LIFESUPEREU

Scaling Up Peatland Restoration in Europe



**** FINAL REPORT

Knowledge Report on Current Gaps in Standard Models Used for Estimating GHG Emissions from Peatlands in Europe

MAPPING · ASSESSMENT · RECOMMENDATIONS

Imprint

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Disclaimer

The statements attributed to interviewees reflect their personal expert views and do not necessarily represent the positions of their institutions. The report reflects the state of knowledge and of the frameworks reviewed between June and September 2026; some frameworks, notably the draft CRCF methodology, may change after this date.

Use of AI

AI tools were used to support parts of the qualitative analysis and the preparation of selected figures, as described in the Introduction (section b) and Annex 2. The author retains full responsibility for all content and interpretations.

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Abbreviations

AECO	AECO GmbH (company name)
AI	Artificial intelligence
BfN	Bundesamt für Naturschutz (German Federal Agency for Nature Conservation)
C	Carbon
CF	Certification framework
CH_4	Methane
CO_2	Carbon dioxide
CO_2-C	Carbon dioxide expressed as carbon
CO_2-eq	Carbon dioxide equivalent
COST	European Cooperation in Science and Technology
CRCF	Carbon Removals and Carbon Farming Certification Framework
DIC	Dissolved inorganic carbon
DNDC	DeNitrification–DeComposition model
DOC	Dissolved organic carbon
EC	Eddy covariance
EEST	Evapotranspiration Energy Site Types
EF	Emission factor
ER	Emission reduction
EU	European Union
FLUXNET	Global network of eddy covariance flux measurement sites
FMI	Finnish Meteorological Institute
GEST	Greenhouse Gas Emission Site Type
GHG	Greenhouse gas
GWP	Global warming potential
ICOS	Integrated Carbon Observation System
ICR	International Carbon Registry
IPCC	Intergovernmental Panel on Climate Change
IUCN	International Union for Conservation of Nature
LTER	Long-Term Ecological Research
M-ICR007	Methodology for Rewetting of Peatlands under the International Carbon Registry
MRV	Monitoring, reporting and verification
NABU	Naturschutzbund Deutschland (Nature and Biodiversity Conservation Union)
NEST	Nitrogen Emission Site Type
N_2O	Nitrous oxide
PEATLAND-VU	Process-based peatland model developed at Vrije Universiteit Amsterdam to simulate peatland hydrology, vegetation dynamics, peat decomposition, and carbon and nitrogen cycling
PEP	Peatland Emissions Predictor
POC	Particulate organic carbon
QA	Quality assurance

SCM0010-M1	SOCIALCARBON methodology SCM0010, Module 1: Rewetting of Drained Peatlands for Climate Change Mitigation
SET	Site Emission Tool
SLU	Swedish University of Agricultural Sciences
SUPER-EU	Scaling Up Peatland Restoration in Europe
UAV	Uncrewed aerial vehicle
UCD	University College Dublin
UNFCCC	United Nations Framework Convention on Climate Change
VM0036	Verra methodology for rewetting drained temperate peatlands
WT	Water table
WTD	Water-table depth

For definitions of key terms, see Annex 4.

Country codes used in the report

DE	Germany
FI	Finland
IE	Ireland
IS	Iceland
LT	Lithuania
LV	Latvia
PL	Poland
SE	Sweden
UK	United Kingdom

Introduction and analytical approach

a. Background and purpose

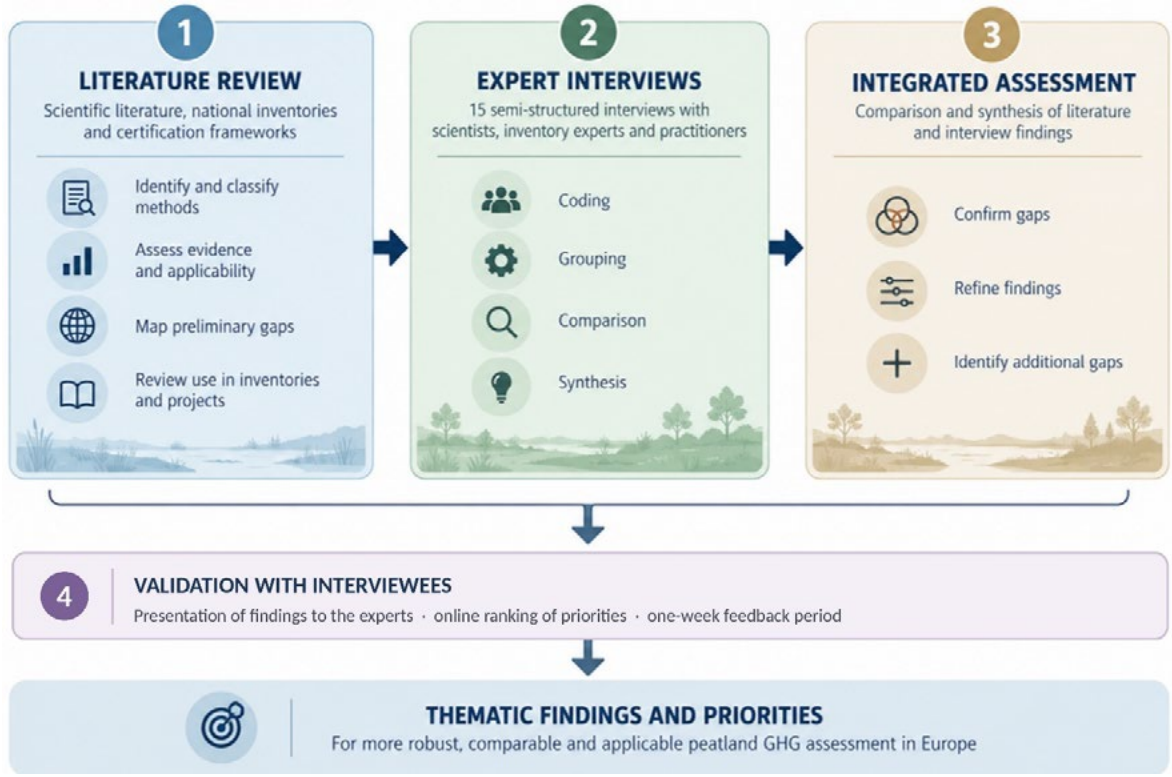
This Knowledge Report was commissioned by NABU within LIFE SUPER-EU – Scaling Up Peatland Restoration in Europe. It reviews the methods used to estimate greenhouse gas (GHG) emissions and emission reductions from European peatlands, with a focus on restoration, carbon accounting and climate finance.

The report examines the strengths, limitations and empirical basis of existing approaches. It identifies the main scientific and methodological gaps and assesses their implications for restoration planning, for monitoring, reporting and verification (MRV), and for carbon certification. The scope focuses on reliability and applicability: where existing approaches can support reliable GHG assessment, where uncertainty remains, and what needs to improve as peatland restoration expands across Europe.

b. Analytical approach and evidence base

The assessment combined a literature and documentary review with semi-structured interviews with 18 experts from nine European countries. The interviews were analysed through qualitative analysis. The work followed four consecutive stages, summarised in Figure 1.

Figure 1: Illustration of the Analytical Approach and Evidence Base



Stage 1. Literature review and preliminary gap identification

The first stage was a preliminary review of scientific literature, national accounting approaches and selected carbon-accounting and certification frameworks. It served three purposes:

i) to identify the main approaches to peatland GHG estimation and classify them by their underlying measurement or estimation principles, examining the datasets used to develop emission factors and proxy relationships, their geographic and ecological representativeness, their treatment of individual gases and carbon pathways, their temporal coverage and uncertainty, and the extent to which they had been independently validated;

ii) to map gaps in the available evidence, distinguishing limitations inherent to the estimation approaches from limitations in the empirical monitoring programmes that support their calibration and validation;

iii) to describe how scientific approaches are translated into operational accounting, including their use in national GHG inventories and in selected restoration and carbon-certification frameworks.

The preliminary findings were consolidated in an Inception Note and validated through an online presentation to members of the GEST Group coordinated by NABU within the LIFE SUPER-EU project on 24 June 2026. This stage established the analytical framework, the interview guide and the initial, deductive part of the codebook used in Stage 2.

Stage 2. Expert interviews and qualitative analysis

Interview design and sample. A semi-structured interview guide (Annex 1) was developed from the literature review. It followed the analytical dimensions of the report: current estimation approaches, scientific robustness, geographic and ecological representativeness, methodological and monitoring gaps, and the requirements for European harmonisation. The final questions asked experts to identify priorities and main bottlenecks. The semi-structured format made it possible to confirm, refine or challenge the preliminary findings, while allowing issues not addressed in the literature to emerge from the experts' experience. Fifteen interviews were held between 16 July and 14 September 2026 with 18 experts from nine countries (Table 1).

Table 1: Experts interviewed

Country	Interviewee(s)	Institution	Profile	Date
DE	Julia Averkamp, Malte Schneider	AECO GmbH	Project development (carbon market)	10.09.2026
DE	Klaus-Holger Knorr	University of Münster	Empirical research	22.07.2026
DE	Felix Reichelt	Greifswald Mire Centre / DUENE e.V.	Method developer (GEST)	27.07.2026
FI	Sari Juutinen	Finnish Meteorological Institute (FMI)	Empirical research, flux monitoring & modelling	18.08.2026
IE	Terry Morley	University of Galway	Empirical research & Irish Peatland Standard	16.07.2026
IE	Florence Renou-Wilson	University College Dublin	Empirical research & national inventory	29.07.2026
IE	Matthew Saunders	Trinity College Dublin	Empirical research	14.08.2026
IS	Sunna Áskelsdóttir, Sigurður Loftur Thorlacius, Aron Alexander Thorvardarson	Land og Skógur (Land and Forest Iceland)	National inventory, research & restoration practice	20.08.2026
LT	Nerijus Zableckis	Foundation for Peatland Restoration and Conservation	Restoration practice & project assessment	17.08.2026
LV	Arta Bardule	Latvian State Forest Research Institute "Silava"	Empirical research & national inventory	23.07.2026
LV	Andis Lazdiņš	Latvian State Forest Research Institute "Silava"	Empirical research & National inventory	22.07.2026
LV	Māra Pakalne	University of Latvia	Restoration practice & vegetation research	04.08.2026
PL	Wiktor Kotowski	University of Warsaw	Empirical research	12.08.2026
SE	Sabine Jordan	Swedish University of Agricultural Sciences (SLU)	Empirical research	20.08.2026
UK	Renée Kerkvliet-Hermans	IUCN UK Peatland Programme	Certification (UK Peatland Code)	14.09.2026

Profiles summarise each interviewee's main perspective in the interview; several experts combine more than one role.

Analysis. The interviews were analysed in six steps adapted from thematic analysis (Braun & Clarke, 2006) and the Framework Method (Gale et al., 2013):

i) **Familiarisation** and **documentation**: Transcripts were cleaned and sent to the interviewees for review, allowing them to correct or clarify statements. The validated transcripts were then analysed, capturing each expert's main arguments, contextual information and examples.

ii) **Coding**: A total of 352 analytical paragraphs across 15 interviews were coded using a researcher-defined codebook of 26 deductive and inductive codes, covering assessment methods, scientific robust-

ness, gases and carbon pathways, peatland systems, and implementation issues.

iii) **Charting**: Coded material was organised into a matrix to examine the distribution and co-occurrence of issues across interviews. Petal charts in Chapters 2 to 4 and in the Conclusions count only quotations from the corresponding part of the interviews. Their numbers are lower than the totals per code in Table 14, which cover all 352 quotations (see Annex 2, sections 2 and 5).

iv) **Grouping** and **clustering**: Related statements were grouped into analytical themes, identifying connections between methodological limitations, ecological contexts and implementation challenges.

v) **Comparison**: Findings were compared across experts, countries and professional profiles to identify recurring concerns, contrasting perspectives and context-specific observations.

vi) **Synthesis**: The resulting themes were integrated into the report chapters, preserving attribution to individual interviewees.

Use of AI during analysis: The AI assistant Claude (Anthropic) supported the analysis by a) reviewing the consistency of code assignments across interviews; b) compiling the coding matrix and code co-occurrence tables and c) verifying the traceability of statements attributed to interviewees against the interview fiches.

The researcher conducted all interviews, reviewed transcripts, defined the codebook and analytical themes, validated all AI outputs, and retained responsibility for all interpretive and analytical decisions. The coding matrix, including original and revised paragraph-level code assignments, is provided in Annex 2.

Stage 3. Integration and verification

The findings of the first two stages were brought together through thematic synthesis. Interview findings were compared with the published evidence to distinguish established scientific limitations, gaps in empirical monitoring, and challenges in applying existing methods to national inventories and restoration projects. These results form the basis of the thematic chapters. As a final check, each statement that the report attributes to an interviewee was traced back to the corresponding interview fiche, and attributions that could not be traced were revised.

Stage 4. Validation with interviewees

Finally, the findings were validated with the interviewed experts (respondent validation). They were presented in an online meeting [on 30.09.2026], after which participants received an online poll through the platform Slido (www.slido.com) to rank proposed priorities and were given one week to provide further feedback. The results of this step are reported in the conclusions.

c. Scope and limitations

The interviews cover nine countries in northern, central and north-western Europe. Mediterranean, Alpine and coastal or brackish peatlands, identified in the literature as under-represented, were not covered by interviews. Descriptions of national monitoring and accounting reflect the research and institutional contexts described by the interviewees and the literature reviewed; they are not comprehensive evaluations of national systems. Finally, the interviews and document review were conducted between June and September 2026. Some frameworks reviewed, notably the draft CRCF peatland methodology, may change before final adoption.

d. Organization of the chapters

The report is organised into five thematic chapters followed by conclusions, moving from the review of existing GHG estimation approaches to the identification of evidence gaps, practical implications and priorities for improvement. Table 2 summarises the main question addressed in each chapter. Key terms are defined in the glossary in Annex 4.

Table 2: Chapters and Guiding Questions

Chapter	Guiding question
1. Current approaches	What methods are available for GHG estimation, and what are their strengths and limitations?
2. Scientific robustness	How reliable is the evidence behind existing estimates?
3. Geographic and ecological gaps	Which peatland types, land uses and regions remain insufficiently represented?
4. Methodological and monitoring priorities	What is needed to strengthen the evidence base?
5. Operational Applications and Limitations of GHG Assessment for Project Applicability	What do the findings mean for restoration projects, MRV and carbon certification?
6. Conclusions and priorities	What are the main bottlenecks, and where should future efforts be directed?

1 Current approaches to GHG and implications for peatland restoration

The literature review identified four broad approaches to assessing greenhouse gas (GHG) emissions from European peatlands: direct flux measurements, vegetation-based proxies, hydrological proxies, and multivariable and hybrid models. Across these approaches, the central operational question is how measured fluxes can be translated into estimates that remain credible when applied across larger areas, different ecological settings and the years following rewetting (IPCC, 2014; Couwenberg et al., 2011; Tiemeyer et al., 2020; Koch et al., 2023).

In this chapter these approaches are reviewed, identifying their difference in the quantification of GHG emissions and the data they require. Table 3 groups them and summarises their main methods and quantification basis, while the sections below examine some of these approached in detail, including their strengths, limitations and relevance for applicability at project scale.

Table 3: Overview of peatland GHG assessment approaches reviewed in this report for Europe

Approach	Main methods	Main quantification basis
Direct measurement	Chambers; eddy covariance	Measured CO_2, CH_4 (and, less consistently, N_2O) fluxes at plot or ecosystem scale; the reference data against which all other approaches are calibrated
Vegetation-based proxy	GEST and NEST/EEST derivatives; peatland condition categories (UK Peatland Code)	Vegetation composition or peatland condition classified into site types or condition categories, each linked to an empirically derived emission factor
Hydrological proxy	Empirical water-table response functions (i.e. Gompertz Function); SET tool; Valuta voor Veen	Mean or spatially distributed water table converted to GHG flux through nonlinear response functions calibrated with direct measurements
Multivariable and hybrid models	Continuous multivariable proxies; machine-learning upscaling; Yasso and mass-balance models; DNDC Forest; PEATLAND-VU; atmospheric inversion; drone/UAV time-series	Combinations of hydrology, vegetation, remote sensing, climate and process representation, calibrated or cross-checked against direct measurement

Almost all of the approaches reviewed here share the same methodological point of departure — the IPCC Guidelines and Wetlands Supplement (IPCC, 2014)— which is then refined, in different ways, into the country- and site-specific approaches described below (Wilson et al., 2015; Lapveteläinen et al., 2007; Lindgren & Lundblad, 2014). These guidelines provide a common accounting framework for national GHG inventories and distinguish three methodological Tiers according to their level of specificity (summarized in Table 4).

According to the sources reviewed for this report, this landscape of peatland GHG accounting in Europe comprises a wide range of methods with different purposes: some approaches are used to evaluate the success of restoration projects and to underpin project-level certification standards; others carry institutional weight and feed national GHG inventories.

Table 4: IPCC Tier levels in national GHG inventories: examples for peatland accounting

Tier	Definition	Example for peatland GHG accounting
Tier 1 – Default approach	Uses IPCC default emission factors and basic activity data.	Area of drained agricultural peatland × IPCC default CO_2 emission factor.
Tier 2 – Country-specific approach	Uses national emission factors derived from country-specific data.	National GHG measurements are used to derive EFs for different peatland land uses or drainage conditions.
Tier 3 – Advanced national approach	Uses detailed, country-specific methods and datasets.	National water-table maps and calibrated CO_2 and CH_4 response functions are combined to estimate emissions spatially.

Adapted from Amaro (2024, p. 8), with peatland-specific examples based on the 2013 Supplement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories: Wetlands (IPCC, 2014).

What is still missing is a sufficiently tested framework for which combination of methods offers the best balance of robustness, cost, scalability and verifiability for restored peatlands specifically. At project scale, the need is to demonstrate a change attributable to an intervention at a specific site — the difference between a baseline condition and a post-restoration trajectory — which means the methods used for project-level certification should in principle be as scientifically robust as those developed for individual research sites. In practice, the most robust methods are those designed for direct GHG measurement, and these are too costly, or too complex, for widespread application. This matters most for the emerging restoration-financing context: if small restoration projects are to generate credible carbon benefits, their climate performance has to be measurable without prohibitively expensive monitoring infrastructure. The central question running through this chapter, and returned to more directly in Chapter 5, is therefore which approaches can provide sufficiently robust, transparent and scalable estimates of GHG outcomes from restored peatlands to support project assessment and, potentially, carbon certification.

1.1. Direct GHG measurements: the empirical foundation

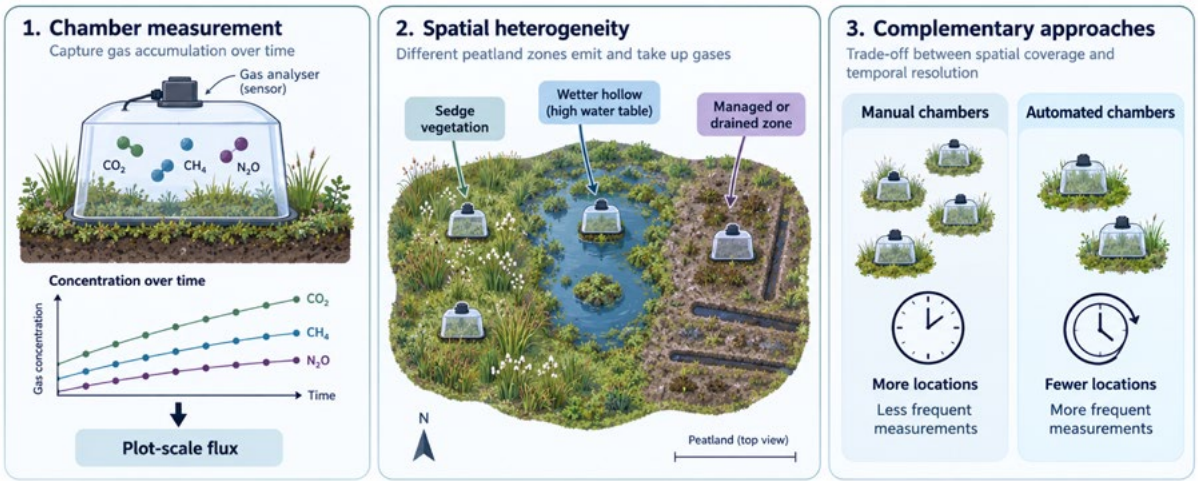
Direct measurements establish the empirical basis for peatland GHG assessment. Their results are used to calibrate the proxy-based approaches discussed later in this chapter. Two methods are the most used across the peatlands reviewed in this report — chambers and Eddy Covariance (EC). Chambers quantify fluxes at individual plots and can be replicated across vegetation, hydrological and management conditions, whereas Eddy Covariance (EC) integrates exchange over a larger, variable footprint and provides continuous time series. The sections below discuss how each method works, what it requires, and what it means for scalability at project level.

a. Assessment principles and scope of application

Chambers estimate fluxes from the change in gas concentration inside a small enclosed headspace placed over the peat surface or vegetation. Because they can be deployed across different vegetation communities, hydrological conditions and management zones, they are well suited to capturing spatial heterogeneity and linking emissions to specific site conditions (Pavelka et al., 2018). Manual chambers give high spatial replication but limited temporal coverage; automated chambers improve temporal resolution at higher cost, usually with fewer measurement locations. Their output is a set of discrete, plot-scale flux values for CO_2, CH_4 and, less consistently, N_2O. A schematic representation of the chamber system is exposed in Figure 2.

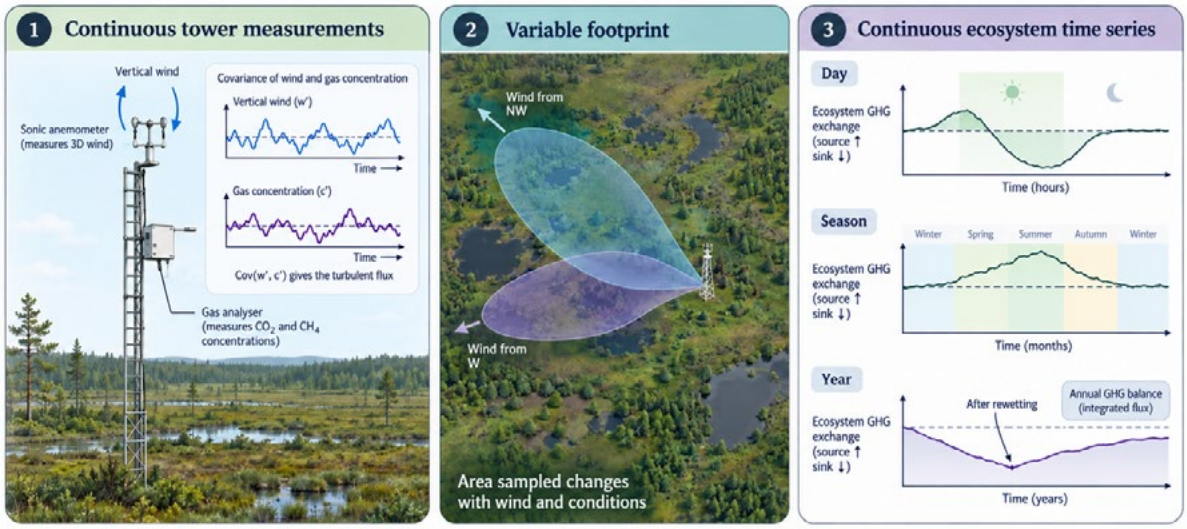
Eddy covariance (EC) estimates ecosystem–atmosphere exchange from the covariance between turbulent vertical air movement and gas concentrations, recorded continuously from a tower. It integrates fluxes over a larger and variable footprint, producing a continuous ecosystem-scale time series that captures diurnal, seasonal, episodic and interannual change — valuable for annual GHG balances and for tracking how a peatland responds over the years following rewetting (Drösler, 2005). Reliable operation requires substantial infrastructure, specialist expertise and data processing. A schematic representation of the EC system is exposed in Figure 3.

Figure 2: Schematic representation of the Chamber-based system for GHG measurement



AI-generated illustration, based on Pavelka, M. et al, 2018

Figure 3: Schematic representation of the Eddy-Covariance (EC) system for GHG measurements



AI-generated illustration, based on Drösler, M., 2005

Together, these approaches support the calibration of emission factors, vegetation classes and water-table response functions used in inventories and restoration assessments. Yet according to the data collected in the interviews, they remain unevenly deployed across countries, ranging from extensive, decades-long networks to only a handful of sites (see section 3.5b). Estimates derived from one measurement design cannot automatically be transferred to another scale or site condition (Couwenberg et al., 2011; Tiemeyer et al., 2020; Koch et al., 2023). On the other hand, infrastructure and cost are among the most consistently documented barriers to their routine use (Günther et al., 2018; Alm et al., 2023). Table 5 compares the two methods in terms of their practical use and applicability.

Table 5: Chambers vs. Eddy Covariance: a comparative assessment

Dimension	Chambers	Eddy covariance (EC)
Measurement principle	Change in gas concentration within an enclosed headspace over peat or vegetation surface.	Covariance between turbulent vertical wind velocity and gas concentration, measured from a tower.
Spatial scale / footprint	Plot-scale (cm^2–m^2); multiple measurement points are needed to represent heterogeneous sites.	Ecosystem-scale; integrates fluxes over a variable footprint extending over tens to hundreds of metres, depending on measurement and atmospheric conditions.
Temporal coverage	Episodic (manual) to near-continuous (automated).	Continuous, high-resolution (typically half-hourly); captures diurnal, seasonal, episodic and interannual variation.
Gases captured	CO_2, CH_4 and, more consistently than EC, N_2O.	CO_2 and CH_4; N_2O measurements are less common.
Main output	Plot-scale flux values, can be aggregated to estimate site-level GHG.	Ecosystem-scale flux time series used to estimate annual GHG.
Cost and infrastructure	Lower cost per unit; total effort increases with the number of locations and repeat visits. Manual campaigns are labour-intensive.	High upfront and operating costs; specialist expertise and data processing; costs increase with number of towers.
Key strengths for restoration	Resolves within-site heterogeneity; links emissions to vegetation, microtopography, water-table conditions and management zones; identifies emission hotspots and treatment-specific responses. Flexible deployment for comparison across restoration stages and reference sites. Gas-specific measurements help identify trade-offs where rewetting reduces CO_2 emissions but increases CH_4 emissions.	Captures episodic events, seasonal fluctuations and interannual variability; supports annual GHG budgets and assessment of multi-year restoration trajectories. Integrates ecosystem-scale responses to determine whether a restored area is becoming a lower-emission system or net GHG sink.

Dimension	Chambers	Eddy covariance (EC)
Key limitations for restoration	Manual chambers may miss diurnal and seasonal peaks, freeze–thaw events and rapid water-table shifts. Repeated measurements across many locations require substantial field effort. Automated chambers improve temporal coverage but are generally deployed at fewer locations, potentially underrepresenting heterogeneous sites.	Variable and heterogeneous footprints complicate attribution to specific restoration treatments, particularly in mosaics of open water, recolonising vegetation and dry or wet patches. High costs limit continuous monitoring across restoration sites, constraining geographic and ecological representativeness.

Note: In the certification frameworks reviewed in this report, neither method serves as the primary routine crediting approach; both contribute mainly to the empirical evidence underlying emission factors, proxies and their validation (see Chapter 4).

b. Strengths and limitations of the approaches

Chambers and EC resolve different scales and are largely complementary as Table 5 shows. But two points deserve extra emphasis:

- Chambers' gas- and process-specificity means they can target particular microsites or gases such as CH_4 and N_2O, capturing trade-offs where rewetting lowers CO_2 but raises CH_4 — a nuance a CO_2-only reading of restoration success would miss.
- Because EC systems are expensive, relatively few restored peatlands can be monitored continuously, which limits the regional representativeness of the resulting evidence base (examined further in section 4.1, "Prioritise compound gaps and redesign networks for representativeness").

c. Implications for project level applicability

Taken together, direct measurements provide the strongest empirical evidence of how restored peatlands actually respond, but their capacity to demonstrate restoration success depends on how their complementary strengths are combined — chambers alone may offer insufficient temporal representativeness, EC alone may not resolve the spatial heterogeneity and treatment-specific effects central to restoration assessment. It is this complementarity that makes both the reference and calibration basis for the proxy approaches discussed next; their usefulness for restoration ultimately depends on how well they, together, overcome the monitoring gaps in spatial heterogeneity, temporal variability, gas coverage, attribution, long-term change and transferability examined throughout the following chapters.

1.2. Vegetation-based proxies

Vegetation-based proxies estimate peatland GHG emissions from plant communities, which reflect site conditions such as long-term water level and nutrient status (Couwenberg et al., 2011; Jarašius et al., 2022). The Greenhouse Gas Emission Site Types (GEST) approach groups plant communities into site types associated with characteristic moisture conditions. Each type is assigned empirically derived CO_2 and CH_4 emission factors from ecologically comparable sites. Soil-moisture classes and, where available, water-level measurements support the classification of each site (Couwenberg et al., 2011; Joosten et al., 2015; Jarašius et al., 2022).

a. GEST: EF fundaments

For each GEST type i, the CO_2 and CH_4 emission factors are combined using the global warming potential of methane ($GWP_(CH_4)$):

$$EF_{\mathrm{GEST},i} = EF_{\mathrm{CO_2},i} + EF_{\mathrm{CH_4},i} \times GWP_{\mathrm{CH_4}}$$

The resulting factor is expressed in **t CO_2-eq ha^{-1} yr^{-1}**. Emissions for a mapped area are then calculated by multiplying the area of each site type by its emission factor and summing across all types:

$$E = \sum_{\mathrm{i}} \mathrm{A}_i \times EF_{\mathrm{GEST},i}$$

For a restoration project, the estimated emission reduction is the difference between baseline and project emissions: $ER = E_{\mathrm{baseline}} - E_{\mathrm{project}}$. Baseline estimates use observed site conditions; estimates for the restored site initially depend on predicted vegetation and hydrological conditions. GEST thus provides discrete, spatially mapped emission estimates rather than a continuous flux estimate based on water-table depth.

b. Application in restoration accounting

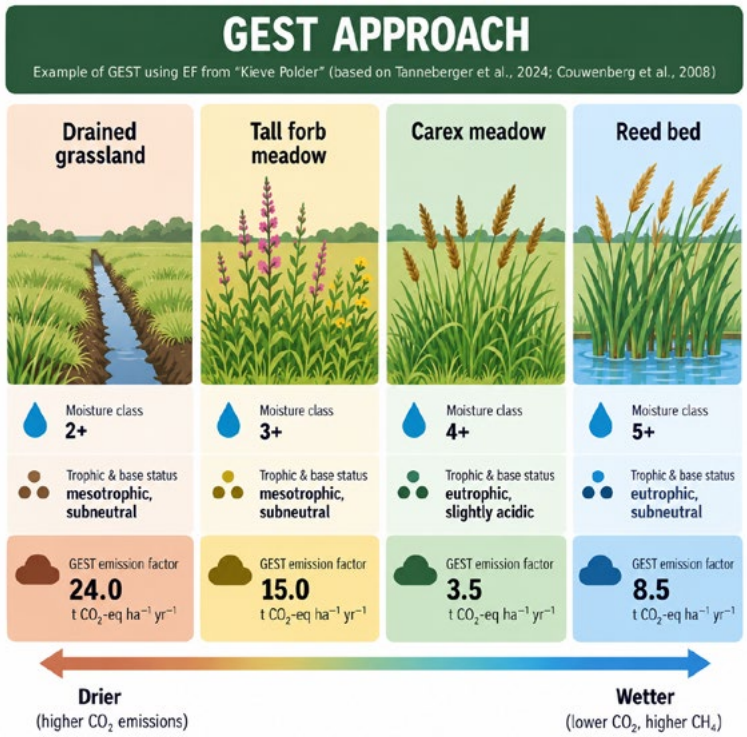
GEST has been used in frameworks including MoorFutures, Verra VM0036 and SOCIALCARBON SCM0010-M1 (Joosten et al., 2015; Verra, 2017; Social Carbon Foundation, 2023; Tanneberger et al., 2024).

Figure 4 illustrates a GEST-based assessment with emission factors reported for the Kieve polder restoration project in Germany (based on Tanneberger et al., 2024). High-intensity grassland represents the baseline site type; tall forb meadows, Carex meadows and reeds represent site types considered for the restored area. The figure reports their emission factors in t CO_2-eq ha^{-1} yr^{-1}, alongside the moisture classes and indicative water-table ranges used by Tanneberger et al. (2024).

At the Kieve polder site, the GEST-based assessment projected a decline from 1,306 to 532 t CO_2-eq yr^{-1} after rewetting. Re-mapping the vegetation five years after restoration and applying the same GEST factors gave 543 t CO_2-eq yr^{-1} (Tanneberger et al., 2024).

This agreement shows that vegetation developed as predicted, but it is not an independent validation of emissions, since both values derive from the same emission factors. According to Felix Reichelt, GEST and peatland-GHG Expert from DUENE e.V. in Germany (Interview, 27.07.2026; and also see Reichelt, 2015), GEST estimates remain dependent on how well the mapped vegetation types and their assigned factors represent local conditions.

Figure 4: GEST applied to "Kieve Polder"(based on Tanneberger et al., 2024).



c. Geographical development and use

Within the countries covered by this report, GEST shows a well-developed but geographically uneven network: strongest and most institutionalised in Germany, substantially tested and adapted in the Baltic region, and applied more selectively elsewhere.

Its methodological core is Germany, particularly the Greifswald peatland research community; the approach was incorporated into MoorFutures and has built a comparatively strong practitioner network, with around 120 practitioners — primarily from planning offices but also public institutions — reportedly trained in its application over the past five years (F. Reichelt; Interview, 27.07.2026).

The Baltic region represents the most important geographical expansion of GEST beyond Germany: LIFE Peat Restore applied and further developed the approach across restoration sites in Poland, Lithuania, Latvia and Estonia, with regional adaptation operationally necessary there, as the project's development of 29 GEST types across 11 sites shows (Jarašius et al., 2022; reasons for this adaptation are discussed in section 2.7).

In Finland, GEST is less prominent: highly detailed vegetation classes have proven difficult to upscale using remote sensing and require aggregation (S. Juutinen; Interview, 18.08.2026) — a scalability constraint rather than a transferability one. In Sweden, it has been used to assess GHG from peatland study sites of the Swedish University of Agricultural Sciences (SLU) (S. Jordan; Interview, 20.08.2026).

In the Atlantic region, primarily Ireland, GEST-related approaches have been applied through restoration initiatives and the development of the Irish Peatland Standard, requiring regional recalibration of the Central European relationships. Early research supporting the UK Peatland Code explored vegetation- and condition-based approaches for blanket bogs (Reed et al., 2013). Today the Code does not use GEST, which it does not consider directly applicable to UK conditions: its bog methodology relies on condition categories, while its fen methodology combines condition categories with water-table depth. GEST-type approaches may nevertheless be explored for UK paludiculture (R. Kerkvliet-Hermans; Interview, 14.09.2026).

At the international carbon-market level, Verra VM0036 explicitly permits ground vegetation composition and water-table depth to be used as GHG proxies under the GEST approach (Verra, 2017).

d. Strengths and limitations

Table 6 summarises the practical strengths and limitations of the vegetation proxy-based method GEST as mentioned by the interviewed experts.

Table 6: Strengths and limitations of Vegetation-Based Proxies (GEST)

Assessment Dimension	Strengths	Limitations
Monitoring requirements and cost	**Substantially lower monitoring costs and technical requirements** than direct GHG measurement, suiting large and heterogeneous restoration areas where chamber or EC coverage would be impractical.	**Indirect estimation**. Not a site-level measurement. GEST outputs are estimates calibrated against representative sites.
Spatial representation and upscaling	**Spatially explicit design suitable for upscaling**: vegetation mapping captures heterogeneous hydrological and ecological mosaics and translates limited GHG measurement into project/landscape-scale estimates.	**Discrete classes misrepresent a continuous ecological reality**. Moving between adjacent GEST classes can shift an estimated emission sharply even though the underlying ecosystem changes gradually.
Ecological integration and transferability	**Integrates longer-term ecological conditions**. Because vegetation responds to hydrological and ecological conditions over time, it reduces dependence on individual water-table observations and can also reflect factors such as nutrient status and land-use legacy that are not captured by WTD alone.	**Regional and type-specific transferability is limited.** Central European site types do not transfer uniformly to other climatic and ecological contexts and require regional calibration before being applied elsewhere (section 2.3).
Methane representation and classification resolution	**Additional information for CH_4**: vegetation composition — particularly aerenchymatous plants — carries information about methane and emissions transport beyond what water-table data alone can explain (Couwenberg & Fritz, 2012).	**Fine-grained classifications can be difficult to operationalise at scale**. A GEST assessment at a Finnish aapa mire produced classes too detailed for remote-sensing-based upscaling and had to be aggregated (S. Juutinen; Interview, 18.08.2026).
Restoration monitoring and assessment scope	**Combines GHG assessment with ecological monitoring** through repeated vegetation surveys, supporting emission estimation and document broader restoration trajectories.	**Coverage gaps affect specific ecosystems**. Several peatland and land use types remain poorly represented (examined in Chapter 2). N_2O and pathways such as DOC/DIC fall outside GEST's original scope (implications are discussed in section 2.1).
Operational maturity and certification	**Operationally established**: already incorporated into MoorFutures, Verra VM0036 and SOCIALCARBON, and so demonstrated beyond research settings.	**Emission factors as point values without standardised uncertainty ranges**; confidence in results depends on the quality of the underlying measurement database and on mapping accuracy

e. Implications for project level applicability

GEST is currently the most operationally mature approach for estimating GHG emissions from peatland at project and landscape scale. The method covers large and heterogeneous areas at a fraction of the cost of direct measurement. It combines GHG accounting with ecological monitoring, and is established in several certification frameworks.

GEST performs best where the vegetation–hydrology–GHG relationships applied represent the peatland type and climatic region concerned. The method can be extended if its calibration is undertaken to fit outside Central Europe. On the other hand, since right after rewetting, vegetation responds more slowly than hydrology, early estimates should be treated as provisional and updated through repeated vegetation mapping and water-level observations, which fits the ex-ante/ex-post logic of certification schemes.

The priority is therefore not to replace GEST but to strengthen it. This means expanding the emission-factor database for underrepresented ecosystems (forested peatlands, blanket bogs, extensive grasslands) and using targeted direct measurements to validate and recalibrate site types.

1.3. Hydrological Proxies

The principle behind hydrological approaches is the estimation of emissions through empirical relationships between water-table depth and GHG fluxes.

A practical example is the German methodology developed by Tiemeyer et al. (2020). Based on a Gompertz Response Function, they combine water-table information with land use to derive estimates for national reporting. This principle of using water-table-based relationships to support spatial assessment and restoration planning was also applied in Denmark (Koch et al., 2023) and in project-oriented tools such as the Site Emission Tool – SET (Van Belle, J., & Elferink, E., 2021; Van der Snoek, 2026).

These approaches make the effect of changing hydrological conditions more explicit, but their application depends on the quality of water-table information and on whether the response functions are appropriate for the peatland types and conditions under assessment (Danevcic et al., 2010; Yang, 2025).

During the interviews conducted for this report, a number of experts identified hydrological proxies as among the most promising methods for assessing peatland GHG emissions, even though many of them do not apply these methods directly. Some experts, however, cautioned that water-table data alone are not always sufficient without complementary information on peat type, land-use history and vegetation (see Section 2.2a).

a. Assessment principles and scope of application: the empirical hydrological response function - an example from Germany

Germany provides a good example of how hydrological proxies are used in practice. For the national GHG inventory, Tiemeyer et al. (2020) developed an indirect approach that the authors describe as a Tier 3 method simplified to Tier 2. Using 261 annual CO_2 balances from 118 sites, along with a large set of CH_4 and N_2O measurements, they derived response functions that link mean annual water table depth to gas fluxes.

For CO_2-C, a Gompertz function was fitted to account for the nonlinear relationship with water level. CH_4 emissions were estimated with an exponential function. The national water-table maps used as input were also modelled, with Boosted Regression Trees relating measured water levels to landscape variables. This means the method can be applied to areas without direct hydrological monitoring.

Höper (2022) adapted the approach for Lower Saxony. Where no detailed hydrological data exist, each mapped biotope is given a representative water level. The calculation then follows this chain:

Measured water table or biotope → mean water table → response function → GHG emission factor.

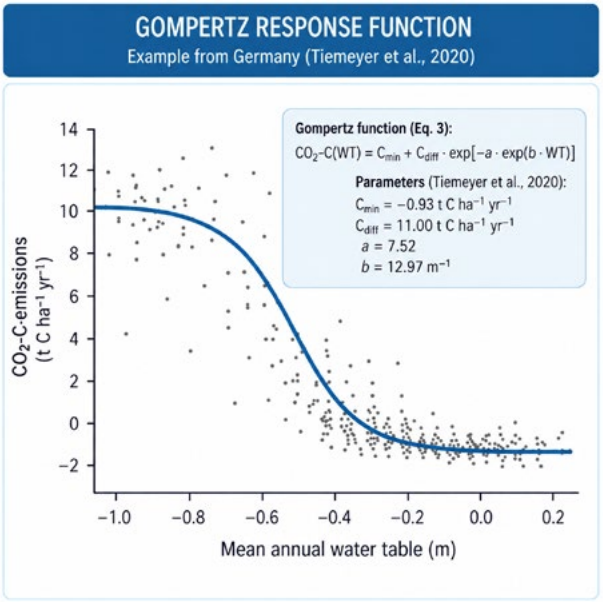
The corresponding response functions are:

$$CO_2\text{-}C(WT) = CO_2\text{-}C_{min} + CO_2\text{-}C_{diff} \cdot \exp[-a \cdot \exp(b \cdot WT)]$$

$$CH_4\,(WT) = CH_{4\,min} + c \cdot \exp(k \cdot WT)$$

In Figure 5, CO_2 emissions increase as the water table falls, with the fitted Gompertz curve approaching a plateau under deeper drainage, while CH_4 emissions rise sharply as the water table approaches or exceeds the surface. N_2O, poorly explained by mean water table, uses a mean emission factor per land-use category instead.

Figure 5: CO_2-C emissions in relation to mean annual water table (Gompertz response function)



Gompertz response function in blue line and observed site data in grey points (AI-generated illustration, based on Tiemeyer et al., 2020)

According to the literature, three choices determine how useful water-table proxies are for restoration assessment:

- How water-table data are aggregated. Because CO_2 and CH_4 response functions are nonlinear, applying them to the full distribution of water-table depths can produce different estimates from applying them to a category mean, particularly for CH_4. Höper's biotope-level approach accepts this simplification to make assessment feasible. A complete GHG balance also needs N_2O and other relevant pathways, including dissolved organic carbon and drainage-ditch CH_4; IPCC defaults fill gaps where national data are unavailable.
- Where the response functions come from. Denmark combines national water-table mapping with its own CO_2 and CH_4 response functions (Koch et al., 2023). Slovenian assessments draw on functions derived from Central European datasets, making their transferability an explicit concern (Danevcic et al., 2010; Section 2.7). Valuta voor Veen uses groundwater change to estimate avoided peat oxidation, while SET combines hydrological and management information with emission factors, including GEST-based factors (Van Belle & Elferink, 2021; Yang, 2025; Kazmere et al., 2024). These examples differ in their data requirements and degree of local calibration.
- Which drivers the model leaves out. Water-table depth is central to rewetting, but its relationship with CO_2 exchange also varies with temperature and site conditions, as reported by Behrens et al. (2026).

Estimates therefore need hydrological data that represent the baseline, the years immediately after rewetting and the later restored condition.

b. Strengths and limitations of the approach

Table 7 summarises the strengths and limitations of hydrological approaches.

Table 7: Strengths and limitations of Hydrological Proxies

Assessment dimension	Strength	Limitation / condition of applicability
Monitoring requirements and scalability	Once a representative water-table distribution has been established, GHG emissions can be estimated across larger areas and multiple restoration projects without maintaining chambers or EC infrastructure at every site.	Lower GHG measurement requirements do not eliminate the need for representative hydrological monitoring. Sparse water-table observations may fail to capture spatial heterogeneity, seasonal fluctuations, drought duration or inundation.
Representation of hydrological change	Water table is a continuous variable, allowing response functions to represent gradual changes without the artificial jumps associated with categorical emission factors.	Mean water-table depth alone may not adequately represent hydrological dynamics. Two sites with similar mean conditions can differ in emissions because of fluctuations, extreme events or the duration of inundation (sections 2.2 and 2.4).
Connection to restoration objectives	Water table is both a principal target of rewetting and an input to GHG estimation, linking restoration measures directly to their expected climate effects.	Achieving a hydrological target does not necessarily demonstrate the expected GHG outcome. Estimates remain dependent on the response function and the conditions under which it was calibrated.
Scientific basis and gas coverage	Water-table depth is a mechanistically plausible predictor because it influences the balance between aerobic and anaerobic peat decomposition, which affects CO_2 and CH_4 fluxes.	Predictive power differs among gases. N_2O is not adequately represented by water table alone, while CH_4 also responds to vegetation, temperature and other site conditions (section 2.1).
Transferability and regional application	Water table can be measured or estimated through piezometers, topographic modelling, remote sensing or vegetation indicators, supporting application across different sites where suitable response functions exist.	Response functions calibrated under particular climatic, ecological and management conditions may not perform equally well elsewhere. Regional application requires evidence that the calibration domain is representative of the target sites (section 2.7).
Flexibility under different data conditions	Where direct water-table measurements are unavailable, secondary indicators such as vegetation or biotope type can help infer representative hydrological conditions within the same response-function framework.	Indirectly inferred hydrology introduces an additional source of uncertainty. The reliability of the GHG estimate depends on both the hydrological inference and the calibrated relationship between water table and emissions.

c. Implications for project level applicability

At project level, water-table depth is both a target of rewetting and an input to estimating its climate effect. The reliability of that estimate depends on whether hydrological data adequately represent baseline conditions, conditions after restoration, and the transition between them.

These data requirements determine when a hydrological proxy can be scaled up reliably and when its estimates need further validation.

Hydrological proxies can estimate the climate effect of rewetting across large project areas when water-table monitoring represents site conditions and the response functions are calibrated for those conditions. The estimate remains indirect: project reporting should specify how water-table data were collected, which response functions were used and whether their calibration covers the peatland being assessed.

1.4. Multivariable and hybrid models

Multivariable approaches combine measurements or emission factors with several ecological and spatial predictors rather than relying on a single site indicator.

The literature exposes examples about process-based models of hydrology, vegetation and carbon or nitrogen cycling, as well as spatial approaches that use remote sensing and machine learning to map water-table conditions or GHG-relevant site classes (Alm et al., 2023; Tiemeyer et al., 2020; Koch et al., 2023; Van den Berg et al., 2024; Isoaho et al., 2026).

These approaches can support scenario analysis, national estimation and the spatial targeting of restoration but their use at project-level MRV requires explicit documentation of model inputs, calibration, validation and uncertainty.

Only a few of these approaches are currently operational, for example in the national inventory in Finland or in long-term research monitoring in Sweden, and none was reported by interviewees as an established method for GHG accounting in restoration projects. Empirical experience with the approaches in restoration contexts therefore remains limited. Nevertheless, they are included here because the interviewed experts mentioned them as promising approaches under development or validation, particularly for capturing spatial heterogeneity and validating simpler proxies against broader evidence. Each is briefly introduced, together with its current geographical reach and recommendations for further reading.

a. Continuous multivariable proxies (water table–vegetation–remote sensing)

Continuous multivariable proxies treat water table, vegetation and remote-sensing indicators as continuous variables within a single regression. This avoids the artificial jumps that occur when a site crosses a class boundary. One example is the Sentinel-1/2 water-table modelling tested in Ireland and Scotland (Reddin et al., 2025). Germany's EO4Nature project is testing remote-sensing detection of inundation events to complement GEST's vegetation classification but the approach is not yet an operational network. According to the interviewed experts, remote-sensing proxies still need field calibration (F. Reichelt; Interview, 27.07.2026; W. Kotowski; Interview, 12.08.2026) and cannot yet estimate CH_4 or N_2O directly (A. Lazdiņš; Interview, 22.07.2026).

Further reading: Reddin et al. (2025), *Science of Remote Sensing*; Minasny et al. (2024), *Biogeochemistry*.

b. Machine learning / AI-based variable ranking and flux upscaling

These approaches use random forest or gradient-boosting models trained on large combined datasets — climate reanalysis, satellite vegetation and soil-moisture indices, topography — to predict fluxes and rank which drivers matter most, something that conventional regression struggles to do with many correlated variables (Ying et al., 2025; Khan et al., 2025). Its strength is ranking variable importance objectively to help prioritise what to measure at new sites.

Behrens et al. (2026) provide a recent peatland-specific example of using explainable machine learning to examine the combined influence of hydrological, climatic and site-specific variables on annual CO_2 exchange.

Matthew Saunders, peatland expert of the Trinity College Dublin, describes these approaches as an emerging opportunity for Ireland, but its application is limited by the scarcity of sufficiently large and representative flux datasets for training and validating the models, and its comparatively low interpretability against a simple emission factor (Ireland; Interview, 14.08.2026).

Further reading: Ying et al. (2025), Khan et al. (2025); *ESSD (WetCH4)*; Isoaho et al. (2026).

c. Yasso and mass-balance models

Process-based models are built on explicit inputs and outputs, capturing temporal change (what static factors cannot), grounded in checkable input/output terms. These models were mostly built originally for forest or mineral soils and need demanding input data (litter production, decomposition rates by site type) that restoration projects rarely have to hand.

Yasso simulates litter and soil-carbon decomposition as a function of temperature and moisture. Mass-balance approaches calculate net CO_2 as litter carbon input minus heterotrophic respiration.

Finland's national inventory now uses a dynamic mass-balance method for drained peatland forest soils (Alm et al., 2023), and Yasso itself, originally built for forest mineral soils, was revised in 2024 to represent peat and paludified soils correctly (Ťupek et al., 2024), running within Finland's wider integrated system of eddy covariance, chambers, meteorology, vegetation and ecosystem modelling (S. Juutinen; Interview, 18.08.2026).

Latvia applies a comparable mass-balance logic to forested organic soils (A. Bardule; Interview, 23.07.2026).

Finland and Germany have explored DNDC Forest to simulate carbon and nitrogen cycling in peat soils (Alm et al., 2023), and the Netherlands has developed PEATLAND-VU, a mechanistic model explicitly simulating hydrology, vegetation dynamics, peat decomposition and carbon and nitrogen cycling under different management scenarios (Van den Berg et al., 2024).

Further reading: Alm et al. (2023); Ťupek et al. (2024).

d. Atmospheric inversion modelling

Atmospheric inversion modelling estimates GHG fluxes from changes in atmospheric GHG concentrations and models of how gases are transported through the atmosphere. It provides an independent, larger-scale estimate that can be used to evaluate and calibrate bottom-up models. In Finland, this is an active area of research. Sari Juutinen, empirical researcher for GHG fluxes and monitoring of the Finnish Meteorological Institute (FMI), recommends systematically comparing both approaches to identify discrepancies and improve emission estimates (Interview, 18.08.2026).

Basso et al. (2026) show that in this model no single parameter works globally for wetland methane, reinforcing the need for its regional calibration. The value of the model lies in being an independent, large-scale check on whether bottom-up estimates are plausible, though it is far too coarse to attribute emissions to one restoration site.

Further reading: Basso et al. (2026).

e. Drone/UAV-based vegetation time-series extrapolation

Drone- and UAV-based vegetation time-series extrapolation uses repeated surveys to track vegetation development at rewetted sites over several years. When combined with flux measurements, these time series can be used to link observed vegetation succession to GHG dynamics and extrapolate carbon balances over the following one to two decades.

The approach is being tested at research sites of the Swedish University of Agricultural Sciences (SLU) in Sweden, where drone surveys are conducted roughly three times per year. One monitoring series now covers about eight years and is complemented by chamber and EC measurements (S. Jordan; Interview, 20.08.2026). A comparable published approach combining chamber measurements with drone- and satellite-based vegetation classification has been applied in Finland (Isoaho et al., 2026).

A key strength is that the approach captures observed vegetation succession rather than assuming a fixed post-restoration end state, while requiring less infrastructure than permanent flux towers. Its main limitation is that vegetation classes do not always correspond closely to measured emissions. Reliable extrapolation therefore depends on robust links between mapped vegetation dynamics and flux measurements, supported by cross-validation (topic cross-validation is discussed in section 2.8)

Further reading: Isoaho et al. (2026).

Overall pattern

The methods reviewed in this chapter serve different purposes. Chambers capture variation among site conditions; eddy covariance tracks ecosystem exchange over time; vegetation and hydrological proxies extend estimates across larger areas; and multivariable models can combine these sources of information.

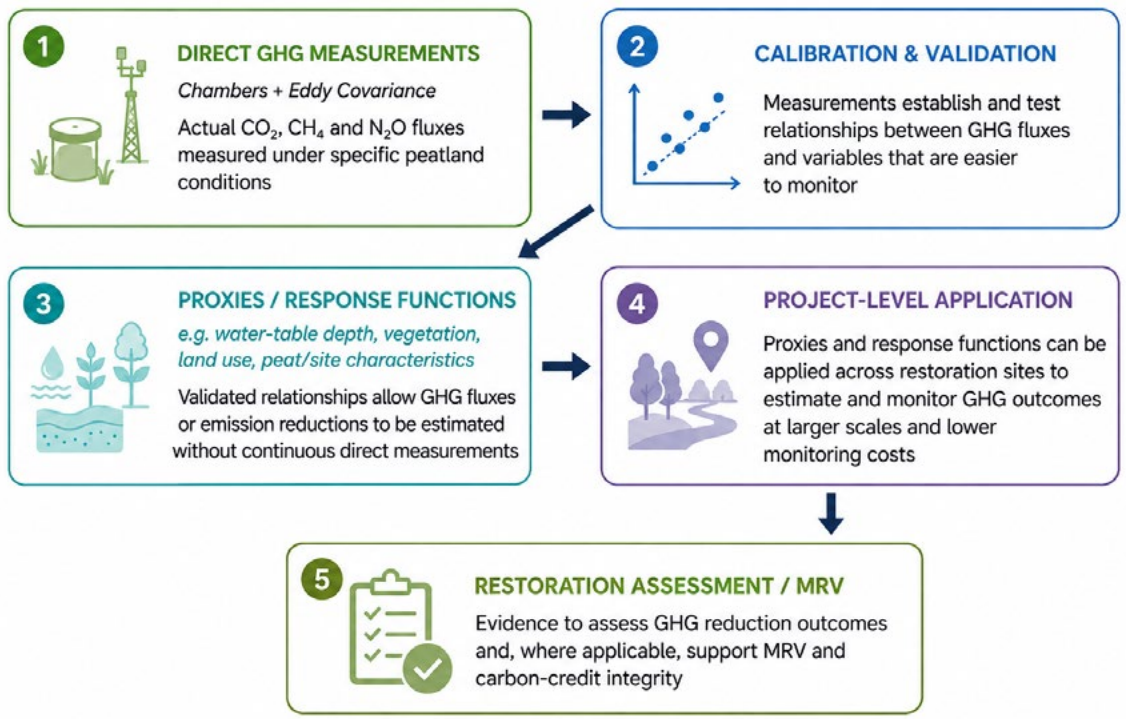
Adding variables or model detail may improve an estimate, but it also increases data, expertise and cost requirements.

At project scale, the appropriate method is therefore the one that provides sufficiently reliable estimates for the assessment purpose and can be maintained throughout monitoring. A practical design should combine scalable proxies with periodic calibration and validation at well-monitored sites.

Figure 6 illustrates the role of each assessment for developing and validating more scalable data.

A proposal for a tiered monitoring design, combining intensive reference sites with lighter assessment across restoration projects, is discussed later in Chapter 4.

Figure 6: Schematic role of GHG assessments for peatland projects

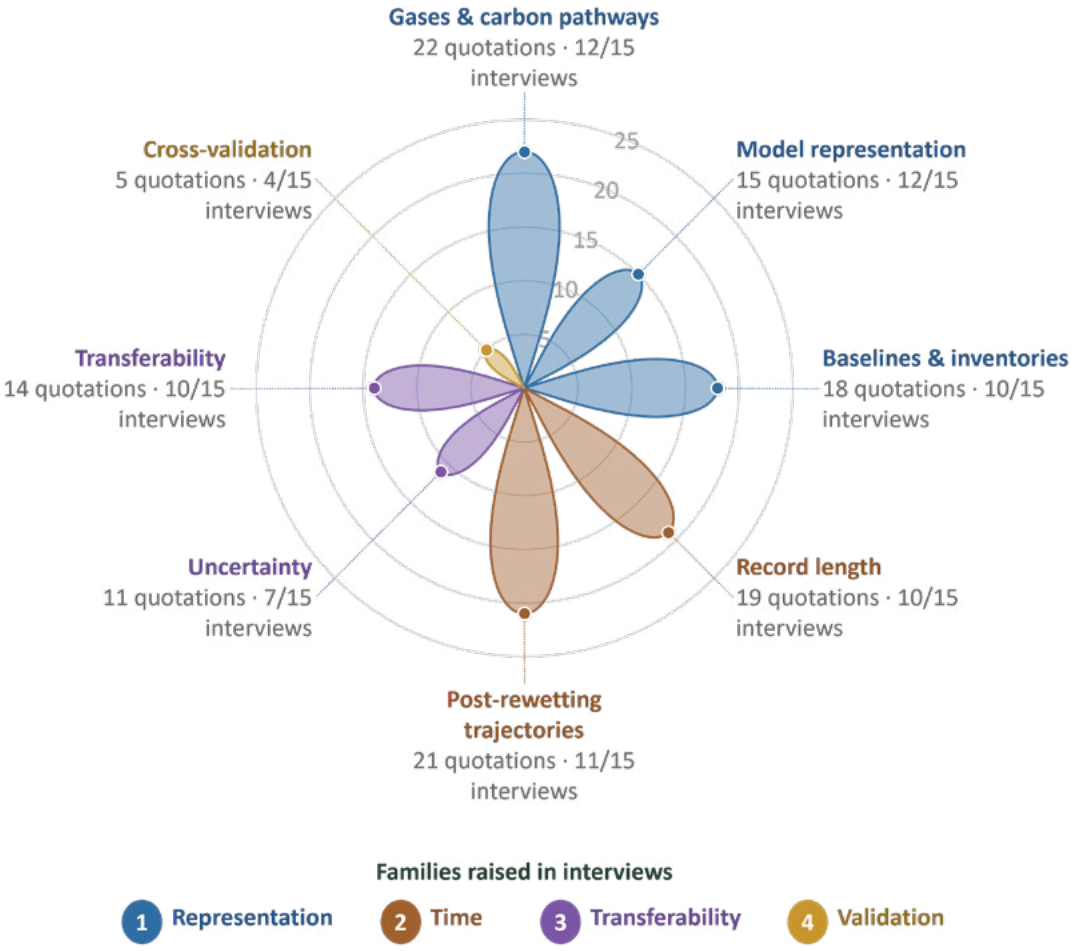


2 Scientific robustness and evidence base

Whichever combination of methods is chosen, its estimates are only as reliable as the evidence behind them. This chapter examines where that evidence can lose robustness on its way from measurement to accounting

Of the 352 quotations coded across all interviews, 78 addressed scientific robustness. They raised eight issues, grouped into four families according to the question each addresses: **representation** (are we capturing the right things?), **time** (are records long enough?), **transferability** (does evidence from elsewhere apply here?) and **validation** (do independent methods agree?). Figure 7 shows how often each issue was raised and in how many interviews. The issues are discussed in turn below.

Figure 7: Robustness issues raised across the expert interviews, grouped into four families



Petal length = number of quotations raising each issue (n = 78). A quotation can address several issues. Frequencies show where experts directed their attention, not the relative importance of each issue or the degree of consensus among them. Underlying data in Annex 2, Table 17.

REPRESENTATION
Are we capturing the right things?

2.1. Gases and carbon pathways

The evidence is uneven across gases and carbon pathways. Three main topics matter across the interviews:

a. Gases that can be estimated with confidence. Interviewees agree that CO_2 has the strongest evidence base and its measurement protocols and empirical relationships are comparatively well established. CH_4 was mentioned as harder to predict after rewetting because it responds to interacting site conditions like water level, temperature, redox conditions, substrate availability and vegetation-mediated transport (M. Saunders; Interview, 14.08.2026; F. Renou-Wilson; Interview, 29.07.2026).

b. Emissions that measurements might miss. Short-lived N_2O and CH_4 peaks can escape intermittent chamber measurements, especially in nutrient-rich or managed systems (K.-H. Knorr; Interview, 22.07.2026; A. Lazdiņš; Interview, 22.07.2026). GEST does not estimate N_2O because its proxies do not represent it adequately

(F. Reichelt; Interview, 27.07.2026). The importance of N_2O varies by peatland type: it is comparatively well constrained in the nutrient-poor bogs studied by F. Renou-Wilson, but Iceland's evidence rests on a single study (F. Renou-Wilson; Interview, 29.07.2026; Land og Skógur team; Interview, 20.08.2026).

c. Carbon losses falling outside atmospheric measurements. Carbon can also leave through water as DOC, DIC and POC, or through harvested biomass. It was mentioned that these pathways are inconsistently measured across all Europe, with POC particularly poorly documented, as well as DOC for agricultural peatlands (S. Juutinen; Interview, 18.08.2026; M. Saunders; Interview, 14.08.2026; F. Renou-Wilson; Interview, 29.07.2026; T. Morley; Interview, 16.07.2026). In Iceland, volcanic and aeolian mineral depositions add a further complication, since they can dilute measured soil-carbon percentage independently of any management effect, and its explanatory importance relative to climate and hydrology has not yet been empirically tested (Land og Skógur team; Interview, 20.08.2026).

Some frameworks already internalise part of these losses: in the UK Peatland Code, particulate and dissolved organic carbon losses are included within the emission factor rather than calculated at project level, so site differences in erosion, for example between steep and flat blanket bog, are averaged out (R. Kerkvliet-Hermans; Interview, 14.09.2026). The European Commission's 2026 draft CRCF methodologies recognise DOC, DIC and POC as relevant to peatland carbon balances (European Commission, 2026).

2.2. Models and assessments representation

A recurring concern in the interviews was that a model can include the right processes and still produce weak estimates if its input data or categories do not adequately represent the peatland being assessed. What matters is not how many variables a model includes, but whether it captures the site differences that actually affect emissions. Three recurring concerns emerged from the interviews:

a. Measurement of relevant conditions. Florence Renou-Wilson, peatland and GHG expert from the University College Dublin (UCD, Ireland), warned that water-table data alone are not always sufficient: robust interpretation also requires information on peat type, land-use history and vegetation (F. Renou-Wilson; Interview, 29.07.2026). A. Lazdiņš distinguishes between understanding these processes and having the data to represent them, and pointed out that for Latvia frequent groundwater measurements and biomass data outside forests are often lacking (A. Lazdiņš; Interview, 22.07.2026). Especially in forested peatlands, Māra Pakalne (restoration practitioner and vegetation researcher of the University of Latvia), pointed out that measurements with chambers involve mostly only soil respiration, and photosynthetic uptake, including light, soil and air inputs, as well as root-related components are missed (M. Pakalne; Interview, 04.08.2026).

b. Model's categories reflecting real differences between peatlands. A change of vegetation class can make an estimated emission jump even when the ecosystem changes gradually. Wiktor Kotowski, empirical researcher of the University of Warsaw, raises this concern about applying GEST classes to Polish plant communities and about predicting which class will emerge after restoration, adding that water-table level can be defined and monitored more directly (Interview, 12.08.2026).

c. Critical application of assumptions from other soils or peatland types. Mineral-soil models do not necessarily work on organic soils, and peat depth alone does not describe peat quality or carbon content. So describes Sabine Jordan from the Swedish University of Agricultural Sciences of Uppsala (SLU), also cautioning against assuming that nutrient-rich peatlands always emit more: different peatlands can have different carbon and N_2O dynamics (S. Jordan; Interview, 20.08.2026).

2.3. Bias in baselines and inventory assumptions

An estimate can be biased even when its measurements are sound. Three topics summarized that bias across the interviews:

a. Choice of reference conditions. Robust estimates first depend on having an appropriate reference against which change can be attributed. A. Lazdiņš illustrates this problem with DOC export: if it is measured in drained peatlands but not in comparable undrained sites, the entire export may be attributed to drainage (Interview, 22.07.2026). This requires adequate measurements from reference systems, which are not always available. The Land og Skógur team from Iceland points to this limitation in that country, where measurements from undisturbed wetlands remain insufficient to establish a strong reference (Interview, 20.08.2026). F. Renou-Wilson adds a related perspective from Ireland: although emissions from natural erosion or degradation are small compared with drainage-driven emissions, year-to-year variability and the absence of truly pristine Irish bogs complicate a strict natural-versus-degraded comparison (Interview, 29.07.2026).

b. Representativeness of measured sites. The same problem arises when measurements from a limited number of research sites are used to represent a larger peatland population. These sites do not necessarily capture the distribution of land uses, drainage intensities or hydrological conditions found across a region. For

Poland, W. Kotowski highlights this problem particularly for strongly drained peatlands (Interview, 12.08.2026). K.-H. Knorr extends the argument to hydrological conditions in Germany, noting that measured sites may have different average water tables from other peatlands under the same land use (Interview, 22.07.2026). Similarly, N. Zableckis questions whether Lithuania's national soil-monitoring grid adequately represents peatlands (Interview, 17.08.2026).

c. Resulting bias. Weak reference conditions or unrepresentative measurement sites become particularly problematic when they introduce systematic rather than random errors. Regarding this, R. Kerkvliet-Hermans distinguishes between errors that vary in direction and may partly cancel when estimates are aggregated, and systematic errors that do not (Interview, 14.09.2026). A similar concern emerges from the project-level experience of J. Averkamp and M. Schneider (AECO), who noted that consistently overestimating emissions before rewetting or underestimating them afterward would systematically bias the estimated effect of restoration (Interview, 10.09.2026).

TIME
Are we observing for long enough?

2.4. Record length and interannual variability

The evidence is strongest when it spans multiple years and captures the events that shape each year's balance. Two problems arose in the interviews:

a. Interannual variability. F. Renou-Wilson and M. Saunders illustrate this with a six-year record from an Irish bog, where the same site shifted between a carbon sink and source across years. A single year could therefore give a misleading picture of longer-term GHG performance (Interviews, 29.07.2026 and 14.08.2026 respectively). Measurements must also cover the parts of the year when emissions change sharply. M. Pakalne and A. Bardule stress the need to capture contrasting seasonal conditions (Interviews, 04.08.2026 and 23.07.2026 respectively). The Land og Skógur team highlights freeze–thaw events in Iceland as an example of short periods that can contribute substantially to the annual balance but may be missed by intermittent measurements (Interview, 20.08.2026).

b. Winter measurement limitations, particularly in northern and boreal Europe. S. Jordan and the Land og Skógur team highlight a winter blind spot in continuous monitoring: eddy-covariance data quality can deteriorate below roughly −15 °C, potentially missing important freeze–thaw periods even at continuously monitored sites (Interviews, 20.08.2026).

2.5. Post-rewetting trajectories

Restoration changes emissions over time, but assessments often compare only a drained state with a restored state. Short evaluation periods may therefore misrepresent longer-term GHG performance and ecological recovery. Three topics remain important across the interviews:

a. Application of a new emission factor. Emission factors describe conditions before and after rewetting, but not how or when a site moves between them. K.-H. Knorr highlights the lack of measurements documenting this transition (Interview, 22.07.2026).

b. Interpretation of early emissions. N. Zableckis notes that CH_4 may rise soon after rewetting and decline as the ecosystem develops, so the first years may not represent longer-term performance (Interview, 17.08.2026). S. Juutinen similarly stresses that rewetted managed peatlands remain transitional and should not immediately be treated as pristine systems (Interview, 18.08.2026).

c. Consideration of long-term trajectories. S. Jordan illustrates the remaining evidence gap in Sweden: even an eight-year drone and flux series cannot yet demonstrate the ten- to twenty-year outcome, which remains projected rather than observed (Interview, 20.08.2026).

TRANSFERABILITY
Can what we learned here be applied elsewhere?

2.6. Capture of uncertainty

An emission factor is an average derived from measurements at a limited set of sites. The interviews show that the uncertainty attached to such an average can mean two different things, and usually only one of them is reported:

a. Variation among the measured sites. The reported uncertainty range typically describes how much emissions differed among the sites from which the factor was derived. It shows the spread of the underlying data, not whether the factor fits a particular peatland. According to K.-H. Knorr, this is well reported (Interview, 22.07.2026).

b. Applicability to the peatland being assessed. A second, less visible uncertainty arises when the average is applied to a site that differs from the measured ones in water level, vegetation, management or peatland type. In that case the estimate may be unreliable even when the reported range is narrow. K.-H. Knorr argues that this second source of uncertainty is often insufficiently recognised (Interview, 22.07.2026).

This distinction connects concerns raised by other interviewees from two directions. On the side of the reported ranges, A. Lazdiņš questions whether detailed GEST classes add useful precision when the uncertainty ranges of their emission factors overlap substantially (Interview, 22.07.2026). If neighbouring classes cannot be told apart, a finer classification adds little information. On the side of application, S. Juutinen stresses that an emission factor is an average for a defined area, not an exact value for each peatland within it (Interview, 18.08.2026).

How far an average can be trusted depends on how closely the assessed peatland resembles the sites behind it, which is the question of transferability addressed in the next section.

2.7. Transferability across regions

An emission factor or proxy calibrated in one setting may be used elsewhere only if the conditions that shape GHG emissions are sufficiently comparable. Regarding this, five topics emerged during the interviews:

a. Comparability of ecological and climatic conditions. Transferability starts with whether the conditions shaping emissions are sufficiently comparable. T. Morley illustrates the problem in Ireland, where GEST relationships developed mainly under continental conditions tend to overestimate emissions from Atlantic peatlands (Interview, 16.07.2026). F. Renou-Wilson sees such ecological, climatic and historical differences as a major source of uncertainty, while M. Saunders frames it as a space–time problem: sites within the same broad category are not necessarily functionally equivalent (Interviews, 29.07.2026 and 14.08.2026). For F. Reichelt, this makes regional evidence essential when applying proxy-based emission factors (Interview, 27.07.2026).

b. Local evidence to test transferred estimates. Comparability needs to be tested locally. N. Zableckis points to Lithuania, where flux measurements remain too sparse to validate many GEST classes (Interview, 17.08.2026). The project developers at AECO apply the same logic operationally: using GEST in Germany, Poland, Latvia and Lithuania, but avoiding regions they consider less comparable, including Ireland and south-western France (Interview, 10.09.2026).

c. Supplementing weak local data with evidence from comparable regions. Where local evidence is limited, data from similar regions can partly fill the gap. R. Kerkvliet-Hermans illustrates this with the UK Peatland Code, which relies mainly on UK measurements but also draws on peatlands within the same north-west European climatic envelope (Interview, 14.09.2026). Where evidence remains insufficient, categories are kept broader: raised and blanket bogs, for example, share a single factor in the current UK Peatland Code (Evans et al., 2022). This issue extends beyond GEST: hydrological response functions and default emission factors are equally constrained by their calibration domain, and CO_2 exchange may differ with temperature even at similar water-table depths (Behrens et al., 2026).

d. Upscaling from sites to larger areas. Transferability also matters when moving from individual sites to national inventories: Sari Juutinen from the Finnish Meteorological Institute (FMI) identifies site-to-inventory upscaling as a major analytical challenge in Finland, despite the country's strong, long-term and multi-method evidence base. Spatial and interannual water-table variability, areal coverage by peatland type, and classification of forest–peatland transition zones remain as important sources of uncertainty (Interview, 18.08.2026).

e. Building regional evidence where it is missing. The CRCF translates this scientific problem into an operational requirement: proxy models must be calibrated and validated against direct measurements representative of the region where they are applied. Models developed elsewhere may be used under comparable conditions, but require additional year-round measurements in the project region (European Commission, 2026, Annex, Section 2.4.3.1). This allows existing models to be used while progressively strengthening the regional evidence base.

VALIDATION
Can we independently test the resulting estimate?

2.8. Cross-validation of proxies and direct measurements

Cross-validation tests whether different approaches applied to the same peatland tell a consistent story. Two comparisons emerged from the interviews:

a. Coherence of proxy estimates and measured fluxes. K.-H. Knorr illustrates this at Amtsvenn-Hündfelder Moor: GEST estimates about 12 t ha^{-1} yr^{-1}, while eddy-covariance measurements range from close to zero in wet years to around 6–8 t ha^{-1} yr^{-1} in dry years (Interview, 22.07.2026 and Behrens et al., 2026). The comparison reveals both a systematic difference and interannual variability that a category-based factor cannot capture. A related limitation was noted in Sweden, where S. Jordan reports that vegetation-based site classes used in internal assessments do not always match measured GHG emissions. Vegetation may help identify peatland type without reliably predicting its emissions (S. Jordan; Interview, 20.08.2026).

b. Compatibility among methods. Chambers capture variation within a site, while eddy covariance measures exchange across a larger area over time. Comparing them can test whether each captures the processes needed for an annual estimate (K.-H. Knorr; Interview, 22.07.2026). The Land og Skógur team is testing this combination in Iceland, although records remain short, while S. Juutinen describes a more integrated approach in Finland, combining both methods with modelling, meteorology and vegetation observations (Interviews, 20.08.2026 and 18.08.2026). Shared Baltic–Nordic chamber protocols further support comparison across sites (A. Bardule; Interview, 23.07.2026; A. Lazdiņš; Interview, 22.07.2026).

The value of cross-validation is therefore not that different methods must agree, but that their comparison helps distinguish expected variability from systematic bias and identify where estimates need adjustment.

Overall pattern

The lines above describe eight issues recurring in the literature and interviews, about where an estimate can lose robustness on its way from measurement to accounting.

Table 8 summarizes the issues per families with their key findings and provides guiding questions to facilitate its identification. Because these weaknesses can propagate into restoration assessments, MRV systems and carbon-credit accounting, they raise the question addressed in the next chapter: where, geographically and ecologically, the evidence base is thinnest.

Table 8: Key issues affecting robustness and evidence base of peatland GHG estimates

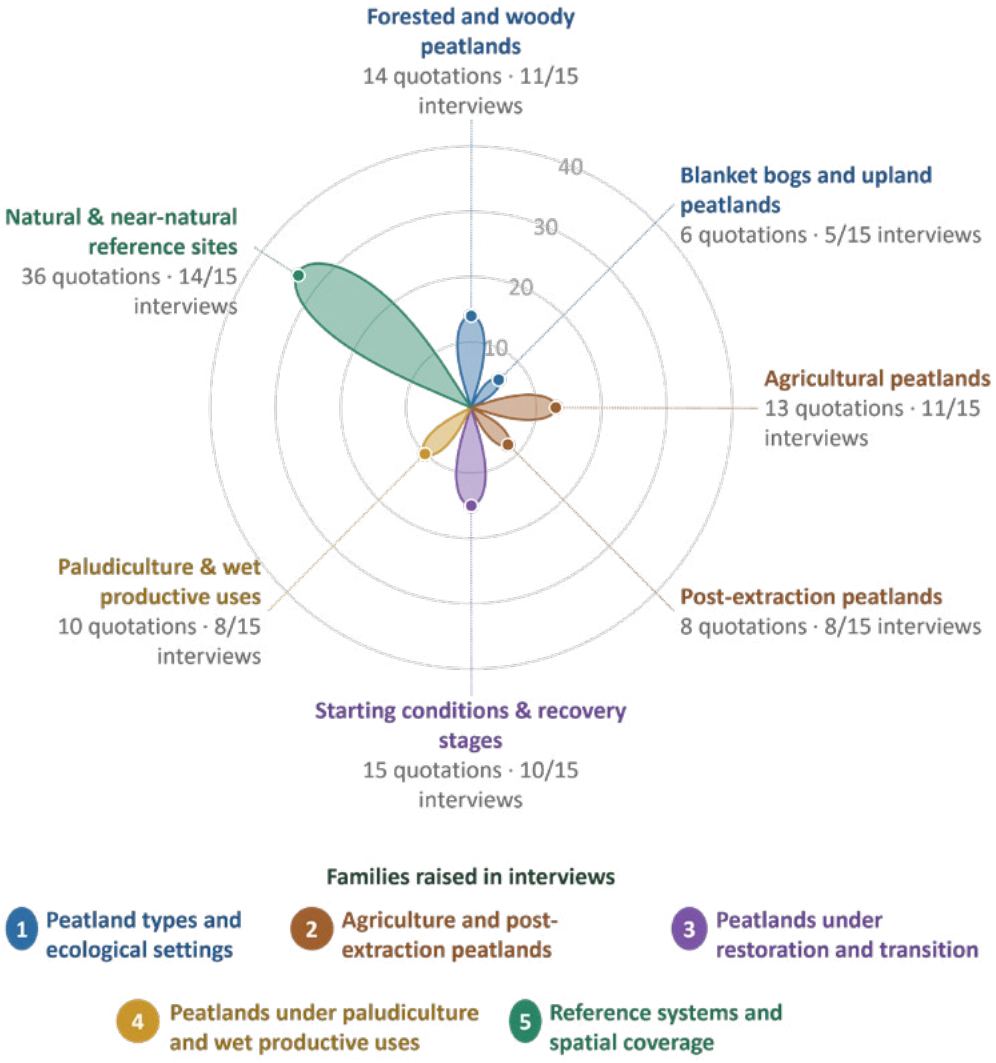
Family	Issue	Key finding	Guiding question
Representation	2.1 Gases and carbon pathways	CO_2 is well supported; CH_4 and N_2O peaks and carbon lost through water or harvest are often missed.	What remains poorly measured or omitted?
	2.2 Model & assessment representation	More variables do not help if site data are weak or classes miss real differences.	Do inputs and categories reflect the peatland?
	2.3 Bias in baselines and inventory assumptions	Weak references and unrepresentative networks can introduce systematic bias.	Are reference conditions and measured sites representative?
Time	2.4 Record length	Single years, seasonal events and winter fluxes can be missed.	Do measurements capture a typical year and its critical periods?
	2.5 Post-rewetting trajectories	Before/after factors do not describe the transition, including early CH_4 peaks.	How do emissions change after restoration?
Transferability	2.6 Capture of uncertainty	Ranges describe variation among measured sites, not fit to a new site.	Does the reported range capture the uncertainty of applying the estimate here?
	2.7 Transferability	Comparable conditions and local measurements are both needed.	Does evidence from elsewhere apply here?
Validation	2.8 Cross-validation	Comparison separates expected variability from systematic bias.	Do independent methods give compatible results?

3 Geographic and ecological gaps: where the European evidence base remains weak

This chapter maps where the evidence behind peatland GHG assessments is thinnest: the peatland types, land-use systems, restoration contexts and regions for which empirical data remain scarce, fragmented or absent, even where the methods discussed in the preceding chapters are well established elsewhere. The interviews covered Finland, Iceland, Germany, Ireland, Sweden, Latvia, Lithuania, Poland and the UK, but not all European peatland regions. The preliminary literature review had already identified Mediterranean, Alpine and coastal or brackish peatlands as underrepresented in the published evidence base. The interviews added gaps in specific peatland types, land uses and restoration contexts, and pointed repeatedly to remote or poorly accessible peatlands and to systems for which specialised expertise and monitoring capacity remain limited.

Of the 352 quotations coded across all interviews, 70 addressed these gaps. They raised eight issues, grouped into five families: peatland types and ecological settings, peatlands used for agriculture and post-extraction, peatlands under restoration and transition, peatlands under paludiculture and wet productive uses, and reference systems and spatial coverage. Figure 8 shows how often each issue was raised and in how many interviews. The gaps are discussed in turn below.

Figure 8: Geographical and ecological gaps raised across expert interviews, grouped into five families



Petal length = number of quotations raising each issue (n = 70). A quotation can address several issues. Frequencies show where experts directed their attention, not the relative importance of each issue or the degree of consensus among them.

3.1. Peatland types and ecological settings

a. Forested and woody peatlands

Evidence for forested peatlands remains geographically uneven, with limited region-specific data available to support emission factors definition across different forest and peatland conditions. This point emerged repeatedly in the evidence discussed by interviewees. Emissions from forested peatlands depend strongly on drainage and site condition: naturally occurring woodland on peat can differ substantially from forest established on drained peat. Robust accounting therefore requires empirical evidence that captures these different conditions across regions, which remains limited.

K.-H. Knorr identified this among the major gaps in current GHG knowledge for Germany, and related concerns were raised by experts working in Lithuania, Poland and Finland (Interviews: K.-H. Knorr, 22.07.2026; N. Zableckis, 17.08.2026; W. Kotowski, 12.08.2026; S. Juutinen, 18.08.2026).

Transitions between open, shrub-dominated and forested conditions. Other examples point to a broader lack of evidence for peatlands transitioning between open, shrub-dominated and forested conditions. W. Kotowski identified drained forest peat soils and shrub-dominated systems as poorly represented in the Polish measurement evidence available to his research context (Interview, 12.08.2026). Similarly, N. Zableckis noted woody encroachment as a relevant condition in Lithuanian project sites that is not well captured by existing assessment approaches (Interview, 17.08.2026).

Exclusion from crediting frameworks. In the UK, R. Kerkvliet-Hermans explained that the Peatland Code excludes forested peatlands because the available emission factor is based on insufficient evidence for carbon crediting (Interview, 14.09.2026). AECO project developers reported a similar lack of data across several European countries in which they work. M. Schneider noted that small forested inclusions can be accommodated within predominantly agricultural peatland projects, but accounting for forest-dominated peatlands remains unresolved in current practice (AECO Team; Interview, 10.09.2026). These examples show how limited regional evidence for forested peatlands can directly restrict their inclusion in operational GHG accounting and carbon-crediting frameworks.

A workaround from the literature. An interesting attempt to address this representativeness gap was made by Frömberg (2025). In her master thesis, she applied the Peatland Emissions Predictor (PEP; Drösler et al., 2013) to the predominantly forested Venner Moor in north-western Germany. PEP is an empirical German approach that assigns mean CO_2, CH_4 and N_2O emission factors to broad land-use and site-condition categories, derived largely from managed or agricultural peatlands. Frömberg transferred emission factors from hydrologically comparable non-forested categories to dry and wet forest classes, and accounted for woody biomass separately using inventory data from the German Thünen Institute. However, the PEP water-table classes matched site conditions poorly. Frömberg therefore questioned the transferability of the estimates and identified a potential underestimation of emissions.

b. Blanket bogs, upland peatlands and other region-specific peatland types

Blanket bogs were repeatedly identified as insufficiently represented in the interviews with Irish experts. They highlighted gaps across mountain and lowland Atlantic systems, as well as east–west and elevation gradients (F. Renou-Wilson; Interview, 29.07.2026; M. Saunders; Interview, 14.08.2026; T. Morley; Interview, 16.07.2026). In the UK, the same limited evidence is reflected in the single emission factor shared by raised and blanket bogs in the Peatland Code (section 2.7).

K.-H. Knorr extended this gap to shallow organic soils in upland areas of Germany. Although Germany has no blanket bogs in the strict sense, its low mountain ranges contain extensive organic soils that are too shallow to qualify as peatlands and therefore fall outside standard peatland categories. These soils can be major sources of dissolved organic carbon (DOC) export, yet little is known about their overall carbon balance (K.-H. Knorr; Interview, 22.07.2026).

In northern Europe, coverage is uneven across peatland types. Aapa mires in Finland are well studied and supported by several research stations (S. Juutinen; Interview, 18.08.2026), as are palsa mires in Lapland, but other northern peatland types receive considerably less attention (S. Jordan; Interview, 20.08.2026).

3.2. Agricultural and post-extraction peatlands

A second family of gaps concerns peatlands shaped by intensive land use, mainly agriculture and peat extraction, and the degraded organic soils these uses leave behind. Two evidence problems overlap here. First, common land-use and management types remain poorly represented in measurements and emission factors. Second, long-term drainage, cultivation and extraction alter the peat itself, through decomposition, loss of peat depth and residual or transitional soils. As a result, these sites become harder to classify and to compare with the conditions for which existing factors were developed. These gaps are particularly relevant because degraded sites under these uses hold substantial potential for emission reductions through rewetting and restoration.

a. Agricultural and highly degraded peatlands

Agricultural peatlands are managed differently across the European landscape. This range of land uses and management practices is not sufficiently or adequately differentiated in existing measurements and emission factors. In Poland, drained fens used for agriculture are almost entirely missing from the empirical evidence base (W. Kotowski; Interview, 12.08.2026). A similar pattern emerges in Iceland, where research has focused mainly on peatlands drained since the settlement period (called Landnámsöld, pprox.. 870–930 CE) that remained uncultivated or abandoned. In contrast, agricultural land on drained peat, although widespread, is represented by only one or two relevant datasets (Land og Skógur team; Interview, 20.08.2026).

In Ireland, measurements remain insufficient across combinations of drainage depth, nutrient status and management intensity (M. Saunders; Interview, 14.08.2026; T. Morley; Interview, 16.07.2026). Existing classifications can further obscure these differences: GEST, for example, groups grassland uses relatively broadly and does not capture management-specific variation such as grazing intensity (F. Reichelt; Interview, 27.07.2026).

Experts from Latvia and Poland highlighted a further gap: long-cultivated peat and organic soils that have shifted towards the mineral-soil boundary. These transitional soils are difficult to accommodate within standard peatland categories and may therefore be underrepresented or excluded from existing assessments (A. Bardule; Interview, 23.07.2026; W. Kotowski; Interview, 12.08.2026).

Together, these gaps limit the ability of existing datasets and emission factors to distinguish between agricultural peatlands with different management histories, soil conditions and mitigation potential.

b. Post-extraction peatlands

Irish interviewees highlighted insufficient characterisation of cut-over and former industrial peatlands across restoration conditions (F. Renou-Wilson; Interview, 29.07.2026; T. Morley; Interview, 16.07.2026). F. Reichelt noted that extraction sites have relatively limited weight in the German national inventory because of their area, but cautioned against transferring that assessment to countries where peat extraction has been more extensive (F. Reichelt; Interview, 27.07.2026). Former extraction sites can follow very different trajectories after abandonment or rewetting, depending on residual peat depth, hydrology, vegetation development and restoration treatment (see 2.5).

3.3. Peatlands under restoration and transition

Since agricultural peatlands, forestry-drained sites and extraction areas differ in vegetation, nutrient status, soil structure and hydrology, their restoration trajectories cannot be assumed to be equivalent. Therefore, restored sites that have been measured do not always represent the diversity of starting conditions and recovery stages encountered in the practice (S. Juutinen; Interview, 18.08.2026).

The same is pointed by M. Saunders, who identified insufficient representation of different recovery stages among the Irish raised bog rehabilitation sites discussed in his interview (14.08.2026). In Iceland, the Land og Skógur team reported that restoration chronosequences are largely absent from the Icelandic research context discussed: older rewetted projects often lack baseline measurements, while current projects cover only the first years after intervention (Interview, 20.08.2026).

F. Reichelt identified fluctuating water tables, coastal peatlands, heavily inundated systems and areas with tall vegetation as conditions that can be difficult to represent or monitor adequately in restoration projects (Interview, 27.07.2026).

The gap is therefore not simply a shortage of restored sites, but insufficient evidence covering the range of conditions through which restored peatlands may pass.

3.4. Peatlands under paludiculture and emerging wet productive uses

Interviewed experts pointed out that emerging productive uses of rewetted peatlands, particularly across crops and management systems are poorly covered in databases, and that the available findings should not be treated as equally transferable between different forms of paludiculture.

Particularly relevant is that the evidence for productive use of wet peatlands varies considerably among systems. F. Reichelt distinguished between Sphagnum cultivation on bogs, which is supported by comparatively longer-term monitoring, and grass-like paludiculture, for which the evidence remains less certain (Interview, 27.07.2026).

Interviews from other countries point to a broader pattern of experimentation, but with limited evidence for deriving robust emission factors. In Latvia, the available evidence for Sphagnum cultivation trials is too limited to derive robust emission factors (A. Lazdiņš; Interview, 22.07.2026). S. Jordan similarly described paludiculture in Sweden as largely confined to small research trials (Interview, 20.08.2026), while S. Juutinen referred to Finnish experiments with raised-water-table agriculture and wetter forestry (Interview, 18.08.2026).

This suggests that productive wet-use systems are being tested across several countries, but their empirical maturity and coverage remain highly uneven.

3.5. Reference systems and spatial coverage

a. Natural-near and baseline peatlands

A gap family is related to where measurements are made and whether natural reference systems exist against which changes can be interpreted. The importance of reference conditions for attributing emissions is discussed in section 2.3 and this section shows that such references are scarce in several countries.

Lazdiņš identified relatively natural Latvian wetlands as insufficiently characterised in terms of GHG and carbon fluxes, despite their importance as reference conditions (A. Lazdiņš; Interview, 22.07.2026). In Iceland, monitoring has given greater attention to drained and degraded sites than to natural wetlands (Land og Skógur team; Interview, 20.08.2026). In Ireland, genuinely near-natural reference conditions are scarce: even Clara Bog, an important research site, has been influenced by past human activity (M. Saunders; Interview, 14.08.2026; F. Renou-Wilson; Interview, 29.07.2026). Better characterisation of functioning peatlands would also support the assessment of conservation alongside restoration.

b. Uneven geographic coverage and monitoring activities

In Iceland, most evidence comes from the capital region and surrounding areas, where staff capacity is greatest; monitoring has begun in the north-east, but large parts of the country remain poorly represented (Land og Skógur team; Interview, 20.08.2026). M. Pakalne highlighted stronger habitat information inside Latvian protected areas than outside them, and the continued use of older information in parts of the national peatland inventory (Interview, 04.08.2026). Some Irish emission-factor classes rely on few underlying studies (M. Saunders; Interview, 14.08.2026). Remote ecosystems with limited road access are difficult and costly to monitor, particularly where specialised expertise and research capacity are limited. As a result, ecological conditions and changes in these systems may remain poorly documented and underrepresented in existing emission factor catalogues.

The interviews also illustrate differences in the scale and continuity of monitoring. S. Juutinen reported more than twenty peatland EC stations in Finland, including one with over thirty years of data, alongside extensive chamber measurements (S. Juutinen; Interview, 18.08.2026). Irish researchers described a near-decade-long EC record at Clara Bog, complemented by chamber measurements (M. Saunders; Interview, 14.08.2026; F. Renou-Wilson; Interview, 29.07.2026). K.-H. Knorr highlighted the German empirical evidence supporting water-table response functions, without providing a national station count (K.-H. Knorr; Interview, 22.07.2026).

S. Jordan described SLU's EC and chamber measurements at three to four sites in the Umeå region (Interview, 20.08.2026). A. Bardule reported extensive Latvian chamber data and recent EC monitoring (initiated in 2025), although the scope and comparability of the resulting data were not established in the interview (23.07.2026). The Land og Skógur team described one EC site with approximately three years of data and around one hundred lower-intensity monitoring points (Land og Skógur team; Interview, 20.08.2026). W. Kotowski referred to three or four measured sites, including two EC towers, in the Polish research context he described (W. Kotowski; Interview, 12.08.2026). N. Zableckis reported no EC measurements in the Lithuanian context discussed and considered the LIFE Peat Restore measurements insufficient to validate emission factors (N. Zableckis; Interview, 17.08.2026).

The central issue is therefore not simply the number of measurement sites, but whether the available evidence covers the ecological conditions to which emission factors and models are applied. How the evidence base should be stratified, and the consequences for transferring emission factors and proxies between regions, are discussed in section 2.7 and 4.1.

Overall pattern

Table 9 summarises the geographical and ecological gaps per family and country. Across the groups, evidence tends to be weakest where peatland systems are heterogeneous, difficult to measure, rapidly changing or poorly aligned with existing classifications. "Underrepresented" therefore does not necessarily mean absent from the landscape, but insufficiently captured by the datasets and categories used for accounting. Future monitoring should not aim for equal coverage of every peatland type. Instead, as discussed in the next chapter, priority should be given to systems where high mitigation relevance, weak empirical coverage and poor transferability coincide, where additional data could make the greatest difference to restoration planning, national inventories, MRV and certification.

Table 9: Geographic and ecological gap families and countries in which they were identified (by interviewees)

	DE	FI	IE	IS	LT	LV	PL	SE	UK
1. Peatland types and ecological settings									
Forested and woody peatlands	●	●	·	·	●	·	●	·	●
Blanket bogs		·	●	·	·	·	·	·	●
Shallow organic soils	●	·	·	·	·	·	·	·	
Northern and mountain mires	·	●	·	·	·	·	·	●	·
2. Intensively used and degraded peatlands									
Agricultural peatlands	·	·	●	●	·	●	●	·	·
Post-extraction trajectories	●	·	●	·		·	·	·	·
3. Restoration and transition systems									
Restoration and transition sites	●	●	●	●	·	·	·	·	·
4. Paludiculture and emerging wet productive uses									
Evidence across crops and systems	●	●	·	·		●	·	●	·
5. Reference systems and spatial coverage									
Natural and near-natural reference sites	·	·	●	●	·	●	·	·	·
Uneven spatial coverage of measurements	·	·	●	●	●	●	●	·	·

A dot marks a gap raised by at least one interviewee for that country. An empty cell does not mean the evidence is adequate.

4 Methodological, monitoring and data priorities

Interviewees emphasised that addressing the gaps described in chapter 2 and 3 requires more than simply increasing the number of measurements. Six priorities were pointed out to improve the current assessments. These priorities focus on where monitoring should be concentrated, how long it should continue, how methods should be combined and documented, which carbon pathways should be covered, how evidence can remain usable beyond individual projects, and how it can feed into national inventories and certification methodologies.

Of the 352 quotations coded across all interviews, 78 addressed monitoring and data priorities. Figure 9 shows how often each priority was raised and in how many interviews. The priorities are discussed in turn below.

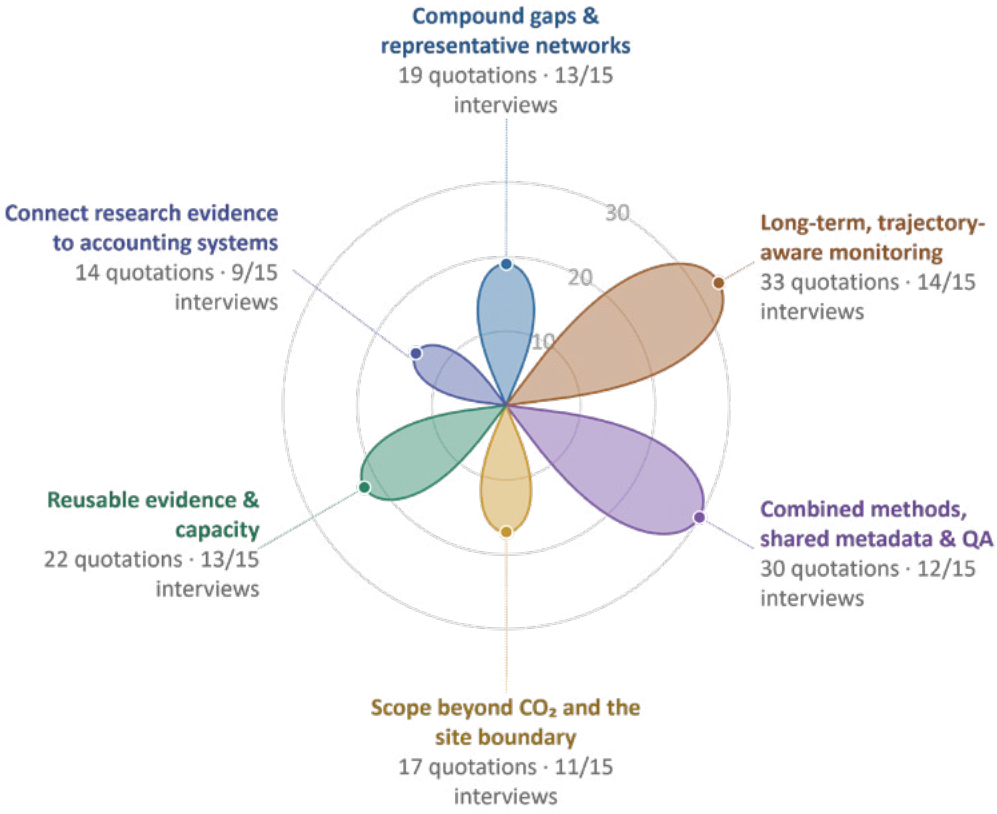
4.1. Prioritise compound gaps and redesign networks for representativeness

Uniform data coverage across all peatland types is not a realistic goal. Future monitoring should focus on systems where several problems overlap: high mitigation relevance, thin empirical evidence, limited transferability and methodological uncertainty. The interviews suggest this calls for representativeness at two scales: across sites and within them.

Across sites, networks should be built to cover the gradients that matter most for emissions: land use, drainage intensity, water-table regime, peat type and depth, nutrient status, vegetation, climate, restoration stage and management history. A. Bardule stressed the need to measure across differences in land use, vegetation, moisture and fertility (Interview, 23.07.2026). W. Kotowski criticised the tendency to choose sites because research infrastructure already exists there, rather than because their conditions matter for emissions (Interview, 12.08.2026).

Within sites, the spatial design has to reflect local heterogeneity. One or two water-level loggers say little about water-table variability across a large restoration area. Measurement points should therefore be distributed to cover the hydrological and vegetation patterns within the site (N. Zableckis; Interview, 17.08.2026).

Figure 9: Six main priorities raised across the expert interviews, to improve methodological, monitoring and data



Petal length = number of quotations raising each recommendation (n = 78). A quotation can address several recommendations. Frequencies show where experts directed their attention, not the relative importance of each issue or the degree of consensus among them.

The two scales can be brought together in a tiered network along the lines of ICOS.[1] In such a network, a small number of intensively monitored reference sites support lighter assessments across many restoration projects, while remote sensing extends spatial coverage (see section 4.3) (M. Saunders; Interview, 14.08.2026). In short, networks should be designed around the conditions for which GHG estimates are needed, not around the infrastructure that happens to exist.

4.2. Replace short campaigns with long-term, trajectory-aware monitoring

Restoration monitoring needs to capture both interannual variability and ecological change over time. Short campaigns cannot reliably distinguish climatic fluctuations from sustained ecosystem responses, particularly when they miss wet, dry or extreme years. S. Juutinen considers approximately ten years a useful starting point for restoration monitoring, while acknowledging that substantial variability may persist even in longer records (Interview, 18.08.2026). S. Jordan cautions that two- to four-year projects separated by long gaps cannot establish whether restoration remains functional after five, ten or twenty years, or how it responds to drought and heavy rainfall (Interview, 20.08.2026). F. Renou-Wilson therefore favours a smaller number of representative long-term sites over repeated short campaigns (Interview, 29.07.2026).

Two recommendations emerge from the interviews:

Start before restoration and follow the transition. Monitoring should begin with an assessment of baseline conditions and the peatland's hydrological potential. It should then follow the immediate response to rewetting, the transition phase and the longer-term ecosystem state. S. Jordan stresses the importance of assessing peat and landscape water balance before intervention (Interview, 20.08.2026). This also matters for project accounting: post-rewetting hydrology can be monitored prospectively, but a multi-year pre-project water-table record cannot be generated once restoration has begun, which increases reliance on historical information and proxies (AECO Team; Interview, 10.09.2026).

Track ecological responses over realistic time

1 ICOS (Integrated Carbon Observation System) is a European research infrastructure providing standardised, long-term observations of greenhouse gas concentrations and fluxes. Its ecosystem stations contribute empirical data for assessing peatland carbon exchange, evaluating restoration trajectories and improving the calibration and validation of GHG estimation methods (www.icos-cp.eu).

horizons. As shown in section 2.5, rewetting does not produce an instantaneous shift from one emission factor to another. Early CH_4 peaks may make restoration appear unfavourable when interpreted over short evaluation windows (K.-H. Knorr; Interview, 22.07.2026; N. Zableckis; Interview, 17.08.2026).

Over time, monitoring should follow the variables that change with restoration: pre-restoration GHG fluxes where feasible, water-table response, vegetation succession, CO_2 and CH_4 trajectories, relevant soil changes, and management interventions and disturbances as they occur. Water-table monitoring is particularly useful in the first project years because it responds faster than vegetation or peat properties (N. Zableckis; Interview, 17.08.2026). Where long-term before–after records are unavailable, chronosequences can provide complementary evidence, but they should not replace continued monitoring of individual sites. The aim is to build records that explain how restoration outcomes develop, not merely whether conditions differ before and after intervention.

4.3. Combine methods, define shared metadata, and strengthen quality assurance

Reliable peatland GHG assessment requires complementary measurements, adequate site documentation and consistent quality controls. The interviews do not point to a single monitoring method. They point to the need to combine approaches that capture different spatial and temporal scales and can validate one another. Four recommendations emerge:

Combine complementary methods and validate proxies. Eddy covariance provides continuous ecosystem-scale measurements. Chambers capture local heterogeneity that may be obscured within an EC footprint, which matters wherever conditions vary within a site. Both need to be linked to hydrological, ecological and biogeochemical observations to explain the measured fluxes (S. Jordan; Interview, 20.08.2026; M. Saunders; Interview, 14.08.2026). Proxy relationships should be tested against direct measurements under the conditions in which they are applied, and recalibrated as new evidence becomes available (F. Reichelt; Interview, 27.07.2026; K.-H. Knorr; Interview, 22.07.2026). The German experts emphasised that remote sensing can extend spatial coverage, especially for inundation extent and duration, biomass and land-use patterns, but cannot replace continuous field observations (F. Reichelt; Interview, 27.07.2026; K.-H. Knorr; Interview, 22.07.2026). Where robust absolute emission estimates are needed, S. Juutinen proposes comparing bottom-up inventories and process-based estimates with atmospheric modelling and inversion approaches (Interview, 18.08.2026). The aim is triangulation across methods and scales.

Define minimum site metadata. Flux measurements need to remain linked to the site conditions that explain them. A shared minimum dataset should document water table, vegetation, peat type and depth, soil properties and fertility, climate, degradation status, prior land use, and management and restoration history. Depending on the site, additional variables may include elevation, maritime influence, soil moisture, evapotranspiration and locally important processes such as volcanic or aeolian deposition (Land og Skógur team; Interview, 20.08.2026; S. Jordan; Interview, 20.08.2026; F. Renou-Wilson; Interview, 29.07.2026). For restored sites, documentation should also record the date and method of intervention, previous extraction or after-use, peat decomposition and carbon content (S. Jordan; Interview, 20.08.2026). This dataset is also what makes measurements comparable across sites and countries (see section 4.5).

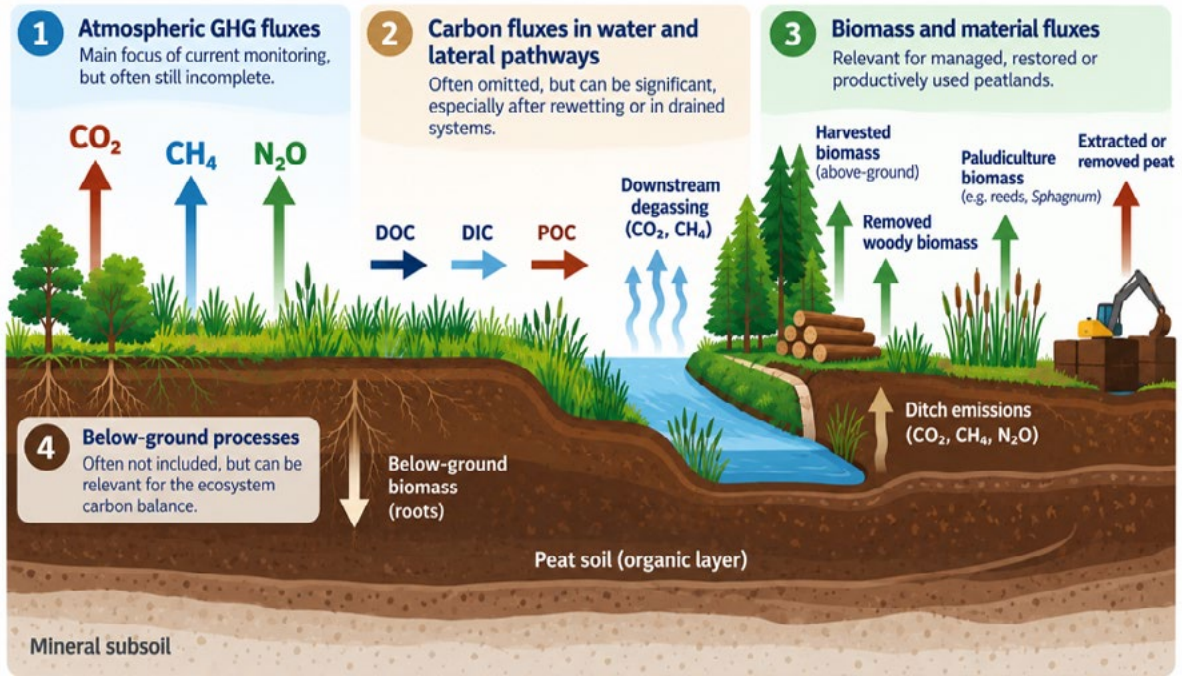
Design monitoring around model requirements. Data collection should be planned with its analytical use in mind. M. Saunders notes that field campaigns are not automatically model-ready. Valuable datasets may be unsuitable for Tier 3 modelling when timestamps, temporal resolution or the combination of static site variables and dynamic flux measurements do not match model requirements (Interview, 14.08.2026). These requirements should be defined before field campaigns begin, not addressed afterwards.

Apply quality assurance from sampling to data processing. More measurements do not necessarily produce better estimates. S. Jordan describes how elevated initial chamber concentrations can generate apparent CO_2 uptake that reflects measurement artefacts rather than ecological processes. She also highlights the need to document and validate instrument performance under severe boreal winter conditions, when equipment may operate outside its specified temperature range (Interview, 20.08.2026). Quality assurance must also cover training, diagnostic checks, staff continuity and experimental design. S. Juutinen cautions that large datasets may still lack true replication when the sampling structure does not distinguish independent sites from repeated measurements of the same system (Interview, 18.08.2026).

4.4. Expand monitoring scope beyond CO_2 and the site boundary

Peatland GHG assessment should account for carbon and GHG pathways that may materially affect the ecosystem balance but fall outside the main atmospheric flux measurements or the physical restoration boundary. These components do not need to be measured everywhere. Whether they are included should depend on the peatland system, land use and intervention being assessed. A schematic summary is presented in Figure 10.

Figure 10: Schematic of components to be considered in Peatland GHG assessments beyond main atmospheric fluxes (AI-assisted illustration).



Three recommendations emerge from the interviews:

Include relevant gases and carbon pathways. Depending on site conditions, monitoring may need to capture CH_4 under wet and transitional conditions, episodic N_2O emissions, dissolved and particulate carbon exports (DOC, DIC and POC), downstream degassing and ditch emissions. Biomass harvesting, removed woody biomass, paludiculture biomass, extracted peat and below-ground biomass may also be relevant, particularly in agricultural, forested and post-extraction peatlands and productive wetland systems (see section 2.1). S. Juutinen highlights the frequent omission of lateral carbon fluxes and biomass harvesting from datasets, while M. Saunders points to downstream degassing of dissolved carbon and methane (Interviews, 18.08.2026 and 14.08.2026, respectively). N. Zableckis identifies removed forest biomass, paludiculture biomass and emissions from extracted peat as further accounting gaps in the projects discussed during his interview (Interview, 17.08.2026).

Account for the fate of removed peat, topsoil and biomass. Material removed during restoration should not automatically be treated as an instantaneous CO_2 emission. Its carbon balance depends on subsequent use, decomposition and the time over which emissions occur. K.-H. Knorr also raises the unresolved question of substitution effects when peat removed during restoration replaces peat that would otherwise have been extracted elsewhere (Interview, 22.07.2026). F. Reichelt distinguishes between reusing removed grass sward within a restoration site and exporting substantial quantities of topsoil, while noting that their net GHG effects remain insufficiently quantified (Interview, 27.07.2026). The draft EU Carbon Removals and Carbon Farming Certification Framework (CRCF) methodology distinguishes shallow removal of degraded topsoil, a permissible restoration intervention, from peat extraction, which is prohibited within the certified activity area. However, this distinction does not resolve how removed material should be accounted for according to its subsequent fate, decomposition or potential substitution effects (European Commission, 2026, draft Annex, Sections 1.1.2.1–1.1.2.2).

Consider omitted sinks and disturbance risks. Accounting boundaries should be checked for omitted carbon uptake as well as omitted emissions. S. Jordan raised the example of carbon uptake at rewetted former extraction sites that, according to her account, has not been credited in Swedish climate reporting (Interview, 20.08.2026). Project scenarios should also account for disturbances that can alter restoration trajectories and carbon balances, including drought, fire and extreme flooding. N. Zableckis highlighted fire risk in particular for former extraction sites (Interview, 17.08.2026).

4.5. Make existing evidence reusable and build the capacity to sustain it

Closing the evidence gaps identified in this report requires not only new measurements, but better use of existing data. The literature review and interviews point to fragmented datasets, inconsistent documentation and limited capacity to process and share observations as obstacles to improving emission factors and validating models. The challenge is to turn dispersed observations

into a cumulative evidence base that can be maintained, compared and updated beyond individual research projects. Five recommendations emerge from the interviews:

Make existing datasets accessible and reusable. Peatland GHG data are spread across research projects, institutions, national inventories and publications, often without enough documentation to integrate them. W. Kotowski proposes a shared European peatland GHG database, modelled on FLUXNET, with transparent measurement methods, applied correction factors and site metadata (Interview, 12.08.2026). F. Renou-Wilson similarly emphasises the value of making accumulated Irish research data available for modelling and uncertainty reduction, while recognising the researchers who generated them (Interview, 29.07.2026).

Build on shared infrastructures and harmonised standards. Existing resources provide a starting point. ICOS, the European Fluxes Database and FLUXNET-CH_4 can support access to long-term flux observations for regional calibration and independent validation. FLUXNET-CH_4 v1.0 compiled methane observations from 81 sites worldwide, including 42 freshwater wetlands and seven formerly drained ecosystems analysed by Delwiche et al. (2021). At European scale, WET Horizons published a harmonised dataset of annual wetland and peatland GHG emission factors in 2025, updated in March 2026 (Pugliese et al., 2026). These infrastructures show that shared evidence systems are feasible, but data availability alone does not ensure comparability. That also requires consistent terminology, transparent methods and the minimum site metadata described in section 4.3 (W. Kotowski; Interview, 12.08.2026; M. Pakalne; Interview, 04.08.2026). S. Juutinen notes, for example, that inconsistent regional terms such as "boreal" and "temperate" can obstruct comparison and upscaling (Interview, 18.08.2026).

Strengthen the capacity to process and publish data. Some evidence gaps reflect limited capacity to turn existing measurements into usable datasets, rather than an absence of field observations. The Land og Skógur team described substantial measurements from Icelandic research projects, including CH_4 data, that remain partly unprocessed, unpublished or available only in Icelandic. Limited staff affects field coverage, winter measurements, data processing, publication and the management of increasingly large datasets (Interview, 20.08.2026).

Secure monitoring beyond project cycles. Long-term records depend on someone being responsible for instrument maintenance, data management and access after project funding ends (T. Morley; Interview, 16.07.2026). M. Saunders points to ICOS and LTER as examples of how this continuity can be secured institutionally (Interview, 14.08.2026).

Establish sustained European coordination. Several interviewees propose stronger coordination between research groups and data infrastructures. T. Morley suggests a permanently funded European GEST-type network linking site-level observations to national databases and a shared European resource (Interview, 16.07.2026). M. Saunders proposes a consortium or COST Action to coordinate monitoring priorities and protocols, while W. Kotowski identifies PaluWise as an existing, though geographically limited, example of collaboration (Interviews, 14.08.2026 and 12.08.2026, respectively). F. Reichelt and K.-H. Knorr also call for a European data infrastructure that would make emission data comparable and independently reviewable across countries (Interviews, 27.07.2026 and 22.07.2026, respectively).

4.6. Connect research evidence to accounting systems

The interviews point to an institutional challenge alongside the scientific and methodological gaps discussed in previous chapters. How new evidence is evaluated, maintained and translated into operational accounting depends not only on methodological maturity, but also on institutional capacity, data availability and the organisation of the science–policy interface. This applies to national inventories as well as to the methodologies used in certification and voluntary-market projects. Table 10 summarises the accounting approaches and research–inventory linkages identified for the countries covered by the assessment. It distinguishes the reported use of IPCC Tiers from the institutional mechanisms through which new peatland GHG evidence may enter national accounting.

Table 10: Integration of peatland GHG evidence into national accounting across selected European countries

Country	IPCC Tier / accounting status	Research–inventory linkage	Institutional feature
IS	Predominantly Tier 1; Tier 2 development underway	Direct	Research, restoration and inventory functions are combined within one institution (Land og Skógur).
FI	Tier 1–3 depending on category; Tier 3 for drained forest organic soils (Alm et al., 2023)	Direct	Research groups and inventory authorities are institutionally distinct; evidence enters the inventory through publication and formal review processes.

Country	IPCC Tier / accounting status	Research–inventory linkage	Institutional feature
UK	Tier 2; national inventory provides the factors used by the Peatland Code	Direct	The certification framework draws on the national inventory and has funded its latest update of peatland emission factors, a strong link that depends on initiative from the certification side.
DE	Tier 2 for main estimates from organic soils	Selective	Applied monitoring feeds into national reporting; university-based restoration research is less systematically connected.
IE	Predominantly Tier 1–2; further Tier 2 development underway	Selective	Monitoring is increasingly aligned with the development of country-specific emission factors.
SE	Tier 2 for drained organic soils in major land-use categories	Selective	National reporting relies strongly on soil-inventory evidence; restoration-specific monitoring is less integrated.
LV	Tier 1–2; Tier 2 for major drained-organic-soil components	Selective	Scientific evidence is developing, but how new measurements are evaluated and incorporated into official emission factors is unclear.
LT	Tier 2 for CO_2 from major drained-organic-soil categories; Tier 1 elsewhere	Separate	Project-level methodological development (e.g. GEST-based) takes place in restoration and voluntary-market projects outside the official inventory.
PL	Predominantly Tier 1	Separate	Sparse representative evidence and limited specialist capacity constrain methodological development.

Note: Accounting status is reported by category and should not be interpreted as a single national Tier. Linkage categories: **Direct** – established institutional or procedural pathways through which research evidence regularly informs the national inventory; **Selective** – some evidence streams enter national reporting, while others, particularly restoration research, are integrated less systematically; **Separate** – project-level or research evidence develops largely outside the official inventory, without an established pathway into it. Linkage categories describe institutional connection, not methodological maturity, and are independent of the IPCC Tier applied. Institutional descriptions reflect the mechanisms exposed in interviews and preliminary literature reviews conducted July–September 2026 and are not a comprehensive evaluation of national inventory systems.

Direct institutional links (IS, FI, UK). In Iceland, peatland research, restoration and inventory functions are closely connected within Land og Skógur, giving emerging evidence a pathway into country-specific emission factors (Land og Skógur team; Interview, 20.08.2026). Finland illustrates a different arrangement: research groups and inventory authorities are institutionally distinct, but published scientific evidence can contribute to inventory development through established review processes (S. Juutinen; Interview, 18.08.2026). The UK Peatland Code shows another relationship: it draws emission factors from the national inventory, while certification needs have helped stimulate and fund revisions to the underlying evidence base. Whether a new category can be separated is governed by inventory criteria on sample size and representativeness across the country; data from a single location are not sufficient (R. Kerkvliet-Hermans; Interview, 14.09.2026).

Selective integration (DE, IE, SE, LV). In Germany, applied monitoring by institutions such as the Thünen Institute is closely linked to national reporting, while K.-H. Knorr described a less systematic connection between university-based restoration research and inventory development (Interview, 22.07.2026). In Sweden, national reporting relies strongly on soil-inventory evidence, while restoration-specific monitoring is less integrated (S. Jordan; Interview, 20.08.2026). In Latvia, scientific evidence is developing, but according to M. Pakalne, the way new measurements are evaluated and incorporated into official emission factors still needs to be strengthened (Interview, 04.08.2026). Irish interviewees described efforts to design monitoring more deliberately around the development of country-specific emission factors and inventory improvement (F. Renou-Wilson; Interview, 29.07.2026; T. Morley; Interview, 16.07.2026).

Separate pathways (LT, PL). N. Zableckis explained that GEST is used in Lithuanian restoration and voluntary-market projects but is not incorporated into the official inventory (Interview, 17.08.2026). In Poland, national reporting still relies predominantly on older IPCC Tier 1 emission factors, and sparse representative evidence and limited specialist capacity constrain methodological development (W. Kotowski; Interview, 12.08.2026).

Certification methodologies. Similar questions arise for the methods used outside official inventories. This was raised particularly for GEST, whose methodological development and underlying database of GEST remain closely tied to the Greifswald network. Facilitated access to data and defined standards to contribute with new data could support regional calibration and a locally built approach (T. Morley; Interview, 16.07.2026; F.

Reichelt; Interview, 27.07.2026). From the perspective of project developers, M. Schneider argues that an updated GEST should document not only revised emission factors, but also the origin of the underlying measurements, the climatic and ecological conditions they represent, and the limits of their transferability. Harmonised protocols and quality criteria are also needed so that new measurements can be incorporated into emission-factor catalogues and used to update GEST classes (AECO Team; Interview, 10.09.2026).

These examples show that scientific progress and institutional uptake do not necessarily advance together. For inventory agencies and organisations developing peatland emission factors, this points to the need for durable mechanisms to evaluate new evidence and update emission-factor databases accordingly.

Overall pattern

Across the interviews, the same concerns recur: records too short to capture restoration trajectories, sites that do not represent the conditions to which estimates are applied, proxies used beyond their calibration range, measurements lacking ecological context, and datasets that are hard to find, compare or reuse. These problems reinforce the two weaknesses identified in Chapters 2 and 3: limited transferability and insufficient representation of the ecological and geographic diversity of European peatlands. Better evidence, however, only improves GHG accounting if it can move from the field into official methods. That requires a continuous pathway from measurements to validated methods and regularly updated accounting systems, with clear responsibility at each step. The interviews suggest that the technical solutions are largely known.

5 Operational Applications and Limitations of GHG Assessment for Project Applicability

Chapters 2 to 4 examined the scientific basis of peatland GHG assessment and the evidence needed to strengthen it. This chapter turns to practice: how assessment methods are currently used in peatland carbon projects, what trade-offs they involve, and how practitioners deal with their limits. It draws mainly on interviews with project developers, certification experts and researchers, complemented by a review of selected framework documents. It does not evaluate individual frameworks; it describes patterns that emerged from the interviews.

5.1. How certification frameworks currently use GHG evidence

Projects that generate carbon credits from peatland rewetting need methods to establish baselines, estimate expected mitigation and monitor outcomes at a reasonable cost. Direct flux measurements cannot provide this for every project. Frameworks therefore rely on proxies, meaning indicators such as vegetation, water-table depth or land use from which emissions are estimated. Table 11 summarises selected peatland GHG certification frameworks, their GHG assessment basis and main applicability issues. Most voluntary standards build on GEST, often combined with water-table depth and land use (MoorFutures, Verra VM0036, SOCIALCARBON). The draft EU CRCF follows a similar approach but adds requirements for calibration and validation. The national codes of the UK and Ireland rely mainly on condition classes or hydrological indicators, with emission factors drawn from or aligned with national inventories. Beyond formal certification, GEST is also used by project developers such as AECO and in privately financed restoration (AECO Team; Interview, 10.09.2026; N. Zableckis; Interview, 17.08.2026).

Table 11: Selected peatland GHG certification frameworks (CF)

Framework	Scope	GHG assessment basis	Main applicability issue
MoorFutures	Germany	GEST / vegetation-based emission factors	Regional validity of vegetation–GHG relationships.
Verra VM0036	International voluntary carbon market	Vegetation (GEST based) + Water-table depth	Project-specific applicability and calibration.
SOCIALCARBON SCM0010-M1	International voluntary carbon market	Vegetation (GEST based) + Water-table depth + land-use type	Representativeness of emission factors for temperate agricultural peatlands.

Framework	Scope	GHG assessment basis	Main applicability issue
EU CRCF (2026 draft)*	European Union	Vegetation (GEST based) + Water-table depth + land-use types, calibrated and validated against direct GHG measurements	Regional transfer requires comparable environmental conditions and additional GHG measurements for validation.
Irish Peatland Standard	Ireland	Vegetation-unit EFs (semi-natural raised bog, eroded blanket bog); WTD and ecosystem scorecard for other sites; condition categories recorded	Calibration for Irish and Atlantic peatland conditions.
UK Peatland Code	United Kingdom	Condition categories (bogs); condition categories + water-table depth (fens); emission factors from the UK GHG inventory	Raised and blanket bogs share one factor; forested peatlands excluded; methodology under expert review

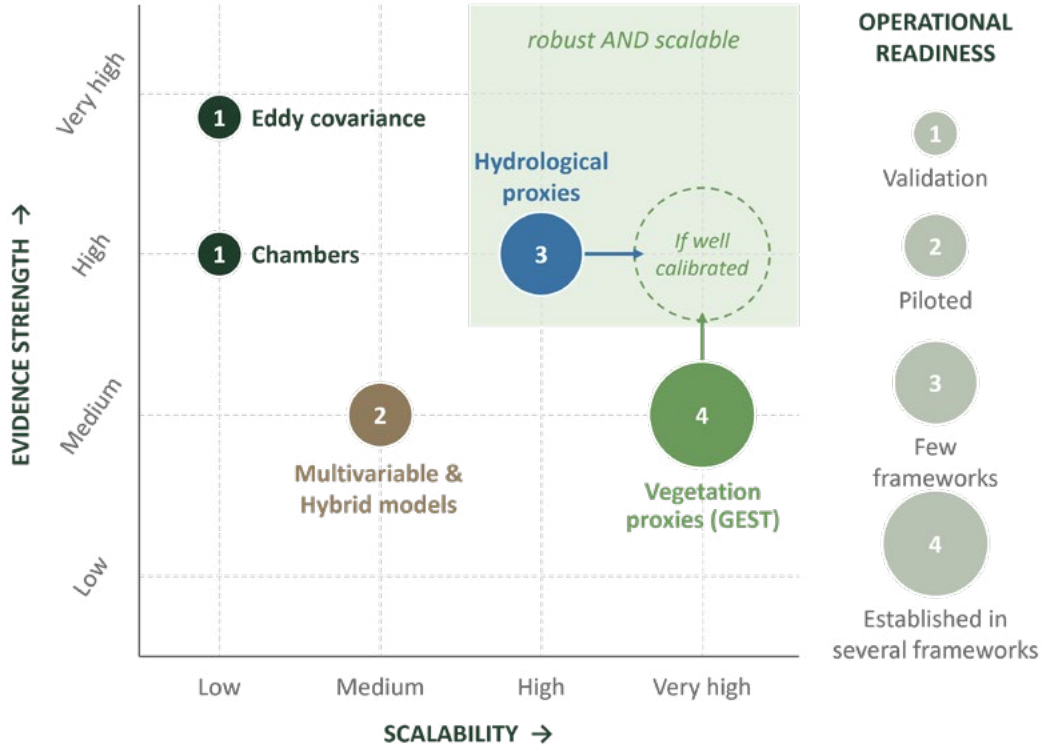
*The CRCF entry refers to the 2026 draft certification methodology; requirements may change before final adoption. The selection is based on the frameworks discussed in the interviews and their publicly available documentation (July–September 2026); it is not a comprehensive inventory of peatland carbon standards in Europe.

5.2. Comparative assessment: evidence strength, scalability and operational readiness

Any GHG assessment approach used in projects has to balance three properties: Evidence strength (how directly and reliably the approach represents GHG fluxes, and whether its relationships have been independently validated); Scalability (how easily the approach can be applied across many restoration sites without a proportional increase in monitoring cost and field effort); and Operational readiness (whether the approach already serves as a primary quantification pathway in an operational restoration or carbon-accounting framework).

Building on the preceding chapters, Table 12 assesses the approaches reviewed in this report against these three dimensions, while Figure 11 illustrate the result. The scores are qualitative and based on the literature review and the interviews (scoring criteria in Annex 3). The approaches are discussed in turn below.

Figure 11: Positioning GHG assessment approaches by evidence strength, scalability and operational readiness (the "Scaling Challenge")



Bubble position = qualitative scores for evidence strength and scalability; bubble size = operational readiness. Scores are based on the literature review and interviews, not on measurements. They show how each approach performs relative to the others, not an absolute assessment of its quality.

Table 12: Cross-assessment of GHG approaches for restoration and certification

Approach	Evidence strength	Scalability	Readiness	Functional interpretation
Eddy covariance	4 (Very high)	1 (Low)	1 (Validation /calibration)	**Reference method**. Robust ecosystem-scale flux data with strong temporal integration, but equipment cost, siting constraints and specialist requirements limit deployment across restoration portfolios. No certification framework reviewed uses EC as the primary crediting method.
Chamber measurements	3 (High)	1 (Low)	1 (Validation /calibration)	**Reference method, complementary to EC**. Strong for process attribution and spatially explicit measurement, but recurring field effort scales with the number of sites. Shares EC's certification limitation, and is particularly valuable for developing and validating emission factors, proxies and models.
Vegetation-based proxies	2 (Medium; higher if well calibrated)	4 (Very high)	4 (Established in several frameworks)	**Highest operational scalability reviewed**. Vegetation mapping covers large restoration areas at low marginal cost and already underpins MoorFutures, Verra VM0036 and SOCIALCARBON; the UK Peatland Code applies a comparable logic through condition categories (5.1).
Hydrological proxy methods	3 (High where calibrated)	3 (High)	3 (Operational in few frameworks)	**Strongest current robustness–scalability compromise**. Water-table-based proxies retain a direct mechanistic link to peatland GHG emissions while allowing repeated, comparatively low-cost monitoring. Used in the Irish Peatland Standard and, combined with condition categories, in the UK Peatland Code's fen methodology (5.1). Wider use is limited by lack of regionally calibrated response functions and representative data (5.4).
Multivariable and hybrid models	2 (Medium; unevenly validated)	2 (Medium)	2 (Under development)	**Integration method**. Able in principle to combine water table, vegetation, climate, peat properties and direct measurement into more robust, spatially transferable estimates, but constrained today by operational validation and certification uptake — a maturity gap, not a conceptual one. Scalability could increase once combined with a scalable proxy.

Dimensions are scored from 1 to 4 (1 = low, 2 = medium, 3 = high, 4 = very high). For Readiness, 1 = used mainly for validation and calibration; 2 = under development or piloted; 3 = operational in a limited number of frameworks or regions; 4 = established in several operational frameworks. Scoring criteria and basis detailed in Annex 3.

No approach scores very high on all three dimensions. Hydrological proxies come closest, but only where response functions have been regionally calibrated. None of the frameworks reviewed uses it as a primary crediting method, although it remains essential for validation. Chamber measurements play a similar role and capture local heterogeneity. Multivariable and process-based models integrate several drivers and have considerable potential. So far, however, their performance has been demonstrated mainly in countries with long monitoring records and substantial technical capacity, such as Finland (see Table 10). Hydrological proxies can be scientifically strong where water-table–emission response functions have been calibrated regionally, but such calibrations are not available everywhere. Vegetation proxies, and GEST in particular, are the most widely applied in certification. Their evidence strength is moderate and can increase where they are calibrated against local measurements.

The comparison illustrates a central finding of this report: operational readiness does not guarantee scientific robustness. Wide use of a method reflects its practicality, not necessarily the strength of its evidence base.

5.3. Strategies for making assessment operational

Interviewees from project development and certification described three ways of dealing with the gap between what is scientifically robust and what is operationally feasible. The strategies are not mutually exclusive, and projects often combine them.

Validate under new conditions. Models and emission factors transferred to a new region can be tested against local measurements before they are used for crediting. The draft EU CRCF takes this approach. Established by Regulation (EU) 2024/3012, the CRCF provides a voluntary EU certification framework for carbon farming activities, including peatland rewetting; its peatland methodology was still in draft in 2026 (European Commission, 2026). It requires comparable environmental conditions and additional GHG measurements when models are transferred to a new region. Several of its provisions address gaps identified in this report, at least in part: recognition of lateral carbon pathways (section 2.1) and regional calibration of transferred models (2.7), and a distinction between shallow topsoil removal and peat extraction, although it leaves open how removed material should be accounted for (Chapter 4).

Complement estimates with additional evidence. Where proxy-based estimates cannot be validated directly, project developers can support them with independent site data. AECO, for example, supports its GEST baselines with peat cores, historical maps, water-table and subsidence data, and monitors water levels continuously after rewetting (AECO Team; Interview, 10.09.2026). This reduces reliance on a single proxy and partly compensates for the lack of pre-project measurements discussed in section 4.2.

Recognise the limits. Where evidence is insufficient to support credible crediting, frameworks can narrow their scope instead of extending methods beyond their basis. The UK Peatland Code excludes forested peatlands, and its methodology is currently under expert review (R. Kerkvliet-Hermans; Interview, 14.09.2026). A narrower scope limits the number of eligible projects, but it protects the credibility of the credits issued.

Overall pattern

GEST holds an important position in European peatland restoration because it translates vegetation and site conditions into spatially explicit GHG estimates at comparatively low monitoring cost. This operational value, summarised in Table 6, does not remove the limitations identified in this report.

Water-table-based approaches are an important alternative, particularly for representing the continuous hydrological changes that follow rewetting. The interviews, however, reveal a gap between their scientific potential and their operational availability. W. Kotowski favoured continuous WTD–GHG relationships (Chapter 2), but noted that Poland lacks the representative measurements and monitoring capacity needed to calibrate them (Interview, 12.08.2026). In Iceland, a nationally adapted methodology combining hydrological and vegetation indicators is still under development (Land og Skógur team; Interview, 20.08.2026). These examples do not diminish the scientific value of hydrological approaches, which are already well established in some contexts, including Germany. They show that a promising approach does not automatically become an available, regionally calibrated method for restoration projects.

For project developers, the relevant question is therefore not whether other approaches could eventually improve on GEST, but whether a sufficiently calibrated and operational alternative exists for the peatland conditions being assessed. In most of the contexts discussed in the interviews, it does not yet. Direct measurements remain indispensable for developing and validating emission factors, but they cannot feasibly replace scalable proxies in every project. Multivariable models offer further possibilities but are not yet established as a general operational substitute.

GEST should therefore be treated neither as universally transferable nor as obsolete. Improving a method already in use appears more realistic than waiting for an alternative to become operational. This means expanding its empirical basis, strengthening regional calibration, documenting the conditions its emission factors represent, and periodically testing estimates against direct GHG measurements and hydrological observations (see Chapter 4). This should go hand in hand with developing and validating complementary approaches. Where hydrological response functions or multivariable models are well calibrated, they can complement GEST estimates or validate them. GEST's reliability has to improve alongside its application.

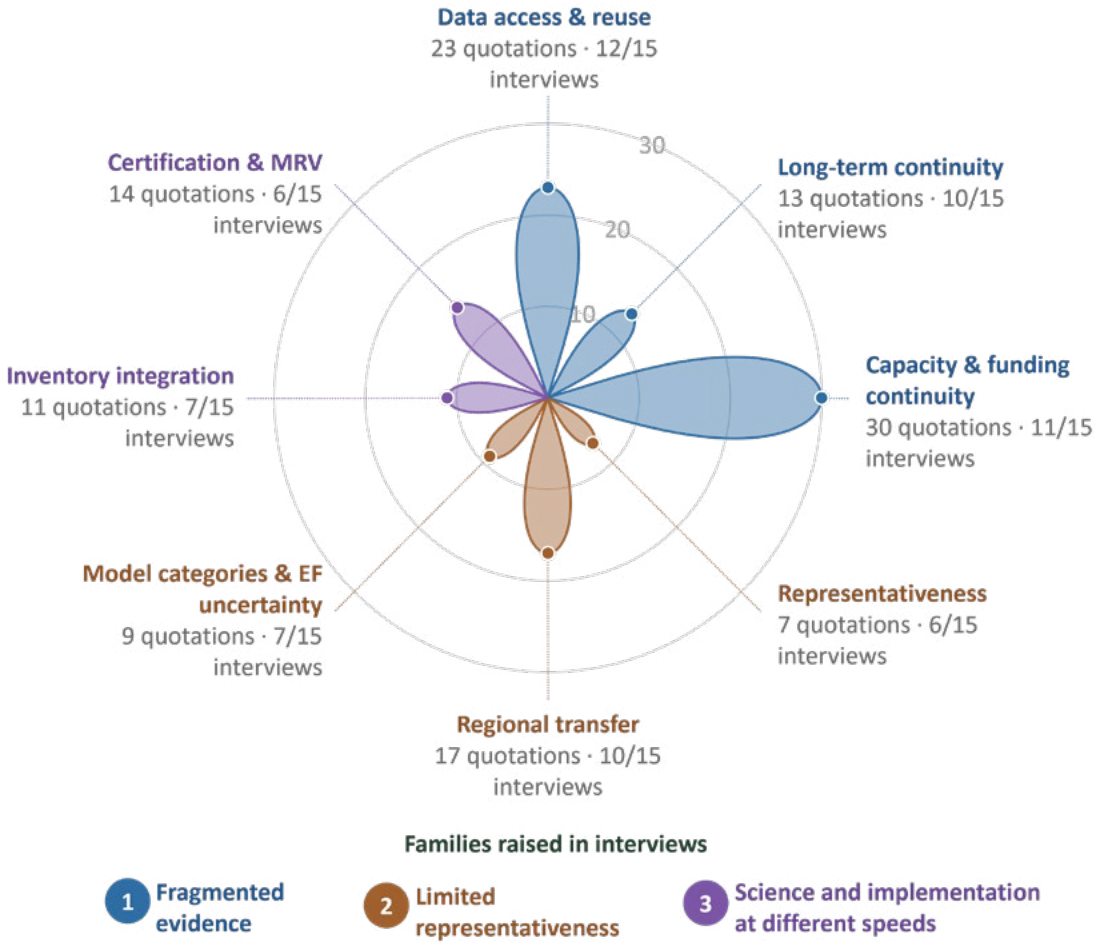
Conclusions and priorities for European peatland GHG assessment

The findings point to a clear conclusion: Europe does not primarily need a single better method; it needs a stronger evidence base for the methods already in use. Considerable expertise, data and operational approaches already exist, but reliable and comparable assessments remain constrained by fragmented datasets, uneven ecological and geographic representation, and weak links between research and implementation.

Restoration cannot wait for all uncertainties to be resolved, but neither should operational needs exceed what the evidence can support. The way forward is therefore to use existing methods within their demonstrated limits while strengthening the evidence behind them: applying conservative assumptions where needed and updating approaches as stronger evidence emerges (J. Averkamp & M. Schneider; Interview, 10.09.2026). As Chapter 5 shows, operational readiness does not guarantee scientific robustness: widely used methods need to be strengthened alongside their application.

Of the 352 quotations coded across all interviews, 81 addressed priorities and the main bottlenecks. They raised eight issues across three families: fragmented evidence, limited representativeness, and gaps between science and implementation. Figure 12 shows their frequency across interviews; the main bottlenecks are summarised below.

Figure 12: Main bottlenecks raised in the final interview questions, grouped into three families



Petal length = number of quotations raising each issue (n = 81). A quotation can address several issues. Frequencies show where experts directed their attention, not the relative importance of each issue or the degree of consensus among them.

The findings point to three closely connected bottlenecks:

- **Bottleneck 1**: evidence remains fragmented and discontinuous. Long-term datasets and substantial expertise exist, but they are unevenly distributed, often project-bound and not always accessible or reusable across institutions and countries.
- **Bottleneck 2**: representativeness limits transferability. The reliability of emission factors, proxies and models outside their original context depends on whether their empirical basis captures the ecological and regional conditions in which they are applied.
- **Bottleneck 3**: science and implementation move at different speeds. Inventories, restoration projects and certification frameworks require operational estimates before all uncertainties can be resolved, while scientific credibility requires that those estimates remain open to validation and revision.

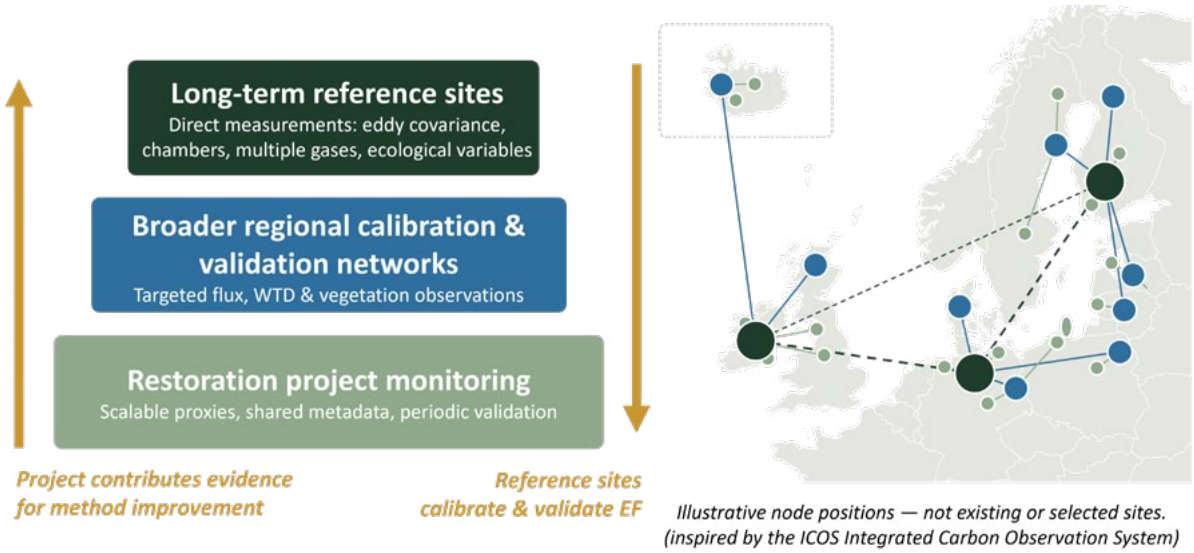
These bottlenecks suggest five priorities for improving European peatland GHG assessment:

- **Priority 1**: Make better use of existing evidence and fill gaps strategically. Existing datasets should be easier to identify, access and reuse before additional measurement programmes are developed. New monitoring can then target compound gaps where poor representation, methodological uncertainty and relevance for restoration or accounting coincide.
- **Priority 2**: Protect long-term monitoring as scientific infrastructure. Long-term sites and existing time series should be maintained beyond individual project cycles. Particular attention is needed to continuity across pre- and post-restoration conditions and climatic variability, together with the specialist capacity required to interpret these records.
- **Priority 3**: Define and test applicability domains. Emission factors, proxies and models should state more explicitly the climatic, ecological and management conditions for which they are supported. Cross-regional validation should identify where relationships remain robust, where recalibration is required and where the available evidence is not yet sufficient for application.
- **Priority 4**: Harmonise evidence standards rather than methods. European comparability does not require methodological uniformity. Greater value would come from common core variables, metadata, terminology, quality assurance, data provenance and documentation standards that allow different approaches to be compared, independently scrutinised and updated.
- **Priority 5**: Strengthen the connection between research, monitoring, inventories and implementation. Evidence generated through research and restoration projects should feed more systematically into national accounting and methodological development. Conversely, inventory and MRV needs should help identify where new empirical work has the greatest value. This requires stable coordination, data stewardship and mechanisms for periodically revising emission factors and assessment approaches.

The findings and priorities of this report were presented to the interviewed experts at an online presentation on 30.09.2026], who were invited to comment on them through an online polling tool (Slido) and had one week to provide further feedback. Three participants ranked the five priorities. In their ranking, strengthening the connection between research, monitoring, inventories and implementation (Priority 5) came first, followed by harmonising evidence standards rather than methods (Priority 4). Given the small number of responses, this ranking is indicative only, but it is consistent with the bottlenecks identified in the interviews.

Taken together, these priorities point towards an adaptive evidence network that connects three levels (Figure 13). Long-term reference sites provide direct, multi-gas measurements and ecological observations to calibrate and validate emission factors. Regional networks test these relationships across different climatic, ecological and management conditions. Restoration projects apply scalable methods, such as vegetation and hydrological proxies, while contributing monitoring data under shared metadata standards. Evidence would thus move in both directions: from research to application, and from projects back into method improvement. Following the tiered approach of ICOS (section 4.1), such a network should build on existing infrastructure rather than create a parallel system. The key question is therefore less who owns it than who ensures that its existing layers work together.

Figure 13: Towards an adaptive European evidence network for peatland GHG assessment



Schematic illustration. Points and connections on the map do not represent actual monitoring sites; they illustrate how reference sites, regional networks and restoration projects could be linked across countries.

The central challenge is one of continuity, connection and generalisation: sustaining existing scientific capacity, making evidence reusable and determining where, when and with what confidence current approaches can be applied. How reliable, then, are current peatland GHG estimates? They are reliable where they are supported by representative, well-calibrated data, and less so where methods are applied beyond that evidence. Closing this gap depends less on new methods than on stronger cooperation, shared evidence standards and demonstrated applicability across the conditions in which estimates are used. Scaling up peatland restoration therefore also requires scaling up the evidence behind its GHG estimates.

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Annexes

Annex 1 Interview Guide

Background

Which of the following best describes your primary role?

- ☐ Developer of process models and/or proxy-based approaches
- ☐ Scientist with a focus on empirical research
- ☐ Practitioner in greenhouse gas accounting
- ☐ Expert in national greenhouse gas inventories
- ☐ Expert in carbon accounting or certification systems
- ☐ Practitioner in peatland restoration
- ☐ Other:

A. Current Practice (Understanding the current state of GHG accounting)

1 Which approaches to peatland GHG accounting are you most familiar with?

- What are they mainly used for?
- Who are their main users?

2 Which approach do you currently consider the most scientifically robust? Why?

- What are its main strengths?
- Under which conditions does it performs particularly well?

B. Scientific robustness (Understanding confidence and uncertainty)

Our literature review suggests that Europe currently suffers less from a lack of methods than from limited empirical evidence and the fragmented application of existing approaches. Would you agree with this assessment? Why or why not?

3 Which aspects of current peatland GHG accounting are scientifically well established, and where do you still see major uncertainties? (i.e.: C CO_2, CH_4, N_2O, DOC, DIC, POC, water table, vegetation, emission factors, models.)

4 How well do current approaches represent the underlying biogeochemical processes in peatlands?

- What is still missing?
- Which processes should receive more attention?

5 If you could improve one scientific aspect of peatland GHG accounting, what would it be? Why?

C. Applicability across Europe (Understanding transferability)

Our literature review identified important knowledge gaps for forested peatlands, blanket bogs, post-extraction peatlands, and paludiculture systems.

6 Does this match your assessment, or would you prioritize other gaps?

7 For which peatland types or regions do current approaches work particularly well?

8 Where do current approaches become less accurate or reach their limits? Why?

9 How could emission factors and models be better transferred between different regions of Europe?

D. Monitoring and Evidence (Understanding data needs)

10 Which monitoring data are currently the most important for reliable peatland GHG accounting? (e.g. water table, vegetation, chamber measurements, eddy covariance, remote sensing, soil properties, etc.)

11 Where do you see the greatest weaknesses in peatland monitoring across Europe?

- Which data are missing?
- Where is the greatest need for improvement?

E. European harmonisation (Understanding the steps towards implementation)

12 Our literature review suggests that future peatland GHG accounting will combine different approaches, including proxies, models, and direct measurements. At the same time, European countries currently apply very different approaches. (If needed: science, data availability, monitoring, funding, institutions, policy.)

- What do you think should happen first to move towards a common European framework?

13 Looking ahead to future MRV systems, which components do you think should be essential? (e.g. common monitoring protocols, European databases, long-term monitoring, funding, or collaboration.)

F. Looking ahead (Priorities for future development)

14 There is often a trade-off between scientific accuracy and practical applicability.

- Where do you think Europe should strike the right balance?
- In your view, what are the three most important steps to improve peatland GHG accounting in Europe over the next five years?

15 If you could identify only one major bottleneck, which one currently limits progress the most?

☐ Methodological limitations

☐ Insufficient empirical evidence

☐ Lack of long-term monitoring

☐ Lack of harmonised monitoring protocols

☐ Limited transferability across peatland types or climatic regions

☐ Limited data access and data sharing

☐ Institutional or policy barriers

☐ Limited funding

☐ Other.

Annex 2 Summary of the interview coding

This annex summarises the qualitative coding of the 15 expert interviews that underpins the thematic chapters of the report. It documents the coded material, the codebook and the distribution of codes across interviews, so that readers can trace how the interview findings were organised. The procedure is described in the section "Introduction and analytical approach" (Introduction, section b, Stage 2). The complete coding workbook (LIFE_SUPER_EU_interview_coding.xlsx), including every coded quotation, has been submitted to NABU together with this report.

1. Coded material

Each interview was summarised in a structured interview fiche organised by the five sections of the interview guide. The unit of coding was the analytical paragraph of each fiche (one quotation), excluding key-message summaries, verbatim quotations and cross-interview notes. In total, 352 quotations were coded with 26 codes. A quotation could receive more than one code; 350 of the 352 quotations received at least one code (891 code assignments). Table 13 summarizes the coded interview documents.

Table 13: Coded interview documents

ID	Interviewee(s)	Country	Profile	Quotations	Codes used
D1	Florence Renou-Wilson	IE	Empirical research	23	21
D2	Matthew Saunders	IE	Empirical research	25	23
D3	Terry Morley	IE	Empirical research	19	18
D4	Renée Kerkvliet-Hermans	UK	Certification	26	17
D5	S. Áskelsdóttir, S. L. Thorlacius, A. A. Thorvardarson (Land og Skógur)	IS	Inventory & restoration	36	21
D6	Sari Juutinen	FI	Empirical research	31	22
D7	Sabine Jordan	SE	Empirical research	31	22
D8	Andis Lazdiņš	LV	National inventory	22	22
D9	Arta Bardule	LV	Research & inventory	16	18
D10	Māra Pakalne	LV	Restoration practice	16	12
D11	Nerijus Zableckis	LT	Restoration practice	25	17
D12	Wiktor Kotowski	PL	Empirical research	19	19
D13	Klaus-Holger Knorr	DE	Empirical research	16	24
D14	Felix Reichelt	DE	Method development	20	21
D15	J. Averkamp, M. Schneider (AECO GmbH)	DE	Project development	27	16

Quotations = analytical paragraphs of the fiche. Codes used = number of the 26 codes applied at least once in the interview. Differences in quotation counts partly reflect the length and style of each fiche.

2. Codebook

The codebook combined deductive codes derived from the literature review and the report structure with inductive codes that emerged from the interviews. The 26 codes are organised in five code groups that follow the report chapters. The codebook, with number of coded quotations and interviews per code is summarized in Table 14 and the number of coded quotations per code and interview in a code-document in Table 15.

Table 14: Codebook

Code	Definition	Quotations	Interviews (n: 15)
Methods (Ch. 1)			
Eddy covariance	Eddy covariance measurements, towers or their limits.	27	12
Chambers	Manual or automated chamber measurements.	29	11
GEST / vegetation proxy	GEST or other vegetation-based proxies and condition classes.	45	11
Water-table proxy	Water table as proxy, predictor or indicator for GHG estimation.	24	11
Hybrid / process models	Process-based, Tier 3, multivariable, remote-sensing, drone or inversion approaches.	28	12
Robustness (Ch. 2)			
Uncertainty & EF averaging	Reported EF ranges vs. uncertainty of applying an average to a site; conservativeness; systematic vs. random error.	20	8
Long-term / seasonal coverage	Record length, interannual, seasonal and winter variability, monitoring continuity.	63	12
Spatial representativeness	Representativeness of sites and datasets; under-represented systems; upscaling.	85	15
Regional transfer / calibration	Transfer of EFs, proxies or models across sites and regions; regional calibration.	47	14
Restoration trajectories	Post-rewetting dynamics, transition periods, restoration stages and scenarios.	58	12
Cross-validation of methods	Comparison or validation between methods (proxy vs. flux, chambers vs. EC).	30	12
Model inputs & categories	Whether classes and inputs capture emission-relevant differences	41	14
Baselines & references	Baselines, reference sites and natural vs. anthropogenic fluxes.	26	12
Gases & carbon pathways (Ch. 2.1)			
Methane (CH_4)	Methane fluxes, peaks, hotspots and accounting.	24	11
Nitrous oxide (N_2O)	N_2O fluxes, episodic peaks, exclusion from methods.	14	10
Aquatic / lateral carbon	DOC, DIC, POC, downstream degassing, ditches.	20	10
Biomass / carbon pools	Harvested/removed biomass & peat/topsoil, tree biomass, C inputs.	16	10
Peatland systems (Ch. 3)			
Forested peatlands	Forested, woody or forestry-drained peatlands.	31	11
Blanket / Atlantic bogs	Blanket bogs and Atlantic peatlands.	11	5
Post-extraction peatlands	Cut-over and post-extraction peatlands; extracted peat.	15	10
Paludiculture / wet use	Paludiculture and wet productive uses.	15	10
Agricultural organic soils	Grassland, arable and degraded agricultural peat soils.	28	12
Evidence & implementation (Ch. 4–5)			
Metadata / data sharing	Metadata, documentation, protocols, QA/QC, databases, data sharing.	55	15
Coordination, capacity & funding	Coordination, networks, staff and expertise, funding continuity.	43	12
National inventory integration	National inventory methods, IPCC Tiers, research–inventory link.	49	12
Certification / MRV	Project certification, carbon markets, crediting and verification.	47	9

Table 15: Code–document table (number of coded quotations per code and interview)

Code	D1	D2	D3	D4	D5	D6	D7	D8	D9	D10	D11	D12	D13	D14	D15	Total
Methods (Ch. 1)																
Eddy covariance	·	6	1	1	5	3	5	·	1	1	1	1	1	·	1	27
Chambers	2	4	1	·	5	2	6	2	2	2	·	1	2	·	·	29
GEST / vegetation proxy	·	·	4	4	·	1	2	1	·	1	9	5	3	7	8	45
Water-table proxy	3	1	·	1	1	2	·	4	·	·	2	4	1	2	3	24
Hybrid / process models	3	2	·	·	2	5	4	5	1	1	·	1	1	2	1	28
Robustness (Ch. 2)																
Uncertainty & EF averaging	·	1	·	3	·	2	·	2	1	·	·	·	2	4	5	20
Long-term / seasonal coverage	4	7	4	·	10	6	9	2	4	3	4	·	7	3	·	63
Spatial representativeness	6	14	6	3	7	9	6	6	7	3	4	6	4	3	1	85
Regional transfer / calibration	3	2	2	3	1	3	2	5	4	2	6	6	·	3	5	47
Restoration trajectories	7	4	·	·	4	7	11	2	3	·	7	1	5	5	2	58
Cross-validation of methods	2	4	·	2	2	6	3	·	·	1	1	2	3	1	3	30
Model inputs & categories	3	3	2	1	4	3	5	6	2	1	·	4	3	2	2	41
Baselines & reference conditions	2	1	1	1	6	1	3	4	1	·	·	1	1	·	4	26
Gases & carbon pathways (Ch. 2.6)																
Methane (CH_4)	2	2	1	·	5	2	1	2	2	·	2	·	3	2	·	24
Nitrous oxide (N_2O)	1	1	1	1	3	·	2	2	1	·	·	·	1	1	·	14
Aquatic / lateral carbon	2	1	4	2	5	1	·	2	·	·	·	1	1	1	·	20
Biomass / carbon pools	1	·	·	·	1	1	1	4	·	1	4	·	1	1	1	16
Peatland systems (Ch. 3)																
Forested peatlands	·	1	·	2	1	4	3	1	4	·	3	1	2	·	9	31
Blanket / Atlantic bogs	1	1	3	4	·	·	·	·	·	·	·	·	2	·	·	11
Post-extraction peatlands	1	2	1	·	1	1	3	·	1	·	3	·	1	1	·	15
Paludiculture / wet use	1	1	·	1	·	1	1	2	·	·	2	2	2	2	·	15
Agricultural organic soils	1	2	5	·	4	1	2	1	2	·	·	3	2	1	4	28
Evidence & implementation (Ch. 4–5)																
Metadata / data sharing	5	3	4	1	7	4	5	1	3	6	1	4	4	5	2	55
Coordination, capacity & funding	2	6	4	·	8	·	3	1	1	3	4	4	3	4	·	43
National inventory integration	3	3	2	5	10	7	4	4	3	·	2	4	·	2	·	49
Certification / MRV	·	·	3	21	·	·	1	1	·	·	3	1	2	1	14	47

D1 Renou-Wilson (IE) · D2 Saunders (IE) · D3 Morley (IE) · D4 Kerkvliet-Hermans (UK) · D5 Land og Skógur team - A. A. Thorvardarson, S. L. Thorlacius & S. Áskelsdóttir (IS) · D6 Juutinen (FI) · D7 Jordan (SE) · D8 Lazdiņš (LV) · D9 Bardule (LV) · D10 Pakalne (LV) · D11 Zableckis (LT) · D12 Kotowski (PL) · D13 Knorr (DE) · D14 Reichelt (DE) · D15 AECO team - J. Averkamp & M. Schneider (DE). · = code not applied in the interview. Darker cells = more quotations.3. Main patterns

The distribution of codes across interviews (Table 15) and their co-occurrence within quotations (Table 16) show the following descriptive patterns:

- **Shared concerns**. Spatial representativeness and metadata/data sharing appear in all 15 interviews; regional transfer/calibration and model inputs & categories in 14. These issues are shared across countries and professional profiles rather than confined to one research community.
- **Most frequently coded issues**. Spatial representativeness (85 quotations), long-term/seasonal coverage (63), restoration trajectories (58), metadata/data sharing (55) and national inventory integration (49).
- **Context-specific issues**. Blanket/Atlantic bogs are raised in 5 interviews (Ireland, the UK and Germany), reflecting where these systems are relevant. Certification/MRV is concentrated in 9 interviews, mainly those with certification, project-development or GEST-related roles. The uncertainty of applying emission-factor averages is raised explicitly in 8 interviews.
- **Linked issues**. The most widespread co-occurrences connect temporal and spatial representativeness (10 interviews); data sharing with coordination, capacity and funding (9); methane with restoration trajectories (9); and GEST with regional transfer and with model categories (8 each). They mirror the report's main lines of argument: evidence must represent both place and time, the CH_4 response after rewetting is a key uncertainty, and the debate on GEST concerns calibration and classification rather than the proxy concept itself.

Table 16: Most widespread code co-occurrences

Code A	Code B	Interviews	Quotations
Long-term / seasonal coverage	Spatial representativeness	10	17
Coordination, capacity & funding	Metadata / data sharing	9	17
Methane (CH_4)	Restoration trajectories	9	15
Chambers	Eddy covariance	8	18
Long-term / seasonal coverage	Restoration trajectories	8	18
GEST / vegetation proxy	Regional transfer / calibration	8	14
Spatial representativeness	Restoration trajectories	8	14
GEST / vegetation proxy	Model inputs & categories	8	11
Forested peatlands	Spatial representativeness	8	10
National inventory integration	Spatial representativeness	8	10

Co-occurrence = both codes applied to the same quotation. Interviews = number of interviews with at least one such quotation. A co-occurrence indicates a candidate thematic link, not an explicit causal claim.

4. Notes on interpretation

- **Descriptive counts**. Counts show how often, and in how many interviews, an issue was raised. They are not a statistical measure of agreement among experts or of the importance of an issue.
- **Coding basis**. Coding was carried out on the structured interview fiches, which summarise the interviews, rather than on verbatim transcripts.
- **Coding process**. Coding was carried out by a single researcher. An AI assistant (Claude, Anthropic) reviewed the consistency of code assignments. Every KI proposal was reviewed, corrected or rejected by the researcher. No inter-coder reliability is claimed.
- **Software**. The coding was organised in a spreadsheet; no dedicated qualitative-analysis software was used.

5. Data underlying the petal charts

The petal charts in Chapters 2 to 4 and in the Conclusions (Figures 7, 8, 9 and 12) draw only on the quotations from the corresponding part of the interviews. Their counts are therefore lower than the totals per code in Table 14. Table 17 lists the values shown in each figure. Family totals count each quotation once and are not the sum of the issue counts

Two points should be considered when reading the figures. First, a quotation can address several issues, so the issue counts within a figure may add up to more than n. Family totals count each quotation only once and are therefore not the sum of the issue counts. Second, because each figure is limited to one part of the interviews, its counts are lower than the totals per code in Annex 2 (Table 14), which cover all 352 quotations.

Table 17: Quotations and interviews per issue and family in the petal charts (Figures 7, 8, 9 and 12)

Family	Issue	Quotations	Interviews
Figure 7 – Scientific robustness (n = 78)			
Representation (family total: 44 · 15/15)	Gases & carbon pathways	22	12/15
	Model representation	15	12/15
	Baselines & inventories	18	10/15
Time (family total: 31 · 13/15)	Record length	19	10/15
	Post-rewetting trajectories	21	11/15
Transferability (family total: 23 · 14/15)	Uncertainty	11	7/15
	Transferability	14	10/15
Validation (family total: 5 · 4/15)	Cross-validation	5	4/15
Figure 8 – Geographic and ecological gaps (n = 70)			
Peatland types and ecological settings (family total: 18 · 13/15)	Forested and woody peatlands	14	11/15
	Blanket bogs and upland peatlands	6	5/15
Peatlands used for agriculture and post-extraction (family total: 18 · 13/15)	Agricultural peatlands	13	11/15
	Post-extraction peatlands	8	8/15
Peatlands under restoration and transition (family total: 15 · 10/15)	Starting conditions & recovery stages	15	10/15
Peatlands under paludiculture and wet productive uses (family total: 10 · 8/15)	Paludiculture & wet productive uses	10	8/15
Reference systems and spatial coverage (family total: 40 · 14/15)	Natural & near-natural reference sites	6	5/15
	Uneven geographic coverage	36	14/15
Figure 9 – Methodological, monitoring and data priorities (n = 78)			
Compound gaps & representative networks (4.1) (family total: 19 · 13/15)	Representative monitoring networks	19	13/15
Long-term, trajectory-aware monitoring (4.2) (family total: 33 · 14/15)	Long-term & continuous records	20	11/15
	Baselines & restoration transition	15	10/15
Combined methods, shared metadata & QA (4.3) (family total: 30 · 12/15)	Combining methods & validating proxies	8	6/15
	Monitoring designed for models	9	6/15
	Minimum metadata & quality assurance	18	9/15
Scope beyond CO_2 and the site boundary (4.4) (family total: 17 · 11/15)	Relevant gases & carbon pathways	12	8/15
	Removed peat, topsoil & biomass	7	6/15
Reusable evidence & capacity (4.5) (family total: 22 · 13/15)	Accessible & reusable datasets	17	11/15
	Capacity, funding & coordination	8	7/15
Connect research evidence to accounting systems (4.6) (family total: 14 · 9/15)	Inventory & MRV links	14	9/15
Figure 12 – Main bottlenecks (n = 81)			
Fragmented evidence (family total: 46 · 13/15)	Data access & reuse	23	12/15
	Long-term continuity	13	10/15
	Capacity & funding continuity	30	11/15

Family	Issue	Quotations	Interviews
Limited representativeness (family total: 30 · 13/15)	Representativeness	7	6/15
	Regional transfer	17	10/15
	Model categories & EF uncertainty	9	7/15
Science and implementation at different speeds (family total: 24 · 12/15)	Inventory integration	11	7/15
	Certification & MRV	14	6/15

Annex 3 Scoring criteria for the comparative assessment

Table 12 and Figure 11 compare five GHG assessment approaches along three dimensions: scientific robustness (shown as evidence strength in Figure 11), scalability and operational readiness. The scores are qualitative judgements by the author, based on the literature review and the expert interviews. They are not derived from measurements and express how the approaches perform relative to one another, not an absolute assessment of their quality.

Table 18 defines the criteria used for each score. Table 19 summarises the main reasons for the scores given to each approach and indicates where the underlying evidence is discussed in the report.

Table 18: Scoring criteria for the comparative assessment (Table 12, Figure 11)

Dimension	1 – Low	2 – Medium	3 – High	4 – Very high
Evidence strength (Scientific robustness)	Relationship to GHG fluxes weakly supported or not empirically tested.	Empirically derived, but with limited independent validation or uneven calibration across the conditions where it is applied.	Direct measurement with limited spatial or temporal integration, or a mechanistically grounded proxy validated where regionally calibrated.	Direct, continuous measurement of ecosystem-scale fluxes using established protocols.
Scalability	Requires dedicated infrastructure or repeated field campaigns at each site; effort grows in proportion to the number of sites.	Applicable to several sites, but requires substantial site-specific input data, expertise or calibration.	Applicable across many sites with routine, comparatively low-cost monitoring (e.g. water-table loggers), once calibrated relationships exist.	Applicable across large areas and project portfolios through mapping or remote sensing at low marginal cost.
Operational readiness	Used mainly for research, validation and calibration.	Under development or piloted; not yet a primary quantification pathway.	Primary quantification pathway in a limited number of frameworks or regions.	Established as a primary quantification pathway in several operational frameworks.

Scores refer to the typical use of each approach in European peatland restoration and accounting. Individual applications may score higher or lower depending on local data, calibration and capacity.

Table 19: Basis for the scores assigned to each approach

Approach	Scores (R / S / O)	Main basis for the scores	Where discussed
Eddy covariance	4 / 1 / 1	Continuous, ecosystem-scale flux time series; high infrastructure, expertise and processing costs; not used as a primary crediting method in the frameworks reviewed.	Sections 1.1, 2.4, 2.8; Tables 5 and 11
Chamber measurements	3 / 1 / 1	Direct, gas-specific plot-scale measurements that support process attribution; episodic coverage; field effort grows with the number of sites.	Sections 1.1, 2.1, 2.8; Table 5
Vegetation-based proxies (GEST)	2* / 4 / 4	Empirically derived emission factors applied through vegetation mapping at low cost; discrete classes and limited regional transferability; established in MoorFutures, Verra VM0036, SOCIALCARBON and the draft CRCF.	Sections 1.2, 2.2, 2.6, 2.7, 2.8, 5.4; Tables 6 and 11

Approach	Scores (R / S / O)	Main basis for the scores	Where discussed
Hydrological proxies	3* / 3 / 3	Mechanistic link between water-table depth and CO_2/CH_4; requires representative water-table monitoring and regionally calibrated response functions; used in national inventories and in the Irish Peatland Standard and UK Peatland Code (fens).	Sections 1.3, 2.2, 5.4; Tables 7 and 11
Multivariable and hybrid models	2 / 2 / 2	Integrate several drivers and can capture temporal change; demanding input data and uneven validation; operational mainly in national inventories with long monitoring records (e.g. Finland).	Sections 1.4, 5.2; Table 10

R = scientific robustness; S = scalability; O = operational readiness. * Higher where calibrated against local or regional measurements.

Annex 4 Glossary of key terms

The definitions below explain how key terms are used in this report. They are intended to support readers without a specialist background in peatland GHG assessment.

Table 20: Glossary of key terms

Term	Definition
Applicability domain	The climatic, ecological and management conditions for which an emission factor, proxy or model is supported by evidence.
Baseline	The GHG emissions expected without the project, usually the drained pre-restoration condition, against which emission reductions are calculated.
Calibration	Adjusting a proxy relationship or model with measurements from the conditions in which it will be applied.
Chamber measurement	Direct measurement of gas exchange from the change in gas concentration inside a small enclosure placed over the peat surface or vegetation.
Cross-validation	In this report, the comparison of different methods (e.g. proxy estimates and measured fluxes, or chambers and eddy covariance) applied to the same peatland.
Eddy covariance	Direct, continuous measurement of ecosystem–atmosphere gas exchange from a tower, based on turbulent air movement and gas concentrations.
Emission factor (EF)	The average annual GHG emission per unit area for a defined land use or site type, usually in t CO_2-eq ha^{-1} yr^{-1}.
Emission reduction (ER)	The difference between baseline emissions and project emissions.
Ex-ante / ex-post estimate	An estimate made before an intervention, based on expected conditions, and one made afterwards, based on observed conditions.
GEST (Greenhouse Gas Emission Site Type)	A vegetation-based proxy approach that assigns emission factors to site types defined by plant communities and moisture conditions.
Global warming potential (GWP)	A factor that expresses the warming effect of a gas, such as methane, relative to CO_2 over a given period.
Hydrological proxy	An approach that estimates GHG emissions from water-table depth through empirically calibrated response functions.
IPCC Tier 1, 2, 3	Levels of methodological detail in national GHG inventories: default factors (Tier 1), country-specific factors (Tier 2) and advanced, country-specific methods or models (Tier 3).
Lateral carbon fluxes	Carbon leaving a peatland through water, as dissolved organic carbon (DOC), dissolved inorganic carbon (DIC) or particulate organic carbon (POC).
MRV	Monitoring, reporting and verification of emissions or emission reductions, for example within a certification framework.

Term	Definition
Paludiculture	Productive use of wet or rewetted peatlands, for example cultivation of reeds, cattail or Sphagnum.
Proxy	An indicator, such as vegetation or water-table depth, from which GHG emissions are estimated instead of being measured directly.
Quotation	A coded analytical paragraph (see Annex 2)
Reference site	A natural or near-natural peatland used as a comparison to interpret emissions from drained or restored sites.
Representativeness	The extent to which measured sites or datasets reflect the conditions of the peatlands to which estimates are applied.
Restoration trajectory	The development of hydrology, vegetation and GHG fluxes over time after rewetting, including the transition phase.
Rewetting	Raising the water table of a drained peatland, usually by blocking ditches, to reduce peat decomposition.
Tiered monitoring network	A network in which a few intensively monitored reference sites support lighter assessments across many restoration projects.
Transferability	Whether an emission factor, proxy or model developed under certain conditions can be applied reliably under other conditions.
Validation	Testing estimates against independent measurements that were not used to develop or calibrate them.

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