do so, the Mission gathers updates on the Research and Innovation (R&I) activities provided by affiliated members and compares these against the Action Plan. The aim is to monitor the progress of the Mission with respect to the accomplishment of its 2030 goals and to present to the wider community what has been achieved during the last twelve months.

### TAG Review 2023

In November 2023, the GPFM underwent review by the MI Technical Advisory Group (TAG), an independent panel of experts of diverse geographical and technical backgrounds, to ensure that the Mission is on track, uncover any opportunities, risks or barriers to progress.

The review was very positive overall; the panel appreciated the structure of the Mission, the clarity of the goals, and the plans and implementation strategies set out in the Joint Roadmap and Action Plan

2022-24. The TAG panel's main recommendations were:

- ❖ Identify and share the lessons learned from pilots, including an understanding of factors affecting failure and success;
- ❖ Elaborate on the value proposition that makes it attractive for the private sector to engage with the Mission;
- ❖ Further engage with fora in different regions that convene decision makers to bring key policy recommendations to their attention.

The content of this report will demonstrate the ways in which the Mission has addressed the TAG recommendations.

### 2.1 Gantt Chart

The Gantt chart shown in [Figure 1](#) summarizes all the ongoing and planned activities and key milestones of the GPFM in the period of 2023-2025, including R&I, flagship projects, collaborations and engagement events. Main events and meetings that are organised by, or relevant to, the GPFM are also highlighted.

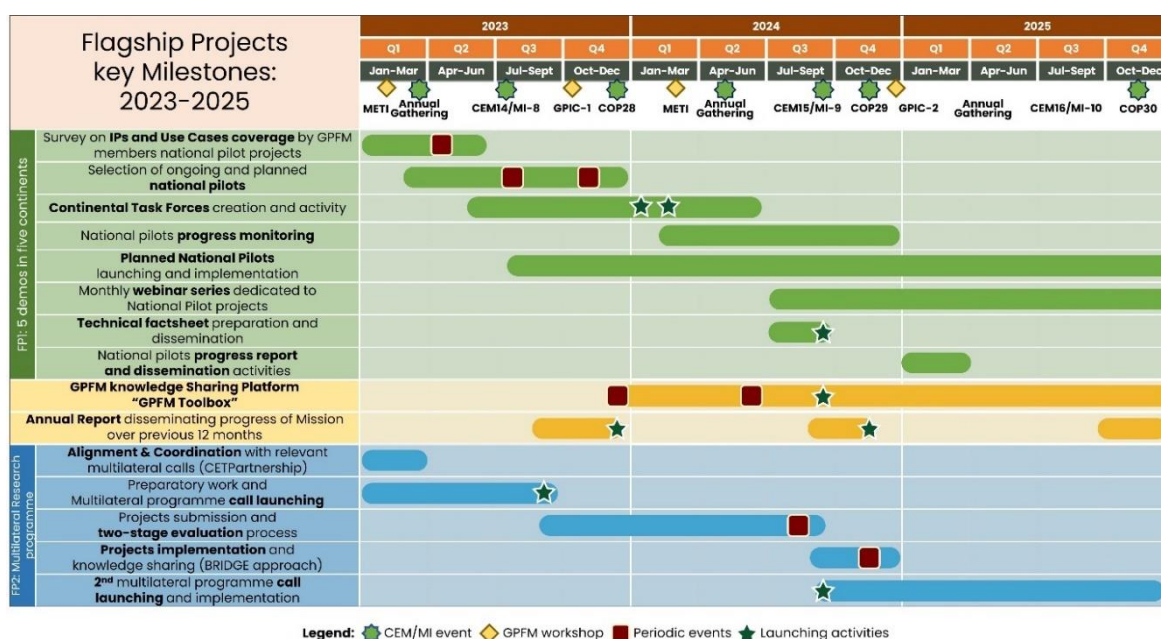


Figure 1: Flagship projects milestones and MI/GPFM events 2023 - 2025



For example, this year the 15<sup>th</sup> Clean Energy Ministerial (CEM) and the 9<sup>th</sup> Mission Innovation (MI) Ministerial joint event (CEM15/MI-9) convening clean energy experts was held in Foz do Iguaçu in Brazil at the beginning of October 2024. At this event, the GPFM released some key deliverables: the ‘GPFM Toolbox’ and a series of 4 technical factsheets. Additionally, this year the Mission launched three continental task forces and a monthly webinar series to facilitate knowledge sharing from the National Pilots under FP1 and announced the successful projects to be funded under the inaugural joint call module of FP2 and the new joint call for future projects.

## 2.2 KPIs

The seven Key Performance Indicators (KPIs) used to monitor the GPFM progress, as defined in the Action Plan 2022–2024, are:

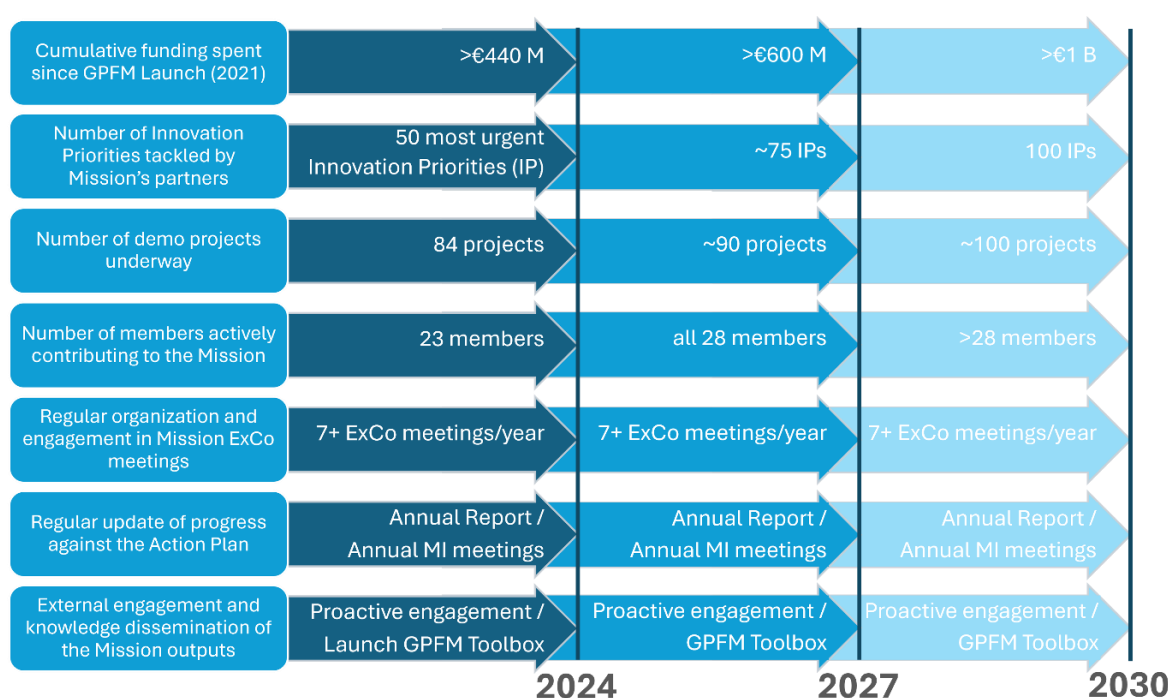
1. Cumulative funding spent.
2. Number of Innovation Priorities tackled by Mission’s partners in their R&I activities.
3. Number of demo projects underway.

4. Number of members actively contributing to the Mission.
5. Regular organisation and engagement in Mission ExCo meetings.
6. Regular update of the GPFM progress against the Action Plan.
7. External engagement and knowledge dissemination of the Mission outputs.

### Progress against KPIs

In September 2024, members were issued a survey to provide updates on their National Pilots projects from the last 12 months, including financial and progress updates. Based on the received responses, the updated progress of the KPIs towards the Mission goals is summarised in [Figure 2](#). For this year’s report, the Mission has included interim 2027 goals to show progress towards 2030 targets.

According to member updates, there are 84 National Pilot projects currently in the GPFM portfolio, a net change of 4 projects from the original 80 published in the National Pilots report in 2023. These projects encompass a total initial investment of



*Figure 2: GPFM progress so far against the KPIs set out in the Action Plan 2022–24, and the Mission’s ambitions out to 2030.*

around €1.2 billion, with over €440 million spent as of October 2024.

The type of funding varies across the project portfolio with almost half of existing projects being co-funded by public-private partnerships, about 31% by public funds, and another 17% of projects being supported by EU funding. Privately funded projects represent about 5% of the total 84 GPFM projects (see Figure 3).

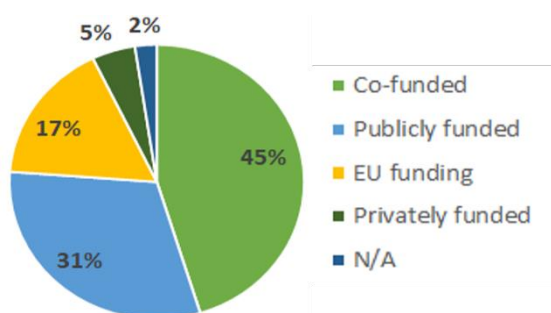


Figure 3: Type of funding scheme of GPFM National Pilot projects.

In the last 12 months, six projects have reached completion, including three projects from Spain and three projects from the National Grid, UK. Moreover, five GPFM projects are close to completion, and another 29% of projects are more than 50% completed.

Members have been actively engaging with the Mission and other stakeholders in disseminating the key outcomes from their pilot projects. These include national and international conferences<sup>1</sup>, public webinars, and Government forums. Results have also been published in different formats from

peer-reviewed academic publications<sup>2</sup>, reports<sup>3</sup>, blogs<sup>4</sup>, project websites, and posts on social media such as LinkedIn.

Other global activities that members have undertaken in the past year include issuing funding calls such as Canada's 'Smart Grid Program', China's 'Renewable Energy Technology R&D program' and Germany's '8<sup>th</sup> Energy Research Program'.

More details of the Mission's progress towards its objectives are presented in the next sections.

## 2.3 Flagship Projects

The Action Plan 2022-24 outlined the Mission's two Flagship Projects, which were set up to accelerate clean energy innovation and tackle the Mission's 50 most urgent IPs.

### Flagship Project 1 (FP1) "5 demos in five continents"

This flagship project was launched with the objective of demonstrating innovation activities in the five continents of Asia, Australia, Europe, North America, and South America, where the national pilot projects are tackling one or more of the 50 most urgent innovation priorities (see Appendix A). FP1 provides all 28 GPFM members with the opportunity to collaborate and share results between their pilot projects. The large demos, launched with the goal of

<sup>1</sup> Events included for example, Utility Week, NY Climate Action Week, National Grid Innovation Day, among others.

<sup>2</sup> Some academic papers included: <https://doi.org/10.1016/j.epsr.2024.110710>; <https://ieeexplore.ieee.org/document/10562006>; <https://ieeexplore.ieee.org/document/10540632>

<sup>3</sup> Examples of reports published: [https://cigreconference.ca/papers/2022/paper\\_52\\_2.pdf](https://cigreconference.ca/papers/2022/paper_52_2.pdf); [https://sje-corp-site.cdn.prismic.io/sje-corp-site/d70f05cf-f131-43a2-a565-732a77dcaabb\\_Public+Report+-+FINAL.pdf](https://sje-corp-site.cdn.prismic.io/sje-corp-site/d70f05cf-f131-43a2-a565-732a77dcaabb_Public+Report+-+FINAL.pdf)

<sup>4</sup> Examples of blogs: [ARENA backs eight big batteries to bolster grid – Australian Renewable Energy Agency](#); [\\$12.4 million to support international clean innovation researcher networks | Ministers](#)

reaching up to 80% VRE by 2024, have been grouped continentally as follows:

1. Asian Pilots
2. European Pilots
3. North and South American and Australian Pilots
4. International Organisation Pilots

Since the launch of FP1 and the publication of the National Pilots report in July 2023, six pilots have completed successfully. Many projects are still ongoing and have hit some important milestones in the last 12 months.

Key project include [‘BeFlexible’](#) which is delivering hardware and software solutions for customers to participate in flexibility services, and National Grid carrying out the largest domestic heat pump flexibility trial with over 1000 customers in Project [‘EQUINOX’](#) in the UK. The Chinese project *‘Design and control technology of high efficiency and high power density electromechanical drive system and DC boost converter for offshore wind turbines’* developed an experimental prototype of a direct current (DC) boost conversion power module. Also, a model of a 10 MW DC wind turbine was built and completed as part of the *‘Research and equipment development of key technologies for DC conversion and overall control of high-power offshore DC wind turbines’* project. Germany developed a prototype platform to test new flexibility concepts through the *‘DigIPlat’* project. Icebreaker One [Perseus](#) project convened a constellation of stakeholders to co-design and implement a data governance solution for businesses to automate their emissions reporting. Furthermore, various numerical and technical models were developed, tested and implemented in projects dealing with, e.g., [EV adoption and charging infrastructure](#) as well as other topics such as energy efficiency part of the investigation carried out in [three living labs](#).

## Flagship Project 2 (FP2)

### “Multilateral research programme”

Launched in Q1 2023, FP2 is a Multilateral Research Programme aiming to address 20 of the most urgent 50 innovation priorities and to promote engagement and collaboration with other international initiatives.

The first implementation of this project was the launch of the joint call module with the Clean Energy Transition Partnership (CETPartnership), in July 2023, which focuses on “Energy system flexibility: renewables production, storage and system integration” and tackles 11 IPs. Following the review of 22 submitted proposals, 8 projects were officially approved in June 2024. A total of \$12M was awarded to the projects, which involve 15 agencies across 13 countries. These projects began in September 2024.

A [new joint call module](#), targeting the same 11 Innovation Priorities plus three additional ones, was launched in September 2024.

## 2.4 Collaborations Launched

### Joint Agenda for Action on Power Systems Solutions.

At the CEM15/MI-9 Ministerial meeting, the GPFM joined forces with the power workstreams of CEM, namely the International Smart Grid Action Network (ISGAN) and 21<sup>st</sup> Century Power Partnership (21CPP), to advance power system solutions and tackle the following challenges:

- ❖ Improve planning and investment certainty
- ❖ Support modernizing and expanding transmission and distribution grids
- ❖ Unlock power system flexibility
- ❖ Deploy e-mobility infrastructure

- ❖ Strengthen energy supply chain resilience and sustainability
- ❖ Advance a just and inclusive transition

This agenda, endorsed by Mission Innovation and Clean Energy Ministerial member countries, highlights the crucial role of power systems in enabling the clean energy transition. Together, CEM and MI are reaffirming their commitment to COP28, G7, and G20 objectives, recognizing that collaboration is key as we work to drive innovation, investment, and implementation of real-world solutions.

### **African Union Development Agency**

The GPFM has begun expanding its focus from 5 continents to 6, and has engaged several stakeholders in Africa. In particular, the Mission found alignment with the African Union Development Agency – New Partnership for Africa's Development (AUDA-NEPAD) on R&I topics of joint interest. A fruitful interaction with AUDA-NEPAD tackling grid Innovation Priorities in Africa is ongoing.

### **Urban Transitions Mission (UTM)**

In 2024, the GPFM and the UTM jointly applied for a project called "Urban Photovoltaic System Planning" which will be funded by the Ministry of Science and Technology of the People's Republic of China (MoST). Running from 2025–2027, this project will develop methods and software for optimizing urban PV system planning. This joint effort represents an excellent example of the synergies between the two Missions, involving academia and research organisations from several countries.

## **2.5 GPFM Events and Deliverables**

In the last 12 months, the GPFM has been very active organising events and other tangible deliverables with aim of reaching

the Mission's goal through knowledge sharing and collaboration:

**ExCo Meetings:** The Mission receives strategic guidance and direction from the Executive Committee (ExCo), composed of representatives from member countries, private sector companies and international organizations. The Mission Director convenes ExCo members every two months to inform and discuss on mission progress and planned future engagement and activities. It also drives high-level engagement with Ministers and CEOs and provides strategic advice and guidance for the overall Mission's activity. During 2024 the ExCo members were actively engaged in discussions about GPFM main activities related to the FPI and FP2 progress, approval of main deliverables and next steps towards the 2025–2027 Mission's period of activity.

### **1st Green Power Innovation Conference**

**(GPIC-1):** The inaugural international workshop "Global GPFM: Embracing Offshore Wind and PV Brilliance", co-organized by the Institute of Electrical Engineering, Chinese Academy of Science (IEECAS) and GPFM was successfully held in Yancheng in October 2023. The conference held in-depth discussions around the vision of the Mission, cutting-edge research and innovations, and FPI "5 Demos in Five Continents".

Alongside the Mission co-leads China, Italy and the UK, more than 300 experts from countries such as Japan, India, Sweden and Denmark, as well as international and private sector organizations, attended the conference.

Topics under discussion at GPIC-1 included the importance of international cooperation and emerging business models to accelerate energy innovation, renewable energy grid connection and clean energy technology to help power



system transformation, and private sector innovation strategy deployment.

Additionally, a launching ceremony was held to announce the Asian Demonstration project (Figure 4). This project is a collaboration between China, India, Japan and South Korea, and covers 16 global innovation challenges such as high-efficiency photovoltaic cells and floating offshore wind power.



*Figure 4: Launch Ceremony of Asian Demo Project (China, Oct 2023)*

**COP28:** In December 2023, the GPFM organized two side events at the Italian Pavilion at COP28 in Dubai. The first was a dedicated GPFM event “National Pilot Projects for Net Zero Power Systems”, where the Mission delved into GPFM Flagship Project 1 with stakeholders, publicly released the Annual Report 2023, and showed the preliminary launch video for the GPFM knowledge sharing platform ‘GPFM Toolbox’. Co-organized with the Urban Transitions Mission (UTM), the “Innovation Catalysts: Powering Cities on a Mission Towards Net Zero” event presented the joint activities on common innovation areas focusing on urban networks. Additionally, the Mission had the opportunity to link with key international initiatives and contribute to the several other events during COP28.

**Technological Reports:** At COP28, four summary reports were released under R&I Pillar 1. These reports address four themes: Novel Wind Power; Offshore Wind; Novel PV Cells; and Reliability of Emerging PV;

representing the full scope of innovation for green power generation. The reports were compiled by a group of experts in their fields, and describe the current innovation landscape of their respective areas.

**METI Workshop:** In March 2024, the GPFM held a virtual workshop on “Policy and Technology for Grid Flexibility and Stability”, hosted by the Ministry of Economy, Trade and Industry, Japan. The 2-day event featured contributions from 18 international experts from 7 different countries, along with IEA and IRENA keynotes. This collaborative workshop fostered the exchange of global and national perspectives, best practices, and innovative solutions for grid flexibility and stability.

**Continental Taskforces:** The GPFM set up 3 continental Task Forces (TF) to monitor the progress of the National Pilots. Through the TFs, project coordinators can share relevant results and update the information with respect to the National Pilots Report. Each Task Force has two co-leads, who are responsible for overseeing the activity in a certain region (TF I Asia: China & India, TF II Europe: Italy & Spain, TF III: Australia & Italy).

**Private Sector Workshops:** In April 2024, the GPFM organised a workshop for members of the Mission hailing from private sector to provide their views on the innovation priorities of the global power sector and the overall direction of the Mission in this regard. This was a first step towards establishing a Private Sector Advisory board. This board would provide strategic advice to ensure that the Mission is pursuing activities that align with the needs of emerging power sector innovations so that it can better support, enable and scale those technologies.

**Annual Gathering:** The MI Annual Gathering was held from 15-17 May 2024 in Bali, Indonesia (Figure 5). The GPFM contributed to several high-level sessions on various

aspects of the power sector, featuring fruitful discussions with key representatives from relevant countries and international organizations. The Mission also organized a closed-door meeting to discuss its strategic implementation plan with members, including representatives from China, Italy, UK, Australia, Brazil, Japan, Spain, Saudi Arabia, and the participation of two South African Ministry representatives as observers.



*Figure 5: CEM and MI senior representatives at the Annual Gathering in Bali*

**MI9 Ministerial:** The 9<sup>th</sup> Mission Innovation Ministerial and 15<sup>th</sup> Clean Energy Ministerial (CEM15/MI-9) took place alongside the G20 in Foz do Iguaçu, Brazil. At the three-day event, Ministers, CEOs, academics, innovators and civil society participated in a high-level plenary, roundtables and high-level dialogues, and topical side events.

The GPFM organised three side events at CEM15/MI-9:

- ❖ GPFM event focused on the Mission's demo approach to addressing the power system's most urgent innovation
- ❖ Joint event with the Urban Transitions Mission (UTM), focused on securing green power to local energy communities.
- ❖ Joint event with the CEM power initiatives – ISGAN and 21CPP – which focused on working-level actions for the joint 'Agenda for Action for Power System Solutions'.

Additionally, the GPFM contributed to the preparation phase of the high-level roundtable, featuring Ministers and CEOs, that was aimed to discuss the joint deliverable 'Agenda for Action on Power Systems Solutions'. All of the CEM and MI Ministers signed to endorse the agenda.

**GPFM Toolbox:** Building on the success of the initial launch at COP28, the GPFM devoted significant effort and resources to developing the GPFM Toolbox ([www.mi-gpfm.com](http://www.mi-gpfm.com)), and it was finally officially launched at CEM15/MI9. This cutting-edge platform fosters collaboration among GPFM members, disseminates Mission achievements, and accelerates VRE integration by providing a centralized repository of GPFM projects, data, and insights. It shares key results and best practices from flagship projects, enabling countries to customize innovative solutions for their specific geographical conditions and national strategies. The platform will be continually updated and developed as the Mission and Flagship projects make progress towards the 2030 goals.

**Technical Factsheets:** In addition to the Toolbox, the GPFM also released four technical factsheets at CEM15/MI-9. These factsheets contain case studies from coalition members, featuring projects that address key innovation priorities and showcase key findings from the national pilot projects. One factsheet is from Pillar 1, two from Pillar 2, and one from Pillar 3. This is an ongoing endeavour, with further factsheets planned in the future.

- ❖ Factsheet P1-01 "Renewable systems for enhancing stability and efficiency", featuring contributions from China, India, Italy, and Spain, highlights advancements in improving the integration of renewable energy sources into the existing power system.



- ❖ Factsheet P2-01 "*Tools and solutions for flexible power systems*", featuring contributions from Areti, Australia, Canada, Enel, Italy, and Spain, highlights solutions and opportunities for system operators to procure flexibility services from distributed energy sources to maintain high levels of security and quality of supply.
- ❖ Factsheet P2-02 "*Flexibility from electric vehicles*", featuring contributions from Areti, Canada, China, Italy, National Grid, and Terna, highlights opportunities for the electricity grid to exploit electric vehicle charging infrastructure for flexibility services either via smart charging or vehicle-to-grid.
- ❖ Factsheet P3-01 "*Data and Digitalisation for System Integration*", featuring contributions from China, Icebreaker One, Italy, NESO (UK), Spain, and the UK, highlights smart technologies that will facilitate the transition to a digitalised energy system for improving flexibility,

reliability, and sustainability in the energy sector.

**National Pilots webinar series:** In July 2024, the Mission launched a series of monthly webinars, led by the UK, to allow GPFM project leads to present the progress of their National Pilots and to facilitate discussion with interested stakeholders about the opportunities and challenges emerging from these projects. Four successful webinars have taken place so far:

- ❖ Brazil – “Hybridization of Isolated Systems in Brazil”;
- ❖ IRENA – “Innovation Landscape for Smart Electrification”;
- ❖ Spain – “INCIT-EV” and “SYNERGIES”;
- ❖ National Grid/NESO – “System value from V2G peak reduction in future scenarios based on strategic transport and energy demand modelling” and “Virtual Energy System”.

This webinar series will continue into 2025.

### 3. IMPACT OF GPFM ACTIVITIES

Energy is at the heart of the climate crisis – the burning of fossil fuels to generate electricity and heat is by far the largest contributor to global climate change.

Energy is also key to the solution – we must end our reliance on fossil fuels and reduce emissions by almost half by 2030 and reach net-zero by 2050. To achieve this, we must transition to alternative sources of energy that are renewable, accessible, affordable, sustainable, and reliable.

Innovation has a major role in this transition: according to a [2020 report](#) by the International Energy Agency (IEA), “almost 35% of the cumulative CO<sub>2</sub> emissions reductions seen in the Sustainable Development Scenario by 2070 compared with the current trajectory come from technologies that are currently at the prototype or demonstration phase and that will not become available at scale without further R&D”. Investment in research, development and demonstration is therefore integral to achieving a secure and resilient net zero economy.

The GPFM is a crucial initiative in the global power sector. By sharing the wealth of knowledge generated by the coalition, particularly in the two flagship projects, the GPFM is driving innovation through data generation, the development of advanced tools, and establishment of strong international networks. This strategic approach will accelerate the transition towards a future where more regions can access affordable and reliable VRE.

#### Knowledge Sharing

One of the GPFM’s most significant contribution is the establishment of 80 ongoing and planned national pilot projects that are tackling the most urgent innovation priorities. These projects serve as real-world

test cases, demonstrating how countries can adapt their energy systems to integrate high levels of renewables, regardless of their geography and climate conditions.

To ensure these pilots can be replicated globally, the Mission shares valuable data and insights, and showcase progress, success, and lessons learned, through the creation of knowledge-sharing tools.

With this in mind, the GPFM launched the Continental Task Forces which aim to share progress and insights from national pilots and enhance collaboration among coalition members. By monitoring activities through surveys, meetings, and ongoing engagement, this activity aims to identify key exploitable results and best practices for further analysis and replication. This approach enables the demonstration of different innovative technical, regulatory and market solutions to be implemented and validated in different climates and geographies.

At MI9, the Mission launched the ‘GPFM Toolbox’. This online platform will contain all information and updates pertaining to each to the Flagship projects. The platform will have a dedicated collaborative space for project experts from member countries and organisations to exchange knowledge, catalyzing innovation around the world. The primary goal of the platform is to facilitate access to proven technologies and strategies, which enhances capacity building and empowers nations to implement effective renewable energy solutions tailored to their specific needs.

In addition to the Toolbox, the GPFM released four technical factsheets at MI-9, which share results and recommendations from selected case studies that are addressing key innovation priorities. These

factsheets were shared with Ministers and senior officials, providing an opportunity to showcase the impactful innovation happening across the coalition to the decision makers from MI member countries, who are responsible for >95% of public clean energy RD&D investments globally.

Since July 2024, the GPFM has been hosting monthly webinars dedicated to the National Pilot projects. These webinars facilitate knowledge exchange between the project leads and other innovators from the Mission membership and beyond. There is a particular focus on sharing lessons learned, which accelerates innovation and prevents duplication of effort. Examples of knowledge shared from the webinars include:

- ❖ How Brazil is working to integrate renewable power into primarily diesel-fuelled, remote regions of Amazonia;
- ❖ IRENA's innovation toolbox of 100 technologies for creating a 'smart' future power system, including power-to-mobility and power-to-heat, and policy blind spots to be aware of;
- ❖ National Grid and Spain both separately presented projects that are developing innovative EV charging solutions and understanding user behaviour;
- ❖ Spain and NESO have both showcased innovative data-driven solutions that are facilitating system-wide collaboration on data-sharing for energy management.

The wealth of information shared through the webinars, factsheets, and the 'GPFM Toolbox' are transforming and catalyzing innovation across the GPFM and beyond.

The global reach of these deliverables is a key indicator of the GPFM's success. With 8 member governments, as well as 5 non-governmental organisations, contributing to the factsheets and/or the webinar series so far, these endeavours are creating

significant impact on the global green power innovation landscape.

Lastly, the GPFM hosted its inaugural Green Power Innovation Conference (GPIC-1) in Yancheng, China, in October 2023. Like other international gatherings e.g. MI-9, this event brought together hundreds of experts from around the globe, creating opportunities for knowledge exchange stemming from various research and innovation initiatives. High-level technical discussions among GPFM members, academics, private sector and international organizations, focused on international cooperation to develop clean energy technology to help power system transformation. Such interactions foster fruitful collaborations that accelerate global innovation. A notable example is the launch of the 'Asian Demonstration Project', which encompasses six initiatives focused on clean power generation through solar and wind technologies, thereby serving as a vital partnership for knowledge sharing under GPFM's Pillar 1.

### Collaboration

Collaboration is another cornerstone of the GPFM's approach; partnering with other international organizations and initiatives to advance the Mission's objectives and reach the goal of integrating up to 100% VRE.

The Mission's foremost collaboration is with the CETPartnership, which has led to the launch of two joint calls for projects under (FP2) "Multilateral Research Programme", aiming to increase opportunities for international cooperation. These joint calls address key innovation priorities for power system transformation and represent a valuable opportunity to promote engagement and collaboration among international initiatives.

The GPFM also works closely with several CEM power workstreams, such as ISGAN and 2ICPP. At the CEM13/MI-7 Ministerial in 2022, the GPFM and ISGAN signed a

Memorandum of Understanding (MoU) which states the intention of the two initiatives to establish a long-term fruitful collaboration on projects of mutual interest in the field of Smart Grids. Additionally, the newly launched “Agenda for Action on Power Systems Solutions”, a collaborative endeavour between the GPFM, ISGAN, 21CPP and other CEM workstreams, marks the start of increased international cooperation on the transition to a green powered future.

The GPFM has a fruitful relationship with IRENA (part of the GPFM core team), as their focus on promoting renewable energy worldwide through collaboration and innovation complements the GPFM's objectives. Additionally, thanks to IRENA, the GPFM established connections with the Accelerated Partnership for Renewables in Africa (APRA) and the African Union Development Agency (AUDA). This resulted in the organisation of meetings to identify collaboration opportunities and to understand the overlap of Africa's green power innovation priorities with those identified by the GPFM in the Action Plan 2022–2024. This collaboration will continue to proliferate into 2025 and beyond.

The Breakthrough Agenda, specifically the Power Breakthrough, is another initiative that the GPFM is involved with; as a coordinating initiative for Priority Action P3 'Research and Innovation', and as a partner initiative for P4 'Infrastructure and knowledge, capability & skills': and P6 'Landscape Coordination'. Working with the Breakthrough Agenda further enhances GPFM's impact by fostering international cooperation and sharing best practices across the full clean power landscape.

All of these initiatives have an annual opportunity to gather together at the CEM/MI joint Ministerial event, one of the

largest clean energy forums of the calendar year. Held in 2024 alongside the G20 meetings, this event put innovation in the political spotlight and boosted the momentum of all of Mission Innovation's initiatives. Ministers, CEOs, academics, innovators and civil society participated in roundtables, high-level dialogues, and topical side events. The GPFM organized 3 side events, 2 of which were joint with other MI Missions and CEM workstreams. These dialogues facilitated knowledge sharing and strengthened commitments to actionable solutions in the clean energy sector. By uniting diverse perspectives, they fostered a unified approach to overcoming barriers in the clean energy transition, enhancing the effectiveness of global sustainable power initiatives.

By participating in forums such as CEM/MI and COP events, the GPFM positions its members as leaders in clean energy innovation on a global stage. Members can showcase their commitment to sustainability while attracting investments and fostering collaborations that further enhance their capabilities in renewable energy technologies.

### Summary

The GPFM stands at the forefront of efforts to revolutionize global power systems. It plays a crucial role in addressing climate change by promoting a shift to renewable sources and developing innovative flexible solutions that allow power systems to accommodate the inherent intermittency of these sources. Its impactful activities not only address immediate challenges but also lay a foundation for a sustainable and resilient energy future, making it an indispensable player in the broader green power landscape alongside other key international initiatives.

## 4. CHALLENGES AND BARRIERS

As with many global initiatives, the efforts to decarbonise global power systems face common technical, political, and systemic challenges and barriers. But the advantage of a coalition is that such barriers can be tackled collaboratively and on an individual project level, with lessons learned being shared across the Mission – and beyond.

Some of the challenges and barriers to the GPFM's goal of integrating up to 100% VRE in any global power system include:

**Changes in government policy and global geopolitical shifts:** the complex and ever-changing international political situation could have a profound impact across many aspects of the energy transition, from deprioritizing clean energy innovation in favour of domestic energy security to reduced international scientific and technological cooperation. The multilateral cooperative relationship established by the GPFM coalition brings not only challenges, such as resource constraints, but also important opportunities for cooperation on innovation. Regular engagement with policy and planning bodies of member countries is crucial to keep up to date on future changes and developments.

**Overcrowded landscape of power sector initiatives:** with the power sector playing an increasingly important role in the clean energy transition and increasing political appetite, more initiatives are bound to keep appearing. The GPFM must therefore

continue to articulate and promote its unique selling point by showing real value-add in supporting project demonstrations, while remaining collaborative with partners and other actors in this space. In this view, the Mission is actively collaborating with other key power sector global initiatives (e.g., ISGAN, 21CPP, Power Breakthrough) and has made good progress in identifying synergies on mutually interesting topics and related joint activities, thus minimizing duplication.

**Cyber security threats in a digitalized power system:** as global electricity networks evolve towards greener solutions through the integration of VRE, they are simultaneously transitioning to more digitalized systems. This shift is accompanied by an increasing reliance on 'smart' assets by consumers, which, while enhancing efficiency and connectivity, also heightens the risk of cyber-attacks. These threats pose significant challenges to the security and reliability of modern energy systems.

Lastly, as part of their response to the National Pilots survey, GPFM members stated that some of the challenges they face in the delivery of their projects include pace of policy development and communication; delays due to supply chain disruptions and work authorization; inflation; and permitting and regulatory barriers.

## 5. LOOKING AHEAD

The Mission is committed to driving tangible impact by facilitating strategic implementation of demonstration projects and related knowledge-sharing between its members and beyond. Expanding the Mission's outreach is vital to ensure a green future that is sustainable for all. Next year, 2025, marks the start of the Mission's next 'sprint', and thus many engagements and deliverables are planned.

### **GPFM Toolbox**

The GPFM Toolbox is designed to be a live platform, leading and promoting GPFM technological innovation and multilateral cooperation. Going forward, information pertaining to the Mission, including FPI and FP2 data, will be continuously added to the platform to achieve wider participation. Meanwhile, the Toolbox provides an interactive collaboration platform for all coalition members, thereby improving the efficiency of international cooperation.

### **COP 29 Engagement**

At COP29, the GPFM will host a session entitled "*Actions for Mission Innovation's Green Powered Future for Africa*", which presents a great opportunity for the Mission to showcase its activities and progress, as well as its ongoing fruitful collaborations with key international actors and initiatives. Moreover, it will feature contributions from several international representatives on GPFM Innovation Priorities relevant to Africa, as well as the foreseen joint activity with the Urban Transitions Mission on isolated local communities.

### **Action Plan 2025–2027**

The Mission's first Action Plan 2022–24 detailed how the 50 most urgent innovation priorities would be tackled. As we enter 2025, some of these IPs will be fully

addressed and there will be several that can be brought forward in their place. With this in mind, a new Action Plan for 2025–2027 will be drawn up to detail the Mission's outlook, including how the new list of ~75 urgent IPs will be tackled through research and pilot projects, and how the Mission intends to further improve international cooperation through knowledge sharing and capacity building.

### **2024 MI Green Power Innovation Conference (GPIC-2)**

Building on the success of GPIC-1, the GPFM aims to establish an annual global flagship forum for innovation in the power sector. Therefore, GPIC-2 will be held in Yancheng, China, in December 2024, with the theme "Global Clean Nexus: Collaborating for a Green Powered Future". Through a diverse agenda featuring technical panels, demonstration seminars, stakeholder dialogues, and technical visits, the conference will bridge connections among policy makers, innovators, and investors to accelerate innovation and advance the application of green power solutions.

### **FPI Next Steps and Task Force Activities**

The Mission plans to deliver an updated National Pilots report in line with the updated list of ~75 IPs that will be detailed in the Action Plan 2025–2027.

The Mission will continue to share the knowledge generated from the pilot projects through a variety of media, such as technical factsheets, webinars, the GPFM Toolbox, and side events and workshops at relevant international fora (CEM/MI Ministerial, COP, etc.).

### **Private Sector Advisory Board**

Following the successful private sector engagement workshops held in 2024, the GPFM will use the insights obtained to



guide the process in creating a Private Sector Advisory Board. This board, made up of a handful of green power industry experts, will provide strategic advice to ensure that the Mission is pursuing

activities that align with the needs of emerging power sector innovations so that it can better support, enable and scale those technologies.



# APPENDIX A

List of R&I Topics and the 50 most urgent Innovation Priorities as identified in the GPFM Action Plan 2022–2024.

## Pillar 1 - Affordable and Reliable VRE

### T1.1 – Novel Photovoltaic

- 1.1.1 High efficiency PV cells and modules
- 1.1.3 Reliability evaluation of PV modules and systems
- 1.1.5 Software and database for PV systems
- 1.1.6 Recycling and eco-design of PV cells and modules
- 1.1.7 Agri-PV technologies

### T1.2 - Offshore wind

- 1.2.2 Floating offshore wind turbines

### T1.3 - Integrated Renewable Energy (IRE)

- 1.3.2 Large-scale IRE generation for improving system reliability and stability
- 1.3.3 Distributed IRE generation at grid edge

### T1.5 - Energy Storage Supply Chain, Recycle and Reuse

- 1.5.1 Analysis of batteries life cycle and monitor, test and recycle of batteries
- 1.5.2 Recycling and reuse batteries design
- 1.5.3 Innovation in energy storage technologies
- 1.5.4 Driving cost-reduction across the battery supply chain
- 1.5.6 Safety assessment of electrochemical storage

### T1.6 - Technologies for System Stability

- 1.6.1 Grid-forming devices applied to solar PV and wind
- 1.6.2 Grid-supporting technologies from inverter-based resources

## Pillar 2 - System Flexibility and Market Design

### T2.1 - Flexible Generation

- 2.1.1 VRE flexibility provision and contribution to generation capacity
- 2.1.2 Further exploitation of hydropower and pumped hydro flexibility

### T2.2 - Grid Flexibility

- 2.2.1 Innovative components and dynamic line rating
- 2.2.4 Enhanced control rooms and automated decision systems

### T2.3 - System Stability and Flexible Operations

- 2.3.1 System stability assessment considering high VRE penetration
- 2.3.2 Enhanced TSO-DSO coordination platform for flexibility markets optimisation
- 2.3.3 Innovative frequency and non-frequency ancillary services specifications
- 2.3.4 Tools and solutions for DSO flexibility management
- 2.3.5 DSOs and TSOs enhanced grid and DER observability

### T2.4 - Energy Storage Integration

- 2.4.1 Need and requirements assessment for storage systems new services

## T2.5 - Demand-side and EV Flexibility

- 2.4.3 Utility scale storage systems for innovative flexibility services
- 2.4.4 Assessment of energy management for multi-service energy storage systems
- 2.4.6 Identification of main barriers hindering storage systems mass deployment
- 2.5.1 Methods to estimate the available actual demand-side flexibility
- 2.5.2 Unlocking commercial and residential buildings flexibility potential
- 2.5.4 Demand response, EV services and grid impact assessment
- 2.5.5 Tools for optimal smart charging and V2G management
- 2.5.6 Impact assessment of flexibility services on EV batteries

## T2.6 - Flexible Systems Planning

- 2.6.1 Integrated transmission and distribution planning tool
- 2.6.3 New planning strategies and methods for flexibility solutions and system services
- 2.6.5 EV charging infrastructure planning and deployment

## T2.7 - Markets, Business Models and Regulatory Framework

- 2.7.1 Flexibility markets for innovative ancillary services by VRE and storage
- 2.7.4 Business models and regulatory framework for flexible resources
- 2.7.5 Market access rules, grid tariffs and price schemes to exploit EV flexibility
- 2.7.7 Regulatory solutions to foster flexibility provision from end-uses
- 2.7.8 Output-based regulation to incentivise grid flexibility exploitation
- 2.7.11 Social acceptance of innovative technologies and required behavioural change

## T2.8 - Flexibility from Sector Integration

- 2.8.1 Sector Coupling flexibility assessment
- 2.8.2 Optimal planning and operation of integrated energy systems

# Pillar 3 - Data and Digitalisation for System Integration

## T3.1 - Standards for Interoperability

- 3.1.1 Data discovery, access, and licensing
- 3.1.2 Standardisation of devices and control platforms
- 3.1.4 Data security standards and data privacy
- 3.2.2 Identify priority dataset for system security

## T3.2 - Secure and Resilient Digital Energy Systems

## T3.3 - Integrated Solutions

- 3.3.1 Interoperable markets, devices, and data
- 3.3.2 Connected data platforms for enhanced forecasting and flexible operation



Green Powered Future Mission

**Main contacts:**

If you would like to receive additional information about the Green Powered Future Mission and/or this Annual Report 2024, please contact:

**Luciano Martini**

Green Powered Future Mission Director, Ricerca sul Sistema Energetico, Italy  
[luciano.martini@rse-web.it](mailto:luciano.martini@rse-web.it)

**Yibo Wang**

Pillar 1 lead, Institute of Electrical Engineering Chinese Academy of Sciences, China  
[wyb@mail.iee.ac.cn](mailto:wyb@mail.iee.ac.cn)

**Mattia Cabiati**

Pillar 2 lead, Ricerca sul Sistema Energetico, Italy  
[mattia.cabiati@rse-web.it](mailto:mattia.cabiati@rse-web.it)

**Craig Fraser**

Pillar 3 lead, Department for Energy Security & Net Zero, United Kingdom  
[craig.fraser@energysecurity.gov.uk](mailto:craig.fraser@energysecurity.gov.uk)