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Roadmap for securing the supply of reference materials for the seawater CO_2 system

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1.0 CHALLENGE AND LEVEL OF URGENCY

The ocean absorbs 25% of human-made CO_2 each year, but monitoring this uptake and storage relies on high-quality reference materials . These reference materials are essential for consistent measurements worldwide, enabling scientists to track ocean acidification, shifts in the carbon cycle, and the impact of carbon dioxide removal. At present, the world depends on a single US-based supplier, leaving the continuous monitoring of ocean carbon variables vulnerable to disruption. Europe now has a strategic opportunity to establish its own production and certification hub for reference materials, ensuring scientific research reliability and resilience of its climate and ocean observation systems, and progress towards net zero carbon.

The world's oceans absorb approximately 25% of annual anthropogenic CO_2 emissions, playing a crucial role in mitigating climate change. Monitoring this uptake is essential for understanding climate dynamics and informing policymakers, as understood by the "Ostend Declaration on Operationalising the Surface Ocean Carbon Value Chain". While the CO_2 uptake occurs at the ocean's surface, long-term carbon storage takes place in deeper waters. To properly assess the state of the oceanic CO_2 storage capacity and to detect anthropogenic contributions, precise measurements of the seawater CO_2 system are necessary. A global network of scientists collects data on oceanic CO_2 storage, relying on high-quality reference materials to ensure measurement accuracy and comparability. These reference materials form the backbone of seawater CO_2 system measurements, ensuring that consistent data are collected across laboratories and field deployments worldwide. Such data are fundamental for tracking shifts in the ocean carbon cycle and ocean acidification trends, for accurately quantifying the effects of Carbon Dioxide Removal (CDR) interventions, and for reinforcing broader climate mitigation efforts to achieve net zero.

Currently, the supply of reference materials for the seawater CO_2 system depends solely on the Scripps Institution of Oceanography in the United States of America. The COVID-19 pandemic exposed the vulnerability of this single-point supplier when significant shortages occurred. Should Scripps Institution of Oceanography discontinue production of reference materials for any reason, whether due to funding constraints, logistical challenges or other factors, the lack of reliable RMs would inevitably result in a decline in data quality worldwide, and this will severely affect the reliable observations of essential seawater CO_2 system variables, as well as carbon budget assessments required for safe and effective CDR efforts.

This vulnerability reveals a critical risk to the global climate change monitoring infrastructure and underscores the urgent need to diversify production and certification capabilities for reference materials. Europe is uniquely positioned to address this challenge by establishing a European hub that ensures a resilient and independent supply of certified seawater CO_2 system reference materials.

POTENTIAL OPERATIONAL MODELS

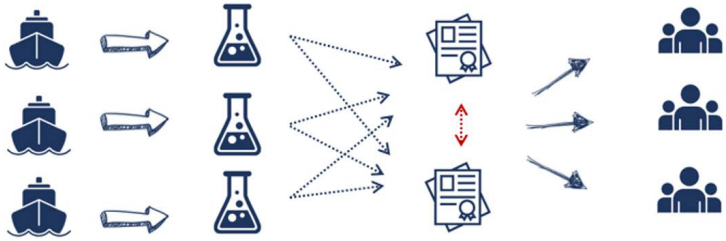
Two models are conceivable for sustaining the reference material supply chain:

1. **A single dedicated facility:** A centralised, self-sustaining facility focused entirely on production and certification of reference materials. This would require a significant upfront investment.

2. **Several distributed facilities:** A coordinated network of producers and certifiers operating under a shared logistical and governance framework. This enhances flexibility, resilience, and scalability of the reference material network. Furthermore, batch production can happen at oceanographic institutes already prepared and trained in bottling while certification will be done by dedicated laboratories in Europe.

Model 1 (Dedicated facility)

Model 2 (Distributed facilities)



Given the infrastructure and expertise already present in Europe, the second option (Figure 1) is prioritised due to its operational resilience and capacity to deliver consistent, high-quality results across institutions.

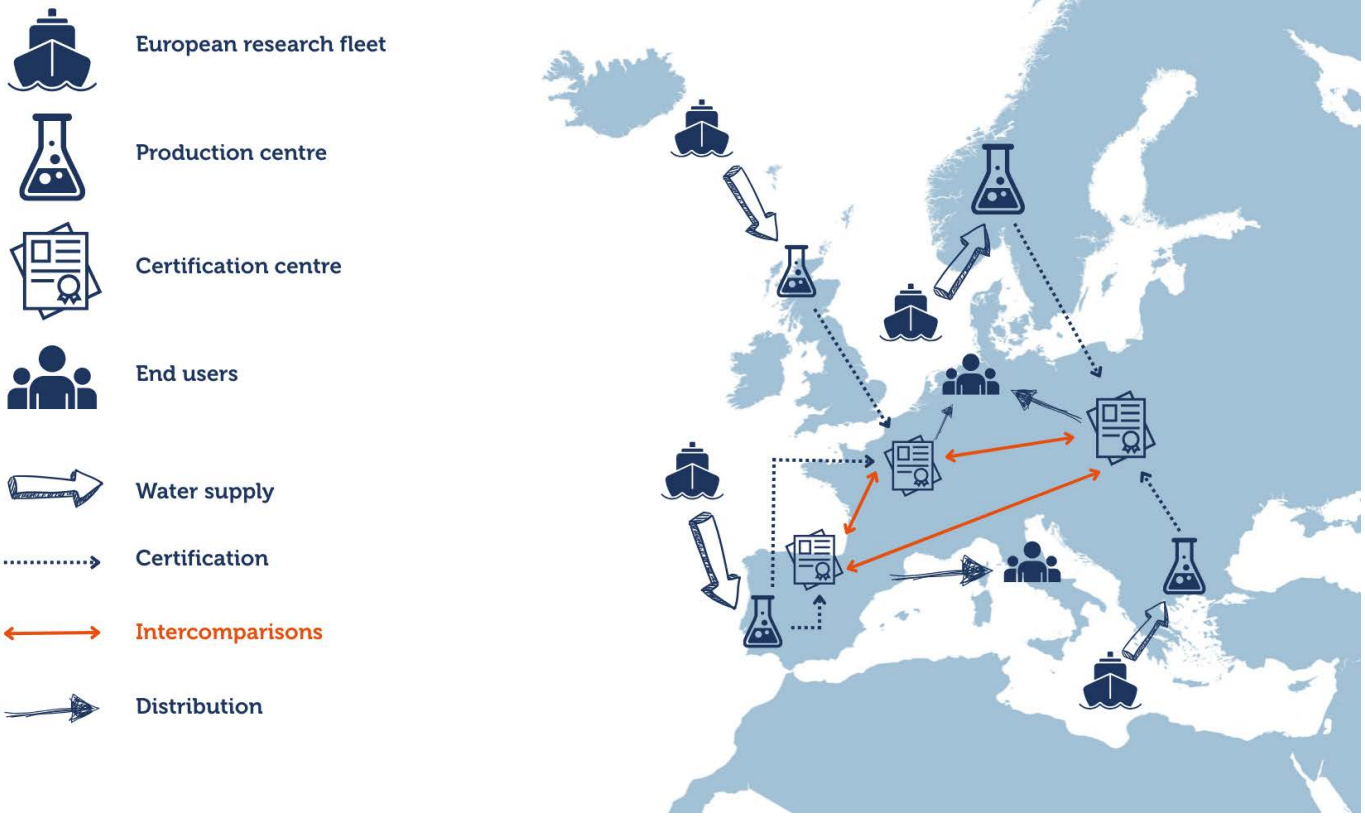


Figure 1. Schematic example of a model network necessary for establishing a European hub for the production and certification of ocean CO_2 reference materials.

2.0 FEASIBILITY OF A EUROPEAN OCEAN CO_2 REFERENCE MATERIAL HUB

The creation of a European Ocean CO_2 Reference Material Hub is both feasible and essential.

Key factors include:

• **Production feasibility:** The experience of the European Research infrastructure "ICOS – Integrated Carbon Observation System" has shown that batch production of seawater CO_2 system reference materials is technically feasible for experienced laboratories, given access to seawater. While value assignment to the reference materials remains a challenge, this can be addressed through structured collaboration between oceanographic and metrology institutions.

• **Infrastructure availability:** Several European research institutions have the expertise to support production of reference materials, and National Metrology Institutes (NMIs) can be engaged in its certification.

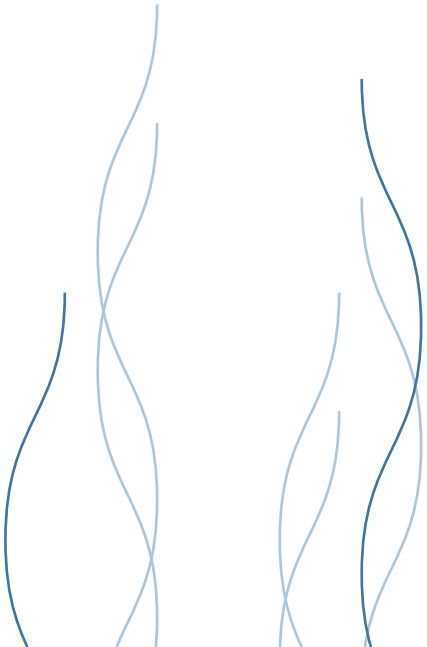
• **Technical capability:** European oceanographic institutions have demonstrated their ability to produce stable in-house reference materials. Collaboration with NMIs will ensure that certification meets global metrology standards.

• **Existing metrology networks:** The European Metrology Network (EMN) for Climate and Ocean Observation provides a strong foundation for integrating metrology and oceanography, enabling the production of internationally comparable reference materials.

• **Engagement in the international metrology community:** European NMIs actively participate in international metrology networks, such as the CIPM (International Committee for Weights and Measures), and in particular its mutual recognition system (CIPM-MRA), strengthening the credibility and global alignment of any European-led initiative for producing and certifying reference materials.

• **National-level connections between metrology and oceanography:** In several countries, synergies already exist between these communities. For example, in Greece, the *National Research Network for Climate Change and Its Effects – CLIMPACT* brings together national metrology and oceanographic research institutions. National funds are jointly distributed for projects related to greenhouse gas emissions, including CO_2. These examples can serve as models for other nations to foster integrated approaches.

• **Community willingness:** The European oceanographic and metrology communities are ready to take action.



3.0 GLOBAL LEADERSHIP AND NORTH-SOUTH ENGAGEMENT

The establishment of a European hub aligns directly with major EU and international policy frameworks and initiatives:

- **EU Oceans Pact, European Ocean R&I Strategy and Ocean Observation Initiative:** Enhancing marine data quality and operationalising the surface ocean carbon value chain.
- **European Green Deal:** Strengthening CO_2 monitoring capacities for achieving net-zero.
- **Paris Agreement and COP29:** Advancing transparency and verification tools for carbon accounting.
- **Africa-Europe Strategy Group on Ocean Governance:** Building capacity and science diplomacy with Africa.
- **ISO/TC8/WG15 contributions:** Supporting ISO's global standards for ocean negative carbon emissions and neutrality, including CO_2 monitoring in the marine environment.

4.0 ADVANTAGES OF A EUROPEAN OCEAN CO_2 REFERENCE MATERIAL HUB

- **Resilience and security:** A European hub reduces reliance on a single supplier, safeguarding continuity against supply chain disruptions.
- **Expanded availability:** As 25-45% of production of reference materials at Scripps Institute of Oceanography currently serves European users, regional production would streamline access and reduce shipping time.
- **Lower costs and increased use:** A local supply chain should cut shipping and customs costs, encouraging wider uptake, especially if regulatory frameworks might enforce the use of reference materials for ocean acidification and CDR monitoring in the future.
- **Global leadership:** Europe can set standards for marine CDR in carbon markets and offer capacity building in the Global South.
- **Strategic autonomy:** The hub enhances Europe's independence by reducing reliance on non-European sources for critical scientific materials, fostering Europe's strategic autonomy in climate monitoring and carbon removal efforts.

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5.0 MINIMUM NEEDS AND POTENTIAL SOLUTIONS

To establish a sustainable European hub for production and certification of ocean CO_2 reference materials (following Model 2, Distributed Facilities), the following requirements must be met:

- Development of a dedicated European network of production sites for reference materials.
- Setup of at least one laboratory facility to certify the reference materials (preferably using existing metrology infrastructure).
- Provision of long-term support for production and certification facilities for reference materials from European institutions and stakeholders, with the goal of developing a cost model that allows for sustainable provision of reference materials (public funding and cost per user).
- A governance structure overseeing the European hub.

6.0 PATHWAYS TO IMPLEMENTATION

SHORT-TERM (6-12 months)

- Conduct feasibility studies and identify host institutions for establishing regional production centres for reference materials.
- Engage European Research Infrastructures (e.g., ICOS, EuroGO-SHIP, ARGO, Jerico-RI, DANUBIUS-RI, EMODnet Chemistry, SeaDataNet, JRC, EuroGOOS) to consolidate expertise and capacity.
- Form a Budget Task Force including EU Commission, European Metrology Network for Climate and Ocean Observation, International Ocean Carbon Coordination Project (IOCCP), National Metrology Institutes (NMIs), Research infrastructure representatives, and consultants.
- Consult with Scripps Institute of Oceanography (SIO) to ensure continuity and knowledge transfer, and transitional support.
- Develop standardised protocols for production, certification, and distribution.

MEDIUM-TERM (2-3 years)

- Establish transitional production and certification in collaboration with Scripps Institute of Oceanography and European Metrology Institutes.
- Implement European production and certification facilities for reference materials.

LONG-TERM (3-5 years)

- Fully integrate production and certification of reference materials into the global metrology framework.
- Secure long-term funding commitments from national and international agencies.
- Conduct annual performance audits and continuous protocol refinement.

7.0 BUDGET CONSIDERATIONS

Production of reference materials is not a profitable activity, requiring sustained public support. A strong and consistent funding commitment is essential to initiate and maintain the proposed activities.

A preliminary cost estimate for a European Ocean CO_2 Reference Material Hub should include:

- Production facility costs
- Certification facility costs
- Personnel costs (for production, certification, logistics, and distribution)
- Logistics costs (including seawater collection, transport and distribution of reference materials)

Market size and current European spend:

- Unit cost and logistics: Each bottle of reference material from Scripps Institute of Oceanography retails at around 65 EUR; depending on shipping and customs, this price can increase by up to 40%.
- European share: Europe represents roughly 25-45% of global demand (~2000 bottles annually), implying a cumulative spend of about 150,000-200,000 EUR.

8.0 CONCLUSION

A European Ocean CO_2 Reference Material Hub is crucial for securing a stable supply of high-quality, stable, homogeneous, and calibrated reference materials for the seawater CO_2 system with appropriate uncertainties. Without it, the global community remains vulnerable to disruptions at Scripps Institute of Oceanography, jeopardising key ocean carbon budget assessments. The European scientific community is prepared to take action, but long-term financial commitments are needed to ensure sustainability. We are actively consulting with Scripps Institute of Oceanography to facilitate a seamless transition and global collaboration in securing availability of reference materials for climate research and CDR assessment.

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