pmr | PARTNERSHIP FOR MARKET READINESS

TECHNICAL NOTE 12 | APRIL 2016

Greenhouse Gas Data Management

Building Systems for Corporate/ Facility-Level Reporting

WORLD BANK GROUP

PARTNERSHIP FOR MARKET READINESS

April 2016

Greenhouse Gas Data Management

Building Systems for Corporate/ Facility-Level Reporting

© 2016 International Bank for Reconstruction and Development / The World Bank
1818 H Street NW, Washington, DC 20433
Telephone: 202-473-1000; Internet: www.worldbank.org

Some rights reserved

1 2 3 4 19 18 17 16

This work is a product of the staff of The World Bank with external contributions. The findings, interpretations, and conclusions expressed in this work do not necessarily reflect the views of The World Bank, its Board of Executive Directors, or the governments they represent. The World Bank does not guarantee the accuracy of the data included in this work. The boundaries, colors, denominations, and other information shown on any map in this work do not imply any judgment on the part of The World Bank concerning the legal status of any territory or the endorsement or acceptance of such boundaries.

Nothing herein shall constitute or be considered to be a limitation upon or waiver of the privileges and immunities of The World Bank, all of which are specifically reserved.

Rights and Permissions

This work is available under the Creative Commons Attribution 3.0 IGO license (CC BY 3.0 IGO) http://creativecommons.org/licenses/by/3.0/igo. Under the Creative Commons Attribution license, you are free to copy, distribute, transmit, and adapt this work, including for commercial purposes, under the following conditions:

Attribution—Please cite the work as follows: World Bank. 2016. "Greenhouse Gas Data Management: Building Systems for Corporate/Facility-Level Reporting." Partnership for Market Readiness, World Bank, Washington, DC. License: Creative Commons Attribution CC BY 3.0 IGO

Translations—If you create a translation of this work, please add the following disclaimer along with the attribution: *This translation was not created by The World Bank and should not be considered an official World Bank translation. The World Bank shall not be liable for any content or error in this translation.*

Adaptations—If you create an adaptation of this work, please add the following disclaimer along with the attribution: *This is an adaptation of an original work by The World Bank. Views and opinions expressed in the adaptation are the sole responsibility of the author or authors of the adaptation and are not endorsed by The World Bank.*

Third-party content—The World Bank does not necessarily own each component of the content contained within the work. The World Bank therefore does not warrant that the use of any third-party-owned individual component or part contained in the work will not infringe on the rights of those third parties. The risk of claims resulting from such infringement rests solely with you. If you wish to re-use a component of the work, it is your responsibility to determine whether permission is needed for that re-use and to obtain permission from the copyright owner. Examples of components can include, but are not limited to, tables, figures, or images.

All queries on rights and licenses should be addressed to the Publishing and Knowledge Division, The World Bank, 1818 H Street NW, Washington, DC 20433, USA; fax: 202-522-2625; e-mail: pubrights@worldbank.org.

Cover design: Bill Pragluski, Critical Stages, LLC.

Contents

Boxes

Figures

Tables

Acknowledgments

This report was prepared for the World Bank's Partnership for Market Readiness (PMR) by David Rosenheim, Alex Carr, Jenna Jorns (The Climate Registry), Toby Mandel Hedger, Deborah Harris, Claire Boland, Sabrina Andrews, and Marian Van Pelt (ICF International), with inputs and supervision from Pierre Guigon (World Bank Group).

We also acknowledge our colleagues from the World Bank Group who reviewed this report and provided valuable feedback. These include Adriana Jordanova Damianova (Lead Environmental Specialist), Maja Murisic (Environmental Specialist), Ernesto Sanchez-Triana (Global Lead on Environmental Heath and Pollution Management), Klaus Oppermann (Senior Carbon Finance Specialist), Pauline Kennedy (Senior Carbon Finance Specialist), and Samira Elkhamlichi (Senior Energy Specialist)

We sincerely thank the policymakers, regulators, representatives from reporting programs, and other experts who participated in interviews and the review process to share their insights and knowledge related to designing and implementing greenhouse gas (GHG) data management systems for corporate/facility-level reporting. These include stakeholders from Australia, Chile, China, France, Germany, Kazakhstan, Mexico, South Africa, Turkey, the United Kingdom (UK), and the United States (U.S.) (at the national and state level). We would also like to acknowledge the input from the PMR Working Group for Measurement, Reporting and Verification (MRV Working Group). Interviewees and reviewers are listed below.

Country/state	Organization	Interviewee and/or reviewers
Australia	Clean Energy Regulator	Jacquie Shannon
Australia	Department of the Environment	Gareth Prosser
California (U.S.)	Air Resources Board	Brieanne Aguila Patrick Gaffney Rajinder Sahota
Chile	Ministry of Environment	Rodrigo Pizarro Gariazzo
China	SinoCarbon	Tang Jin
France	CITEPA	Julien Vincent
Germany	German Emissions Trading Authority GIZ	Doris Tharan Kerstin Dietrich Martin Punsmann
Kazakhstan	JSC Zhasyl Damu (Ministry of Energy)	Sergei Tsoi Botagoz Akhmetova
Massachusetts (U.S.)	Department of Environmental Protection	William Space
Mexico	Secretariat of Environment and Natural Resources (SEMARNAT)	Soffia Alarcon Diaz
South Africa	Department of Environmental Affairs	Jongikhaya Witi

Country/state	Organization	Interviewee and/or reviewers
Thailand	Thailand Greenhouse Gas Management Organization (TGO)	Pongvipa Lohsomboon Sumon Sumetchoengprachya Pathom Chaiyapruksaton
Turkey	Ministry of Environment and Urbanization	Tuba Seyyah Tuğba İçmeli Zeren Erik
United Kingdom	Environment Agency	Haydn Jones Andrew Matterson
United States (Federal)	Environmental Protection Agency	Kong Chiu Natalie Tang

Executive Summary

Over the past decade, greenhouse gas (GHG) reporting programs have emerged at the regional, national, and subnational levels to provide information on emissions sources and trends, inform and shape climate policy, and help companies to make decisions on how and where to reduce their emissions and increase their efficiency. Such developments have particularly occurred as part of countries' efforts to inform their national GHG inventories under the United Nations Framework Convention on Climate Change (UNFCCC) and to implement domestic policies and GHG reduction targets in key sectors, as well as voluntary efforts from an increasing number of companies to assess their climate risks and opportunities. A need for accurate and reliable GHG data has been at the forefront of international discussions, with many countries having recently developed Intended Nationally Determined Contributions (INDCs) outlining their post-2020 mitigation goals and related GHG mitigation policies. The effective design and implementation of these policies can be supported by robust data management systems, which in turn provide the necessary infrastructure underpinning GHG reporting programs.

This report provides guidance to regulators, program and system administrators, and IT/development teams on how to design, develop, and implement the GHG data management systems that support corporate/facility-level reporting programs. There is no one-size-fits all solution, hence this report outlines a process and series of considerations that will help countries develop solutions that are appropriate for their unique needs and requirements, local conditions and policy environment, and capacity (financial, human and technical). It is grounded in the real-life experiences of and lessons learned from more than 10 jurisdictions from around the world, who serve as examples throughout the document.

Defining GHG Data Management Systems for Corporate/Facility-Level Reporting Programs

GHG data management systems are repositories designed and developed to collect and store corporate-level GHG inventory data from companies and organizations, often at the level of the facility (which is frequently but not always the point of regulation in a cap and trade system, for example), but sometimes at the level of a corporation or enterprise.

For the purposes of this report, GHGs refer to the seven Kyoto-defined gases: carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), sulfur hexafluoride (SF_6), and nitrogen trifluoride (NF_3). Other pollutants, such as particulate matter (PM), ground-level ozone, carbon monoxide (CO), sulfur oxides (SOx), nitrogen oxides (NOx), hydrochlorofluorocarbons (HCFCs), chlorofluorocarbon (CFCs), and lead are references in this report, however they are not the main focus.

Depending on their functionality, GHG data management systems enable:

- Data entry for regulated entities.
- Data review, consolidation, and analysis for regulators.
- Increased data accuracy, completeness, and consistency.[1]

[1] These are three of what are commonly referred to as the TACCC principles (transparency, accuracy, consistency, comparability, completeness).

- Centralized data collection, facilitating interaction between regulators, regulated entities and verifiers, as well as efficient communication with key stakeholders.
- Time series tracking of company and facility progress against GHG targets and strategies.

A GHG data management system benefits different stakeholders in various ways. It can help industry demonstrate compliance, leadership, and transparency to shareholders and the public, as well as publicly track reductions. It helps government advance to a paperless form of collecting emissions information, and secures more accurate, consistent data in a centralized repository. A GHG data management system also enables stakeholders to access data more easily so they can make informed decisions about the companies and organizations with whom they interact and do business. By disseminating information that is easily understood, these systems can contribute to empowering communities to function as informal regulators and promote accountability to those being regulated.

The GHG Data Management System in Context

Within any one jurisdiction, there may be a number of data collection systems already in place to support a variety of policies. These systems may have been set up by government agencies and/or regulators that have oversight of pollution control and energy systems, as distinct from GHG reporting programs and systems. These systems are described in brief below in order to distinguish them from GHG data management systems that support corporate/facility-level reporting, but also to highlight any potential synergies. Collaboration between pollution control, energy and climate/carbon departments or agencies may be beneficial during the development of a GHG data management system, given the increasing imperative to collect corporate/facility-level GHG data and the potential opportunity to leverage existing expertise and infrastructure—it is not always necessary to “reinvent the wheel.”

Other systems and databases within the climate and environment arena include:

- **Non-GHG/criteria air pollutant databases**. Many countries collect data on non-GHG or criteria air pollutants (such as PM, ground-level ozone, carbon monoxide, sulfur oxides, nitrogen oxides, and lead) because they are regulated under air quality standards. In some instances, considering leveraging resources and systems associated with non-GHG air pollutants for the purposes of developing a corporate/facility-level GHG data management system may create efficiencies. This is explored in more detail in Sections 3.3.4.4–3.3.4.8.
- **Energy databases**. Some countries collect energy production and consumption data in centralized databases. In some cases this data can be integrated into a data management system for the purposes of corporate/facility-level GHG reporting. This is explored in more detail in Sections 3.3.4.4–3.3.4.8.
- **Data management systems and registries related to GHG policies.** Many countries have systems that support a range of GHG policies and actions, such as national GHG inventories under the UNFCCC, the Nationally Appropriate Mitigation Actions (NAMA) Registry operated by the UNFCCC Secretariat for developing countries to register domestic actions to reduce GHG emissions, or carbon asset registries supporting market-based mechanisms. In some cases, data from corporate/facility-level GHG systems can be used to supplement or support the policies that these other GHG systems or registries support. For instance, the data collected in corporate/facility-level GHG data

management systems can improve the quality of the national inventory and allow a country to track its overarching progress against its reduction commitments, such as those outlined in countries' INDCs. Additionally, a carbon asset registry system may link to the corporate/facility GHG reporting system to confirm that the number of allowances surrendered to comply with an emissions trading system is at least equal to the emissions liability.

Case Study: Mexico Context—Supporting Multiple Initiatives

Mexico built an integrated system that will collect both GHG and non-GHG pollutant data. Although Short-Lived Climate Pollutants (SLCPs) are not the focus of this report, they pose significant health and economic risks in a number of countries, and mitigating Black Carbon is one of Mexico's key objectives. The country has taken important steps in monitoring and defining actions to mitigate SLCPs emissions, including incorporating them into their reporting requirements: all liable facilities must report CO_2, CH_4, N_2O, SF_6, HFCs, PFCs, HCFC, CFC, NF_3, halogenated ether, halocarbon, and black carbon emissions from sources emitting 25,000 CO_2e and above, including mobile sources. The data in Mexico's system will feed directly into the national GHG inventory system and the national toxic release inventory. The decision was made to develop a single, centralized data repository and issue a single report for all companies as a result of stakeholder concerns about potential double counting and reporting burden. The system requires information from activity data as well as emissions. A key priority in the development process was specifying the functional requirements to warrant an "ease of use" software that complies with the National Digital Strategy, and differentiated reporting obligations for all the sectors obliged to report.

The Interaction between Corporate/Facility-Level GHG Reporting Programs and Environmental, Climate and Energy Policies

Corporate/facility-level GHG reporting programs are often not designed in a vacuum, and therefore the interaction between GHG reporting and other environmental policies can influence system design. Whether voluntary or mandatory, GHG reporting programs are typically foundational to a range of policies and objectives, as illustrated in many of the country examples in this report. These policies and their interaction with corporate/facility-level GHG data and associated data systems are summarized below in table ES.1.

Table ES.1. Policies and Interaction with Corporate/Facility Level GHG Data and Associated Data Systems

Type of policy	Corporate/facility-level GHG data uses	Implications for GHG data management systems
Economic and market-based instruments, e.g., emissions trading systems[a], baseline and credit mechanisms.	• Rigorous data also informs on setting the caps or baseline emissions for the program • Establishes GHG emissions for market covered entities • Sets the stage for future linking/harmonization • Establishes liabilities under an emissions trading system, and provides important data for determining the cap and allocating allowances	• Data confidentiality and security • Quality assurance and control • Calculation functionality and data accuracy • User information

table continues next page

Table ES.1. Policies and Interaction with Corporate/Facility Level GHG Data and Associated Data Systems *(continued)*

Type of policy	Corporate/facility-level GHG data uses	Implications for GHG data management systems
Policy-based approaches, e.g., carbon taxes, energy and energy efficiency initiatives, energy consumption taxes, crediting approaches, and national and regional analyses.	• Acts as a planning and decision making tool, helping to inform policymaking and options for reducing emissions • Allows regulators to analyze progress against stated policy objectives • Can be used to determine carbon tax liability	• Integration with other databases • Data analytics, aggregation, benchmarking, and reporting functionality
Data collection, analysis, and reporting in support of national commitments (national GHG inventory) and other mitigation actions.	Aggregating and analyzing facility-level and facility-specific activity data and emissions from corporate-facility-level reporting efforts will result in: • A higher-quality national GHG inventory • The ability to more accurately track the effectiveness of mitigation actions against country GHG commitments	• Integration with other databases • Calculation functionality, ability to customize emission factors • Reporting and data export functionality

Note: GHG reporting may also underpin public disclosure and education efforts, and have some utility with respect to legal actions, voluntary agreements and formal negotiations.

[a] Also known as cap and trade in some jurisdictions.

Case Study: South Africa

South Africa's system is being built in three phases and will support the reporting of GHGs as well as non-GHG pollutants, such as sulphur dioxide (SO_2) and particulate matter (PM), in support of its national inventory process, by 2017. In order to build an integrated system with differing datasets, South Africa identified that defining a framework for data transformation was key, after which common input activity data can be used to generate emissions estimates for air quality and climate change. The framework dictated which data was tagged in the front end; activities that had to be summed and linked to different source categories, the GHGs, and the non-GHG pollutants were then linked to specific calculation methodologies in the system. South Africa found that, in most cases, there was a direct link between air quality-listed activities and IPCC source categories, and this link underpinned a detailed mapping activity between the two. The mapping was then used to develop algorithms.

Program Design and Supporting Legal and Regulatory Frameworks Drive GHG Data Management System Design

GHG reporting program design decisions are outside the scope of this report, and are explained in detail in the World Bank PMR's *Guide for Designing Mandatory Greenhouse Gas Reporting Programs* (PMR & WRI, 2015). However, it is important to stress that a system's functional components are determined by the policy it is being developed to support, the legal and regulatory frameworks establishing the program, and the reporting and verification guidance associated with the program.

Legal and regulatory frameworks and program design decisions will influence, if not determine, the functional requirements of the system, notably approaches to data upload and input, data calculation, quality assurance and control, report generation and data export, and data confidentiality. Therefore, defining the legal and regulatory frameworks for the GHG reporting program **in advance** of developing a data system is critical in terms of efficiency and outcomes—regardless of whether the system is supporting voluntary or mandatory GHG reporting. In addition, incorporating GHG inventory management best practices where possible—data transparency, accuracy, comparability, consistency, and completeness (known as the Transparency, accuracy, comparability consistency, and completeness principles [TACCC] principles[2])—into reporting program guidance helps ensure that the GHG data management system can support intended policy.

While the country examples included in this report do not include any instances of linking infrastructure with other jurisdictions, it is nevertheless an option countries may want to consider in the future. As jurisdictions contemplate linking and aligning with other GHG reporting systems and market mechanisms, it is important to align GHG reporting program design decisions, e.g., sector definitions; reporting thresholds; level of reporting (facility- or source-level); similar data types and formats; calculation methodologies, including values for default emission factors and GWPs; and, common standards for verification. These considerations can then feed into the requirements for the GHG data management system.

Key Considerations in Designing and Developing a GHG Data Management System

Developing a GHG data management system is a resource- and time-intensive process that can be daunting for jurisdictions with limited capacity. Based on the lessons learned from the countries interviewed, this report outlines key considerations and a decision-making process that can be customized to varying circumstances, needs and capacity. Considerations include:

- **Ensuring the system is flexible enough to respond to future requirements and regulatory changes:** To ensure the system is as responsive as possible to an evolving regulatory environment, it is important to consider potential system impacts of changing thresholds; additional sectors; modified GHG reporting and verification guidance; future transition from voluntary to mandatory reporting; future transition to carbon policies, such as a carbon tax or emissions trading system; and future linkages with non-GHG or other GHG reporting systems. If you're taking an iterative approach to system development, it is also useful to incorporate stakeholder feedback after launching the system. In order to remain as flexible as possible—and/or when there are resource and time constraints—it may be beneficial to take a modular programming approach to developing a GHG data management system. Modular programming allows for discrete "modules" of functionality to be designed and deployed independently, and systems designed to be modular can add components over time according to the requirements and resources available.

[2] TACCC is defined by the IPCC Guidelines for National GHG Inventories and is used by the UNFCCC. Note that WRI's GHG Protocol (http:/www.ghgprotocol.org) defines a similar set of principles that includes relevance, completeness, consistency, transparency, and accuracy.

- **Building or buying a GHG data management system (see Step 3 in figure ES.1):** Following an analysis of the system's functional requirements, as well as timing needs and capacity (financial, human, and technical), the key decision is to select one of the following development options: (1) developing a new system in-house or using external resources: (2) re-purposing an existing system, or, (3) customizing a third-party system. The benefits and challenges associated with each of these approaches are summarized below in table ES.2.
- **Mitigating the costs of acquisition, development and maintenance:** The costs of developing a GHG data management system are hugely variable and dependent on the scope of functionality and the development approach (outlined above) selected. A number of funding options were identified by the countries interviewed for this report, including annual appropriations, equity injections, cap and trade allowance auction revenues, and development money from international agencies. Options for funding the ongoing maintenance of a GHG data management system include using revenues earned through charging regulated entities/system users, and charging a licensing and/or annual fee if the system is licensed to others.
- **Integrating data from other data sets or systems:** In some cases, it may be desirable to build a GHG data management system that can exchange data with another system—such as a non-GHG pollutant system, an energy management or fuel tracking system, or a GHG reporting

Table ES.2. Benefits and Challenges Associated with the GHG Data Management System Development Options

System option	Benefits	Challenges
Developing a new system in-house or using external resources	• May be able to better address unique needs and functional requirements associated with the system	• Requires extensive budgetary and human resources • Requires deep expertise and experience in designing and developing systems; expert external teams may mitigate the capacity risk, but typically incurs much greater development costs
Re-purposing an existing system	• May lower costs related to software development and licensing • Potentially increase speed to market • Utilize existing in-house expertise and resources	• May not be flexible enough to support the full range of functionality required by the GHG reporting program, and may also introduce incompatibility and integration issues between existing functionality, specialized business requirements and the resulting new, modified functions • Requires additional analysis of infrastructure, licenses, restrictions, and integration of inputs and outputs • Older technology stack used in an existing system may reach early obsolescence
Customizing a third-party system	• Potentially increases speed to market • Adapting a widely-used system can also support future linkages	• Costs of development are typically much higher in comparison with re-purposing existing infrastructure

system at the state or regional level—which may already contain much of the data needed to produce GHG emissions inventories. GHG data management systems can be built to allow for the automated exchange of data from these existing data sets, but this needs to be well defined from the outset.

Case Study: Turkey

Turkey's system was designed in-house and built around the EU Monitoring, Reporting and Verification Templates. The most significant initial challenge was identifying the experts to design and develop the system; they concluded early on that an interdisciplinary team was critical so they convened a group that included a local IT expert as well as international and local technical experts who were involved in developing a GHG MRV user manuals and guidelines, and also in conducting technical trainings on monitoring, reporting, and verification. The system was built taking a phased approach which allowed for testing to be done in each step, as well as ensured smooth integration. First, the database on the reporting and monitoring plans was completed, following which additional components were added to the system in order to collect emission and verification reports. Turkey also found it useful to cooperate closely with the German Emission Trading Authority (DEHSt), which has operated their own system for ten years now and provided valuable insights during study visits to Germany and on demand.

GHG Data Management Development Process

This report provides specific guidance on how to develop a GHG data management system, illustrating an eight-step process that all jurisdictions can follow and tailor to their needs and circumstances. This process is summarized below in figure ES.1.

Key Enablers of an Effective GHG Data Management System

There are a number of other, non-technology-related activities that underpin the development and implementation of an effective GHG data management system. These activities include:

- **Establishing a clear institutional framework for the GHG data management system:** In addition to defining the legal and regulatory framework for a GHG reporting program (and, by extension, the GHG data management system), establishing the institutional framework for GHG data management system provides proper governance and oversight. This will support effective communication, ensure accountability and support system development, maintenance, and use, and data verification. This process could involve identifying an existing agency, new agency, or multiple agencies to oversee the reporting program and the associated system. Ensuring that the roles and responsibilities of each institution are clearly defined is essential in the instance of shared institutional ownership.
- **Stakeholder engagement and consultation:** Most countries interviewed for this report emphasized the value of early and continued engagement with stakeholders, particularly reporters. Stakeholder engagement can improve system design and yield multiple benefits, including facilitating the development of a system that addresses national priorities and circumstances; obtaining early

Figure ES.1. Process to Develop a GHG Data Management System

1
- **Gathering and analyzing system requirements:** Understanding the context for the system by analyzing relevant regulation(s) and legislation, considering anticipated regulatory changes, gathering input from relevant stakeholders, researching similar systems, assessing existing data systems for re-purposing, and assessing data exchange and integration needs.

2
- **Developing functional requirements:** Identifying what the system must to do in order to serve the program requirements by describing the goals and objectives of the system, and defines the types of data, users, key functional components, and design requirements.

3
- **Deciding on in-house development or outsourcing:** Determining whether to buy or build (in-house and/or using external consultants) based primarily on timing requirements and capacity (financial, human and technological).

4
- **Developing technical requirements:** Providing system developers (whether in-house or outsourced) guidance on system performance, architecture, hardware, software, security, and hosting.

5
- **Developing the software:** Configuring an appropriate development environment for the development team, developing a clear database architecture for the system, adhering to best practices to coding/programming the system, and developing the front end of the system to be consistent with the programs brand/style requirements.

6
- **Integrating the system:** Bringing together the various functional, user interface, and data components into one cohesive system.

7
- **Testing:** Ensuring the system's efficacy by testing every scenario for each functional component on every major operating system and every major browser version.

8
- **Deploying and launching the system:** Installing the database and deploying the software files to a server so the database can be accessed by users.

buy-in from and engagement with key user groups, such as reporters and verifiers; building capacity and improving preparedness within key user groups, ensuring fewer errors when data is entered into the system; and raising and maintaining public support.

Engaging stakeholders when gathering and analyzing system requirements can help to gauge their system-specific needs and to solicit feedback on system functional components. Involving stakeholders in beta testing can also be valuable, as they can provide user-specific feedback that can help to refine a system. This type of engagement can also build familiarity with the system so that—once the system is operational—users submit higher-quality data. Seeking feedback after the system has been launched enables jurisdictions to continually improve functionality.

The type of engagement approach/es selected will be informed by the specific needs and/or issues of a stakeholder group, their knowledge and involvement in the reporting program and/or system, and the engagement objectives. The timing and frequency of stakeholder engagement is also determined by the engagement objectives and resource availability.

- **Training and support can ensure that the system is used effectively and reduces user error:** Once a system is developed, providing support to and building the capacity of GHG data management users are key to ensuring smooth reporting cycles and accurate data input. Available resources, reporting timeliness, and accuracy requirements are important considerations when determining the appropriate type and level of support and training activities. Options for user support include a help desk, dedicated telephone line or email address, and/or website; training options include user guides, frequently asked questions documents, in-person trainings, and webinars. Verifiers (either independent or from the administration) should also be trained in order to increase their understanding of how the system works and support the verification process.

1. Introduction

Measuring greenhouse gas (GHG) emissions is crucial to understanding the emissions trends of companies and facilities so that targeted and effective mitigation strategies can be developed. Measuring GHG emissions is also vital to identifying how to influence the emissions trajectories of different sectors; informing and supporting policies such as emissions trading systems; setting realistic policies and evaluating their effectiveness; helping reporting entities assess their climate risks and opportunities; and providing information to stakeholders (PMR & WRI, 2015).

GHG data management systems for corporate/facility-level reporting programs are the repositories designed and developed to collect this data. Depending on their functionality, these systems can enable:

- Data review, consolidation, and analysis for regulators.
- Data entry for regulated entities.
- Increased data accuracy, completeness, and consistency.
- Centralized data collection, facilitating interaction between regulators, regulated entities and verifiers, as well as efficient communication with key stakeholders.
- Year-on-year tracking of company and facility progress against GHG targets and strategies.

The *Guide for Designing and Developing GHG Data Management Systems for Corporate/Facility-Level Reporting* is intended to serve as a reference document for regulators, GHG reporting program and system administrators, and IT/development teams on all aspects of designing and developing GHG data management systems. The Guide:

- Highlights the legal, regulatory, policy, institutional, and technical considerations associated with designing and developing a system.
- Describes a step-by-step process for determining the functional and technical requirements of a system.
- Provides guidance on whether to design and develop a system using internal or external resources (or a combination of both) and on implementing the system.

By providing a comprehensive overview of all aspects of designing and developing a GHG data management system, the guidance aims to aid in bridging the information and knowledge gaps between the different stakeholders (regulators, IT teams, funders, reporters, and verifiers) who will collaborate on and be users of the system.

The guidance provided in this document is not intended to be applied identically in all jurisdictions; instead, it provides an overview of all significant decision points and allows regulators and program administrators to select the information and steps that are most relevant to their specific circumstances and objectives. It is based on lessons learned in various jurisdictions that have experience designing, developing and deploying GHG data management systems. The guidance is intended to be applicable to countries with varying policy goals and objectives, needs and capacity. It is also expected that the guidance will continue to evolve with advancements in technology, and as a result of additional learnings in the countries that are implementing GHG data management systems.

Where relevant, the report highlights examples of systems from a range of jurisdictions, including Australia, California, Chile, Kazakhstan, Massachusetts, Mexico, South Africa, Thailand, Turkey, the United Kingdom, and the United States. Country examples are presented with a light grey background and bold text at the first mention of the relevant country in each example. The systems for these countries were chosen because they represent a range of experiences and insights. We interviewed staff members from these countries (and U.S. states, in the case of California and Massachusetts) specifically for this report. The guidance provided is based on information synthesized from these interviews, as well as from websites, official documents, and a wider literature review.

This report is organized into three sections. Section 2 describes the legal, regulatory, and institutional frameworks that enable effective GHG data management system design and development. Section 3 describes a step-by-step process for developing the GHG data management system, from gathering system requirements to deployment. Section 4 concludes with options for providing support to and building the capacity of GHG data management users.

2. Legal, Regulatory, and Institutional Frameworks That Enable Effective GHG Data Management System Development

Robust GHG reporting and data collection are foundational to a wide variety of GHG policies, and allow regulators and policy makers to meet or analyze progress toward stated policy objectives. Policy objectives may include: improving national GHG inventories, emissions trading systems , carbon taxes, crediting approaches; energy and energy efficiency initiatives, energy consumption taxes, energy balance, emissions standards, carbon targets or commitments (e.g., NAMAs), and national and regional analyses.

This section provides an overview of the legal, regulatory, and institutional considerations and frameworks that support the development and implementation of GHG data management systems that are then used to support outlined policy objectives.

Legal frameworks, which may comprise primary legislation (i.e., broad frameworks), and secondary legislation (i.e., enabling legislation), give authorization, direction, and verification to determine and implement regulations that put into practice the primary legislative intent.

Institutional frameworks, which may encompass one or more institutions, address GHG system governance and oversight that supports effective communication, ensures accountability, and supports system development, maintenance, and use.

2.1. The Legal and Regulatory Context: Select Developments in Various Jurisdictions

Table 1 highlights select legal and regulatory frameworks in a number of jurisdictions, demonstrating the diversity and overlap of these frameworks. Related climate or energy policies, or program policy objectives, in these jurisdictions range from voluntary programs in the early stages of development to highly-regulated GHG reporting programs that underpin emissions trading systems. The experiences of the jurisdictions highlighted below are discussed as examples throughout this report.

This table introduces a number of program, agency, and system names and acronyms for a number of jurisdictions. For the remainder of the report, these programs and their associated systems will be referred to by their respective jurisdiction. For example, the U.S. EPA’s e-GGRT system will be referred to as the U.S. system.

Table 1. Comparison of GHG Reporting Programs, Data Management Systems, and Legal Frameworks in Select Jurisdictions

GHG reporting program	Administrative agencies	Legal frameworks	Regulatory frameworks	GHG data management system	Description and details
Australia National Greenhouse and Energy Reporting Scheme (NGERS)	Department of the Environment, Clean Energy Regulator	National Greenhouse and Energy Reporting Act, 2007; Clean Energy Regulator Act, 2011	National Greenhouse and Energy Reporting Regulations, 2008; National Greenhouse and Energy Reporting (Measurement) Determination, 2008;National Greenhouse and Energy Reporting (Safeguard Mechanism) Rule, 2015	Emissions and Energy Reporting System (EERS)	• Emissions and energy threshold • All facilities must report if annual emissions ≥ 25,000 metric tons of carbon dioxide equivalent (CO_2e) or if the total amount of energy produced or consumed ≥ 100 terajoules/year. • All corporate groups must report if annual emissions ≥ 50,000 metric tons CO_2e or if the total amount of energy produced or consumed ≥ 200 terajoules/year. • Facilities must report CO_2, CH_4, N_2O, SF_6, specified HFC and PFC) emissions.
California Mandatory GHG Reporting Program	California Air Resources Board (CARB)	California Global warming Solutions Act (AB 32), 2006	Regulation for the Mandatory Reporting of Greenhouse Gas Emissions, 2014	California Electronic Greenhouse Gas Reporting Tool (Cal e-GGRT)	• Emissions threshold and source categories • All facilities must report if annual emissions ≥ 10,000 metric tons CO_2e, and are covered in Cap-and-Trade if emissions ≥ 25,000 metric tons CO_2e. • Some source categories are required to report irrespective of emissions levels (e.g., cement production, lime manufacturing, petroleum refineries). • Facilities can opt for abbreviated reporting if combustion and process annual emissions are ≥ 10,000 and < 25,000 metric tons CO_2e. • Suppliers of petroleum products, natural gas, and natural gas liquids, and CO_2 must report if annual emissions that would result from consumption of products produced and sold are ≥ 10,000 metric tons CO_2e, and are covered in Cap-and-Trade if emissions ≥ 25,000 metric tons CO_2e. • Facilities must report CO_2, CH_4, and N_2O.

table continues next page

Table 1. Comparison of GHG Reporting Programs, Data Management Systems, and Legal Frameworks in Select Jurisdictions *(continued)*

GHG reporting program	Administrative agencies	Legal frameworks	Regulatory frameworks	GHG data management system	Description and details
Chile HuellaChile	Ministry of Environment	Voluntary, but will be required to report when carbon tax is operational (from 2018 onward)	Not applicable	Pollutant Release and Transfer Registry (PRTR)	• Emissions threshold and source categories • Power sector generators ≥ 50 Megawatt thermal (MWth) must report. • Reporting and implementation of the CO_2 tax to begin in 2018.
China (Shanxi and Shandong provinces) Program name	Local Development and Reform Commission (DRC)	Mandatory	Being finalized	Emissions Reporting System	• Emissions threshold and 14 sectors in accordance with national MRV guidelines • Entities with emissions over 13,000 metric tons of CO_2
European Union European Union Emissions Trading Scheme (EU ETS)	Directorate-General for Climate Action (DG CLIMA)	Directive 2003/87/EC, amended by Directive 2009/29/EC; 601/2012; 600/2012	Commission on Regulation 601/2012 on the monitoring and reporting of greenhouse gas emissions; Commission Regulation 600/2012 on the verification of greenhouse gas emission reports and tonne-kilometer reports and the accreditation of verifiers	DECLARE ETS (pilot phase): web-based application to manage submission and reporting on ETS monitoring, reporting and verification. DECLARE ETS is proposed to EU Member States which have no system or plan to change.	• All activities that meet the thresholds described in Annex I of the EU ETS Directive, including power generation, oil refineries, iron and steel works, cement and lime, manufacturing installations, and specified aviation activities. • All entities must report CO_2, N_2O, and PFCs (as application) on a site by site basis.
Germany European Union Emissions Trading Scheme (EU ETS)	German Emissions Trading Authority (DEHSt) at the German Environment Agency	Directive 2003/87/EC, amended by Directive 2009/29/EC; German Greenhouse Gas Emissions Trading Act	Commission on Regulations 601/2012 and 600/2012 (see EU)	Emissions Trading Scheme: Forms Management System (FMS)	• See EU

table continues next page

Table 1. Comparison of GHG Reporting Programs, Data Management Systems, and Legal Frameworks in Select Jurisdictions *(continued)*

GHG reporting program	Administrative agencies	Legal frameworks	Regulatory frameworks	GHG data management system	Description and details
Kazakhstan Mandatory GHG Reporting, Emissions Trading Scheme	Ministry of Energy, JSC Zhasyl Damu	Environmental Code, 2007; Rules on National inventory of GHG emissions sources and removals, 2015	Rules and regulations for the ETS were approved in 2012, and amendments are expected to be finalized in 2015.	National Inventory of GHGs Emissions Sources and Removals	• Emissions threshold • Legal entities of power, oil, and gas sectors must report annual emissions; operators ≥ 20,000 metric tons CO_2 must submit verified inventory reports • All facilities must report CO_2, CH_4, N_2O, and PFCs.
Massachusetts Massachusetts GHG Emissions Reporting Program	Massachusetts Department of Environmental Protection (MassDEP)	Global Warming Solutions Act, 2008	Air Pollution Control Regulations (310 CMR 7.00), 2015	Climate Registry Information System (CRIS)	• Emissions threshold • Facilities must report if annual emissions ≥ 5,000 metric tons CO_2e. • Facilities must report CO_2, CH_4, N_2O, SF_6, HFCs, PFCs, and NF_3.
Mexico National Emissions Registry (RENE)	Mexico Ministry of Environment and Natural Resources (SEMARNAT)	General Climate Change Law, 2012	Regulation to the General Law of Climate Change in Matters Relating to the National Registry of Emissions, 2014	Annual emissions Report (COA) that also integrates the Pollutant Release Transfer Register (PRTR)	• Emissions threshold and source categories • Facilities and companies must report if annual emissions ≥ 25,000 metric tons CO_2e (covers specific activities within the energy, transport, industry, agriculture, waste, and business/service sectors). • All facilities must report CO_2, CH_4, N_2O, SF_6, HFCs, PFCs, HCFC, CFC, NF_3, halogenated ether, halocarbon, and black carbon emissions from sources including mobile sources.
South Africa National GHG Reporting Program	Department of Environmental Affairs	National Environment Management Act; Air Quality Act, 2004	Draft National Greenhouse Gas Emission Reporting Regulations, No. 38857, 2015	South African Air Quality Information System (SAAQIS); GHG module is the National Atmospheric Inventory System (NAEIS)	• In development, regulations expected by 2016

table continues next page

Table 1. Comparison of GHG Reporting Programs, Data Management Systems, and Legal Frameworks in Select Jurisdictions *(continued)*

GHG reporting program	Administrative agencies	Legal frameworks	Regulatory frameworks	GHG data management system	Description and details
Thailand Revised CFO Program (Version 2)	Thailand Greenhouse Gas Management Organization (TGO)	Voluntary; supports Climate Change Master Plan and 11th & 12th National Economic and Social Development Plan	Not applicable	Thailand Carbon Footprint for Organization Platform (Thai CFO Platform)	• Voluntary corporate/facility-level reporting • Entities may report CO_2, CH_4, N_2O, SF_6, HFCs, PFCs, and NF_3.
Turkey GHG Reporting Scheme	Ministry of Environment and Urbanization	Regulation on Monitoring, Reporting and Verification of GHG Emissions, 2012	Regulation on MRV of GHG Emissions, 2012; Revised Regulation (on enforcement dates), 2014; Communique on MR, 2014; Communique on VA, 2015.	National Inventory of GHG Emission Sources and Removals	• Emissions threshold and source categories for production facilities must report. • Facilities with rated thermal input ≥ 20 megawatts must report. • Facilities must report CO_2, PFC for aluminum production, and N_2O emissions for certain facilities. • Scope defined by Annex I of the Regulation.
United Kingdom GHG Reporting Program	Department of Environment, Food, and Rural Affairs	Greenhouse Gas (Directors' Reports) Regulations, 2013; Climate Change Act, 2008; Companies Act, 2006	Department of Environment, Food, and Rural Affairs Guidance Documents, 2013* **Guidance documents are non-binding but requirement to report is mandatory*	None; emissions are reported as part of company annual financial reports	• Publicly-traded companies • All UK-incorporated companies whose equity share capital is listed officially on the main market of the London Stock Exchange, a European Economic Area, or has dealt on the New York Stock Exchange/ NASDAQ must report annual emissions. • The activities within the scope of the policy include: a) the combustion of fuel in any premises, machinery or equipment operated, owned, or controlled by the company, b) the use of any means of transport, machinery or equipment operated, owned, or controlled by the company, and c) the operation or control of any manufacturing process undertaken by the company. • All entities must report CO_2, CH_4, N_2O, SF_6, HFCs, and PFCs on a company/ organizational basis.

table continues next page

PMR | PARTNERSHIP FOR MARKET READINESS

Table 1. Comparison of GHG Reporting Programs, Data Management Systems, and Legal Frameworks in Select Jurisdictions *(continued)*

GHG reporting program	Administrative agencies	Legal frameworks	Regulatory frameworks	GHG data management system	Description and details
United States GHG Reporting Program	Environmental Protection Agency (U.S. EPA)	Clean Air Act, 1970; FY2008 Consolidated Appropriations Act (H.R. 2764; Public Law 110–161)	Mandatory GHG Reporting Rule (40 CFR Part 98)	Electronic Greenhouse Gas Reporting Tool (e-GGRT)	• Emissions and energy threshold, plus source categories • Some source categories must report irrespective of emissions levels (e.g., product of cement, aluminum, lime manufacturing, and industrial waste landfill). • Some source categories must report if annual emissions ≥ 25,000 metric tons CO_2e (e.g., production of lead, iron and steel, and pulp and paper manufacturing). • Facilities not covered by the source category requirements above must report if report if annual emissions ≥ 25,000 metric tons CO_2e and the aggregate maximum rated heat input capacity of stationary fuel combustion units at the facility is ≥ 30 million metric British thermal units per hour. • All facilities must report CO_2, CH_4, and N_2O; some sectors require reporting of additional GHGs (e.g., aluminum production: CH_4 and C_2F_6; magnesium production: SF_6).

Sources: Content for Australia, California, Mexico, Turkey, the United Kingdom, and the United States is modeled after table A1 in PMR & WRI 2015. Other content was informed by interviews and feedback from the jurisdictions, as well as from: Ministry of Environment and Urbanization (Turkey) 2014.

2.2. The Legal and Regulatory Frameworks Determine GHG Data Management System Design

The legal and regulatory frameworks of a GHG reporting program will help frame the design and development of the GHG data management system. The legal and regulatory frameworks may be developed independently, or may take into consideration other existing or planned frameworks, such as those that establish non-GHG pollutant programs.

The primary and enabling legislation, or the legal framework, for a reporting program, broadly addresses overall intent, quality control (QC) and quality assurance (QA) (i.e., internal checks, audit requirements and verification approaches), data use, transparency, and disclosure (i.e., how will the data be used and who will access which information), data sensitivity and confidentiality, and the significance or value of reported data (which will be dependent on the policy objectives of a program). These dictate key program design decisions that need to be considered in data system design. For example, the Fiscal Year 2008 Appropriations Act in the **United States**, which was the initial legislation that authorized funding for a U.S. GHG reporting program, also outlined basic scope of the program.

The legal and regulatory frameworks may also address specific roles and responsibilities/authorities of programs and regulations (see Section 2.1); however, the primary purpose of the regulation is to set standards for how to implement a GHG reporting program, and outline the specific monitoring, reporting, and verification protocols to be followed. Since a GHG data management system is an actualization of the program reporting guidance, establishing clear parameters, rules/guidelines, and processes for the GHG reporting program that the system will support is an essential first step.

The *Guide for Designing Mandatory GHG Reporting Programs* covers important GHG reporting program design elements enabled through legislation and regulation that help ensure data transparency, accuracy, comparability, consistency, and completeness (known as the Transparency, accuracy, comparability consistency, and completeness principles [TACCC] principles[3]). Design elements and decision points covered in the Guide include (PMR & WRI, 2015):

- Defining coverage in terms of applicable entities and emissions sources and GHGs (who reports which emissions).
- Providing calculation methodologies for different emissions sources and data monitoring requirements (how to calculate and measure emissions).
- Determining reporting requirements and schedules (what to report and how often).
- Developing reporting platforms and data disclosure rules (where to report and who has access to reported information).
- Deciding on verification procedures for QA and control (who verifies what and how).

[3] TACCC is defined by the IPCC Guidelines for National GHG Inventories and is used by the UNFCCC. Note that WRI's GHG Protocol (http:/www.ghgprotocol.org) defines a similar set of principles that includes relevance, completeness, consistency, transparency, and accuracy.

- Establishing enforcement rules (what measures to apply in case of noncompliance).
- Determining which, if any, documents and reports are public and if this decision is made by the program or by the reporter.

Program design decisions are discussed in the above-referenced guide and are outside the scope of this report. However, solidifying these key decisions as part of the legal and regulatory frameworks for the GHG reporting program **in advance** of developing a data system is critical in terms of efficiency and outcomes—regardless of whether the system is supporting voluntary or mandatory GHG reporting. The design of various functional components of a system (e.g., online calculations, QA and QC measures, public reporting) are directly related to the reporting and verification guidance of the program that the system is being designed to support. When developing the regulatory guidance and protocols for a GHG reporting program, the following decision points will shape key inputs into the system design and development process:

- **Program Coverage and Scope:** What sectors are covered under the program, and are there specified reporting or program inclusion thresholds (e.g., above a certain emissions limit)? Will the system allow for the registration of GHG reductions or only the integration of GHG data?
- **Level of Reporting:** Is data reported at the unit, facility, or entity level?
- **Data Types and Formats:** What types of data are required to be collected? Are there sector-specific or GHG-specific reporting requirements? What units of measure (UOMs) and conversion factors are required?
- **Calculation Methodologies:** What methodologies are required, and which emission factors (e.g., Intergovernmental Panel on Climate Change (IPCC) default emissions factors or country-specific), carbon contents of fuel and raw materials, and global warming potentials (GWPs) are specified?
- **Data Accuracy:** How accurate does the data need to be to meet the stated policy objective? What verification and QA/QC approaches are required to ensure the level of accuracy?
- **Consistency:** Are consistent GHG calculation methodologies required?
- **Multiple Objectives/Adaptability:** Do multiple policy objectives need to be met through one program, and are there different data collection requirements to meet these different objectives?
- **Frequency:** At what frequency does data need to be provided to meet the stated policy objective(s) (e.g., quarterly, annually)?
- **Access:** Which users may needs access to what data?
- **Confidentiality:** Is there any information being collected that should be kept confidential? What is the level of public access to data being collected? This is heavily related to the level and type of access (see above).
- **Security:** Will the data be collected to support a market-based mechanism?
- **Flexibility:** Are changes in policies or regulations expected?

  In addition, incorporating international best practices for GHG measurement, reporting, and verification (MRV), such as the TACCC principles, will enable stronger alignment with other jurisdictions and ensure greater effectiveness.

2.2.1. Other Relevant Legal and Regulatory Frameworks

Legal or regulatory frameworks may also exist to support the technical aspects of a GHG system. These frameworks may address, for example, technology frameworks, electronic reporting, or cyber security.

In developing and implementing its GHG data system the **United States** complies with the Cross-Media Electronic Reporting Rule (CROMERR). The legal framework of CROMERR provides a uniform, technology neutral framework for electronic reporting across all EPA programs; ensures that electronic reporting under EPA and EPA authorized state programs does not compromise the enforceability of environmental programs; provides states with a streamlined process—together with a uniform set of criteria—for approval of their electronic reporting for all their EPA authorized programs; allows EPA programs to offer electronic reporting as they become ready without any additional rule making beyond CROMERR. The implementing regulation of CROMERR outlines standards for electronically submitted reports including: criteria for establishing a copy of record; integrity of electronic document; validity of electronic signature; determination of the identity of the individual uniquely entitled to use a signature device; and opportunity to review and repudiate copy of record (U.S. EPA 2015a).

2.2.2. Considering Confidentiality of Reported Data in System Design

Legal and regulatory frameworks will define what may be considered confidential business information (CBI), what protections are required, how to handle and treat this type of data, and if and how the data can be used or disseminated. Considerations and potential restrictions related to confidential data will impact the design of a GHG system. Examples of how confidential data is handled in various jurisdictions are presented below.

Chile's Pollutant Release and Transfer Register system currently allows public access to all data submitted through its data management system. This disclosure includes both emission factors and protocols. However, the lack of confidentiality provisions has caused some concerns in the business community and has made data collection challenging. Chile is currently considering a law to restrict some information from being publicly available.

South Africa legally prohibits sharing information that would compromise a company's competitive advantage. Therefore, government authorities must sign a non-disclosure agreement with affected companies, and cannot share the GHG information with other agencies.

The **United States** requires some CBI to be submitted during the reporting process, but has protections in place to ensure CBI is only disclosed in an aggregate, protected format. Additionally, EPA protects CBI data by not requiring all of it to be reported (i.e., some inputs to equations for calculating emissions). In order to ensure accurate, verified data for cases where CBI data is not required to be reported and therefore cannot be used as part of verification checks, the **United States** utilizes an electronic "inputs verifier tool" (IVT) which verifies the reporter's data before a report has been submitted. Reporters enter data inputs for equations in IVT web forms. IVT uses these inputs to equations to calculate emissions for a reporter. IVT also uses these inputs to perform verification checks, which are summarized in the Inputs

Verification Summary.[4] This summary and GHG emissions (which are not CBI) are reported. CBI data used for verification in IVT are not saved nor reported. This structure allows for verification of emissions, but prevents the program from collecting and system administrators from seeing any data for which a CBI determination has not been made as this data is not reported.

2.3. Establishing the Institutional Framework can Include Consideration of Existing Institutions, New Institutions, or Multiple Institutions

Typically, legislation or regulation determines which institutions are responsible for implementing GHG reporting programs. Prior to assigning institutional oversight authority, the country implementing the program would:

- Assess the capacity of existing institutions (including related data systems) and the legal framework they support. These institutions could include agencies that are currently collecting information on non-GHG air pollutants, compiling GHG national inventories, or administering existing voluntary GHG reporting programs at the national and subnational levels.
- Evaluate which established legal and institutional frameworks could align and, where possible, seek to leverage technical capacity, expertise, and available resources.
- Establish the roles and responsibilities of all relevant institutions, if shared ownership is possible.

Coordinating across multiple institutions (or several units within a single institution) can be challenging. In the **United Kingdom**, a large amount of carbon legislation was released and implemented in a piecemeal fashion, and was often handled by different government agencies and teams, so it was difficult to coordinate efforts.

Some countries establish new institutions to manage multiple programs. In **Australia**, the Office of Renewable Energy Regulator and the GHG and Energy Data Office/National Greenhouse and Energy Reporting Scheme (NGERS) managed separate programs. Australia chose to merge these two agencies into the Clean Energy Regulator in 2011 when the Government introduced its Clean Energy Future Plan. The Clean Energy Regulator now (as of 2015) manages the country's Emissions Reduction Fund, Renewable Energy Target, NGERS, and Australian National Registry of Emissions Units.

2.4. Clearly Defined Institutional Roles and Responsibilities Is Critical

Clearly defining the roles and responsibilities of each institution is critical. Establishing a framework for GHG data management system governance and oversight will support effective communication, ensure accountability and support system development, maintenance, and use.

There are four key roles associated with system governance and oversight:

1. Statutory regulator
2. Program administrator

[4] Available online at: http://www.ccdsupport.com/confluence/display/help/About+the+Inputs+Verifier+Tool.

3. IT developer
4. System administrator

For each of these roles the unique responsibilities, rights, and obligations are directed by the regulatory requirements established and program design decisions made. These responsibilities, rights, and obligations are discussed in detail below. The four key roles discussed below align with different types of system users and access. When establishing system user roles and access, as discussed in Section 3.3.3, it is critical to understand and consider the institutional roles and responsibilities for effective system governance and oversight.

2.4.1. Statutory Regulator

The statutory regulator is the entity that sets and enforces the GHG reporting regulation(s), in addition to defining the regulatory/policy content that will dictate the requirements of the system. Regulator responsibilities include:

- Defining the regulatory requirements necessary for the system development and management. The regulatory requirements, such as reporting and calculation requirements, help determine the system functional requirements that must support a program.
- Defining CBI requirements and definitions.
- Communicating any changes in the regulations and working to integrate the necessary changes into the system.
- Providing data from the system and conducting outreach about reported data to the public and other stakeholders. Communicating reported data and information about that data (e.g., potential reasons for trends, potential quality issues) can help the public understand the data and their potential limitations. Any publicly published data may need to be scrubbed to protect CBI, if this is a concern.
- Communicating compliance issues. The regulator reviews the reported data to ensure compliance and communicate any issues to the reporter. This communication, depending on the content, may also include enforcing compliance.

2.4.2. Program Administrator

A program administrator manages, oversees, and implements the GHG reporting program that the GHG data management system is supporting. A statutory regulator may serve as a program administrator, however program administrators have distinctly different responsibilities than regulators. Program administrator responsibilities include:

- Establishing procedures associated with operation of the GHG data management system.
- Ensuring adherence to and updating of reporting and verification guidance and associated program documents and materials.
- Oversight of the overall GHG reporting program budget and financing.

- Planning and ensuring adherence to reporting, verification, and data publication timelines.
- Establishing team structures (e.g., program administration and IT teams) and ensuring proper staffing of the teams implementing the program.
- Training and capacity building of system users.
- Oversight of program outreach and communication efforts, and coordination with other programs within the same agency or across other agencies.
- Procuring the services and products of a third-party developer (if applicable).
- Working closely with the IT team (both internally as well as an IT developer) in developing functional requirements.
- Conducting systems testing before it is released for greater use.

2.4.3. IT Developer

The IT developer is responsible for working with the program and system administrators on the functional requirements of the system, translating these functional requirements into code, developing and implementing the technical requirements, database design and implementation and meeting development deadlines. The IT developer can be either in-house or a third party. Further information on the IT developer's responsibilities can be found in Section 3.3.3.

2.4.4. System Administrator

The GHG data management system administrator is responsible for the day-to-day responsibilities associated with running and maintaining the data management system, as well as overseeing access to the system. There could be possible overlap between the statutory regulator (which may also overlap with the program administrator) and system administrator if the regulator chooses to develop or maintain the system in-house. System administrator responsibilities include:

- Defining and overseeing the roles and responsibilities within the system of the statutory regulator, data oversight team, and the system users and manages the accounts within the system.
- User account management, such as considering how to account for active and inactive user accounts and reporting entities, in the case where reporters cease reporting if their emissions trends meet particular regulatory criteria. They also account for the maintaining historical data and, in the case of mergers and acquisitions.
- Ensuring that technical support is provided to system users as inquiries arise.
- Managing security of the system according to program requirements.
- Overseeing data management, export, and treatment.

3. Developing the GHG Data Management System

This chapter presents an overview of the eight key steps in the GHG data management system development process, and illustrates the main decision points. The steps are as follows:

- **Step 1:** Gathering and analyzing system requirements
- **Step 2:** Developing functional requirements
- **Step 3:** Deciding on in-house development or outsourcing
- **Step 4:** Developing technical requirements
- **Step 5:** Developing the software
- **Step 6:** Integrating the system
- **Step 7:** Testing and QA
- **Step 8:** Deploying and launching the system

These steps are described in detail below. Prior to the onset of system development, there are four key preliminary considerations:

- Software development methodology,
- Best practices in GHG data management system design and development,
- Funding options, and,
- Stakeholder consultation and engagement processes.

3.1. Preliminary Considerations

3.1.1. Software Development Methodology

A software methodology is the process by which software applications and individual features within applications are developed from concept to implementation. Methodologies range from traditional "waterfall" processes to more contemporary "agile" approaches and a range of other approaches, including feature-driven development (FDD), rapid application development (RAD), sync and stabilize, the spiral model, and extreme programming.

The development methodology will be determined primarily by the preferred timeline for the system and available technical and financial resources. The waterfall and agile approaches are the most common and are illustrated in more detail in table 2 and in figures 1 and 2.

A hybrid or fluid approach, incorporating components of both waterfall and agile processes, can also be effective in some cases. For example, the **United States** and its IT developer initiated development on its GHG data management system using a waterfall approach. Upon recognizing that the business requirements for the system were evolving—EPA's Greenhouse Gas Reporting Program supporting regulations had been proposed but not finalized—it shifted to an agile approach in order to allow for more adaptability and flexibility in its development process. This enabled "unprecedented interaction of system development and regulatory development," and underpinned its ability to develop a system that supported and was responsive to the forming regulation (Chiu and Kokopeli 2013).

Table 2. Comparing the Waterfall and Agile Approaches for Developing Software

	Waterfall approach	Agile approach
Characteristics	• Structured approach that follows a linear process with sequential phases, typically: ○ Requirements gathering and analysis ○ Detailed design and requirements documentation ○ Implementation/coding ○ Unit testing ○ Integration ○ Testing	• Non-linear, iterative approach in which software development is broken into small iterations (sometimes called "sprints") lasting a few days to a month or two, with each iteration completing releasable functionality. • Each iteration encapsulates the elements of software development, including requirements analysis, design, coding, testing and deployment. • Requires real-time communication within cross-functional teams, often with daily meetings with programmers, testers, product managers, and business owners.
Advantages	• Allows for compartmentalization and high degree of managerial control. • Enforces discipline and accountability through defined development schedule and trackable milestones. • Rigorous documentation can enhance knowledge transferability and decrease project slippage.	• Allows for more iteration and is more flexible and responsive to changing market or policy needs. • Enhances cross-functional communication. • Working software is released more quickly. • High degree of transparency.
Challenges	• Linear process inhibits learning from mistakes. • Inflexible in responding to unforeseen challenges. • Less responsive to customer/user feedback. • Poor design decisions may not be discovered until much later in process. • Emphasis on documentation can be burdensome. • Longer timeline to deployment.	• May be challenging for large/hierarchical or geographically- disparate organizations. • Less intuitive, harder to understand (initially), may require cultural shift. • Less documentation may impair knowledge transfer. • Less managerial control. • Initial releases will not have complete functionality.
Ideal for projects associated with:	• Fixed scope, stable requirements. • Larger, hierarchical organizations with in-house team that can create requirements for in-house or outsourced developers.	• Quickly changing scope/market. • Smaller, more nimble organizations. • Shorter time lines (only if releasing incomplete or modular functionality is acceptable).

Figure 1. Illustration of the Process Associated with the "Waterfall" Approach to Software Development

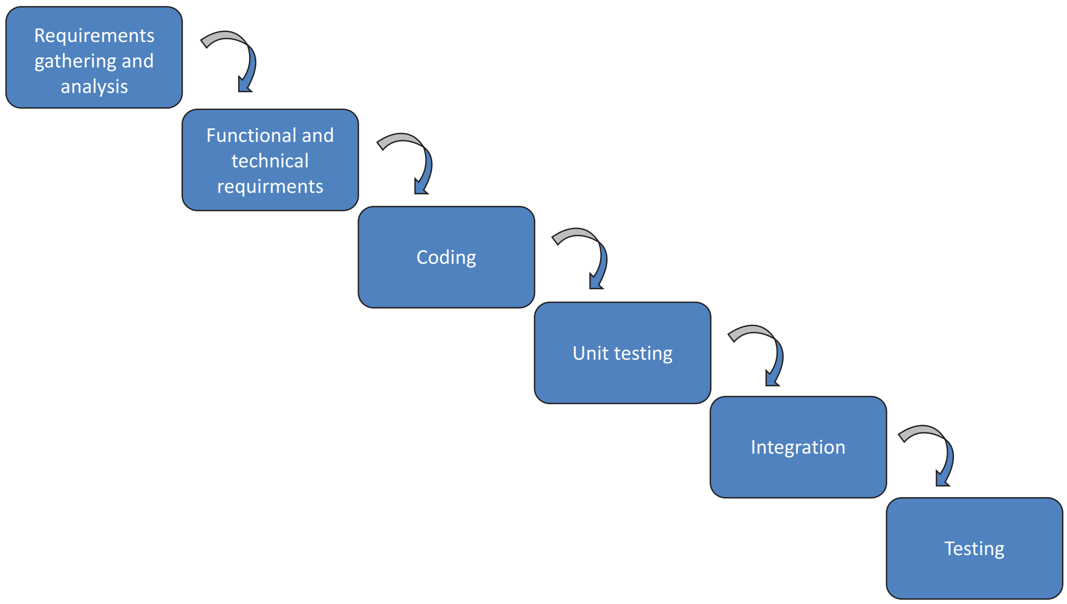
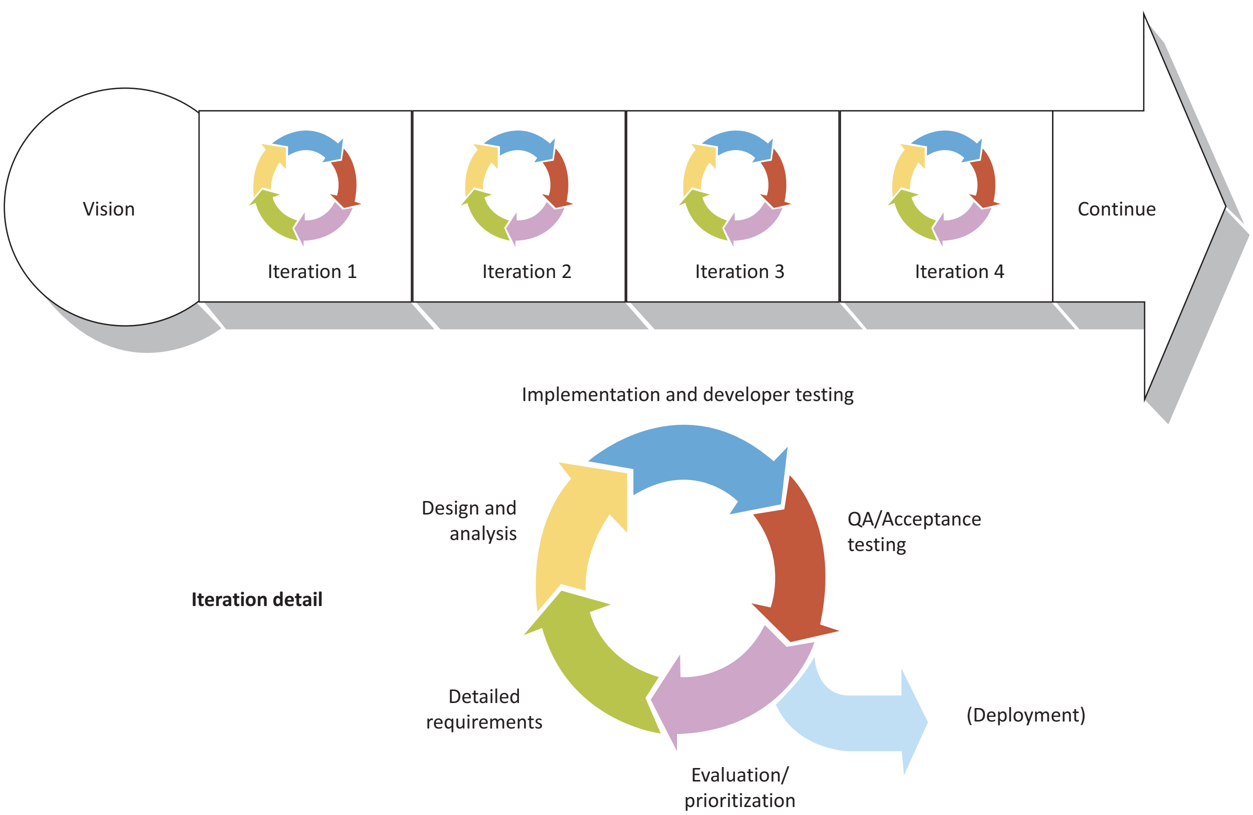


Figure 2. Illustration of the Process Associated with the "Agile" Approach to Software Development



Source: Whipp 2014.

3.1.2. Best Practices in GHG Data Management System Design and Development

PMR Technical Note 4, *Supporting GHG Mitigation Actions with Effective Data Management Systems* (PMR 2013), introduces a number of principles relevant to this report, such as the concept of integrated and independent systems.

Independent systems refer to GHG data management systems that are designed for the specific policies or mandates they serve, but have limited or no linkages between systems. For example, the **United Kingdom** developed several independent systems to address individual policies, reflecting the piecemeal approach to policy development. In addition, many of the UK policies are focused on energy efficiency and reporting of energy use is at the company/corporate level, whereas the GHG reporting requirements for the EU ETS are at the installation/site level. While there is considerable scope to integrate energy and GHG data (based on energy use) at the company/corporate level, integration is not compatible with every requirement of the EU ETS.

Integrated systems are typically web-based, centrally-coordinated systems with common definitions and multiple uses.

As reporting programs are established and policy objectives are developed, statutory regulators and/or program administrators will consider the requirements for system independence and integration. This is explored in more detail in Sections 3.3.4.7 and 3.3.4.8.

The lessons learned described in PMR 2013 are applicable to both independent and integrated approaches, and are incorporated in the detailed guidance provided in this report.

3.1.3. Development Costs and Funding Options

Prior to embarking on designing and developing a GHG data management system, it is important to define a budget for both the design, development, and deployment of the system, as well as for ongoing hosting and maintenance. Financial resources will, to a great extent, determine the scope of the GHG data management system.

It is challenging to determine the potential cost of a GHG data management system until the scope and its many variables are defined, such as the range of users, the division of responsibilities/tasks (internal/external), the scope and the implemented front-end and back-end functionalities. In addition, there are likely maintenance costs with respect to fixing bugs and making continual improvements, and there may be hosting and/or licensing costs. Because of the wide range of scope and functional requirements, potential system development costs can range from several hundred thousand dollars to several million dollars. Table 3 identifies some of the key variables influencing system development costs at each stage of development:

Many of the jurisdictions interviewed for this report indicated that it was difficult to quantify generic costs for system design and development given the number of variables. It was estimated that a system built to unique specifications with a combination of in-house and outsourced developers could cost between USD 1m and 3m; however, **Australia** incurred AUD16.1m ($11.426m USD) in development costs over the

Table 3. Key Variables Influencing System Development Costs

Stage	Variables (partial list)	Potential cost range (USD)
Requirements gathering and analysis	• Volume and status of regulation • Breadth and scope of program coverage (i.e., number of unique industries and methods) • Breadth of stakeholder input • Existing system assessment • Data integration assessment • Extent of prototyping	20K–100K
Functional and technical requirements development	• Core system scope and functionality • Linkages • Extent of data input and output options • Emission factor automation • Additional modules	30K–250K
System development and integration	• Leveraging of existing software • Data input functionality • Homepage and design • Calculation functionality • Emission factor update automation • Linkages and integration with external data sets • Data output and reporting requirements • Performance and scalability • Security • Extent and scope of additional components and modules	250K–5M+ (may be less if modifying existing systems)
Testing	• Size of database • Size of codebase and range of functionality • Number of browsers and OS to test • Extent of performance testing required • Size of engaged testing community	75K–1M+

period 1 April 2012 to 30 June 2015, which were attributable primarily to the engagement of consultants and contractors to develop the software. Similarly, **Kazakhstan** indicated that the primary costs associated with development are staff expenditures.

System costs are typically less if existing software is customized or licensed; for example, the one-time license fee to use the **United Kingdom's** system costs approximately GBP1,500 per operator (excluding hardware and data center costs). For more information on the options for developing a GHG management system, see Section 3.4.

Hosting costs are variable and dependent on existing infrastructure, security, and how much back up space is required (see Section 3.9.1). **California** estimates that its annual operating and maintenance costs are USD 250,000.

With respect to funding the development and operation of GHG data management systems, many of the agencies responsible for the oversight of the systems receive funding through annual appropriations. Some of these agencies also receive equity injections to enable investments in assets. For example, **Massachusetts** partially funds its GHG data management system through allowance auction revenues from the Regional Greenhouse Gas Initiative (RGGI), a cap-and-trade system operating in U.S. eastern states.

Other options for funding the design, development, and deployment of a GHG data management system include:

- Seeking development money from international agencies (e.g., World Bank PMR, USAID).
- Seeking funding from national governments, e.g., **California** had U.S. EPA grant funding for the first few years of development.

Options for funding the ongoing maintenance of a GHG data management system include:

- Using revenues earned through charging regulated entities/system users.
- Charging a licensing and/or annual fee if the system is licensed to others, e.g., the **United Kingdom** Environment Agency manages the UK's system on behalf of all UK regulators. It ensures the software is maintained, bugs are fixed, and improvements are made, and pays the software owner for the overall license and maintenance fees. The Agency then charges each UK regulator in order to recover their share of the license, maintenance costs, etc. Each regulator operates its own help desk.

3.1.4. Stakeholder Consultation and Engagement

The overall importance of and approaches to stakeholder engagement are covered in the *Guide to Designing Mandatory GHG Reporting Programs*. This section builds on that guidance and focuses on approaches to stakeholder consultation and engagement during GHG data management system development. Stakeholder engagement can improve system design and yield multiple benefits, including:

- Facilitating the development of a system that addresses national priorities and circumstances.
- Obtaining early buy-in from and engagement with key user groups, such as reporters and verifiers.
- Building capacity and improving preparedness within key user groups, ensuring fewer errors when data is entered into the system.
- Raising and maintaining public support.

Turkey emphasized the importance of engaging with relevant stakeholders early in the development of the system. The Ministry of Environment and Urbanization worked with the Monitoring and Verification Working Groups initially established to help draft the national MRV legislation and consisting of line Ministries and business sector representatives. Organizing regular training was also found useful to raise awareness and gain ownership from the regulated entities.

Mexico also cited that stakeholder engagement plays an important role in educating constituents about the difference between an ETS and a GHG reporting program, since a number of stakeholders conflate the two.

3.1.4.1. Types of Stakeholders

Table 4 outlines sample key stakeholder groups and their potential information needs. These information needs, in addition to stakeholder knowledge and involvement in the reporting program and/or system, and the engagement objectives, will inform the type of engagement approach taken.

Table 4. Key Stakeholder Groups and Potential Information Needs

Stakeholder group	Potential information needs
Reporters/industry Groups/ federations	• May or may not be familiar with GHG accounting, data collection, monitoring or reporting. • May have concerns about system functionality and ease of use to meet reporting obligations. • May provide expertise on calculation methodologies, QA/QC. • First reporting cycle may be most challenging, comfort will increase in subsequent years.
Verifiers	• Require detailed understanding of program requirements. • May be most interested in how they will interact with system, access submitted data, and complete verification statements. • Helpful to engage to determine how data is reported and in what format, and for QA/QC measures. • Engaging alongside reporters may ease concerns of both groups.
Accreditation bodies	• Need understanding of program requirements and competency requirements of verifiers. • Need to engage early so that an accreditation program ensures sufficiently qualifier verifiers are available to meet program requirements in sufficient volume and to required time scales. • Note: Need to engage alongside verifiers to ensure mutual understanding of requirements and concerns.
Government/regulators (May include national, provincial, regional, state, and local government)	• May want to contribute data or access data reported out of the system. • May be interested in possible integration with existing other programs. • Important to understand data needs and potential for integrations early on. • Important to understand administrative burdens imposed and engage with regulators and regulated entities at an early stage to enable these to be minimized e.g., avoiding collection of unnecessary data.
Technical experts (May include consultants, non-governmental organizations, academia/ research community, and other jurisdictions with expertise or experience)	• May work with reporters and verifiers. • Can draw from previous experience and provide lessons learned. • Early engagement useful to help build capacity/knowledge upon which regulated entities can draw upon when needed.
Civil society	• May be interested in requirements, data availability, and how it impacts decision-making.

3.1.4.2. When to Engage Stakeholders

As stated previously, a GHG data management system is an actualization of the GHG reporting regulation and/or protocol/guidance. Therefore, stakeholder engagement during regulatory development can be an effective way to familiarize stakeholders with program objectives and requirements, and ensure that their input during the system development process is more informed.

Engaging stakeholders when gathering and analyzing system requirements can help to gauge their system-specific needs and to solicit feedback on functional components. In particular, engaging early and often with reporters and industry groups will help to ensure that they are familiar with the program requirements and system.

Involving stakeholders in beta testing can also be valuable, as they can provide user-specific feedback that can help to refine a system. This type of engagement can also build familiarity with the system so that—once the system is operational—users submit higher-quality data. **Australia** indicated that one of its key learnings was that there are benefits associated with allowing reporters from select sectors to participate in user testing of the system—which allows for testing of more complicated data entry requirements against real-world data and situations—before the software is released. Australia contends that allowing additional time for reporters to more fully participate in user acceptance testing (UAT) could be highly beneficial, provided expectations are managed in regard to the capacity to accommodate feedback.

Involving stakeholders in testing can also be time-intensive. Involving them in a pilot of the system, or providing them with a preview, toward the end of the development process can help to reduce the time commitment.

3.1.4.3. How to Engage Stakeholders

The type of engagement approach/es selected will be informed by the specific needs and/or issues of a stakeholder group, their knowledge and involvement in the reporting program and/or system, and the engagement objectives. The timing and frequency of stakeholder engagement is also determined by the engagement objectives and resource availability.

For example, in cases where a reporting program has been recently introduced—or in jurisdictions in which there is not an extensive history of GHG and non-GHG pollutant data collection—the regulated community may have limited knowledge and involvement in the reporting program and/or system, and therefore their feedback and/or input into system development may not be particularly informed. However, the program administrator may wish to engage them at some point during the development process in order to obtain greater buy-in to the program and to build user capacity.

Approaches to stakeholder engagement can include:

- Conducting in-person or virtual meetings:
    - Hosting open meetings for all stakeholders (in-person and/or webinar).
    - Hosting targeted meetings for each group of stakeholders (in-person and/or webinar).
    - Conducting targeted one-on-one meetings with key stakeholders, e.g., representatives from industry sectors that will be most impacted by the GHG system/will be the primary users.

- Soliciting written feedback on system requirements.
- Conducting system testing with key stakeholders prior to launch. Conducting a communications campaign that includes distributing explanatory materials and posting information on a public website.
- Circulating general guidelines on the basics of the GHG reporting program.

Most jurisdictions interviewed for this report mentioned the value of early and continued engagement with reporters. For example, **South Africa** engaged a number of sectors during the requirements gathering and system design phases, which led to the development of calculation methodologies in cases where no IPCC guidance existed, and provided valuable inputs into the development of reporting templates, IT design, and system configuration. This process also led to the development of the Greenhous Gas Improvement Programme (GHGIP), a public-private partnership aimed at developing country-specific emission factors and methodologies.

The **United States** successfully used a "sandbox" (or "sandpit") approach to engage several of its key stakeholder groups in system testing. The sandbox set up allowed for the deployment of a pre-production version of the system code to Amazon Cloud so that future system users could register and set up accounts, as well as enter data, and provide feedback or recommendations.

Australia also made a sandbox training environment available to reporters during the soft launch of its system. Reporters were able to navigate through the system and gain an understanding of how to report their emissions, which helped to ensure that they would continue to meet their compliance obligations and report their emissions correctly.

3.2. Step 1: Gathering and Analyzing System Requirements

Before initiating software development—no matter which development approach is used—it is important to understand and clearly articulate what is being built, and to ensure that the system supports and is aligned with relevant policies and regulations. Gathering and analyzing system requirements is a critical first step in this process. Considerations in the requirements gathering process may include:

- **Analyzing relevant regulation(s)** and legislation that will inform the system's functionality, and the applicability of those to various types of users. Including a regulatory expert(s) to complement a business analyst(s) with more traditional software development skills on the development team can be helpful in this regard.
- **Consideration of anticipated regulatory changes that could impact the GHG program**: To ensure the system and requirements documents are as responsive as possible to the evolving regulatory environment, it is important to include information on potential changes, such as:
  - Changing thresholds,
  - Additional sectors,
  - Additional gases (for example, the EU-ETS started with CO_2 only before N_2O and PFCs were added from 2013 onwards),

- Potential modifications of GWPs,
- Potential changes to codes (i.e., waste codes or other codes for businesses or material/fuel streams)
- Future reporting obligations (i.e., more accurate methodologies such as mass balance and carbon content)
- Future transition from voluntary to mandatory reporting,
- Future transition to carbon policies, such as a carbon tax or cap-and-trade, and
- Future linkages with non-GHG reporting systems (see Section 3.3.4.4).

- **Future linkages with other jurisdictions:** Future linkages can be enabled by aligning GHG reporting program design decisions, e.g., sector definitions; reporting thresholds; level of reporting (facility- or source-level); similar data types and formats (UOMs), metrics, conversion factors; calculation methodologies, including values for default emission factors[5] and GWPs; and, common standards for verification. These considerations can then feed into the requirements for the GHG data management system.
- **Gathering input from relevant stakeholders:** Surveying potential users of the system (e.g., regulators, reporters, verification bodies) on their needs and challenges can provide key inputs into system design. Input can be gathered via interview (with individuals or groups) and/or by questionnaire or survey (see Section 3).
- **Research and analysis of similar systems**: Analyzing similar systems can yield valuable information on a range of best practices and lessons learned from those with experience in building GHG data management systems. This should include "reverse engineering," imitation or re-creation of features from successful systems. This includes applying use cases to and developing diagrams for an existing feature or function (see table 13).
- **Assessing existing data systems for re-purposing**: In some instances, it may be possible to leverage or re-purpose existing GHG data management systems when building a new system. This may have several benefits, including lowering costs related to software development and licensing, potentially increasing speed to market, leveraging in-house capacity, and reducing the need for capacity-building among reporters (if they are already familiar with the system). If considering this option, requirements for the new system would need to be carefully assessed against the functionality of the existing system (see Section 3.4.2).
- **Assessing data exchange and integration needs:** In some cases, it may be desirable to build a GHG data management system that can exchange data with another system, such as a non-GHG pollutant system or an energy management or fuel tracking system, which may already contain much of the data needed to produce GHG emissions inventories.

  GHG data management systems can be built to allow for the automated exchange of data from these existing data sets via interchanges such as application programming interfaces (APIs), XML feeds, or other web services. In order for this exchange to be successful, it needs to be well defined from the outset. Failure to plan and define data exchanges may result in data appearing

[5] For the purposes of this report, default emission factors refer to default values within a single jurisdiction, prescribed by that jurisdiction's GHG reporting program

in the wrong field, data failing to reach the destination database, or a host of other data errors. Information to be gathered includes:

  - Data definitions and database schema from each system to be linked,
  - How data will be mapped, and
  - Method for how the data will be exchanged.

For more information on data exchange and integration, see Section 3.3.4.

- **Prototyping:** Prototyping is the process of developing and testing initial screen shots, system appearance, user experience, or functionality with stakeholders to further refine the system requirements. Ideally, there will be several iterations of early prototyping and user feedback to inform subsequent decisions on the system's functional requirements.

3.3. Step 2: Developing Functional Requirements

Once system requirements are gathered and analyzed, detailed functional requirements can be developed. This documentation is critical, whether insourcing, outsourcing, or deciding if and how to customize an existing third-party system. Defining the functional requirements of the GHG data management system in advance of development will yield a number of benefits, including:

- Helping to inform the "build" or "buy" decision: develop the system in-house, procure a system or outsource the development, or adopt a hybrid approach.
- Reducing implementation risks.
- Lowering development costs (detailed requirements eliminate the guesswork from the implementation phase).
- Leading to the delivery of an end product that matches policy, user, and other requirements.

A functional requirements document describes the goals and objectives of the system, and defines the types of data, users, key functional components, and design requirements, as outlined in more detail below.

3.3.1. Goals and Objectives

A functional requirements document provides an overview of what the system will do, why the system is necessary, and what outcomes it seeks to achieve. This is important in framing the functionality for the IT developers who will be building or customizing the system, whether it is developed in-house or outsourced. The introduction to the functional requirements documentation should include the following components:

- Overview of the legal and regulatory frameworks the system is serving. This can be high level and reference a specific regulation for more detail.
- Overview of the policy goals and the long-term objectives of the system, such as to support voluntary reporting, build private sector-capacity, support mandatory reporting to inform policy makers, and/or collect facility-level data to support an ETS.

- Information about the functional requirements document itself, including how it is organized and the intended audience for the functional requirements.
- Glossary/definitions that will be useful to those using the document. This section can be included near the beginning or at the end of the document.

3.3.2. Types of Data

The types of data required by the GHG reporting programs, including the related source and activity data, should be described in the functional requirements as they directly influence how the system will be used, as illustrated in table 5.

3.3.3. Types of Users

Understanding system users and their needs is critical to developing and implementing a successful system. At a minimum, the user types described below, and the user roles for each type, should be defined in the functional requirements documents. A user role defines the extent to which a particular user can access the system and reporters' data (also known as "permissions"). To mitigate initial scope and cost, systems can be built to start with a limited set of user types and expand this set in future versions.

It is not necessary to define unique roles for each user type; in fact in some cases there may be multiple user roles per user type. For example, there may be many types of public users but, if they will access the system in the same way, they will all correspond to the same user role. Conversely, the verifier user type may have multiple roles.

3.3.3.1. Statutory Regulator, Program Administrator, and System Administrator

It is important to identify and define the primary regulatory agency (the agency that will be overseeing and administering the GHG data management system) as well as any secondary regulatory agencies that may be accessing the system and/or examining or exporting data. For example, an air regulator may be the primary administrator of the system, while energy or public utility commission staff may also need access to the GHG data stored in the system.

The program administrator will likely be the primary regulatory agency; alternatively, it could be another agency or organization (not necessarily a government agency) designated as the secretariat for the GHG reporting program. Within the program administrator, there may be a need for multiple types of user roles.

The system administrator has oversight of the system design, development, and management, and could be the regulator, program administrator, or another third party.

Ultimately, users who will use the platform in similar (though maybe not identical) ways, or for similar purposes, can be grouped together into the same user role. This will make it easier to provide similar users with the appropriate data access and permissions within the system.

Table 5. Types of Data and Key Considerations for GHG Data Management System Functional Requirements

Type of data	Key considerations for GHG data management system functional requirements
Direct anthropogenic emissions: Refers to both stationary and mobile emissions; may include, for example, direct emissions data from continuous emissions monitoring systems (CEMS); and/or activity data from bulk fuel purchases, maintenance records, air permits, vendors, manufacturer information, accounting records, fuel usage logs, fleet management records, expense reimbursement reports, annual mileage records, fuel sampling and analysis records, or process activity data (e.g., production records).	Identify whether or not activity data will be aggregated and converted to CO_2e[a] and if so, offline or within the system through a series of calculations (i.e., application of emission factors and/or GWPs). This will determine whether the data management system should be designed to include a calculation engine. It is best practice to report emissions on an unweighted basis by gas as this allows for the most transparency. However, this may not always be possible. If, due to program design or other reasons, results must be reported in CO_2e, this would not diminish the quality or usability of the data. If data are reported in CO_2e, when possible, GWP that were used should be reported or confirmed values were used to maintain transparency and consistency.
Indirect anthropogenic emissions from purchased electricity, steam, heat or cooling: May include, for example, indirect emissions from the consumption of purchased electricity, heating, cooling, or steam. Activity data from utility invoices, accounting records, administration, fuel usage logs, or bulk fuel purchases.	Identify whether or not indirect emissions from purchased electricity, heating, cooling, or steam is required. If so, determine whether or not activity data will be aggregated and converted to CO_2e and if so, offline or within the system, or whether large data sets should be aggregated/uploaded into the system (see Section 3.3.4).
All other indirect anthropogenic emissions: May include, for example, other indirect emissions activity data from accounting records, expense reimbursement reports, annual employee surveys, vendors, landlords, or suppliers to the reporting entity.	Identify whether or not other indirect emissions data is required. If so, be specific about what data will be included and how it will be input into the system (this will most likely be via manual web entry or spreadsheets, unless API-level integration is available for accounting software or other data sources.
Emission factors	Identify whether the system will support online calculations of activity data to GHG emissions, which will require either 1) the uploading of default emission factors, and/or 2) user inputting of default emission factors or customized emission factors. If so, other considerations include whether to select an option to update emission factors in the system. Depending on the design of the system and how emission factors are used, the system may also need to reference heat content (calorific values) and carbon content values to perform these calculations.[b]
Global Warming Potentials (GWPs)	Similar to emission factors, GWP values are required if the system will support online calculations to CO_2e.[c] These can be loaded into the system or entered manually by the reporter. Updated GWP values are released with each new IPCC climate change assessment report; gaps may exist in the IPCC-provided GWPs and a jurisdiction will need to determine how to handle these situations. Program reporting guidance will determine which set(s) of IPCC GWP values are acceptable and should be incorporated into the system. Acceptable GWPs may be driven by policy such as that set by UNFCCC.

[a] Converting emissions data to CO_2e, within the system or offline, does not prevent the system from also reporting the emissions data by individual GHG.

[b] Certain sectors may also require oxidation factors in the calculation engine. If so, these should considered during the system development process.

[c] Converting emissions data to CO_2e, within the system or offline, does not prevent the system from also reporting the emissions data by individual GHG.

Key considerations in determining user roles for regulators, program administrators, and system administrators include:

- Whether data will be submitted to and reviewed by the regulator or program administrator.
- Whether program administrators or system administrators will regularly assist with trouble shooting.
- Whether regulators, program administrators, system administrators, or all will have full read and/or write access to reported data.
- Whether regulators, program administrators, system administrators, or all will maintain reporting organization contacts or stakeholder lists, provide access, and train other user types.
- Whether regulators, program administrators, system administrators, or all will conduct data analysis and use the data (e.g., for preparation of the national GHG inventory).

For example, in the **United States,** the EPA is responsible for overseeing the GHG data management system, as well as preparing the national GHG inventory. In **Australia**, in contrast, the Clean Energy Regulator oversees the GHG data management system, and they provide access to the data for the Department of the Environment to include reported entity-level GHG data in the national GHG inventory.

3.3.3.2. Reporting Entities

Developing relevant criteria by which to describe and group the types of reporting entities will support data analysis and aggregation. These criteria could include sector, organization size, or types of boundaries.

There may be a need for multiple types of user roles within reporting entities, depending on the level of access required for different staff. Key considerations in determining user roles for reporting entities include:

- Whether user types will be permitted to submit data to the regulatory agency or system administrators.
- Which individual(s) in the reporting entity will be legally authorized to submit reports and maintain responsibility for report accuracy and completeness.
- Whether system administrators, regulators, or entity administrators will be able to provide new users with access to the system and the reporting organization’s data.
- Whether users will have access to multiple entities, facilities, and various user roles for each.
- Which user types will be permitted to create a new emissions report.

3.3.3.3. Verifiers

Verifiers may include third-party verifiers for a single reporting entity; third-party verifiers for multiple reporting entities; and in-house verifiers, if verification is conducted by the program regulators or qualified consultants. Their user roles will typically be defined by the type of access required by the program and verification policy.

3.3.3.4. The Public

Public users include those who are not involved in the reporting or data collection process but are interested in accessing and viewing the data. Data users also have the ability to seek additional information about data and trends from the statutory regulator and/or the program administrator.

Public users who may be accessing the system to view publicly available emissions data may include:

- Other regulators or government agencies,
- Non-governmental agencies,
- Consumer advocates,
- Academics/researchers,
- Investors and analysts,
- Industry groups and trade associations, or
- Civil society.

Table 6 illustrates user types, possible user roles, and system permissions typically granted to each user type.

While the user types above are common to many GHG data management systems, a system can have defined user types that are specific to a regulation or stakeholder ecosystem. For example, **South Africa's** system includes local authorities, provinces, and national authorities as user types. **Chile's** system accommodates company managers as well as sector managers, who have the option to upload sector-specific information.

Table 6. System Permissions by User Type

User types	Possible user roles	Permissions
System administrators	Admin	View and edit details and data for all entities and/or facilities and across user types, create new entities/facilities, and provide access to special/additional functionality
	Regulator	Review and approve/accept data, view and edit details and data, create new report, provide access
Reporting entities	Primary/Signatory/ Authorized	View and edit all organizational and facility details and data, manage other users, create new report, submit report
	Secondary/Technical (entity or facility specific editor)	View and edit details and data for assigned entity or facility
	Viewer	View details and data only
Verification bodies	Admin	Manage other verification users for a given verification body
	Lead	Review details and data for assigned entity or facility, coordinate with the reporter, submit verification findings
	Viewer	Review details and data only for assigned entity or facility
Public	Public	View approved/verified and non-confidential data only

Table 7. Australia's System Permissions by User Type

User type	Permissions
Client Portal Manager	• Can use the Client Portal self-service functionality • Can add or remove users, and update existing users' details and roles • Cannot access an organization's account within EERS
NGER contact person	• Can perform any action within an organization's EERS account (except for the final submission of reports) • Is the first point of contact for the Clean Energy Regulator in relation to an organization's reporting obligations • Receives general EERS/NGER information from the Clean Energy Regulator
NGER coordinator	• Can perform any action within an organization's EERS account (except for the final submission of reports) • Does not receive general EERS/NGER information from the Clean Energy Regulator
NGER data provider	• Can add activity data to entities within EERS, such as facilities • Cannot make amendments to the organization's corporate structure but has read-only access to this information
NGER Executive Officer	• Is the only user (other than a nominated report submitter) that can submit reports in EERS • Can perform any of the other functions outlined above if assigned that role in addition to that of the NGER Executive Officer
NGER guest	• Allows read-only access to an organization's EERS workspace
NGER nominated report submitter	• Can submit NGER reports only • Can perform any of the other functions outlined above if assigned that role in addition to that of the NGER Nominated Report Submitter

In **Australia's** system, each user has a unique login and is also assigned a role that is associated with specific permissions and determines what actions they can perform within the system. Examples of these actions include submitting reports, editing a corporate structure, and the ability to enter data or view only.

Table 7 illustrates the types of system permissions typically granted to each user type in Australia's system.

3.3.4. Functional Components

The functional requirements include descriptions of each major functional component to be included in the system, as determined during the requirements gathering and analysis phase.

A list of potential functional components of a web-based GHG reporting system includes:

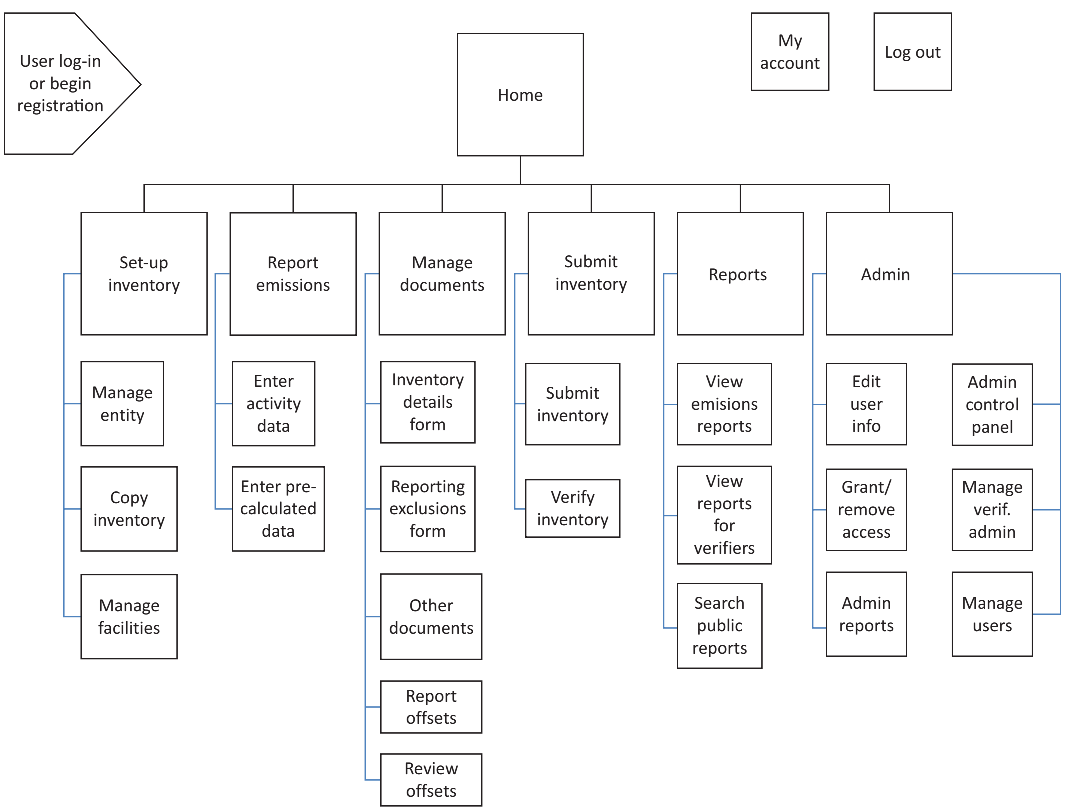
1. Data upload and input
2. Calculation engine
3. Document management

4. Quality assurance (QA) and quality control (QC): internal checks and verification
5. Report generation and data export
6. Data confidentiality requirements
7. GHG data management system home page
8. Analytics
9. Language requirements
10. User information
11. Communicating with users within the system
12. System documents
13. Relevant legislation and regulation

Each of these components is explored in more detail in Sections 3.3.4.4–3.3.4.21.

Using a diagram similar to a web site map is a useful way of plotting functional components, their interrelationship, and how they may be presented in a user interface. Figure 3 provides an example of the major functional components (housed on web "screens") for a GHG data system. The diagram maps the platform's major functional options as they are presented in the main navigation menu and sub-menus, respectively.

Figure 3. Sample Functional Requirements Diagram



3.3.4.1. The Importance of Use Cases

As the functional components of a system are detailed, use cases or user stories can be used to describe how users interact with functional components to achieve their desired outcome(s). Use cases enable IT developers to think through and articulate all possible user scenarios for a given function. This takes the guesswork out of software development and results in better software and optimized user experience.

Use cases typically incorporate written narrative and flow charts to illustrate which user types will use each functional component, as well as how they will use it. Use cases define:

- Primary and secondary users of the functional component. Primary users are the target group for whom the functionality is intended; secondary users might access the functionality, but it is not intended for them (e.g., the system administrator is generally a secondary user for most functionality).
- Primary objectives/goals for each user type, i.e., what each user type is trying to achieve by using the functional component.
- Pre-conditions under which the user needs to access the function.
- Post-conditions that will exist if the function is successful in executing the stated objective, or any that will exist if the function is not successful.
- Story, i.e., the user's interaction with the function—what does the user actually do, what choices does the user make (what click-path do they follow)? Diagrams or mock-ups, where appropriate, make this more useful.
- Any extensions, i.e., how the function may be used elsewhere in the system or in future versions of the system, or any additional considerations.

The following is an example of a use case for a data input module:

- **Use Case—Enter Pre-Calculated Emissions Data:** Users can add/edit/delete pre-calculated emissions data in appropriate UOMs through the web interface.
- **Primary User**: Entity Administrator and Entity Editor.
- **User Objectives**: Enter pre-calculated emissions data into application.
- **Pre-Conditions**: User has logged on and has been granted access to an entity. The Report Status is Checked In and the Reporting Progress is Draft. User has created facilities for the entity and emissions year selected, either through the Manage Facilities module or by copying a previous report using the Copy Report module.
- **Post-Conditions:** User enters pre-calculated emissions totals in appropriate fields. This information is included in applicable emissions reports and analysis.
- **Story:** User navigates to the Report Emissions menu and selects the Enter Pre-calculated Data menu item. They receive the blue search bar where they can select an entity and emissions year for all entities for which they are granted access. If the Report Status for the entity and emissions year is not Checked In the user will not be able to click the View button. Similarly, if the Reporting

Progress is anything other than Draft, the user will not be able to click the View button. If the Report Status is Checked In and the Reporting Progress is Draft, clicking the View button will render a list of all active facilities for that entity and emissions year.

The user will select a facility and click the "Edit" button. This will return a screen showing all the pre-calculated emissions that have been reported for the chosen facility. Each grid will house emissions data for a single activity type.

If there are no emissions reported for the facility yet, the user will not see an emissions grid and will need to choose Add Emissions in order to start reporting pre-calculated data. Users can edit existing emissions data or choose Add Emissions to add new activity types and report emissions for those activity types. Reported gases are entered in metric-ton values. Users should not be able to report two different emissions amounts for the same activity type within a single facility (these amounts should be reported in aggregate). Users are able to remove one or more of the activity types by choosing the delete button. When finished making changes, the user can either save or cancel their changes.

- **Extensions:** Error message on failure to enter correct data types (e.g., text instead of numbers) or no data entered at all.

3.3.4.2. The Importance of Modularity

In some instances, such as when there are resource and time constraints, it may be beneficial to take a modular programming approach to developing a GHG data management system. Modular programming allows for discrete "modules" of functionality to be designed and deployed independently, which is associated with the following benefits:

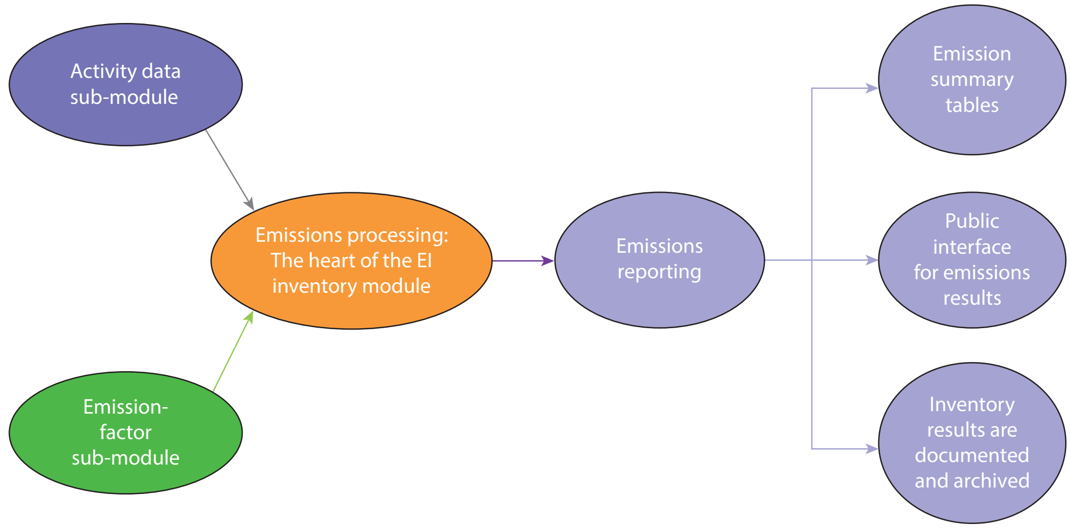
- Developers can prioritize and build key functional components, incrementally adding others over time.
- Developers can develop and deploy separate functionality without it affecting the user experience in the other modules.

Systems designed to be modular can add components over time, according to the requirements and resources available.

Examples of modular approaches to GHG data system development include the following:

- The **U.S.** system was built in a modular fashion so that each component could be developed independently of the others. A key driver for the modular approach was the tight development timeline. Each emissions source category in the U.S. e-GGRT is a standalone module, allowing for parallel development to meet deadlines.
- **South Africa's** system is being developed in three phases and also incorporates a number of modules: an activity data module, emission factor module, emissions processing module, and emissions reporting module, as illustrated in figure 4. The functionality of the system is linked to the emissions inventory compilation schedule. The phases and modular approach reflect the reality of the regulatory framework: while the non-GHG pollutant regulations are finalized and reporters are already reporting these into the system, the system will need to be updated in 2016 to

Figure 4. South Africa's GHG Reporting Platform Modules



Source: Manzini et al. 2013.

accommodate ongoing GHG policies. It is expected that 2017 will be the first year when reporters will report both non-GHG pollutants and GHGs simultaneously.

- **Chile's** system incorporates a voluntary GHG reporting module into the Pollution Release Transfer Registry (PRTR). The modular registry system is programmed with Programming Software Linux Cemtos 6.5, Kernel 2.6.3X in PHP 5.3.3 and PostgreSQL 8.4.20.
- **Kazakhstan's** system allows for the calculation or data collections modules to be switched on and off. In addition, verification processes are under development and will be integrated in a form of a module with the time. This incremental approach has allowed Kazakhstan to add on to the system without having to re-design the core structure.

3.3.4.3. Configurability

A unique characteristic of **Australia's** GHG data management system is that it was designed to be configurable: the configuration engine allows anyone with the right level of access to make changes to some parts of the system without having to code them. For example, the majority of their calculations are part of a "configuration engine," which is essentially a large spreadsheet containing all the formulas. Whenever the legislation is changed and emissions factors, etc. are updated, staff with the correct level of access are able to make the required updates. This is as opposed to requiring a developer to make a code change. In addition, there are a number of text fields that can be easily updated, rather than requiring code changes.

Australia's experience is that being able to make changes without having to change the code results in an overall reduction in time, cost and effort. This is another consideration when developing a nimble and flexible system.

3.3.4.4. Data Upload and Input

There are a number of ways in which emissions data can be input into a GHG data management system:

- **Option 1:** Manual entry of data into a web interface
- **Option 2:** Manual entry of data into formatted spreadsheets, uploaded into the system
- **Option 3:** Integration of separate data sets via web services (linking systems)

Each option above requires some element of data validation and mapping, and may require or allow for data transformations.

Detailed descriptions of the options are provided in the following sections.

3.3.4.5. Data Validation, Mapping, and Transformation

When automatically integrating (or loading) large data sets from one web system to another, the data must be validated, mapped, and possibly transformed to ensure that it is in the correct format when it is received by the system. These processes can be defined in the functional requirements document.

Data Validation

The data validation process ensures that incoming data is correct and usable by the system. A data validation system will:

- Define data rules (including data types such as GHG nomenclature, specific units of measure or date/time, field sizes, defined by number of characters and table properties).
- Reject any data that defy the rules.
- Trigger an on-screen error message or email, notifying the user of the validation error.

Once incoming data has gone through validation, it can be mapped and/or transformed to match the formatting and database schema requirements of the system.

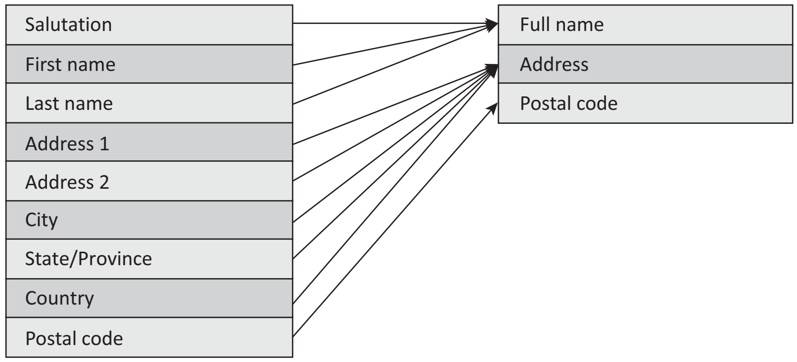
Data Mapping

In order to integrate data from spreadsheets, .csv files or XML feeds or APIs into a GHG reporting system, incoming elements must be mapped to the destination system database for storage or use in calculations or analytics.

Data mapping establishes the relationships between terminology in data fields that may be mismatched (i.e., “raw data” equals “activity data”). Data mapping can be facilitated by the assignment of “keys,” which are unique numeric or alphanumeric codes that identify unique data, such as an individual person or facility, or a code that represents multiple data (i.e., facility name plus sector plus city).

The mapping process may be complicated by one-to-many (one item of incoming data is represented by many items of data in the new system) or many-to-one (many items of incoming data are represented by one item of data in the new system) relationship requirements. A single column of incoming data may

Figure 5. Illustration of Many-to-One Mapping



need to be dispersed into several columns in the destination database (one-to-many), or multiple columns of data may need to be condensed into a single column in the destination database (many-to-one). Figure 5 illustrates a simple example of many-to-one mapping.

Data Transformation

After data has been either manually entered or mapped from previously existing data sets, the data can be transformed as needed. The level of data transformation required by the system will depend on the type and granularity of that data that is input and the output values prescribed by the program requirements.

Transformation may refer to simple changes in data formats (e.g., scientific notation to decimal values, aggregation of data, established number of significant figures) or to larger transformations such as a calculation engine converting activity data to emissions data (see Section 3.3.4 for more information on calculation engine functionality). The functional requirements document will dictate the development of functionality that will facilitate the data transformation.

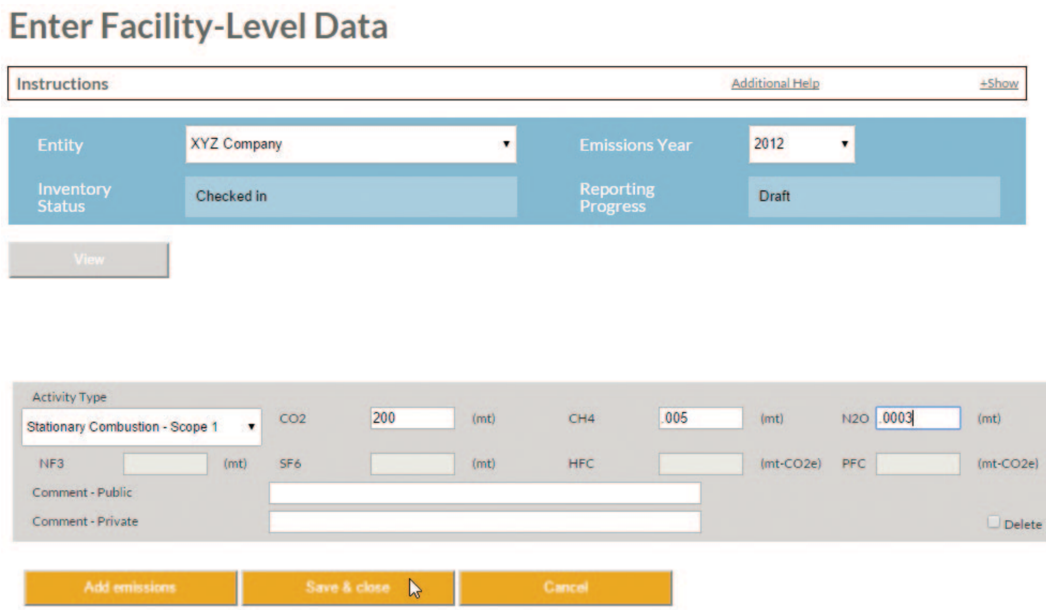
3.3.4.6. A Closer Look at Option 1: Manual Input into a Web Interface

Using a web interface, users are required to input their data into online fields on various web forms, and are typically taken through a series of steps to complete their facility/corporate-level GHG inventory. These steps may include entering source and facility-level data, as shown in figure 6 below. Data entry through web interface 1) allows for immediate data validation, 2) removes the need for data mapping, and 3) allows varying levels of automated data transformation. This allows users to enter data in multiple formats and at varying levels of granularity.

3.3.4.7. A Closer Look at Option 2: Integrated Upload to a Web Interface Using Formatted File Types

Large sets of pre-existing data that are contained either in Excel or XML spreadsheets or text files can be uploaded to a GHG data management system. This can be a faster and more nimble approach, since web forms require significant development effort and time—particularly where conditional logic is required to establish page-to-page workflow—and are more challenging to modify after they have been completed. Formatted Excel or XML spreadsheets can be used as a lower-cost transitional tool to allow for the user feedback and system validation before developing a web-based system.

Figure 6. Example of a Web-Based Form in The Climate Registry's GHG Data Management System



Source: TCR 2015.

Examples of this approach include:

1. The **U.S.** system allows reporters to submit data for certain source categories (where the associated data collection was fairly simple or more amenable to spreadsheet data entry, i.e., involving dozens or hundreds of rows of similar data) via a Microsoft Excel spreadsheet template as opposed to a web form. This approach expedited the software development process and also provided more flexibility with respect to accommodating changes as a result of the ongoing rulemaking process. Additionally, reporters have the option of uploading XML files to report their data.
2. In addition to a comprehensive web interface, **California's** system allows data uploads as XML, from a standard spreadsheet provided to reporters by ARB into its database for specific sectors with more complex reporting requirements, such as oil and gas and electricity importers. This approach was less costly and time-consuming than incorporating all of the necessary fields in the web interface. In addition, California found that users preferred to use the spreadsheets, as opposed to a new interface in the system; and the spreadsheet upload process allowed for much more flexibility and responsiveness in the face of a number of policy changes in a short period of time. For more complex sectors, the XML proved an easier mechanism to change and adapt than a traditional table structure in a web interface.
3. **Chile's** system allows users to upload formatted text files into the database.

Key considerations when developing integrated upload functionality include:

- Format the spreadsheet or text file as specifically as possible to direct the consistent inputting of data into the database (e.g., define all column headers).

- Allow for comprehensive data validations to ensure that the system will not accept data with errors, but will also not be too restrictive such that it will not accept “good” data.
- Employ rigorous security provisions to mitigate the risk of viruses, malware, or other hacks.

3.3.4.8. A Closer Look at Option 3: Integration of Separate Data Sets via Web Services

If the GHG data management system is being built to exchange data with another system, such as a non-GHG pollutant system or an energy management or fuel tracking system, the exchange must be well-defined in order to ensure that the system linkages are accurate and complete, including:

- Data definitions and database schema from each system to be linked.
  - Data definitions are unique IDs or “keys” and definitions for formulas (e.g., surname = last name, entity year = emissions year).
  - Database schema refers to the formatting or skeleton of the database and its rules. There are rules for the type of data available in each column of the database, as well as the type of data that can be accepted in each column (e.g., the column accepts text values only).
- How data will be mapped (see Section 3.3.4.5).
- Method for how the data will be exchanged (e.g., APIs, XML feeds, or other web services).
  - In order to facilitate data exchange, tagging should be considered and coded at the onset of the integration process. Tagging allows for additional granularity in reporting so that comparisons can be made between data sets, reporting periods, or when changes in scope are made. Tagging can also help to differentiate between reported data and GHG national inventory data.
  - Regions take different approaches to tagging. For example, the **United States** uses XML, and while the **United Kingdom** currently uses XML as well, it has proposed to use the EU ETS eXtensible Emissions Trading Language in the future. The EC will be using XML V1.1, which has data validation capabilities, in the future. Using metadata-tagging conventions such as XBRL can increase the fungibility of GHG data with other business data, such as financial information.

In terms of system integration, **Chile** integrates GHG and pollutant data collection efforts through web services using Simple Object Access Protocol (SOAP) technology, a messaging protocol that allows programs running on different operating systems (OS; e.g., Linux and Windows) to communicate (TechTarget 2014). Text files with defined formats are uploaded through a single web interface/portal, which allows reporters to access and manage their information for both programs. Data exchange can also be facilitated by XML, which defines the rules for documents, such as a document containing GHG input data, by which an application should read/import that data. Reporters access the centralized web interface with an identification number and password, and can then view a survey—based on their identification number—that indicates what they are required to report. This is illustrated in figure 7.

Australia’s system was designed to be a single national reporting framework for the reporting and dissemination of information relating to GHGs, energy consumption and energy production above certain thresholds. The data is exchanged between government agencies through a centralized web portal and is intended to be integrated with other agencies’ information systems in a manner that best suits the needs of that agency.

Figure 7. Screenshot of Chile's Centralized Web Interface

Source: Ministry of the Environment (Chile) 2014.

South Africa's system is being built in three phases and will support the reporting of GHGs as well as non-GHG pollutants, such as sulphur dioxide (SO_2) and particulate matter (PM), in support of its national inventory process, by 2017. In order to build an integrated system with differing datasets, South Africa identified that defining a framework for data transformation was key, after which common input activity data can be used to generate emissions estimates for air quality and climate change. The framework dictated which data was tagged in the front end; activities that had to be summed and linked to different source categories, the GHGs, and the non-GHG pollutants were then linked to specific calculation methodologies in the system. South Africa found that, in most cases, there was a direct link between air quality-listed activities and IPCC source categories, and this link underpinned a detailed mapping activity between the two. The mapping was then used to develop algorithms.

South Africa also built a data mining tool into the infrastructure. The tool is similar to the Microsoft Locator tool, which they had been using for its national GHG inventory; they chose to design and develop the tool in-house with the support of an IT service provider since they did not find the Microsoft tool user-friendly or easily accessible. However, South Africa has also recognized that the GHGs associated with some of the IPCC sectors, such as waste, will have to be computed outside the system, and the emissions data fed into the system in a way that will allow it to generate summary reports.

While integration and/or exchange between data collection systems can often benefit reporters by reducing duplication and reporting burden, some jurisdictions identified a number of challenges associated with this—and, in some cases, good reasons for keeping data collection efforts separate.

Mexico built an integrated system that will collect both GHG and non-GHG pollutant data. The data will feed directly into the national GHG inventory system and the national toxic release inventory. The decision was made to develop a single, centralized data repository and issue a single report for all companies as a result of stakeholder concerns about potential double counting and reporting burden. The system requires information from activity data as well as emissions. A key priority in the development process was specifying the functional requirements to warranty an “ease of use” software that complies with the National Digital Strategy, and differentiated reporting obligations for all the sectors obliged to report.

In the **United States**, some states define their GHG reporting requirements as “all the data U.S. EPA collects” plus additional data elements and a lower emissions threshold for reporting. This is the case for the state of Washington, where the reporter can download an XML file from the U.S. system to submit to the state. While the United States does not directly transfer these data to the states due to CBI regulations, the reporter can access the reported data, download it in XML format, and then resubmit it to the state of Washington.

While the initial intention was that **California**’s GHG data would feed into the U.S. GHG data management system, and therefore reduce the burden on reporters, this proved challenging and no exchange is currently taking place. While California’s system is based on the U.S. system (see Section 3.4.3), the output is different due to a divergence in reporting requirements: the national, EPA reporting program s only requires a subset of California’s data, and in some cases it also uses different definition, GWPs, emission factors, and missing data provisions, so it would be a significant undertaking to align systems in such a way that would make data exchange possible.

In addition, California has no plans to link its GHG data collection efforts with its criterial pollutant data collection, primarily due to the fact that a significant amount of market-sensitive and business-sensitive data is collected that cannot be shared. California acknowledges that this sensitivity relates directly to the cap and trade program it operates, and that this type of exchange and linkage may be more feasible in jurisdictions without a market mechanism in place.

Finally, there is no data exchange between California’s GHG data management system and its official market system, in which the cap and trade participants in California and Quebec hold compliance instruments. The market system remains separate due to the need to protect the data (traded instruments with financial value) from security issues that could arise from having open portals with other systems. The market system also requires individual account holders to go through a know-your-customer process prior to receiving an active account, a process that deemed unnecessary for emissions reporting. From a GHG reporting perspective, California has statutory requirements in place with respect to handling CBI data received under its reporting programs. Accessing this CBI data within an integrated data management system would not only be unnecessary, but it is a potential liability for California.

Some jurisdictions, such as **Massachusetts**, indicated that, in some cases, statutory language directed that GHG reporting be set up independently. Others, such as the **United Kingdom**, suggested that the mandate to deliver a GHG data collection system within a tight timeframe prevented the consideration of and integration with other carbon and energy policies that were introduced before and after GHG reporting. This was exacerbated by a "silo" effect, in which different governmental departments were accountable for different policies and implemented them in isolation. The United Kingdom is currently pursuing a more integrated approach for energy efficiency, and the GHG mandatory reporting policy was tweaked to take into account other policies. In general, the United Kingdom accepts GHG data that is reported for other programs, but the systems are not integrated.

Table 8 provides a summary of data input and upload options, as well as the benefits associated with each.

Table 8. Comparing Data Input and Upload Options

Option	Data input type	Ease of data entry (varies with data granularity)	Likelihood for error	Automated data validation	Automated data mapping	Automated data transformation	Time and resources to create (varies with level of transformation)
1	Manual entry of data into web interface	Intensive	Intermediate	✓	✓	✓	Minimal–Intensive
2	Integrated upload	Intermediate	Intermediate	✓	✓	✓	Intermediate
3	Integrated web systems	Minimal	Minimal	✓	✓	✓	Intensive

Table 9 itemizes and provides examples with respect to the challenges and benefits of integrating GHG and air pollutant reporting in a single data management system.

3.3.4.9. Key Considerations for Choosing Data Input Options in Web-Based Systems

In addition to analyzing existing data sets and data input options based on available resources and program needs, there are two key considerations that will directly impact the amount of data transformation that is required:

- The format of data sets that will be manually entered or integrated into the system (e.g., granularity, activity data vs. pre-calculated emissions data, units of measure versus the desired data outputs (see Section 3.3.4.10).
- The existence of a calculation engine that supports the necessary data transformations (see Section 3.3.4.11).

Table 9. Challenges and Benefits of Integrating GHG and Air Pollutant Reporting into a Single Data Management System

Benefits	Challenges
Ensures the **consistency/comparability** between the different reporting obligations. Example: In Europe, reports can be used for the following regulatory obligations: UNECE (air pollutants reporting obligations at national levels), UNFCCC (GHG emission inventories), LCP (SO_2, PM and NOx emission inventory for Large Combustion Plants above 50 MWth), ETS (CO_2, N_2O and PFC emissions for installations covered by EU-ETS such as combustion plants above 20 MWth, refineries, metal production such as steel or aluminum, mineral product production such as cement, chemical production such as ammonia, etc.), PRTR (covering emissions when above certain thresholds, Solvent Management Plans (for installations consuming solvents), etc. This consistency is based on the following items: • Data collection/Monitoring: for most of the pollutants, the same data or source of data (quantity of products used or produced, quantity of fuel burned, etc.) is used to estimate GHGs and air pollutants; • Reporting: all emissions are reported by the same expert (plant manager) in the same tool/ database. This avoids mistakes in the reporting process; and, • Verification (QA/QC): checks are usually performed by the same expert (e.g., internal checks, independent checks, local authority) and are conducted for all the pollutants in parallel. The verifier can check the consistency and the comparability of the emissions.	Difficult to reconcile differences between the different reporting obligations, such as: • Differences of perimeters: according to the report considered, only some or all the appliances of a specific site have to be taken into account. For example: For ETS obligations, only GHG emissions (CO_2, N_2O or PFC) of appliances covered by the ETS system have to be considered while all GHG emissions have to be reported under PRTR; For LCP obligations, only NOX, PM and SO_2 emissions of combustion appliances with a power rate above 50 MWth have to be reported. One way to overcome these differences is to split the report according to the different appliances. As a result, plant reports can be very complex. • Differences in time schedule: dates of reporting might be very different according to regulations: there is one year between the PRTR report date and ETS report date. The integrated approach requires reporting all emissions according to the most restrictive date for the site. Effectively, in practice, it is too complicated in terms of data management to report emissions at different dates for the same installation. • Differences of the units used: units used to report emissions are different according to regulations (e.g., tons for ETS report and kg for PRTR reports).
Increases the efficiency of the data collection: to fulfill regulation reporting requirements, a lot of data is required at a plant level. This might require significant technical work and the development of specific monitoring tools, so it can be time-consuming for plant manager. A substantial amount of this information is the same between the different needs (quantity of products or fuel burned, description of appliances, general description on the site, plant manager and the owner, etc.). It saves time to collect and report common information only once.	

3.3.4.10. Granularity of Data Inputs and Outputs

Functional requirements specify the level of granularity of the data being input into the GHG data management system versus the required outputs (see Section 3.3.4.14).

Key things to consider for data input formats:

- Activity data versus emissions data: some program requirements may require some types of raw data or non-default emission factors to be reported, in which case it is not appropriate to allow for input of pre-calculated emissions totals.
- Level of aggregation, i.e., source-, facility-, or entity-level data: if program requirements specify the need for data output specific to a given source type (e.g., combustion versus process emissions), it is not appropriate to allow the input of aggregated facility emissions totals.

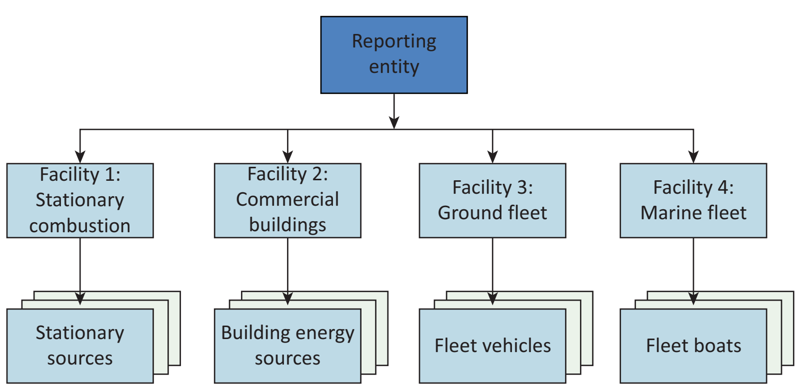
The data output specifications are typically defined in regulations and guidance documents, and may not map perfectly to data entry methods; in these cases, data transformation will be required. For example, a GHG data management system that supports regulations which require final GHG emissions reports to be broken out by facility or source details and to include activity data in addition to emissions data should not allow for the input of pre-calculated, entity-wide emissions totals.

As displayed figure 8 below, GHG data management systems will generally allow for data aggregation but not disaggregation. Therefore, the most granular data entry method that is the least possible burden to the reporter is typically the best option.

3.3.4.11. Calculation Engine

A calculation engine is used to transform data within a GHG data management system. Data that is pre-calculated and aggregated into the appropriate UOM offline can be entered into the system without further transformation. Although this method of data input removes the need for a calculation engine, and therefore requires less development, it also results in decreased transparency, consistency, and ability to ensure data quality.

Figure 8. Illustration of the Hierarchy of Corporate-, Facility-, and Source-Level Data in System Architecture



Alternatively, when raw activity data is entered or uploaded to the system by the reporter, emission factors and GWP values are required to transform the data into the appropriate format. Transforming the emissions data and reporting in CO_2e does not preclude the system from also reporting emissions data by individual GHG; this is often dictated by the reporting program. After activity data has been manually entered by the reporter or integrated from an existing data set, the GHG system can be used to calculate the amount of unweighted (mass of) GHG or CO_2e emissions associated with each activity.

If a calculation engine will be used to support the transformation of activity data into emissions data, a key decision will be to determine whether to store emission factors, default heat (calorific values) and carbon contents, and GWPs directly in the system. Alternatively, these data sets can be provided offline and the conversion factors can be entered manually by the user before the system completes a computation. Loading default emission factors and GWPs, including default heat and carbon contents, into the system may be substantial work upfront during system development, but this decreases the burden on reporters and verifiers, reduces the possibility for error and compliance issues, and can ensure that consistent emission factors and GWP values are used by the reporter. Regardless of the approach chosen, the activity data will be stored in the system.

If emission factors, default heat and carbon contents, and GWPs will be stored directly in the system, a further consideration includes whether to provide the ability to update these factors directly in the system's user interface. If so, this functionality will ensure that the GHG management system maintains consistency with program requirements, such as consistency with updated IPCC guidelines, and GWP requirements, and contains the most up-to-date default factors available. As an alternative to developing an automatic update feature, updated emission factors and GWP tables will need to be created offline, formatted appropriately, mapped to the system database, and transformed as necessary by developers to accommodate each update.

There are several examples illustrating approaches to and challenges of system calculation engines. The **Australian** system applies default emission factors according to program requirements. Reporters also have the option to customize emission factor values that are not incorporated into the system. Lower tier calculation methods built into the system allow for default emission factors to be used, while higher tiers require more specific values. Depending on the sector and emissions source, the reporter may be required to enter additional variables into the system, generating a customized emission factor. The system configuration engine stores the default emission factors and calculation methodologies, and is used by system administrators to update these values during yearly system maintenance.

As another example, in **California**, reporters enter data into the system. Acceptable default emission factors, which are defined by regulation, are built into the system, but reporters can override these and customize their own values, subject to verification that the reported emission factor meets the requirements of the Regulation. The default values are stored in a table within the database, but are not frequently updated according to program requirements. The California rulemaking process prohibits updating of emission factors or GWP values without regulatory approval, which ensures the values are fully vetted through an open stakeholder process. In addition, since California's system supports cap and trade, it may be challenging to update these values as they may affect historical emissions data. These types of constraints are important considerations when determining how to incorporate emission factors into the system.

In the **United States**, year-specific default emission factor values are written into the regulatory rule, stored in a database, and can be updated by EPA as needed. For incorporating GWP values, the United States first used values from the IPCC Second Assessment Report. These values were set up in database design and drawn from a table, similar to default emission factors. Beginning with the 2013 reporting year, the United States used values from the Fourth Assessment Report (AR4), and the year-specific emission factor values stored in the system allows older, pre 2013 reports or resubmissions to be calculated using AR2. All published data is converted to AR4 values for a continuous timeline, although actual emissions, as submitted (AR4 or AR2 depending on year) can be looked up by the public.

3.3.4.12. Document Management

GHG data management systems often allow for the uploading of a range of relevant supplementary documents (required and optional) where core reporting functionality is not yet available, or to provide more contextual information to complement the data that has been entered in the system. Supplementary documents may include:

Documents relevant to GHG MRV, such as:

- Verification statement
- Monitoring and management plans
- Reporter certification statements
- Reporting exclusions forms (i.e., in cases of a de minimis threshold or reporting exclusions provision in the GHG reporting program)
- Offset reporting form/s (to establish quantity of offset tonnage)
- Base year documentation
- Utility-specific emission factor template
- Calculation spreadsheet/s

Policy related documents or information, such as:

- Renewable Energy Credit (REC) certification document
- Offset certification document

Contextual documents relevant to reporting organizations, such as:

- Organizational chart/s
- Climate, carbon or inventory management plan
- Other corporate documents

Once these documents are uploaded, a GHG data management system may handle them in a number of ways, such as:

1. Allowing preview functionality for certain types of documents
2. Associating the documents with specific data within the system
3. Only allowing for re-download

Although documents are typically stored within the system, the data contained in those documents often remains static and separate, and is not integrated directly into a web application. Examples of this include the **U.S.** system, **California's** system, and **Thailand's** reporting program. In **Turkey's** system, uploaded documents can be linked to sections within the emissions plans and reports, such as procedures, measurement devices, source streams, and calculation methods. The competent authority and verifiers can access and download the documents during the inspection process.

3.3.4.13. Quality Assurance and Quality Control

QA and QC provisions ensure that high quality, accurate, consistent, and complete data are reported in accordance with the Transparency, accuracy, comparability consistency, and completeness principles (TACCC) principles. The extent to which QA/QC elements are incorporated into a GHG data management system is a function of several factors:

- Program objectives and design determine how detailed and accurate the data need to be. This may be different, for example, for a data management system designed to support a national inventory versus a cap-and-trade program.
- Budget for developing numerous internal checks.
- Institutional capacity for conducting QA/QC activities.

Germany's system performs cross-checking and plausibility checks with their national inventory. While there is no linkage between systems due sensitive business information (SBI), the cross-checking provides a level of QA.

Quality Control

Quality control refers to procedures undertaken by reporters, program administrators, or internally by the system itself prior to submittal of the GHG report.

The degree of QC is determined by the reporting program requirements and continues through the chain of activities from data collection, quantification, reporting, and verification. This can include:

- Providing default emission factors and calculation methodologies in the system (see Section 3.3.4.11).
- Prescribing acceptable levels of uncertainty.
- Performing internal system checks before submission.
- Automated sense checking, such as range checks (confirming a numerical response lies within an expected range) and completeness checks (such as requiring data fields to be completed before the user can move to the next stage) in the system itself.

- Performing checks between data reported for one year and the previous year to highlight potential errors.
- Requiring self-certification by the reporter.

In the **United States**, submitted data has already undergone substantial QC during data entry into the system through real-time feedback to reporters. Each submission is evaluated against a substantial array of electronic checks that "flag" potential errors, which are summarized in a report. Review of these reports is then conducted manually and electronically by subject matter experts, depending on the sector and source categories. Program administrators then decide what flags are significant and require correction (U.S. EPA 2015b). Validation and verification checks used by the United States include:

- Completeness: Check evaluating whether all relevant quantitative and qualitative has been included.
- Statistical: Check assessing whether specific calculations fall within the expected range for a particular reporting element (e.g., activity data). Year over year: Check comparing a reported value to that of previous reporting periods.
- Range: Check gauging whether a reported value falls outside of a given quantitative range.
- Algorithm/logic: Check assessing the compatibility of input selections and reported values.

The **United Kingdom's** system includes uncertainty values, i.e., narrowly defined data entry fields, to reduce the number of input errors, and built-in emission factors to minimize calculation errors. There are also some semi-automatic checks in the system that flag unusual data, e.g., checking data against the previous year. The United Kingdom acknowledges that adding more controls will improve the quality of the data, but this benefit needs to be balanced with the added cost to the administrator and complexity for the user.

Australia has been working on incorporating more validation checks into its system. Australia contends that more checks will help to promote voluntary compliance, improve the quality of the dataset, and reduce the government's need to follow up with reporters on what are easily-avoided mistakes in submitted reports.

Quality Assurance

Verification refers to QA activities that take place after the data has been submitted by the reporter. It can include internal review by program regulators (in-house) or verification by an independent third-party. Internal system checks are covered in the Quality Control section above.

When developing the functional requirements for verification, the initial decision point is whether verification will be conducted in 1) the same GHG data management system as reporting activities, 2) an independent system, or 3) offline. This decision could be dictated by regulatory, reporting guidance, or CBI requirements.

Using a common system for reporting and verification has several advantages, including more robust QA/QC, since the same data set is being used for reporting and verification. The same data set could also be used if data is exported from the system and the verification is conducted offline. However, this may be more time intensive and less transparent.

If verification is integrated into a GHG data management system, the workflow and required functionality will in part be prescribed by the reporting program requirements. For example, in programs that require self-certification, the system should include functionality for the reporter to upload a self-certification statement. In programs that require third-party verification, the workflow permissions for reporters, verifiers, program administrators, system administrators, and regulators must be explicitly defined. Figure 9 represents an example of how verification workflow is incorporated into Thailand's GHG data management system.

The deadline for reporting is typically 3–6 months after the fiscal or calendar year closes, and corresponds with the first step in figure 9. The verification deadline is typically six months after the reporting deadline, and corresponds with the fourth step in figure 9. The intervening steps vary by company and verifier.

Thailand's system enables third-party verifiers to access and review completed emissions reports that have been submitted in the system, and then move these reports through a verification workflow before the reports are accepted and published by system administrators. The workflow includes the following steps (illustrated in figure 9) (USAID 2015):

1. "Locking" the report so that no other changes to the report can be made during verification.
2. During the process of verification, the verifier can use the system to request corrective action if they identify any errors.
3. Once all necessary corrective actions have been taken and verification is complete, the verifier submits the report to the system administrator.
4. The program administrator can then review the submitted report and submit the signed verification statement.
5. The regulator then accepts and publishes the final report and verification statement.

In **South Africa**, QA occurs at multiple levels and is performed within the system. For GHG emissions, data is reported to the statutory regulator who performs audit checks internally. Verification for large emitters and companies who use carbon balance methods must disclose their worksheets for review. For non-GHG emissions, the system contains internal checks such as range, completeness, and year-over-year checks. During each district's audit, if their reported value is below a determined threshold, the system

Figure 9. Example of How Verification Workflow Is Incorporated into a GHG Data Management System

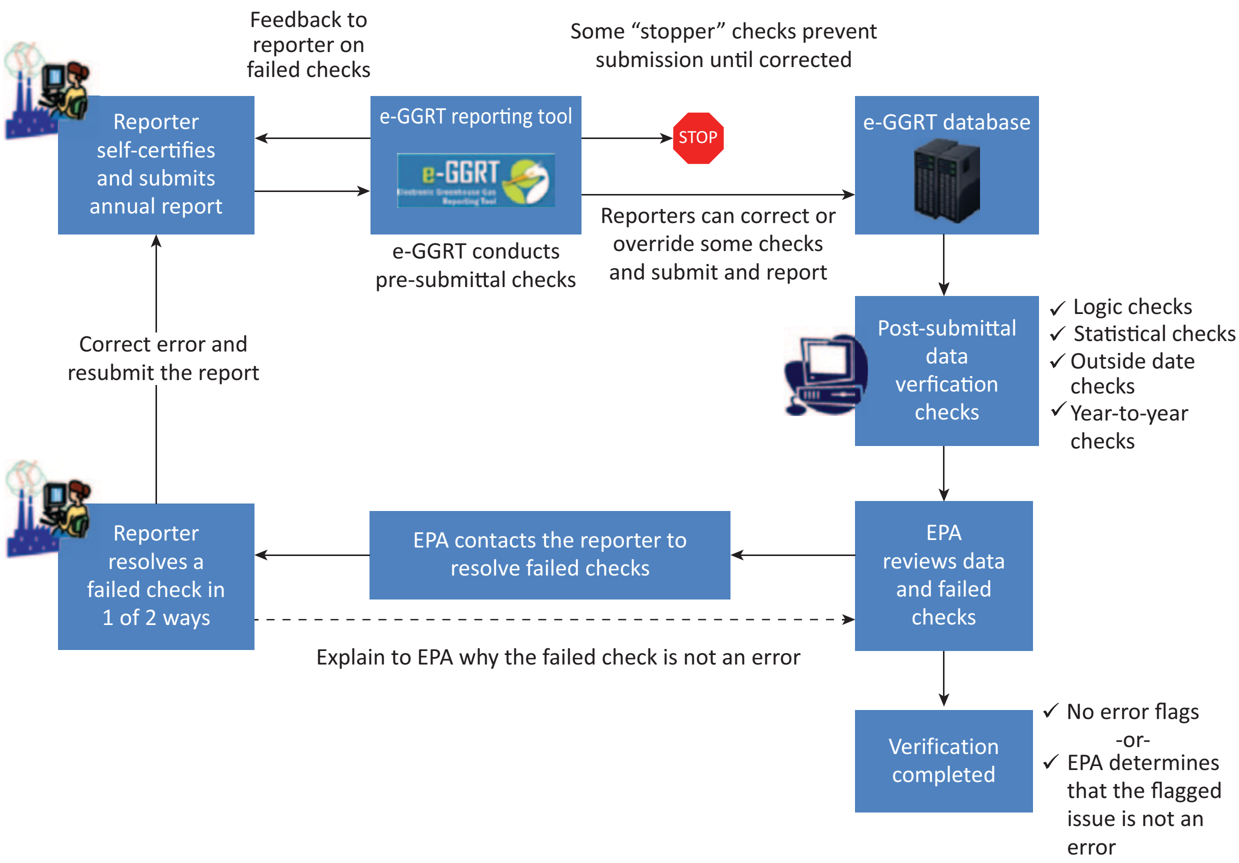
[a] Only inventories which are specified as public.

will recommend an on-site audit or request for additional information to justify the report. The local authority is then responsible for any outstanding issues.

Massachusetts integrates its third-party verification process into their system. Program administrators are responsible for managing verifier user roles and, after a report has been approved by a verification body, the program administrators also conduct a final check of the verification report. When the administrator accepts the report, all documents marked to be released publicly are made available.

The **United States** contends that another way of supporting high-quality data submissions is to provide real-time data quality feedback to users before they submit their reports. Its system uses Validation Language (Valang) to run data validation on any data entry field in the application. Valang is an open source module within Java's Spring Framework that enables the easy expression and use of validation rules that are incorporated into metadata files accessed by the software application. Use of Valang enables the development team to work with EPA's subject matter experts to efficiently develop, incorporate and edit data quality checks within the data management system. Figure 10 illustrates the complete QA/QC process in the United States.

Figure 10. QA/QC Workflow in the U.S. System



Source: U.S. EPA 2015b.

3.3.4.14. Report Generation and Data Export

The functional requirements should describe the types of reports that will be produced by the system, and which user types can generate them. The types of reports that are produced will be determined by:

- The GHG reporting program requirements,
- The level of detail required to be reported,
- Confidential or SBI concerns (see Section 2.2.1), and
- The granularity of data entered.

The GHG reporting program requirements will determine and define the types of reports that will be produced by the system, and which user types can generate them. Table 10 lists a number of report options and their relevance to key stakeholder group/s.

Reports may also be based on industry sectors or jurisdictions. **South Africa's** system, for example, generates default reports on the front end: emissions by sector, gas, and jurisdiction. Where there are very few reporters (less than three) in the sector, reports will aggregate to the next-higher level.

Most database software packages have reporting tools that will offer different export file formats, such as .CSV, .XLS and PDF. For example, Microsoft SQL, which uses SQL Server Reporting Services (SSRS), offers a

Table 10. List of Potential Reports and Their Relevance to Specific Stakeholder Groups

	Regulator/ policy maker	Reporter	Verifier	Public and other stakeholders[a]
Detailed report: entity-wide report with breakdown by facility and sources	✓	✓	✓	
Summary report: entity-wide report that includes summary totals of emissions only (no activity data)	✓	✓	✓	✓
Facility report: detailed list of sources in specific facilities	✓	✓	✓	
Reports by boundary: • Geographic (global vs. national) • Organizational (control vs. control plus equity share) • Operational (direct vs. indirect)	✓	✓		
Data extract: export of data in an excel spreadsheet		✓		
QA reports: checks against program requirements and thresholds	✓	✓	✓	
Administrative reports: • Reporter statistics • Total reported emissions by year	✓			
Benchmarking reports, e.g., by region, sector, etc.	✓	✓		✓

[a] Non-government organizations, academia, peer groups interested in benchmarking.

variety of export options. In addition to file format export capabilities, SSRS can create data visualizations including charts, maps, and spark lines.

Turkey's system enables monitoring plans and emission reports to be converted to a PDF file that is digitally identified with a QR code, which is a unique identifier. Since the PDF is static and the database is dynamic, the QR code is important to link the data back to the database and any changes that have been made since the PDF was produced.

For open source MySQL databases, there are a range of free and commercial reporting tools, such as ReportServer (free), NextReports (free) and JReport (commercial) that developers can employ for data export, visualizations and other uses. Some of these packages may require additional third-party plug-ins to export to specific formats, such as PDF.

3.3.4.15. Data Confidentiality Requirements

Data confidentiality requirements will vary from program to program, although most GHG programs will have provisions for protecting CBI or SBI, as well as personal user information.

The statutory regulator is responsible for identifying what information will be considered CBI both for inputs/reported data and outputs/data publication prior to system development. The functional requirements should describe and define all data or report types as being public or private (protected). If private, user types that will have access to the reports should be listed. A user's access to CBI can be restricted based on his or her log-in credentials.

Security requirements pertaining to the GHG data management system itself should be defined in detail in the technical requirements (see Section 3.5.6).

3.3.4.16. Analytics

The functional requirements should describe any analytics functionality that will be included in the GHG data management system. An analytics layer can allow for data to be retrieved for display in dashboards or reports that contain tables, charts, and other data visualizations (e.g., pairing facility emissions data with geographic information systems [GIS], such as the Google Maps) within the application.

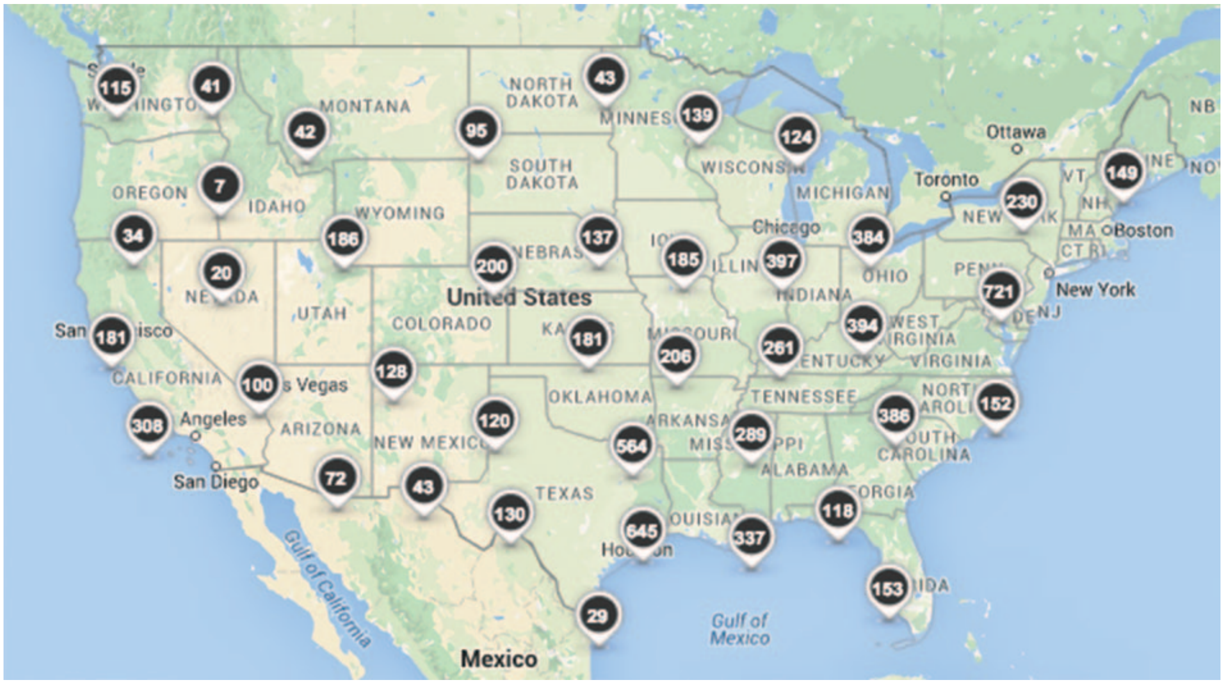
Another option is to export data via APIs or XML to external analytics applications. For example, the **U.S.** system exports data that is then integrated with Google Maps to support its Facility Level Information on Greenhouse Gases Tool (FLIGHT), as shown in figure 11.

Turkey's system incorporates query and statistical analysis tools that allow emission factors, GHG emissions, and facility groups to be queried and converted to Excel or PDF reports. The Excel export feature enables the competent authority to customize analyses and reports.

3.3.4.17. Language Requirements

Functional requirements define all necessary languages that will be accommodated in the GHG data management system, which sections of the system and which supporting materials (e.g., user guides and supporting documents) will be translated, and how users will access different language versions of the system.

Figure 11. Screen Shot of U.S. EPA's FLIGHT, Integrated with Google Maps



Source: U.S. EPA 2015c.

3.3.4.18. User Information

Key data elements to be defined in functional requirements and included in user account/account settings include:

1. Basic user information
2. Username (may be email address)
3. First name/last name
4. Email address (if different than username)
5. Contact information
6. Security information
7. Password reset
8. Other security checks (i.e., security questions)
9. Usage information
10. Activity history
11. Alerts/messages

It is also necessary to determine where users will link to their user accounts on the home page or navigation (header, persistent above-header, footer), and how this link will be presented (icon, text link, thumbnail image of user, or company logo).

Standard practice among popular web portals (e.g., Google, Yahoo, and Amazon) is to display a link to user account details in the upper right corner of the page in a persistent header.

3.3.4.19. Communicating with Users within the System

To support transparency within the system, the functional requirements can define notifications and alerts for the various user types. For example, automatic notifications can be sent to:

- Regulators when reporters submit reports for verification.
- Reporters when verifiers submit corrective action requests or when program administrators accept reports as verified.
- Verifiers when reporters submit reports for verification or when reporters submit corrected reports.
- Reporters or public users when reports are made publicly available.

3.3.4.20. System Documents

The functional requirements should define where system documents are housed and how the user will access them. System documents are different from user-uploaded documents in that they a) house information about the system or related regulation, and b) do not contain user-submitted data or information. Common practice is to house these documents as stand-alone web pages or PDFs, and to link to them from the footer.

System documents will vary based on the specifics of the program, but common document types include:

- Legal disclaimers,
- Terms of use,
- Information on data exporting options, such as API documentation, and
- Forms, applications and surveys.

3.3.4.21. Relevant Regulations and Legislation

If the GHG data management system is housed within another website (for example, a regulator's), that website will likely also house the relevant GHG regulations and legislation. If the system is a stand-alone site, the relevant regulations and legislation should be housed on separate web pages as PDFs, or accessible via a link from the main navigation or footer in the system to the relevant section/s of the external website. These documents may include:

- Reporting regulations and guidance,
- Voluntary reporting protocols or guidance, and
- Verification protocols or guidance.

3.3.5. System Design Requirements

Regardless of whether the software is developed in-house or through outsourcing (see Section 3.4), it is important to clearly define any system design requirements (also called a "style guide") in order to ensure consistency with regulator/program administrator branding. System design requirements can be included in the functional requirements or incorporated into a separate document that is referenced in the functional requirements, and should include guidance on:

- Logo and logo usage,
- Fonts and typography,
- Colors,
- Images, and
- Text and tone.

3.4. Step 3: Making the Decision to Develop In-House or Outsource

There are a number of approaches to consider for developing a GHG data management system:

1. Developing a new system in-house or using external resources
2. Re-purposing an existing system
3. Customizing a third-party system

This section will focus on key considerations for choosing between these approaches.

3.4.1. Developing a New System In-House or using External Resources

Developing a new GHG data management system entirely in-house can be challenging, given that it requires extensive budgetary and human resources and deep expertise in designing and developing systems. **Kazakhstan** claims that one of its key lessons learned from building its system in-house was that it had no feasibility study or terms of reference, and did not have the right expertise in-house to understand that principles of data processing, data calculation, and workflows. However, developing a GHG data system in-house can be preferable if there are unique needs and functional requirements associated with the system, and if the in-house development team has the requisite skills and experience.

In other cases, countries may choose to collaborate with an external provider (either local or international) to develop and implement a custom-built system. For example, the **United States** contracted with SAIC; the **United Kingdom** contracted with SFW; **Mexico** contracted with National Institute of Geography and Statistics; and **Australia** contracted with Microsoft. This is a good option for jurisdictions that have the time and money to invest in system development, and that similarly have unique and specific needs and requirements.

Australia's system was tailored to its unique requirements and governing legislation, and was built to ensure that system updates could be managed without the long lead times and high costs required by the previous system. Responsibility for ongoing maintenance of the system was transferred to the Clean Energy Regulator during the first reporting period (2012–13). Ongoing maintenance and development is now conducted in-house within the agency and occurs on an annual cycle. This process involves several steps and several skilled staff including business analysts, an application architect, subject matter experts, and software developers.

Taking into account existing international experience and systems, **Turkey** opted to design its system in-house. Such approach is expected to help build and internalize local capacity and thus facilitate the process of future revisions and updates of the system. The most significant initial challenge was identifying the experts to design and develop the system; they concluded early on that an interdisciplinary team was critical so convened a group that included a national IT expert as well as technical experts who were involved in developing a GHG MRV user manual for MRV and conducting technical trainings on monitoring and reporting. This team worked closely with the implementing agency, the Ministry of Environment and Urbanization, to develop a system that suited the MRV requirements. During development it was helpful for Turkey to cooperate closely with the German Emission Trading Authority (DEHSt). Through study visits to Berlin and on demand communication, Turkey benefited from the lessons learned by Germany in operating their data management system for 10 years.

The following table illustrates a breakdown of how many days it took to complete key activities during Turkey's design and development process.[6]

Activity	Number of man days required to complete the activity
• Design setting of the Turkish DMS	• 50
• Development of data model	• 50
• Development of data base	• 50
• Development of online tool	• 50
• Programming of queries	• Currently 50, likely to be more
• Advice to the Ministry and facilitating decision making process	• 100
• Fine tuning of system	• 50

3.4.2. Re-Purposing an Existing In-House System

In some instances, it may be possible to leverage or re-purpose an existing in-house system when building a GHG data management system. Many developing countries have quite sophisticated systems and infrastructure in other sectors, such as energy; it may be worth exploring to what extent such capacity could be leveraged to develop GHG data management systems. This approach may have several benefits, including lowering costs related to software development and licensing, potentially increasing speed to market, and leveraging existing in-house expertise and resources.

However, an assessment of functional requirements for the new system against the functionality of any existing system/s is needed. Potential pitfalls of re-purposing an existing system include:

- The existing system may include outdated technology.
- The existing system may be rigid and difficult to modify, particularly if the policy or functional requirements for the new system differ significantly from those associated with the existing system.

[6] This information was kindly provided by the Turkish Ministry of Environment and Urbanization (MoEU) and the international and local experts involved in the development of Turkey's GHG reporting system. This project was supported by the German Ministry for the Environment, Nature Conservation, Buildings and Nuclear Safety (BMUB) and the Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) in the framework of the project "MRV Capacity Development for Turkey".

Re-purposing an existing system requires additional analysis in the requirement gathering phase, with key considerations including infrastructure, licenses, restrictions, financial and technical capacity, and integration of inputs and outputs.

In **Chile**, the Pollutant Release and Transfer Register (PRTR) is a one-window system that is being leveraged to report CO_2 emissions for the internal revenue service, who will then determine the carbon tax to be paid on the basis of the regulatory statute Chile is developing. They expect to undertake a three-year development process (2015–18). While there are no plans for an ETS at present, Chile is also committed to developing an MRV system that is ETS-compatible. The PRTR system registers contaminants at the source level—capturing 90 percent of all sources in Chile—and enables disclosure of information to the necessary stakeholders, including communities and the public. Chile designed and conceptualized the structure, but sub-contracted experts to develop the information system, implement it, and to support the government in developing additional modules (e.g., environmental expenditures, voluntary GHG reporting).

3.4.3. Customizing a Third-Party System

Another lower-cost approach is to use an existing third-party system, particularly if it is already in use by other governments. Third-party software solutions have been developed and deployed around the world, including by companies such as:

- enfoTech & Consulting Inc., for **South Africa**,
- SAIC, for **California**, and
- The Climate Registry (TCR), for **Massachusetts** and **Thailand**.

In almost all cases, these third-party solutions will require a degree of customization to meet the functional requirements of a particular GHG data management system. This customization is typically done by the original third-party developer, in consultation with the government agency commissioning the system.

As with re-purposing an existing system, the benefits of customizing a third-party system are that it potentially increases speed to market and adapting a widely-used system can also support future linkages. However, the costs of development are typically much higher in comparison with re-purposing existing infrastructure.

California chose to customize the **U.S.** system to support its mandatory GHG reporting program. The key considerations for this decision were as follows:

- California had based many of its reporting methods on those of the United States and wanted to further harmonize its program with the U.S.' system. A benefit of this harmonization was to reduce the reporting burden and redundancy on reporters subject to both state and federal regulations.
- California was limited to a five-month window to develop a functioning reporting tool that conformed to the regulatory requirements. Since the United States had already provided initial funding to support states building GHG data management systems, leveraging the U.S.' pre-existing system was the most cost- and time-efficient solution.

California found this approach to be beneficial to reporters, since the similar look and feel of the two systems streamlined reporting. They were also able to take advantage of the thousands of internal system checks already built into the U.S.' system to improve QC. The biggest challenge in customizing the system to California's requirements was the addition of the electric power and oil and gas sectors. It was difficult to map out and determine how production information would be collected, since the level of detail of data required for cap and trade was beyond the United States' requirements.

Massachusetts chose to work with TCR to modify its existing platform, with a major decision point being that they believed other states would also adopt it and therefore future linkages would be streamlined. TCR went on to further modify its system and Massachusetts' system became part of a wider rebuild process. One of the key learnings they gleaned from their experience was the importance of selecting a system that is both stable and widely used.

South Africa's system is a customized version of a web-based reporting system built for the state of Michigan by InfoTech. South Africa developed the system over a two-and-a-half-year period, working directly with InfoTech during that time.

Procurement Approach

The process for procuring the services and products of an external software developer/IT company is described further below.

As part of the procurement process, the statutory regulator will need to:

- Identify in-house responsibilities for management and oversight of the external developer.
- Consider whether the country is going to provide all technical (IT) guidance and subject matter expertise (SME), or whether both IT and SME services will be outsourced to the external developer.
- Understand available methods for engaging external developers.
- Define developer qualifications and requirements.

Identifying a Qualified Third-Party Developer

To identify qualified third-party developers, the program administrator can (a) conduct market research through analysis of known external developers or IT firms and their qualifications, and/or (b) issue a request for information (RFI).[7]

Figure 12 identifies typical information provided in RFIs and the information requested from companies in their response.

Engaging a Qualified External Developer

There are two options for engaging a qualified external developer: a non-competitive process (or sole source award); or a competitive process (request for proposal [RFP]).

[7] An RFI, or market research may not need to be conducted if an agency already knows a qualified external developer(s). In this case, there may already be a contract mechanism in place to access the developer(s).

Figure 12. Typical Information Provided in RFIs and Information Requested from Companies

Information provided in RFIs	Information requested from RFIs
• Background • Specifications of requested services and deliverables (e.g., software development and maintenance, testing, hosting, help desk staff and operation, training) • Limitations on the types of companies that can respond to the RFI (e.g., only small businesses or only businesses that hold certain basic purchasing agreements (BPAs) or other types of contracts with the government	• Company name, identifying information, and characteristics • Company description and experience • Key personnel qualifications and resumes • Relevent services or products provided by the company • Current relevent contracts held by the company • Relevent approaches, best practices, and protocols • Relevent past and current experiences

Non-Competitive Process Sole source awards may be granted if there is sufficient evidence from market research to prove that the external developer is best qualified and offers the best value, and there is no other developer that could offer the same. Sole source awards may only be appropriate in situations where a developer has a history of strong performance while working with a government entity and has scope within a current contract for another relevant system or as a continuation for the system. The practice of sole source awards also needs to be institutionally authorized. The practice may not be legally supported by all government entities.

Competitive Process An RFP may be sent to a select group of qualified external developers or to developers who already hold certain BPAs or contracts with an agency, or they can be open solicitations to which any external developer is eligible to respond. This decision is often based on market research and the flow or source of funding.

Regardless of whether there is a competitive or non-competitive process, it is advisable to issue an RFP in order to clarify the intended approach, budget, etc. Figure 13 identifies typical information provided in RFPs and typical information requested from bidding companies.

Proposals are evaluated based on a set of weighted criteria, where the weights of the criteria are determined by the agency releasing the RFP. Criteria typically include:

- Price
- Past experience, technical (e.g., software development, database architecture, etc.), or subject matter experience (e.g., GHG reporting)
- Personnel
- Approach (technical and management)

Technical and price proposals are reviewed and scored by an evaluation panel that may include technical staff, program managers, and contract staff. Scores are considered and an external developer is selected based on the best balance of value and expertise.

Figure 13. Typical Information Provided in RFPs and Typical Information Requested from Companies

Information provided in RFPs	Information requested from RFPs
• Submission information • Background • Specifications of requested services and deliverables • Contract clauses and requirements (terms and conditions) • Government point of contact • Assumptions and schedules • Selection criteria	• Company name, identifying information, and characteristics • Company description and experience • Key personnel qualifications and resumes • Management structure and approach; roles and responsibilities of team members • Project plan • Technical approach to work • Past performance references • Budget and costing assumptions

3.4.4. Key Considerations for Making the Decision to Develop In-House or Outsource

Table 11 compares the two approaches to system development across a number of key considerations.

Table 11. Comparing "Build" or "Buy" Approaches to System Development

	Build: In-house development	Buy: Outsourced development / customizing a third-party solution
Timing	May take more time, given that in-house development teams are typically limited in size.	Time to implementation is a limiting factor. Outsourcing can save on time because consultants can deploy more development resources. Customizing an existing system can save on time throughout the development cycle, as long as the customization requirements are realistic and well-articulated in the functional requirements.
Cost of acquisition, development and maintenance	Cost is a limiting factor. If there is an existing in-house team, it may be less expensive to develop in-house than going to external sources. When factoring costs, consider the full range of development and hosting costs, including: • Initial development • Testing • Deployment • Ongoing licenses • Ongoing maintenance and support • Future modifications	Using a third-party system may be more costly than developing in-house. Conversely, customizing an existing system may reduce a range of development costs, as long as customization requirements are realistic and fixed (at least for the initial deployment). Changing requirements or adding to the project scope after the initial requirements have been set will require more time and/or money.
The need for flexibility with respect to adapting to and evolving with the regulatory environment	Extensibility is a major requirement. If the system will need significant modifications over time (i.e., if the regulation is still evolving, or new functionality or linkages are anticipated), it may make sense to own and operate the system in-house in order to build capacity and mitigate future outsourcing costs.	Ongoing modifications, if outsourced, may be expensive and subject to the priorities/availability of outsourced providers.

table continues next page

Table 11. Comparing "Build" or "Buy" Approaches to System Development *(continued)*

	Build: In-house development	Buy: Outsourced development /customizing a third-party solution
Security	In-house expertise on security matters may be more limited.	Outsourced development teams may have more expertise in current industry standard security practices.
Capacity and skill requirements of in-house staff	Staff have skills and experience in both content and programming, including: • Subject matter expertise in GHG data management • Project/product management • Systems architecture • Software development/coding • Database administration • Testing/QA • Performance and security Staff have a proven track record of working together to build and launch large scale software systems It is also critical that the right conditions for success are in place, see the "Joel Test" in table 12.	Outsourced resources may have many generic software development skills, but may be more limited in subject matter expertise.
Functional requirements	The business needs, functional or regulatory requirements are so unique that that a custom built system is the only solution.	The business needs, functional or regulatory requirements are similar to those of an existing program. However, clearly analyzing and articulating (in the functional requirements) the customization requirements is critical.

A useful framework for thinking about the trade-offs in system development is the "resource triangle," as depicted in figure 14. To develop a system more quickly, one needs fewer features, more money, or both. To save money, one needs either fewer features or more time. The more complex the platform, the more time, money, or both are required.

3.4.5. A Closer Look at Assessing an In-House Team

When determining whether to outsource or develop a GHG data management system in-house, assessing the development team's environment and capacity is the critical first step. The Joel Test illustrated in table 12 is an effective guide for assessing the quality of a software team and the potential risks to a software development project.

Figure 14. The Resource Triangle

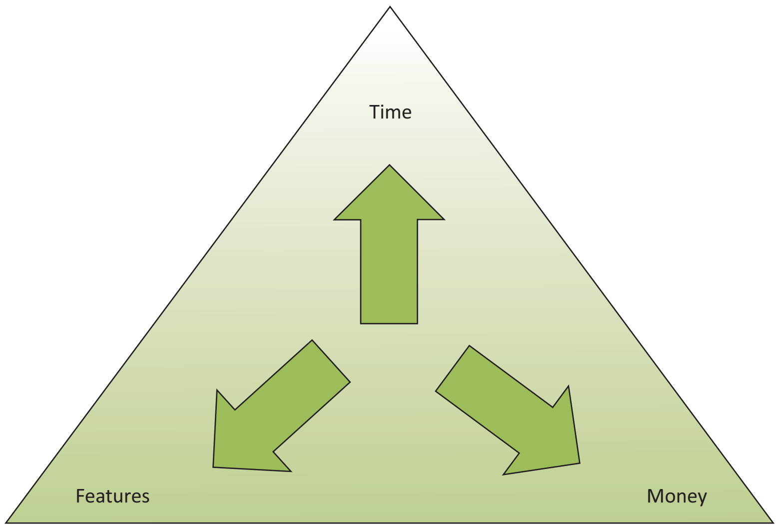


Table 12. The Joel Test for Assessing the Capacity and Environment of the In-House Team

Do you use source control? (an application that allows for tracking of changes to the software code)	
Can you make a build in one step? (from the latest source code snapshot)	
Do you make daily builds? (this shortens the time between fixing bugs, and having those fixes appear to the development/testing team)	
Do you have a bug database? (tracking software that records all bugs and their progress toward being fixed)	
Do you fix bugs before writing new code? (can be challenging when adhering to a strict development schedule)	
Do you have an up to date schedule?	
Do you have a spec? (can include functional and technical requirement documentation)	
Do programmers have quiet working conditions?	
Do you have the best tools money can buy? (compiling code takes processing power, inadequate machines will be slow and developers will lose focus)	
Do you have testers? (not programmers who test, but actual testers)	
Do new candidates write code during their interview? (Would you hire a magician without seeing some tricks?)	

3.4.6. Survey of Existing GHG Data Management Systems

Table 13 provides a high-level comparative survey of existing GHG data management systems in PMR jurisdictions, considering the development process, components, considerations, and lessons learned.

Table 13. Comparing GHG Data Management Systems in PMR Jurisdictions

Jurisdiction and system	Origins of system	Components and key characteristics
Australia Emissions and Energy Reporting System (EERS)	• Outsourced • Developed in conjunction with Microsoft • Replaced Online System for Comprehensive Activity Reporting (OSCAR)	• Integrated • Reporting: single annual reporting for multiple programs (NGER) so reporter enters data one time in one system • QC: internal system validations, communicated to reporter to be rectified • QA: independent audits conducted outside the system • Publicly available AGEIS has aggregated data from EERS to facilitate data sharing and transparency between government agencies
California California Electronic Greenhouse Gas Reporting Tool (Cal e-GGRT)	• Outsourced • Science Applications International Corporation (SAIC) customized U.S. EPA's system	• Independent • Reporting: Oracle-based database system; supports but not linked to cap-and-trade compliance Instrument Tracking System Service (CITSS) • QC: internal system checks • QA: annual third-party verification facilitated in the system
Chile Pollutant Release and Transfer Registry (PRTR)	• Adapting existing PRTR system for GHG reporting	• Integrated; planned linkage with internal revenue service • Reporting: one-window system planned to support source-level reporting and future CO_2 tax • QA: third-party verification
China (Shanxi and Shandong provinces) Emissions Reporting System	• Outsourced • Designed and developed by SinoCarbon	• Independent • Reporting: web-based system to support mandatory reporting at provincial level for national ETS • QC: internal system checks against defined criteria • QA: annual third-party verification and audit by the system administrator conducted in the system
Germany Emissions Trading Scheme Forms Management System (FMS)	• Specifications of data model developed in-house • Programming outsourced	• Independent front-end for ETS data acquisition • Reporting: web-based form system using installation based and approved monitoring plans as acquisition basis • QC: automatic checks in the system for required information, plausibility checks • QA: third-party verification conducted in the system, audit checks by national authorities in a separately featured back-end system
Kazakhstan National Inventory of GHGs Emission Sources and Removals	• In process of adapting system	• Integrated; planned linkage to carbon units registry • Reporting: paper-based *to support* mandatory reporting at the national level, including for national ETS • QC: in development • QA: in development

table continues next page

Table 13. Comparing GHG Data Management Systems in PMR Jurisdictions *(continued)*

Jurisdiction and system	Origins of system	Components and key characteristics
Massachusetts Climate Registry Information System (CRIS)	• Outsourced • Customized version of The Climate Registry's system	• Independent; no link to Regional Greenhouse Gas Initiative (RGGI) or to non-GHG pollutant systems • Reporting: web-based system to support mandatory state reporting • QC: internal system checks for required information • QA: third-party verification conducted via CRIS
Mexico COA	• Outsourced • System being developed by National Institute of Geography and Statistics	• Integrated; COA system supports GHG and non-GHG reporting • Reporting: web-based system for single, centralized data repository and a single report for companies • QC: system checks information is complete • QA: third-party verification every three years
South Africa South African Air Quality Information System (SAAQIS)	• Outsourced • enfoTech developing in three phases	• Integrated; system supports GHG and non-GHG pollutant reporting • Reporting: system supports national inventory; National Atmospheric Inventory System (NAEIS) • QC: internal system checks against defined criteria • QA: audit checks by national authorities
Thailand Thailand Carbon Footprint for Organization Platform (Thai CFO Platform)	• Outsourced • Customized third-party system from The Climate Registry (TCR)	• Independent • Reporting: web-based system to support voluntary reporting • QC: internal system checks for required information • QA: third-party verification conducted via CRIS
Turkey GHG Reporting Scheme within Environmental Information System (EIS)	• Web-based system, integrated with Environmental Information System.	• Semi-independent: although the national GHG reporting program operates independently, the reporting system is built-in the Environmental Information System which collects data and information on waste, non-GHG emissions, licensing of environmental laboratories, tracking of marine waste, inventory of ozone-depleting substances etc. • Reporting: web-based system developed • QC: in development • QA: in development
United Kingdom Emissions Trading Scheme Workflow Automation Project (ETSWAP)	• Outsourced • Developed by SFW; designed in multiple phases	• Independent; four main systems support four separate policies no linkages between systems • Reporting: web-based form system • QC: semi-automatic checks in the system and acceptable levels of uncertainty • QA: third-party verification conducted in the system
United States Electronic Greenhouse Gas Reporting Tool (e-GGRT)	• Outsourced • Developed by Science Applications International Corporation (SAIC)	• Independent; no linkages to other systems • Developed services to use EPA legacy platform to handle user authentication and report submission (electronic signature and non-repudiation) • Reporting: Oracle-based database system supporting reporting for US mandatory reporting • QC: automated internal system checks pre-submittal and self-certification • QA: automated internal system checks post-submittal that facilitate in-house verification within the system

3.5. Step 4: Developing Technical Requirements

The technical requirements document/s will provide system developers (whether in-house or outsourced) guidance on system performance, architecture, hardware, software, security, and hosting. Technical requirements can also clarify processes related to software development, integration, testing, and deployment. The following sections describe decision points and key considerations for developing technical requirements.

3.5.1. Performance Requirements

The technical requirements typically specify clear performance targets in the areas of:

- Estimated system usage metrics, including total projected users, with projected cyclical impacts due to reporting or verification deadlines. Usage estimates should encompass total monthly users, as well as concurrent users and likely session length. It is also important to project likely usage growth over time.
- Response time.
- Page loading.
- Search query response.
- Report generation.

Failing to meet performance targets such as page loading and response time can mean a frustrating and slow user experience, and may result in system outages. Performance requirements will vary based on system usage metrics, including the number of concurrent users and the performance intensity of user tasks. For example, expected response times for loading simple web pages should be fast—usually under 2–3 seconds. Complex report generation that requires many processing intensive computations (complex calculations, for example), by contrast, can take much longer. As a rule of thumb, optimal response times (i.e., page loading or query response) are less than 2–3 seconds. If more time will be required for more complex actions, the user appropriate user notifications can be used.

3.5.2. Data Storage Considerations

Archival data that won't be used for current, real-time reporting can be archived on secondary servers, back-up drives, or tapes and accessed via special request—although the decreasing costs of real-time storage may allow for more accessible, data storage options. Data archival must comport with any relevant data confidentiality and data protection requirements. For example, Amazon's Simple Storage Services (S3), Google Cloud Storage, Microsoft Azure, and others offer affordability, flexibility, and scalability.

3.5.3. System Architecture

The technical requirements typically describe the full system architecture, including the:

- Code.
- Database schema (see Section 3.6.2).

- Data dictionary, describing the contents, format, and structure of a database and the relationship between its elements, used to control access to and manipulation of the database. Logging of user actions, storing records in the database of actions such as inventory submission, approval/rejection for audit and future reference purposes.
- Stored procedures behind all main functional components of the system, from user registration through report generation.
- Overviews of any inbound or outbound data linkages with other systems (i.e., any API or other technical documentation for these linkages).
- Commonly-used database classes and business rules for each major function (such as facility-level reporting, source-level reporting, or document management). Examples of technical requirements for system-wide functions are provided in table 14.

3.5.4. Hardware

There are many ways to configure hardware for development and a live system. Ideally, the technical requirements will specify servers (see Section 3.9.1) for each stage of development, including:

- Software development
- Testing
- Staging
- Production

The technical requirements will also specify who "owns" these servers and where they will be housed, i.e., are they owned by the government/regulator or a vendor. Hosting considerations are discussed in

Table 14. Examples of Technical Requirements for System-Wide Functions

Type	Description
Database/Classes	**clsCupBusinessRules class** table : tblEntityAccess, tblOrganization, tblVerificationAccess, tbllogin, tblEntityHolding function : *GetUniqueEntitiesWithMemberPermissons(string email)* Loads accessible entities per member. **clsLIBusinessRules class** table : Tbllogin, tblEntityAccess function : *GetPermissions(string emailname, string groups)* Finds out if a user is in a set of groups (more than one) **clsLIBusinessRules class** table : tblogin function : *IsUserAnAdmin(string email)* function checks if a user is an admin and has rights to edit an entity **clsWERBusinessRules class** table : tblogin function : *GetRegions GetRegions(string countrycode)* function returns the region based on a country chosen

more detail in Section 3.9.1 below. For the live "production" system, hardware requirements will be dictated by performance requirements and should include the following:

- Processing power
- Storage
- Memory (RAM)

If high traffic volumes are anticipated for the system in live production, consider dedicated servers with load balancing. For lower-traffic systems, shared servers may be sufficient, provided that security requirements are met. Given performance requirements, a professional hosting vendor may be consulted on the right production environment for the system.

3.5.5. Software

The technical requirements typically specify the technology to be used for the system. This decision may be influenced by the skills and experience of the development team, previously existing technologies (and associated licenses) within the organization, and financial resources. The technology used to support the system is often referred to as the "stack"—a set of software components needed to run a complete platform. Key software components include the OS, web server, scripting, or programming language and the database management system. Examples of software stacks include:

- Microsoft stack: Windows OS, Internet Information Service (IIS), C# / .NET and the SQL DB.
- LAMP stack: Linux OS, Apache web server, MySQL DB, PHP programming language (PERL and Python are also common programming languages for LAMP stack applications).

Both Microsoft and LAMP stacks are enterprise solutions that can handle demanding performance, data and security needs. Chile's PRTR system uses a version of LAMP: Linux, a PostgreSQL database, and object-oriented application development under the PHP programming language. Massachusetts' system, built by Misys and operated by TCR, uses a Java-based platform. Thailand's reporting system uses a Microsoft stack.

Software requirements also define software accessibility requirements, including:

- Using color to enhance information.
- Exposing screen elements to aid assistive technologies (i.e., screen readers need UI information about a web application in order to effectively read the screen).
- Interoperability with accessibility aids, such as screen readers, auditory or tactile feedback systems.
- Sound alternatives, such as text-to-speech.
- Flexible user interface (UI), such as text enlargement.

3.5.6. Security

For the purposes of the technical requirements, system security, and governance define how different system components are accessed and how they connect with each other, including:

- Web server account details, including server name, IP address, authentication (login ID, password).

- Should be: database account permissions (SQL, MySQL or other), including database server authentication (login ID, password) and default database name.
- Reporting software permissions/path, including name, server and database authentication.

This information—in addition to passwords related to system software, databases, or hardware—can be included in the technical requirements and updated regularly. Since the technical requirements document houses this confidential information, the document itself is typically password protected with limited, defined distribution. Technical requirements also specify both physical and virtual security requirements, as outlined in Section 3.5.6.

In **Australia,** to secure access to EERS, the Clean Energy Regulator creates an EERS account for each reporter and an Executive Officer and contact person is attached to each account. These individuals are verified as part of the NGER registration process. It is then the nominated representatives' responsibility to provide additional users with access to their organization's EERS account, as they see fit. Each year's EERS deployment is subject to penetration testing to ensure that the data housed within EERS is secure.

3.6. Step 5: Developing the Software

While the functional requirements define what the software must do, software development itself is a process comprised of several key steps. These include configuring an appropriate development environment for the development team, developing a clear database architecture for the system, adhering to best practices to coding/programming the system, and developing the front end of the system to be consistent with the programs brand/style requirements.

3.6.1. Configure Development Environment

Once the software "stack" determination is made, system developers will need to access the functioning development environment. To achieve this, software components are defined, installed, and configured on each of the following systems:

- All developers' computers should have developer versions of the database and an integrated development environment (IDE, such as Visual Studio), which is the actual tool used to write and compile code, installed.
- A test server should be deployed to which all developers send their code as it is complete. Source control software (such as such as Team Foundation Server or Sourcebase) should be used to handle version control issues. Bug tracking software should be used to track all outstanding issues.
- A staging server is optional, but can be useful to provide a version of the system that business analysts or other internal testers can access and provide feedback.
- A production server(s) to which the finished system is deployed. This server will replicate the same "stack" used in the preceding instances.

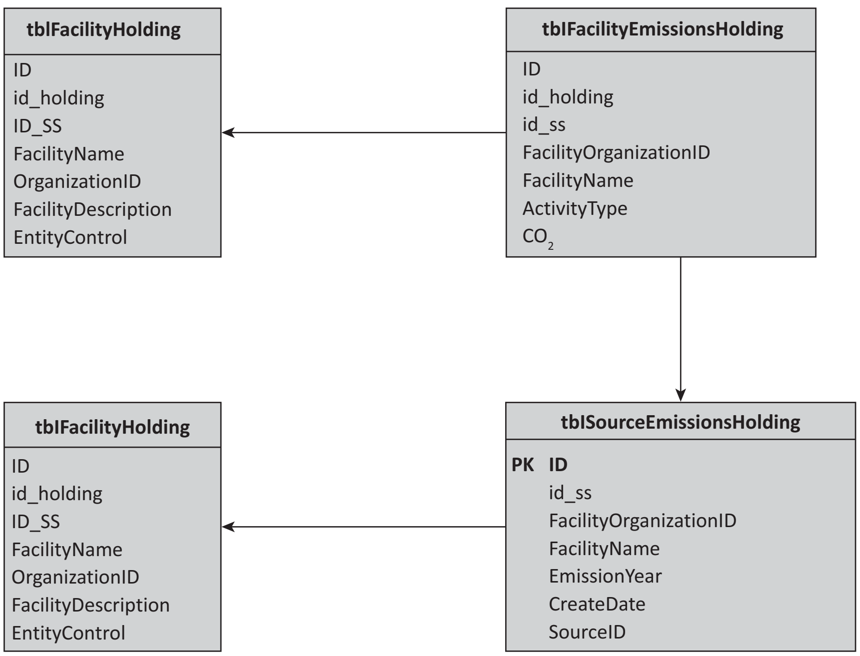
The technical requirements document can include all logins, passwords, and configuration details for these servers and software.

3.6.2. Develop and Implement Database Architecture

The database administrator will develop and implement the architecture for the system database(s) early on in the development process. This architecture will define how data is processed, stored, and utilized by the system. The technical requirements should include visual database schema that define the database table structure and relationships between tables.[8] Requirements typically define all reports that will be generated in detail using schema, such as the Facility Breakdown Report example from TCR's technical requirements below:

Report Path: /rpt/Emission_Report_SEMs

Parameters: emission year, entity organization ID



The database and report queries may need to be optimized to improve performance if the system response times are sub-optimal. The database is where many of the performance gain can be made. If optimizations are made, these are logged in the technical requirements so that they can be referenced in the future.

3.6.3. Coding

Coding, or computer programming, is carried out by software developers and will implement all of the system components defined in the functional requirements. Robust project management is key to the success of the coding phase; this will be more effective if the project management and coding roles and responsibilities are separate and distinct. The project management process will vary depending on the software development process selected. See Section 3 for an overview of software development processes.

[8] Video tutorial on how to build a DB schema from 'Barry's Tutorial on understanding a Database Schema: https://www.youtube.com/watch?v=KqvIGYjcLQ4.

With any software development process, best coding practice dictates that source code management processes and software be in place. A source code management process defines how application code is stored, organized, and shared among developers, and how software versions will be archived and organized. The use of tools such as Team Foundation Server, Sourcebase and Version One is key to successful source code management.

Regardless of the software development approach, it is important to create a conducive programming environment, such as a quiet workspace or offering flexible hours to accommodate work preferences.

It is also important to set guidelines for and adhere to coding best practices, such as:

- Commenting and documentation,
- Code grouping,
- Consistent and documented naming,
- Limit line length and deep nesting,
- File and folder organization,
- Separation of code and data, and
- Favor object oriented code vs. stored procedures.

3.6.4. Front-End Development

Ideally the front end of the system—with which most users interact—will reflect brand and style guidelines (e.g., color, look and feel, fonts) and be optimized (i.e., be simple, intuitive, clean, and consistent with common practice).

An effective user interface (UI) and user experience (UX) are particularly important for data-heavy applications like GHG data management systems, which require inputting large data sets. This process can be tedious and prone to error, and effective UI/UX can help to mitigate these challenges.

In many instances—even when most development is being completed in-house—UI/UX development is undertaken by third-party vendors. Vendors can offer specific expertise and experience with current best practice, and should demonstrate design skills and technical proficiency with technologies including:

- HTML
- CSS
- Ajax and Javascript
- Fluency in chosen platform/stack
- Flash

Vendors may also be required to have proven project management expertise and knowledge of digital marketing best practices, such as search engine optimization and social media, especially if the program will be open to the general public. By optimizing the public-facing portions of the system for search engines and social media, reports, and other content intended for the public will be more accessible.

3.7. Step 6: Integrating the System

System integration is the process of bringing together the various functional, user interface, and data components into one cohesive system. The technical requirements may include a concise written plan that defines:

- How code produced by multiple developers will be integrated in the evolving system, taking into consideration version control management with source control software.
- Frequency of internal releases where code is compiled and "pushed" to the test server should also be defined.

Traditional/waterfall software development approaches tend to have slower, less-frequent release schedules, whereas agile projects sometimes insist on daily micro-releases (see Section 3). Whatever approach is taken, it is important to commit to a release schedule in order to stay on time and on budget.

3.8. Step 7: Testing

Professional, dedicated testers that test every scenario for each functional component on every major OS and every major browser version are critical to ensuring a functional system. Conducting testing throughout development minimizes the risk of error and to flag issues early on so that they can be addressed during development. **Australia** emphasized that early testing is the key to a smooth deployment, and that allowing adequate time for testing and subsequent redesign and fixes makes for a more successful release.

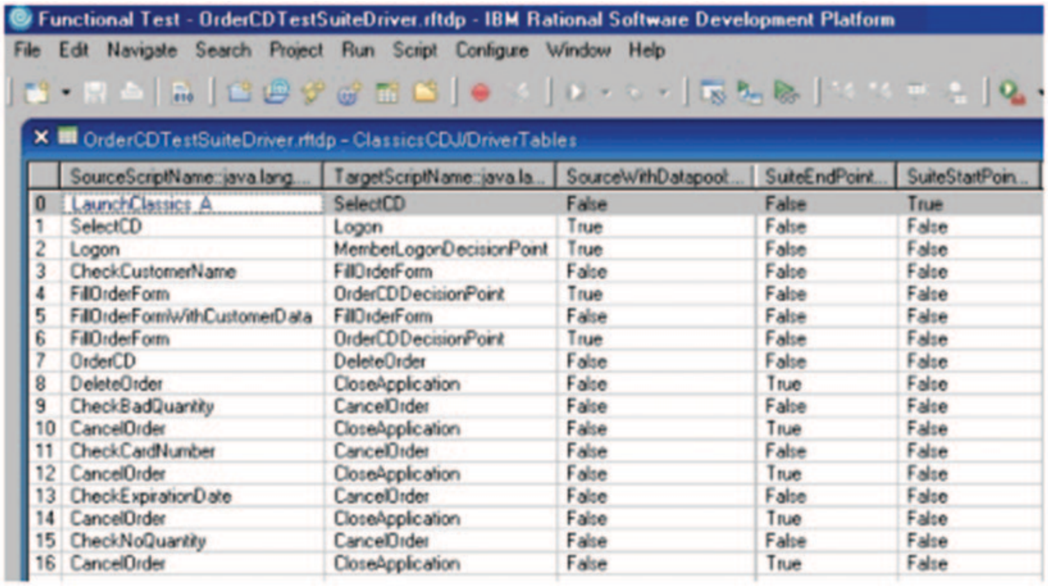
The testing project management tool, referred to as the "test suite," lists all possible use-variations of a given function across different operating systems and browsers. Each of these variations is called a "test case." The test suite includes manual test cases, to be carried out on a case-by-case basis by individual testers; as well as automated testing via scripts written by testing engineers, which can automatically and quickly conduct many test cases. Test suites can be managed via spreadsheets or off-the-shelf test suite management applications. Figure 15 illustrates an example of a small section of a test suite.

Test suites take time and resources to develop, since robust suites include every possible use scenario. It is important to allow ample time in the development cycle to create and manage the test suite, in addition to conducting the testing itself. Bug-tracking software, which testers use for logging all relevant detail of bug instances, helps to manage and prioritize bug fixing.

If system development has been outsourced, an adequate testing plan, test scripts and dedicated testing resources need to be put in place by the developers and testing progress should be reviewed periodically.

If developing a system in-house, it is important that there are dedicated testers and that the system developers are not themselves solely responsible for testing. This separation of duties is critical. Testing is its own project or task, with dedicated project management, testing engineers and tools.

Figure 15. Example of a Small Section of a Test Suite



	SourceScriptName::java.lang...	TargetScriptName::java.la...	SourceWithDatapool...	SuiteEndPoint...	SuiteStartPoin...
0	LaunchClassics_A	SelectCD	False	False	True
1	SelectCD	Logon	True	False	False
2	Logon	MemberLogonDecisionPoint	True	False	False
3	CheckCustomerName	FillOrderForm	False	False	False
4	FillOrderForm	OrderCDDecisionPoint	True	False	False
5	FillOrderFormWithCustomerData	FillOrderForm	False	False	False
6	FillOrderForm	OrderCDDecisionPoint	True	False	False
7	OrderCD	DeleteOrder	False	False	False
8	DeleteOrder	CloseApplication	False	True	False
9	CheckBadQuantity	CancelOrder	False	False	False
10	CancelOrder	CloseApplication	False	True	False
11	CheckCardNumber	CancelOrder	False	False	False
12	CancelOrder	CloseApplication	False	True	False
13	CheckExpirationDate	CancelOrder	False	False	False
14	CancelOrder	CloseApplication	False	True	False
15	CheckNoQuantity	CancelOrder	False	False	False
16	CancelOrder	CloseApplication	False	True	False

Source: Vauthier 2006.

In addition to user testing (both manual and automated), conducting load and performance testing before deployment ensures system performance. Load testing simulates estimated usage and concurrency levels and will test and define the performance limits of the application. Failed load tests may indicate the need for database or database query optimization, optimized code or improved or augmented hardware. If load tests are failing, check to ensure that the Internet connection between the computer running the test script and the test server is not the problem.

3.8.1. Continual Integration Testing

Testing is conducted throughout development. As new functional components are developed and integrated in the overall system, related components will need to be re-tested, as integration may impact components that have already been tested. Regular updates to the test suite will help ensure continual integrated testing.

3.8.2. Alpha Testing and Beta/Pilot Testing

In addition to using professional testing engineers, it will be important for business analysts and users to test the system along the way. This can help to make sure that the functionality is understandable and usable to future users, and also to optimize the user experience. It will also help ensure functional requirements are being met as intended. Alpha (internal group) and beta (external group) tests should occur at key intervals, such as a) after the completion of major components, b) during development and post deployment, and c) prior to launching the system. This will also help inform training materials and key communications/messages.

3.9. Step 8: Deploying and Launching the System

Once the hosting provider is selected, production servers can be configured with the relevant software stack (e.g., OS, database [DB], web). This is typically undertaken several weeks before actual deployment to ensure that everything is working before the system itself is deployed. Actual deployment consists of:

- Copying compiled files to the production server.
- Installing the database. A first time install is often completed with a database back-up and restore. For subsequent releases, changes must be scripted using tools such as SQL Delta, which compare source and destination databases.

Optimizing the release and deployment process based on lessons learned from the first deployment and documenting and automating the process where possible will help make the process more efficient, build institutional capacity and to remove the risk of human error.

California identified that a common challenge is the need to change a GHG data management system once it is in place due to changes and modifications to the rule and the policy that underpins it. This underlines the importance of taking due care and consideration drafting the regulation, given the potential ramifications; but, more realistically, it also points to the need to build in time for continual improvement (development, testing, and deployment) on an annual basis. Since updates generally take a few months to develop, test and deploy, it is also important to ensure these are ready before the reporting cycle begins to ensure that reporters are using the same system. **South Africa's** approach was to conduct a three-month pilot program, which allowed it to refine the system.

3.9.1. Hosting

Technical requirements include detailed information about hosting requirements (examples are listed in table 15).

In general, hosting internally is not recommended, as professional hosting providers often have more robust infrastructure (i.e., scalability, redundancy, security, updated technology). Internal hosting may be considered, however, if sufficient hardware, human resources, and security provisions are in place.

When choosing an external hosting provider, there are the following options:

- Co-location at a data center, which provides the physical infrastructure (a secure building, access to redundant bandwidth, a server rack and power) (Flynn 2015).
- Managed hosting provider, which provides "virtual" server space on a shared physical server and provides a range of managed services.
- Shared IT hosting infrastructure that is already in place.

An example of infrastructure sharing is in **California**: the California Department of Technology, which oversees the Federated Data Center (FDC), provides hosting services to California's Air Resources Board (CARB), which has oversight of the state's GHG data management system. The FDC has the server space, subsidizes the cost for California's GHG reporting system, and ensures that California's GHG reporting

Table 15. Sample Checklist for Evaluating Hosting Options

Requirements	Rating (1–5, with 5 being best)	Notes
Hosting hardware and connectivity		
Dedicated or partially dedicated server(s)		
Storage (should be easily scalable)		
Sockets, processing power, and RAM		
Up-time guarantee		
24x7x365 IT and engineer staff coverage		
Frequency and location of back-ups		
Bandwidth (should define requirement with real-time scalability)		
Network redundancy/site mirroring		
Software		
Web server		
DB		
Anti-virus and anti-malware provisions		
Other software requirements		
Guarantee that software licenses are kept up to date		
Security		
Physical security of hosting facility (provisions for earth quake, fire, water, on-site security, video surveillance)		
Firewall		
DDoS mitigation		
Two-factor authentication		
SSL certification		
VPN encryption		
Periodic third party security and infrastructure audits		

Source: Guiliano 2013.

system is continuously operational (with support from CARB). CARB has implemented a routine back-up schedule and there have been no security issues to date.

Kazakhstan hosts its GHG data management system on its own servers, and the process is supported by government staff.

The following table presents a sample checklist that can be modified to evaluate hosting options. By summing the points in the "rating" column, a quantifiable comparison of hosting options can be achieved.

4. Providing Support to and Building the Capacity of GHG Data Management System Users

Providing support to and building the capacity of GHG data management users are key to ensuring smooth reporting cycles and accurate data input. Available resources, reporting timeliness, and accuracy requirements are important considerations when determining the appropriate type and level of support and training activities.

4.1. User Support

Access to customer support for the GHG data management system is crucial for the primary users: reporters and verifiers. Support for verifiers and reporters could include addressing both system and policy questions. Common questions from reporters include:

- Do I have to report? If yes, what do I have to report?
- How do I correct a mistake within the system?
- How do I change the user who must input the data?
- How do I reset my password?

Interviewed countries noted that they also receive more detailed questions about data requirements and/or how to interpret the program requirements, such as:

- I understand that I need to report this piece of data but I don't understand how to report it within the system.
- My reported values are now under the threshold that is required for reporting. How can I disengage from the system?

There are a number of mechanisms for addressing user questions and supporting their needs. Considerations for determining the type of support include the (a) complexity of regulations, (b) complexity of the GHG data management system, and (c) the available resources. Options are described in more detail below.

4.1.1. Help Desk

A help desk system could be provided to support the system users' needs. It provides a central location for user inquiries and can be staffed by dedicated in-house or third-party experts who, if necessary, can re-route the request to an appropriate point of contact. This type of dedicated support system is especially helpful for new or large programs, allowing for timely support, more in-depth discussion on user questions, and ongoing education.

For **Chile's** Pollutant Release and Transfer Register system (PRTR), officials have implemented a comprehensive help desk system that integrates a call center and online tracking system, and responds to a broad range of questions from different types of users. Registering firms within the PRTR system took longer than expected and resulted in thousands of emails about various aspects of the reporting cycle. Chile now works with contractors to provide support on both technical and system-specific questions, which makes responding to the high volume of questions more manageable.

4.1.2. Telephone and Email

Telephone, email, notifications, and online chat/secure messaging systems can also be utilized to address user questions and to disseminate important system-related communications. For example:

- A dedicated telephone number could be established and promoted, which could be accessed by staff who would then connect the user with the appropriate point of contact.
- A dedicated email address can be set up to which users can send questions. Emails can also be sent from the address to notify users of relevant news, such as the launch of a reporting cycle or system updates. An important consideration is whether resources are available to respond to email queries in a timely manner, and setting an expectation among users accordingly.

In **Kazakhstan**, customer service is provided through a combination of telephone support (via a call center), email and an instant message system within the GHG data management system. **Australia** also employs a call center for its system users. In **Turkey**, similar customer service is supported by technical staff in relevant Departments of the Ministry of Environment and Urbanization.

The **United States** uses a combination of email and secure online messaging to send group notifications and one-on-one communications to reporters. This process is managed through a correspondence mailbox within the system, in order to maintain confidentiality and security. Reporters and verifiers are notified via regular registered email accounts (e.g., company or government emails) that there is new content in the correspondence mail box. This system is modeled after an approach commonly used in consumer banking and finance. Experts verifying reports can also communicate about a specific problem using this messaging system. Overall, the United States estimates that 50 percent of inquiries are source-specific, or related to requirements for a specific industry (e.g., stationary combustion). Inquiries received are related to system use and access.

4.1.3. Website

The GHG data management system website can be an effective way to engage with users and communicate updates and new features, information, and help services. Updates can also be linked to an RSS feed, allowing users to have the updates pushed to them. The website can include instructions to guide users through the registration and reporting process; guidance documents that support these processes, such as frequently asked questions (FAQs); training materials (including pre-recorded webinars); and relevant contact details if they require additional information.

California utilizes its website extensively as a central repository for all information relating to the reporting program and GHG data management system.[9]

[9] California's Mandatory Greenhouse Gas Reporting website: http://www.arb.ca.gov/cc/reporting/ghg-rep/ghg-rep.htm.

4.2. Training and Capacity Building for Users

The development of guidelines and training materials for users is an important component of managing a successfully used GHG data management system. The level of training required will likely be dictated by how familiar the users are with the system; for example, training to support the launch of a new system will typically be more involved than training to support annual updates to the system. Activities and materials may include:

- FAQs documents.
- System user guides/manuals by user type, with step-by-step instructions and associated screen shots. (These were cited by **Kazakhstan** as having the most value.)
- Tool tips and other in-application instructions.
- Training materials and sessions, which may include live or pre-recorded webinars, in-person sessions, and videos.

For example, **Australia** provides updated program information on its website in addition to conducting system training sessions for registered entities and regular webinars on various topics. This information is available to the public.

California maintains a contract with its external IT developer for system operations and maintenance, but program administrators and designated staff conduct all system trainings for reporters and also operate a help desk. Annually updated guidance documents, such as user guides, are available on California's website, and webinars are conducted when updates are made to the system. California no longer conducts in-person trainings, with the exception of verification and stakeholder workshops for regulatory amendments.

Turkey has established a "continuous learning center" which provides regular trainings to stakeholders. Relevant documentation—including legislation, FAQs, guidelines and manuals—is also publically posted on the website of the Ministry of Environment and Urbanization.

5. Abbreviations

ACEEE	An Energy Efficient Economy
API	Application programming interface
Cal e-GGRT	California Electronic Greenhouse Gas Reporting Tool (California)
CARB	California Air Resources Board
CBI	Confidential business information
CEMS	Continuous emissions monitoring systems
CH_4	Methane
CFC	Chlorofluorocarbon
CFO	Thailand Carbon Footprint for Organization Platform (Thailand)
CITSS	Compliance Instrument Tracking System Service (California)
CO_2	Carbon dioxide
CO_2e	Carbon dioxide equivalent
COA	Cédula de operación anual (annual operating certificate) (Mexico)
CRIS	Climate Registry Information System (Massachusetts)
DB	Database
DEHst	German Emission Trading Authority
DSDM	Dynamic systems development model
EERS	Emissions and Energy Reporting System (Australia)
e-GGRT	Electronic Greenhouse Gas Reporting Tool (United States)
EIS	Environmental Information System
EPA	Environmental Protection Agency
ETSWAP	Emission Trading System Workflow Automation Project (United Kingdom)
EU	European Union
FAQ	Frequently asked question
FDC	Federated Data Centre (California)
FDD	Feature-driven development
FLIGHT	Facility Level Information on Greenhouse Gases Tool
GHG	Greenhouse gas
GHGIP	Greenhous Gas Improvement Programme
GIS	Geographic information systems
GWP	Global warming potential
HCFC	Hydrochlorofluorocarbon
HFC	Hydrofluorocarbon
IDE	Integrated development environment
IIS	Internet Information Service
INDC	Intended Nationally Determined Contribution
IPCC	Intergovernmental Panel on Climate Change
IT	Information technology

IVT	Inputs verifier tool
MassDEP	Massachusetts Department of Environmental Protection
MRV	Measurement, reporting, and verification
Mt	Metric ton
MWth	Megawatt thermal
N_2O	Nitrous oxide
NAEIS	National Atmospheric Emission Inventory System (South Africa)
NAMA	Nationally Appropriate Mitigations Actions
NF_3	Nitrogen trifluoride
NGERS	National Greenhouse Gas Emission Reporting Scheme (Australia)
NGO	Non-governmental organization
OS	Operating system
OSCAR	Online System for Comprehensive Activity Reporting (Australia)
PFC	Perfluorocarbon
PM	Particulate matter
PMR	The Partnership for Market Readiness
PRTR[10]	Pollutant Release and Transfer Register (Chile)
QA	Quality assurance
QC	Quality control
RAD	Rapid application development
RAM	Random access memory
REC	Renewable energy credit
REDD+	Reducing Emissions from Deforestation and Forest Degradation
RENE	National Emissions Registry (Mexico)
RFI	Request for information
RFP	Request for proposal
RGGI	Regional Greenhouse Gas Initiative (Massachusetts)
S3	Amazon Simple Storage Services
SAAQIS	South African Air Quality Information System (South Africa)
SAIC	Science Applications International Corporation
SBI	Sensitive business information
SLCP	Short Lived Climate Pollutant
SEMARNAT	Secretariat of Environment and Natural Resources (Mexico)
SF_6	Sulfur hexafluoride
SME	Subject matter expertise
SO_2	Sulfur dioxide
SOAP	Simple object access protocol
SSRS	SQL Server Reporting Services

[10] PRTR systems are used by more jurisdictions than Chile, but for the purposes of this report, PRTR will refer to Chile only.

TACCC	Transparency, accuracy, comparability consistency, and completeness principles
TCR	The Climate Registry
TGO	Thailand Greenhouse Gas Management Organization
UAT	User acceptance testing
UI	User interface
UK	United Kingdom
UNFCCC	United Nations Framework Convention on Climate Change
UOM	Units of measure
USAID	U.S. Agency for International Development
US EPA	U.S. Environmental Protection Agency
UX	User experience
Valang	Validation language

6. Glossary

Activity data[11]	A quantitative measure of an activity that results in greenhouse gas emissions. Activity data is multiplied by an emission factor to derive the greenhouse gas emissions associated with a process or an operation. Examples include kilowatt hours of electricity used, quantity of fuel used, output of a process, number of hours equipment is operated, distance traveled, and floor area of a building.
Administrative agency	The institution or organization responsible for implementing the greenhouse gas reporting program (see table 1).
Agile approach	Non-linear, iterative software development approach in which development is broken into small iterations with frequent delivery of expanded functionality; emphasis is placed on flexibility, collaboration, and continuous testing (see table 2 and figure 2).
Alpha testing	A testing phase used to verify that requirements have been met, which is conducted by an internal group that is independent of the development team.
Analytics	A functional component of the system used to discover insights by producing metrics, summary, or visualization (such as a dashboard) based on methodical and detailed examination of trends in the data stored by the system.
Application programming interface (API)	Specifications of software components that are used to integrate functionality and data from otherwise separate software.
Base year[12]	A historic datum (a specific year or an average over multiple years) against which an entity's emissions are tracked over time.
Beta testing	A testing phase used to elicit feedback, which is conducted by an external group that is independent of the development organization; also known as pilot testing.
Black carbon[13]	A climate forcing agent formed through the incomplete combustion of fossil fuels, biofuel, and biomass.
Bug	An error in software code that prevents a system from successfully supporting functional requirements.

[11] Definition adapted from PMR & WRI 2015.
[12] Ibid.
[13] Ibid.

Build	Refers to the code construction process, which may include a sequence of compiling, linking, testing, installing, and/or deploying new code.
Calculation engine	Functional component of the system used to transform raw data into emissions data using emission factors, and in some cases also GWPs.
Cap-and-trade	See emissions trading system.
Carbon content (TCR 2013)	Refers to the mass of the element Carbon (C) within the total mass of a given fuel or feedstock.
Carbon dioxide equivalent (CO_2e) (PMR & WRI, 2015)	The universal unit of measurement to indicate the global warming potential of each of the seven greenhouse gases covered by the United Nations Framework Convention on Climate Change, expressed in terms of the global warming potential of one unit of CO_2.
Carbon targets	A set of policies, actions or a specific goal that establishes a carbon reduction level that is aimed to be achieved within a specified timeframe. Also known as carbon commitments.
Carbon taxes (PMR & WRI, 2015)	A levy on the carbon content of fossil fuels. Because virtually all of the carbon on fossil fuels is emitted as carbon dioxide, a carbon tax is equivalent to an emission tax of each unit of carbon dioxide equivalent emissions.
Confidential business information (CBI)	Information that must remain private due to competitive harm or trade secret concerns such that only approved parties can gain access, either due to regulation or reporter preference; may be defined by legal and regulatory frameworks.
Configurability	A built-in software feature that allows users to make adjustments to a system's interface or functionality based on a pre-defined menu of options, without requiring coding or new development.
Continuous emissions monitoring systems (CEMS)[14]	Monitors installed in energy and industrial operations to continuously collect, record, and report emissions data.
Corporate/facility-level	The point of regulation or level of detail required for reporting to a greenhouse gas program.
Crediting approaches	A policy that establishes a system in which permits or certificates that correspond to a specified quantity of emissions are issued. The required actions are established within the associated policy and regulatory frameworks. Permits or certificates can be traded if the full allowance is not used.

[14] Definition adapted from TCR 2013.

Data mapping	Second step in integrating data from one system to another; establishes the relationships between terminology in data fields that may be mismatched from incoming spreadsheet, .csv files, XML feeds, or APIs.
Data validation	First step in integrating data from one system to another; ensures that incoming data is correct and usable by the system.
Data transformation	Third and final step in integrating data from one system to another; may refer to simple changes in format or to larger changes such as a calculation engine converting activity data to emissions data.
Database	A repository with specific architecture that allows for the storage, management, retrieval, and analysis of data.
Direct emissions[15]	Emissions from sources that are owned or controlled by the reporting entity (see table 5).
Energy consumption taxes	A levy based on the amount of electricity or natural gas purchased by a consumer or entity.
Energy and energy efficiency initiative	A voluntary or mandatory international, national, subnational, government, or nongovernmental policy or activity that incentivizes the increased installation of renewable energy or energy efficiency equipment. Could include technical or financial support.
Energy efficiency resources standard (EERS)[16]	Specific, long-term targets for energy savings that an entity must achieve through customer energy efficiency programs. The target could be focused on electricity and/or natural gas. It is typically adopted and enforced through regulations.
Emission factor (PMR & WRI, 2015)	A factor that converts activity data into greenhouse gas emissions data (e.g., kilograms carbon dioxide per liter of fuel consumed, kilograms of carbon dioxide per kilometer traveled).
Emissions (PMR & WRI, 2015)	The release of greenhouse gases into the atmosphere.
Emissions standards[17]	The maximum amount of pollutant legally allowed from a single source or entity, mobile or stationary.
Emissions trading system (PMR & WRI, 2015)	A system that sets an overall emission limit, allocates emission allowances to participants, and allows them to trade allowances and emission credits with each other. Also known as cap-and-trade.

[15] Definition adapted from PMR & WRI, 2015.
[16] Definition adapted from American Council for an Energy Efficient Economy (ACEEE) 2015.
[17] Definition adapted from OECD 2001.

Functional requirements[18]	Second step in system development; behaviors that the system should do or support; often expressed as inputs and outputs of the product, or the description of the behavior itself.
GHG Protocol[19]	A multi-stakeholder collaboration convened by the World Resources Institute and the World Business Council for Sustainable Development to design, develop, and promote the use of accounting and reporting standards for business and governments.
Global warming potential (GWP)[20]	A factor describing the radiative forcing impact (degree of harm to the atmosphere) of one unit of a given greenhouse gas relative to one unit of carbon dioxide.
Greenhouse gases (GHGs)[21]	For the purposes of this report, GHGs are the seven gases covered by the United Nations Framework Convention on Climate Change; carbon dioxide (CO_2); methane (CH_4); nitrous oxide (N_2O); hydrofluorocarbons (HCFs); perfluorocarbons (PFCs); sulfur hexafluoride (SF_6); nitrogen trifluoride (NF_3).
Greenhouse gas reporting program[22]	A voluntary or mandatory international, national, subnational, government, or nongovernmental initiative that collects information on, or regulates greenhouse gas emissions or removals from reporting entities (see table 1).
Hardware	The physical components of an electronic system that execute, store, and/or carry software or data.
Heat content (TCR 2013)	Refers to the amount of heat released during the combustion of a specific fuel after returning that fuel to a given temperature, and is expressed as units of energy per unit mass or volume; also known as calorific values, either as net calorific values or gross calorific values.
Hosting	The service of storing and providing accessibility to software and/or data.
In-house	One option for system development, relying on internal expertise of the administrative agency personnel; also known as the build approach.
Independent systems	Systems designed for a specific policy or mandate, with limited or no linkages between systems.

[18] Definition adapted from the University of Alberta 2015a.
[19] Definition adapted from PMR & WRI, 2015.
[20] Ibid.
[21] Ibid.
[22] Ibid.

Indirect emissions[23]	Emissions that are a consequence of the operations of the reporting entity, but that occur as sources owned or controlled by another entity (see table 5).
Information technology (IT) developer	Entity responsible for developing and implementing the functional and technical requirements of the system, including database design and implementation.
Institutional frameworks	Frameworks addressing greenhouse gas system governance and oversight that supports effective communication, ensures accountability, and supports system development, maintenance, and use. May encompass one or more institutions.
Integrated system	Web-based, centrally-coordinated systems with common definitions and multiple uses.
Integrated upload	A method of data entry that allows users to upload a specific file format or formatted data set to a system, after which the data contained in the uploaded file or data set is directly integrated into the system database.
Joel test	An approach to assess the capacity and of the internal software team for in-house development.
Intergovernmental Panel on	International body of climate change scientists.
Climate Change (IPCC)[24]	The role of the IPCC is to assess the scientific, technical, and socioeconomic information relevant to understanding the risk of human-induced climate change.
Jurisdiction[25]	The geographic area within which a greenhouse gas reporting program is administered. Jurisdictions can be subnational, national, or multicounty regions.
Legal framework	Primary (i.e., broad frameworks) or secondary legislation (i.e., enabling legislation) that gives authorization and direction to jurisdictions to determine and implement regulations that put into practice the legislative intent (see table 1).
Linkage	In regards to software systems, refers to automated communication between separate software or databases.
Manual input	A method of data entry that requires users to manually enter each required value, individually.

[23] Definition adapted from PMR & WRI, 2015.
[24] Ibid.
[25] Ibid.

Mass balance method[26]	A method to calculate greenhouse gas emissions based on determining the balance of greenhouse gases entering and leaving the entire entity or a specific unit or process within the entity.
Modularity	Type of programming approach in system development; allows for discrete components of functionality to be designed and deployed independently.
National greenhouse gas inventories[27]	An analysis that accounts for all sources of anthropogenic greenhouse gas emissions by source and removals by sinks. The boundaries for the analysis include all activities that occur within the country's physical boundary. The analysis is based on the application of emission factors to national-level activity data. Native gases are typically converted into CO_2-equivalents using a global warming potential. The main categories within a national inventory, as defined by IPCC, include energy; industrial processes and product use; agriculture, forestry and other land use; waste; and other.
Offset (TCR 2013)	Represent the reduction, removal, or avoidance of greenhouse gas emissions from a specific project that is used to compensate for greenhouse gas emissions occurring elsewhere.
Outsource	One option for system development; relying on the external expertise of a chosen software development team; may also refer to customizing a third-party solution.
Process emissions[28]	Emissions generated from manufacturing processes, such as carbon dioxide that is emitted from the breakdown of calcium carbonate during cement manufacturing.
Procurement	The process of acquiring the services and products of an external software developer or information technology company.
Program administrator	Entity that manages, oversees, and implements the greenhouse gas reporting program that they system is supporting. The statutory regulator may serve as the program administrator, although both roles have different responsibilities.
Prototyping	Process of developing and testing initial screen shots, system appearance, user experience, and functionality.
Quality assurance	Activities undertaken to ensure the reliability, completeness, and accuracy of emissions data after the data has been submitted by the reporter; also known as verification.

[26] Ibid.
[27] Definition adapted from IPCC 2006.
[28] Definition adapted from PMR & WRI, 2015.

Quality control	Procedures undertaken by reporters, program administrators, or internally by system itself prior to submittal of the greenhouse gas report.
Regulatory frameworks[29]	A mandatory international, national, subnational, government, or nongovernmental initiative that outlines requirements for information collection or other actions (e.g., reductions) from applicable entities (see table 1).
Reporting entity (TCR 2013)	Any legally recognized business, corporation, organization, institution, agency, or government that is bound to report emissions under the regulatory framework; will vary by jurisdiction.
Reporting guidance	Document that outlines the reporting and/or verification guidelines associated with the greenhouse has reporting program the system is supporting; a valuable precursor for system development.
Sandbox approach	System testing approach used to engagement stakeholders in system development. An early version of the system is typically deployed to a shared user space so that stakeholders may register, setup account, enter test data, and provide feedback. Also known as a sandpit approach.
Sensitive Business Information (SBI)	See “Confidential Business Information.”
Software	The applications, operating systems, and scripts that are executed, stored, or carried on electrical hardware to support functional requirements.
Source[30]	Any process, activity, or mechanism that releases a greenhouse gas into the atmosphere.
Source control	The automated management of changes to software, which prevents conflicts in segments of code that are contributed by independent developers; similar to version control.
Statutory regulator	Entity that sets and enforces the greenhouse gas reporting regulations and defines the regulatory and policy context that dictates the system requirements.
Systems	Referred to throughout report as GHG data management systems. Repositories designed and developed to collect and store GHG inventory data from companies and organizations, often at the level of the facility, or at the level of a corporation or enterprise.

[29] Definition adapted from PMR & WRI, 2015, definition for GHG reporting program.
[30] Definition adapted from PMR & WRI, 2015.

System administrator	Entity responsible for the day-to-day management of the system and access to the system. May be overlap with the statutory regulator.
System requirements	First step in system development; defining the system to be built based on the policies and regulations it will support; may include analyzing regulations, considering regulatory changes and linkages, engaging stakeholders, researching similar systems, assessing existing systems, assessing data needs, and prototyping.
TACCC	Greenhouse gas accounting best practice principles: data transparency, accuracy, comparability, consistency, completeness. Defined by Intergovernmental Panel on Climate Change *Guidelines for National GHG Inventories.*
Technical requirements	Specifications of system performance, architecture, hardware, software, security, and hosting; may also clarify processes related to software development, integration, testing, and deployment.
Test suite	A collection of use case scripts which are run to receive a pass or fail verdict; these outcomes are used identify errors in code or integration issues.
Third-party verification[31]	An independent assessment of the reliability, completeness, and accuracy of emissions–related information submitted by reporting entities.
Uncertainty[32]	Quantitative definition: measurement that characterizes the dispersion of values that could reasonably be attributed to a parameter. Qualitative definition: a general term that refers to the lack of certainty in data and methodology choices, such as the application of non-representative factors or methods, incomplete data on sources and sinks, or lack of transparency.
User acceptance testing (UAT)	A test that verifies that a functional requirement has been satisfied, conducted by a user following a specific use case script.
User role	The title given to a specific bundle of permissions, or access to functionality and data, within a system; user roles may be specific to an individual user type or accommodate multiple user types.

[31] Ibid.
[32] Ibid.

User type	The different persons who will use the product and may require varying levels of access or functionality; examples include administrators, reporters, and verifiers.
Verifier	Refers to third-party verifiers and in-house verifiers; independent auditor who assesses the credibility of reported data.
Waterfall approach[33]	Linear software development process, typified by phases where approved work products are passed from one phase to the next (see table 2 and figure 1).

[33] Definition adapted from University of Alberta 2015b.

7. References

American Council for an Energy Efficient Economy (ACEEE). 2015. "Energy Efficiency Resource Standard." http://aceee.org/topics/energy-efficiency-resource-standard-eers.

Chiu, K., and P. Kokopeli. 2013. "Challenges and Lessons Learned in Developing an Integrated Data Management System to Support EPA's Greenhouse Gas Reporting Program." Extended Abstract 62, United States Environmental Protection Agency, Washington, DC.

Flynn, T. 2015. "10 Keys to Choosing a Data Center Colocation Provider." http://focus.forsythe.com/articles/379/10-Keys-to-Choosing-a-Data-Center-Colocation-Provider.

Guiliano, S. 2013. "HIPAA Compliant Hosting Requirements: Easy, Solution-Oriented Checklist." https://www.atlantic.net/blog/hipaa-compliant-hosting-requirements-easy-solution-oriented-checklist.

IPCC (Intergovernmental Panel on Climate Change). 2006. "2006 IPCC Guidelines for National Greenhouse Gas Inventories: Overview." http://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/0_Overview/V0_1_Overview.pdf.

Manzini, L., J. Witi, O. Mokotedi, and S. Rahlao. 2013. "Overview of the National GHG Inventory Data Management System: Case Study from South Africa." MAPT National Inventory Case Study Series, Climate Change and Air Quality Management Branch, Monitoring and Evaluation Chief Directorate, Department of Environmental Affairs, Republic of South Africa.

Ministry of Environment and Urbanization (Turkey). 2014. "MRV Data Management System in Turkey." https://www.thepmr.org/system/files/documents/25-TURKEY-MRV%20DMS_2.pdf.

Ministry of the Environment (Chile). 2014. "One-Stop System: Register of Emissions and Transfer Pollutants." Government of Chile.

PMR (Partnership for Market Readiness). 2013. "Supporting GHG Mitigation Activities with Effective Data Management Systems." Technical Note 4. https://www.thepmr.org/system/files/documents/PMR%20Technical%20Note%204.pdf.

Singh, Neelam, Kathryn Bacher, Ranping Song, Mary Sotos, and Lei Yin. 2015. "Guide for Designing Mandatory Greenhouse Gas Reporting Programs." Partnership for Market Readiness Technical Paper, World Bank, Washington, DC.

TCR (The Climate Registry). 2013. "General Reporting Protocol Version 2.0." https://www.theclimateregistry.org.

———. 2015. "User Guide: Climate Registry Information System Version 4.0." https://www.theclimateregistry.org.

TechTarget. 2014. "Simple Object Access Protocol Definition." http://searchsoa.techtarget.com/definition/SOAP.

University of Alberta. 2015a. "Software Processes and Agile Practices Glossary." Faculty of Science, Alberta, Canada.

———. 2015b. "Client Needs and Software Requirements Glossary." Faculty of Science, Alberta, Canada.

USAID (United States Agency for International Development). 2015. "USAID Low Emissions Asian Development (LEAD) Program: Revised CFO Program (Version 2) Functional Requirements." Internal TGO document.

U.S. EPA (United States Environmental Protection Agency). 2015a. "Cross-Media Electronic Reporting Rule Fact Sheet." http://www.epa.gov/sites/production/files/2015-08/documents/cromerr_fact_sheet.pdf.

———. 2015b. "Greenhouse Gas Reporting Program Report Verification Fact Sheet." Greenhouse Gas Reporting Program. http://www2.epa.gov/sites/production/files/2015-07/documents/ghgrp_verification_factsheet.pdf.

———. 2015c. "Facility Level Information on Greenhouse Gases Tool (FLIGHT)." 2014 Greenhouse Gas Emissions from Large Facilities. http://ghgdata.epa.gov/ghgp/main.do.

Vauthier, J. C. 2006. "Decision Tables: A Testing Technique using IBM Rational Functional Tester." IBM Software Group. http://www.ibm.com/developerworks/rational/library/jun06/vauthier/.

Whipp, P. 2014. "Why You Need Agile Development." http://paulwhippconsulting.com/blog/our-brand-of-agile-development/.

8. Appendix: List of Air Pollutants Generated at the Corporate/Facility Level

Impact	Regulatory basis		Pollutant	Main sectors	Monitoring
Climate change	Direct GHG reported under UNFCCC		Carbon dioxide (CO_2) non biomass	Combustion Non energy uses Industrial processes (mineral, chemical, metal industries)	Mass balance Measurement of C content Default Emission Factor (EF)
			Carbon dioxide (CO_2) biomass	Biomass combustion	
			Nitrogen protoxide (N_2O)	Combustion Chemical industry (processes)	Default EF Measurement
			Perfluorocarbones (PFC)	Semiconductor Solvent	IPCC equation Mass balance Reported as total mass of perclofluro fluorocarbons and/or by type of product: CF_4, C_2F_6, C_3F_8, C_4F_{10}, c-C_4F_8, C_5F_{12}, C_6F_{14}
			Sulfur hexafluoride (SF_6)	Electrical equipment Industrial processes	Mass balance
			Nitrogen trifluride (NF_3)	Semiconductor	IPCC equation
		SLCF covered by the Climate & Clean Air Coalition (CCAC)	Hydrofluorocarbons (HFC)	Refrigeration and air conditioning Industrial processes (producers of HFC, manufacturer of aerosols and foam blowing agents)	Mass balance Reported as total mass of hydrofluorocarbons and/or by type of product: HFC23, HFC32, HFC41, HFC4310mee, HFC125, HFC134, HFC134a, HFC152a, HFC143, HFC143a, HFC227ea, HFC236fa, HFC245ca, HFC 245fa, HFC365mfc.
			Methane (CH_4)	Combustion Chemical industry (processes)	Default EF Measurement

table continues next page

Impact	Regulatory basis	Pollutant	Main sectors	Monitoring
Health and air pollution	UNECE Geneva Convention on Long range Transboundary Air Pollution (CLRTAP) Gothenburg protocol amended in 2012	Black carbon (BC)	Mainly combustion	$PM_{2.5}$ speciation
Climate change *Acidification* *Eutrophication* *Photochemical pollution* *Formation of secondary aerosols*	Indirect GHG reported under UNFCCC CLRTAP Gothenburg Protocol NAFTA	Carbon monoxide (CO)	Combustion	Measurement Default EF
		Non methanic volatic organic compounds (NMVOC)	Solvent uses Chemical/ petrochemical industry/refinery (processes and fugitive emissions) Combustion	Mass balance Measurement Model Default EF
		Nitrate oxides (NO_x as NO_2)	Combustion	Measurement Default EF
		Sulfur oxides (SO_x/SO_2)	Combustion Industrial processes	Mass balance (%S) Measurement Model Default EF
Eutrophication *Formation of secondary aerosols*	CLRTAP Gothenburg Protocol	Ammoniac (NH_3)	Chemical industry (processes) NO_x treatment	Measurement Default EF
Climate change	National regulation: e.g., France: BEGES UK: Companies Act Mexico: National emissions register GHG Protocol, etc.	All direct GHGs	Scope 2: Purchased electricity, heat, etc. Scope 3: Purchased products, transport, waste management, etc.	National default EF (database) reported as the sum of GHGs converted in CO_2e

Impact	Regulatory basis	Pollutant	Main sectors	Monitoring
Air pollution *Health* *Deposition on ecosystem*	CLRTAP Gothenburg Protocol	Total suspended particulate (TSP)	Combustion Industrial processes	Measurement Default EF
		PM_{10}	Combustion Industrial processes	Measurement Default EF TSP speciation
		$PM_{2.5}$	Combustion Industrial processes	TSP or PM_{10} speciation
	CLRTAP Aarhus Protocol on HM UNEP Convention of Minamata on Mercury	As, Se, Cr, Cd, Cu, Hg, Ni, Pb, Zn	Combustion Industrial processes	Measurement Default EF Fuel or raw material characteristics
	Aarhus Protocol on POP Stockholm Convention	PCDD + PCDF (as I-TEQ) and others such as PAH, PCB and HCB	Combustion Waste incineration	Measurement Default EF

WORLD BANK GROUP
Climate Change

PMR | *Pricing Carbon to Achieve Climate Mitigation*

http://www.thepmr.org
pmrsecretariat@worldbankgroup.org