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Development of Metrologically Traceable Greenhouse Gas (GHG) Standards for Indonesia

In collaboration with Indonesia's Meteorology, Climatology, and Geophysical Agency (BMKG), SNSU-BSN has developed national-level GHG standards and measurement capability for ensuring the comparability of atmospheric measurements

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The Challenge

Climate change poses a major challenge for Indonesia, affecting food security, public health, biodiversity, coastal communities, water resources, and economic stability. Indonesia has committed to reducing greenhouse gas (GHG) emissions and achieving Net Zero Emissions by 2060 under the Paris Agreement and the United Nations Framework Convention on Climate Change (UNFCCC). Achieving these targets requires GHG measurements that are reliable, internationally comparable, and traceable to recognized standards.

In this context, collaboration between the National Metrology Institute of Indonesia (SNSU-BSN) and the Meteorology, Climatology, and Geophysical Agency of Indonesia (BMKG) is strategically important to strengthen Indonesia's greenhouse gas monitoring capability. BMKG operates atmospheric observation networks under the WMO's Global Atmosphere Watch (GAW) program, including the Bukit Kototabang GAW station, which conducts long-term GHG monitoring in the tropical equatorial region. Meanwhile, SNSU-BSN provides national measurement standards and calibration infrastructure to ensure metrological traceability and comparability of atmospheric measurements.

This collaboration supports Indonesia's climate governance by enhancing the credibility of national GHG inventories, strengthening Monitoring, Reporting, and Verification (MRV) systems, promoting carbon market transparency, and enabling evidence-based climate policies. Strategic initiatives include the development of SI-traceable reference gas materials, calibration systems for GHG analyzers, and interlaboratory comparison programs.

The challenge addressed is not only scientific, but also environmental, economic, industrial, and governance-related, as climate policies and emission-reduction programs depend heavily on measurement quality. Strengthening traceable GHG measurements supports reliable climate reporting, industrial decarbonization, sustainable development planning, and international trust in Indonesia's climate commitments. Improved GHG monitoring also helps protect vulnerable communities affected by climate change, including coastal populations and regions impacted by extreme weather and forest fires. This initiative directly supports the Sustainable Development Goals for climate action by providing trustworthy measurement data essential for climate monitoring, emissions evaluation, and the implementation of national climate policies. Reliable GHG measurements are essential for climate governance, environmental protection, and international accountability.

Currently, Indonesia still depends heavily on imported primary gas standards from institutions such as the National Oceanic and Atmospheric Administration (NOAA) in the US and the Swiss

Federal Laboratories for Materials Science and Technology (EMPA). This is vital for calibrating analytical Cavity Ring-Down Spectroscopy (CRDS) instruments (see **Figure 1**) and ensuring the accuracy, and metrological traceability of GHG measurements. If GHG measurements are inconsistent, or not internationally accepted, national emission inventories may lose credibility, carbon-market transparency may be weakened, environmental policies may rely on uncertain data, industries may face difficulties demonstrating emission reductions, and Indonesia could encounter barriers in international climate cooperation and green trade.

However, reliance on imported reference materials and primary standards creates challenges, including high procurement and shipping costs, lengthy delivery and customs clearance times, limited availability for routine recalibration, and vulnerability to international supply chain disruptions. Such dependence limits the sustainable expansion of national monitoring networks and may affect climate reporting, carbon accounting, and the reliability of MRV systems under the Paris Agreement.

Therefore, the collaboration and support from Physikalisch-Technische Bundesanstalt (PTB), Germany presented here provide an opportunity to strengthen Indonesia's national capability for metrologically traceable GHG measurements through cooperation between SNSU-BSN and BMKG, as shown in **Figure 1**. This is strategically important for Indonesia's environmental governance, economic resilience, and sustainable development agenda.

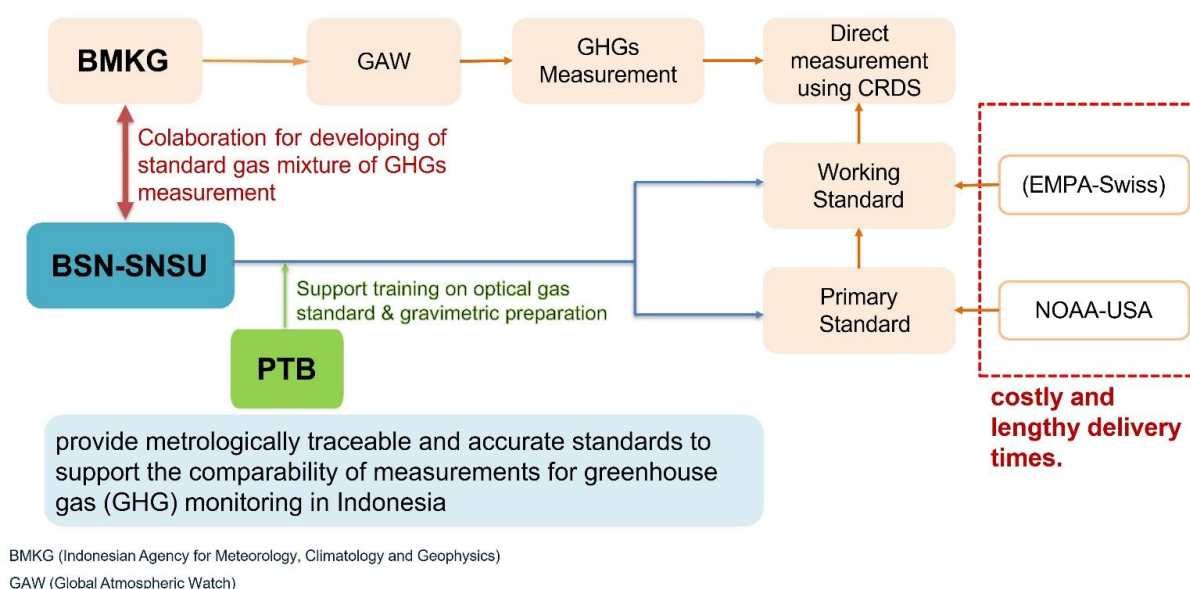


Figure 1. An illustration of the collaboration between the SNSU-BSN and BMKG in the development of a metrologically traceable greenhouse gas standard.

The Solution

An important opportunity has emerged for SNSU-BSN and BMKG to collaborate to develop national capabilities to produce and certify SI-traceable greenhouse gas (GHG) standard gas mixtures domestically, as illustrated in **Figure 1**. This multi-year (2025-2027) collaboration focuses on strengthening Indonesia's capability in traceable atmospheric measurements. This was triggered within a larger collaboration with PTB and worked through activities including feasibility studies for gas standard preparation, purity analysis of high-purity gases based on ISO 19229, preparation of CO₂ and CH₄ gas standards in synthetic air according to ISO 6142, as well as verification and comparability studies, as shown in **Figure 2**.

To date, the collaboration has completed feasibility studies, impurity analysis, first-step dilution preparation of GHG mixtures, and validation of analytical methods for greenhouse gas measurements. Evaluation and verification of gas mixture compositions in accordance with ISO 6143 are currently being prepared, along with comparative studies between gas standards developed by SNSU-BSN and reference standards used by BMKG from NOAA and EMPA.

The strategic collaboration between SNSU-BSN, as Indonesia's National Metrology Institute, and BMKG to develop traceable GHG standards for ensuring the comparability of atmospheric measurements in Indonesia was presented at the 1st Stakeholder Meeting of the CIPM Sectorial Task Group on Climate Change and Environment (CIPM STG-CENV).¹ The meeting highlighted ongoing international collaborations in climate observation, in which metrology plays an essential role, and identified significant opportunities for National Metrology Institutes to strengthen their involvement in climate-related measurement systems.² At the national level, this collaboration has been formalized through a Cooperation Agreement on synergy in the production and development of CRMs for greenhouse gas mixtures. This initiative aims to strengthen Indonesia's domestic capability in producing traceable reference standards to support long-term atmospheric monitoring.

A feasibility study has been conducted covering the design of greenhouse gas standard preparation and gas-cylinder pretreatment. Standard gas mixtures of CO₂ and CH₄ at atmospheric concentration levels in synthetic air matrices have been prepared by a gravimetric method in accordance with ISO 6142-1:2015 and combined using a multistep dilution strategy. In addition, purity analysis of high-purity gases in accordance with ISO 19229:2019 and validation of analytical methods for greenhouse gas measurements have also been completed.

¹ CIPM Sectorial Task Group on Climate Change and Environment (CIPM STG-CENV). <https://bipm-cenv2024.org/wp-content/uploads/abstracts/275.pdf>

² 1st Stakeholders' Meeting of the CIPM Sectorial Task Group for Climate Change and Environment - Summary Outputs. <https://www.bipm.org/en/doi/10.59161/Rapport202501>

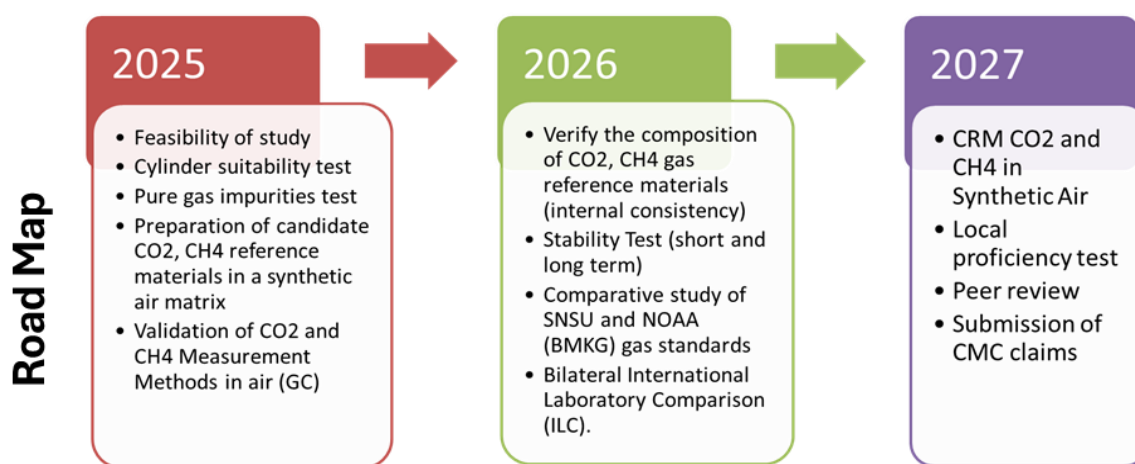


Figure 2. Roadmap activities for the Synergy in the Development and Production of Certified Reference Materials (CRM) Greenhouse Gas Mixtures.

As mentioned above, the collaboration is further supported by the “Strengthening the Quality Infrastructure Services for Environmental and Climate Monitoring (ECMI)” project of the Physikalisch-Technische Bundesanstalt (PTB) and PTB’s environment and climate metrology program (Innovation Cluster for Environment and Climate),³ which supports improvements in laboratory capabilities and the procurement of materials. As part of the capacity-building program, SNSU-BSN personnel also participated in in-house training at PTB on the preparation and verification of greenhouse gas standards.

A Quantifiable Impact

This collaboration has strengthened Indonesia’s national capability to develop SI-traceable greenhouse gas (GHG) standards for atmospheric measurements and has enhanced technical competence in preparing GHG standards. The prepared GHG standards are a set of primary and working standard gas mixtures of carbon dioxide (CO₂) and methane (CH₄) at atmospheric level concentration in synthetic air matrices. In addition, capacity-building activities and technical training have enhanced the competencies of laboratory metrologists and technologists, particularly in preparing low-concentration calibration gas mixtures using gravimetric methods. During her visit to PTB in 2025, an SNSU-BSN scientist was also trained in PTB’s optical gas standard concept and used some CRDS instruments qualified as candidate optical gas standards for CH₄, CO, and CO₂ to validate gravimetric reference material preparations. Preliminary results from these activities will be presented at the 2nd International Conference on Measurement Sciences and Applications, organized by the

³ Physikalisch-Technische Bundesanstalt (PTB). Innovation Cluster for Environment and Climate.
<https://www.ptb.de/environment-climate>

National Institute of Metrology Thailand (NIMT), on 26–28 August 2026, demonstrating Indonesia’s progress in developing traceable GHG measurement capability and strengthening its contribution to international climate metrology efforts.

The collaboration between SNSU-BSN and BMKG demonstrated the importance of integrating national metrology infrastructure into climate governance systems. The initiative supported Indonesia’s Net Zero Emission 2060 targets, the modernization of environmental monitoring systems, the strengthening of MRV frameworks, and the strengthening of the measurement infrastructure needed for carbon accounting, emissions verification, and carbon market mechanisms. This was recently attested by BMKG on the important contribution of metrologically traceable GHG standards to strengthening Indonesia’s climate action governance and atmospheric observation capability:

“Reliable, comparable, and internationally traceable GHG measurements are essential for supporting evidence-based climate policy, improving the credibility of national atmospheric monitoring, and contributing to global climate initiatives.

For BMKG, this intervention is highly relevant to the development of national GHG monitoring systems, including efforts to improve data quality, strengthen calibration practices, and ensure alignment with international measurement standards. These improvements are particularly important as Indonesia continues to contribute to global frameworks such as the Global Greenhouse Gas Watch and other initiatives that require robust, transparent, and scientifically defensible atmospheric data.

The metrological intervention has strengthened the scientific foundation for climate mitigation, monitoring, reporting, and decision-making. This collaboration also demonstrates the value of strong cooperation between the national metrology institute and the national meteorological and climatological service in addressing climate-related challenges.

BMKG appreciates the continued collaboration with SNSU-BSN and recognizes the strategic importance of metrology in ensuring that Indonesia’s GHG observations are credible, comparable, and useful for both national and international climate action.”

The metrological intervention has also strengthened Indonesia’s climate governance to support regulatory implementation and international environmental commitments. Improved calibration capabilities, metrological traceability, and reduced measurement uncertainty has strengthened the technical foundation for national GHG inventories, MRV systems, emissions verification, and reporting under the Paris Agreement by improving the comparability and reliability of atmospheric greenhouse gas measurements

Several governance lessons emerged from this collaboration. Effective, evidence-based climate policy depends on comparable, metrologically traceable, and internationally accepted measurement results. Metrology serves not only as a laboratory activity but also as a strategic infrastructure for environmental governance and climate resilience, sustainable industrial

development, international compliance, and national scientific and technological independence. Cross-institutional collaboration is essential to ensure scientifically robust and globally accepted environmental observations. In addition, developing domestic reference standards and calibration capabilities reduces reliance on foreign standards, while sustained quality assurance, interlaboratory comparisons, and adherence to international standards are critical for international comparability in climate reporting.

This collaboration will deliver, and is expected to continue to provide, several significant national benefits, including reducing dependence on imported standards, lowering operational costs, accelerating calibration processes, strengthening Indonesia's national quality infrastructure, improving measurement sovereignty, and supporting the long-term sustainability of greenhouse gas monitoring. The availability of locally produced gas reference standards will not only reduce costs but also improve the efficiency and sustainability of atmospheric monitoring activities in Indonesia by enabling faster access to calibration gases and reducing operational time and costs associated with overseas procurement and shipping. Based on BMKG's operational experience, obtaining metrologically traceable GHG reference gas mixtures from overseas involves significant costs beyond the price of the gas mixture itself, including international freight, handling of pressurized cylinders, customs clearance, and associated administrative processes. These logistical requirements can substantially increase the total landed cost and may extend procurement lead times to several months.

The availability of nationally produced, internationally traceable reference gas mixtures is therefore expected to significantly reduce logistics-related costs and shorten procurement lead times, improving the operational efficiency and sustainability of Indonesia's atmospheric GHG monitoring network. An estimated 50–70 % reduction in overall procurement-related costs and a reduction in lead time from several months to several weeks may be considered as potential impacts, subject to confirmation through actual procurement records and future operational experience. Beyond technical benefits, the initiative also strengthens Indonesia's position in international climate reporting, carbon market participation, environmental governance, and evidence-based climate policymaking.

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