ICAT INITIATIVE FOR Climate Action Transparency

CBIT CAPACITY-BUILDING INITIATIVE FOR TRANSPARENCY
GLOBAL COORDINATION PLATFORM

A road map for establishing information systems for climate action and support

UNEP DTU PARTNERSHIP

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Table of Contents

Acknowledgements 3

1. Introduction 5

2. Supporting the implementation of the Enhanced Transparency Framework with information systems 8

2.1. Implementation of the UNFCCC's reporting framework 8

2.2. The Enhanced Transparency Framework and information systems 10

2.3. Potential barriers to the development of an information system project 11

3. Information systems for climate action and support 13

3.1. Integrated information systems 15

3.2. Independent information systems 18

4. A road map for establishing information systems for climate action and support 22

4.1. Scoping the information system 22

4.1.1. Mapping and documentation of existing systems 23

4.1.2. Stakeholder engagement 23

4.1.3. The regulatory framework 23

4.1.4. Data requirements 24

4.1.5. Functional requirements 24

4.1.6. Non-functional requirements 25

4.1.7. Hardware and software architecture 26

4.2. Development of the information system 26

4.2.1. Build or buy an information system 26

4.2.2. Best practices for information systems projects 33

4.2.3. Quality and testing 34

4.3. Deploying and launching the information system 36

4.3.1. Hardware and infrastructure 36

4.3.2. Data considerations 37

4.3.3. Schedule of the changeover process 37

4.3.4. Training needs 38

4.4. Maintenance of and improvements to the information system 39

4.5. Indicative time estimate for the road map 40

5. Methodologies and techniques used in the development of information system projects 41

5.1. Methodologies for developing information systems 41

5.1.1. A linear methodology: Waterfall 41

5.1.2. An evolutionary methodology: Agile 42

5.2. Techniques for analysing information systems 43

6. Final remarks 46

Annex A. Template Sections of Request for Proposal 47

Glossary 49

References 51

CHAPTER 1

Introduction

At the Paris climate conference (COP-21) in December 2015, the Conference of the Parties decided to adopt the Paris Agreement under the United Nations Framework Convention on Climate Change. This was the first time that 195 Parties had agreed on a universal, legally binding climate instrument.

During COP-21, the Parties agreed that each Party is to communicate a nationally determined contribution (NDC) every five years. Also, a Party may at any time modify its existing NDC with a view to enhancing its level of ambition.

A country's NDC sets out its efforts to combat climate change, including its mitigation goal, corresponding to its national contribution to global mitigation efforts. At the national level, NDCs will be implemented through individual policies and measures. All these policies and measures will undergo a measurement, reporting and verification (MRV) process nationally. The information collected from the individual policies and measures can be used nationally to monitor the level of achievement of the mitigation goals stated in the NDC and thus contribute to the reporting of progress in implementing NDCs to UNFCCC. In this context, the implementation of measurement, reporting, and verification systems at the national and international levels becomes an important tool for tracking individual countries' implementation of their NDCs.

Reiterating the need to build mutual trust and confidence and to promote effective implementation of the Convention, Article 13 of the Paris Agreement established an enhanced transparency framework (ETF) for action and support. The purpose of the transparency framework of action is to provide a clear understanding of climate change actions taken by countries in light of the objectives of the Convention, including clarity and the tracking of progress towards achieving Parties' individual NDCs. The purpose of the transparency framework of support is 'to provide clarity on support provided and received by relevant individual Parties in the context of climate change … and … to provide a full overview of aggregate financial support provided, to inform the global stocktake´. This framework is thus one of the central pillars for enhancing information on NDC implementation and raising the ambition to meet the Paris Agreement's goal of keeping the rise in global temperatures well below 2 degrees above industrial levels.

The ETF builds upon the MRV system and requirements established under previous COPs. However, it abandons the distinctions between Annex I and non-Annex I Parties and establishes universal and harmonized transparency provisions that apply to all countries. Nonetheless the ETF grants flexibility to those developing countries that need it in light of their capacities. ETF implementation will start in 2024.

At the Katowice climate conference (COP-24) in December 2018, the Conference of the Parties adopted the modalities, procedures, and guidelines (MPGs) for the ETF for action and support.

Under the ETF, the transparency report will be the Biennial Transparency Report (BTR), which will replace the Biennial Update Report (BUR) for non-Annex I Parties. The BTR will contain the information necessary to track progress made in implementing and achieving NDCs. In addition, countries will have to submit a National Inventory Report (NIR), including an inventory of the anthropogenic emissions of greenhouse gases. The NIR must be submitted either as a stand-alone report or as a component of the BTR. Preparing and reporting National Communications (NatComs) will also remain a requirement for all countries.

To produce these reports, a country will have to:

a) Collect and manage a diversity of data nationally
b) Process and prepare those data to meet defined methodologies and requirements
c) Report those data to the UNFCCC in accordance with a defined schedule and format.

The systematic and regular collection, preparation and reporting of data by a country to the UNFCCC is a resource-intensive process that involves a large number of national stakeholders. The use of computer-based information systems can make this process more efficient, reliable, systematic, traceable, and less expensive. Computer-based information systems involve the use of information technologies (hardware, software, communication networks) to assemble, store, process and deliver relevant and useful information to stakeholders.

An information system (IS) that supports ETF implementation has interrelated human and computer elements, the latter being predictable in a way the former are not. The human aspects include, for example, keying in the relevant data, editing data, doing data cross-checking and quality control, and interpreting information. The computer elements will mostly do the processing and storing of data,[1] as well as handling data retrieval and data management requests.

A successful information system is one that actually helps the system's stakeholders achieve their goals. Some information systems may work in the technical sense, but may be unsuccessful due to human problems, such as rejection, unmet expectations and a general lack of adoption of the system. In fact, industry surveys reveal that many information systems projects are not successful. More than fifty percent of these projects experience outcomes that are not aligned with the original goals, or the project is not completed within the specified budget, or the timelines are insuf-

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1 Processing data consists in making operations on data items in order to transform them into meaningful information. Examples are converting activity data into emissions equivalent data, performing automated quality control operations, aggregating data, and presenting data in a graphical form.

ficient.[2] The reasons for failure typically reflect human and organizational factors, rather than technical ones.

This publication is targeted at project developers, that is, climate change practitioners working in governmental institutions who are embarking on projects aiming to build or further develop information systems to support the implementation of the enhanced transparency framework. It aims to provide an overview of the aspects to consider when designing and developing an information system to support the processes leading to the transparency of climate action and support within the country. As such, it provides insights regarding the aspects that are relevant to consider when developing an information system, including methodologies for development and techniques for analysing and documenting the functions and objectives of the system. It also provides recommendations for how to maintain an information system.

2 https://www.cio.com/article/3068502/project-management/more-than-half-of-it-projects-still-failing.html, and https://www.cio.com/article/3282464/14-reasons-why-software-projects-fail.html

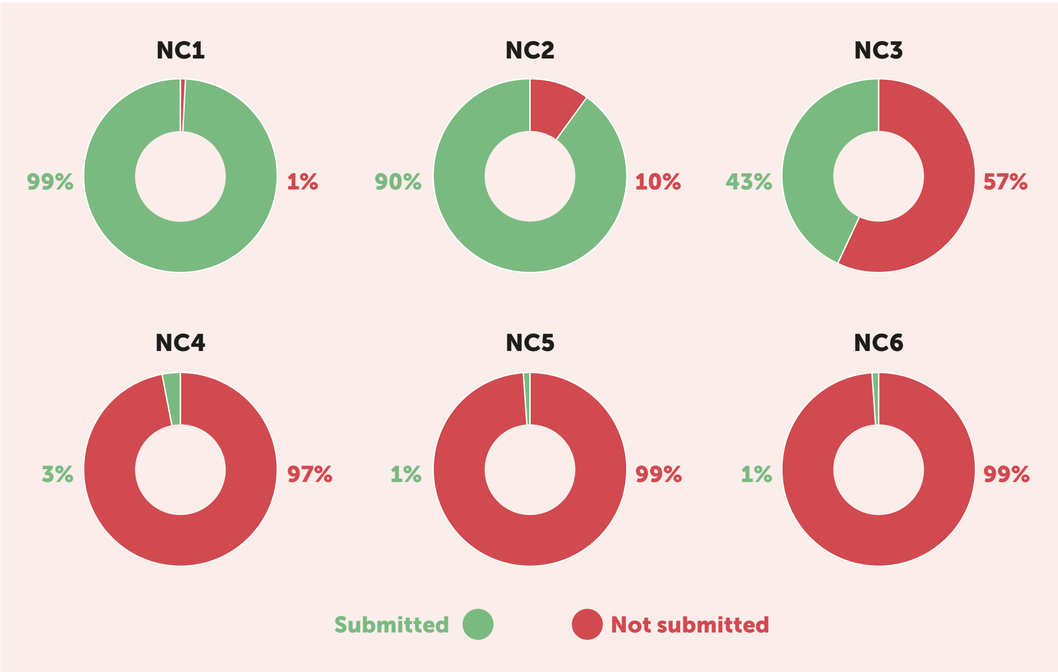
CHAPTER 2

Supporting the implementation of the Enhanced Transparency Framework with information systems

2.1. Implementation of the UNFCCC's reporting framework

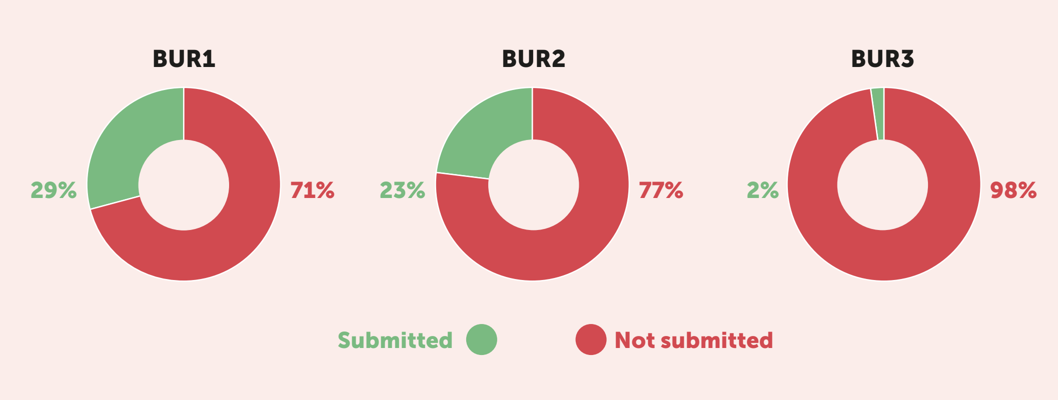
Implementation of the UNFCCC's reporting framework is an ongoing process, and many developing countries have not yet been able to meet all their reporting requirements in respect of preparing and submitting regular National Communications (NatComs) and Biennial Update Reports (BURs) to the UNFCCC. For example, the NatComs cycle, which started in 1997 and runs on a four-year period, has now had six reporting rounds over the last 22 years. The percentage of Non-annex I Parties that had the capacity to meet this regular reporting cycle is quite low (Figure 1[3]); indeed, only 1% of Non-annex I Parties have been able to report their NatComs on schedule. Most countries have been able to submit their first NatCom, a large percentage also submitted a second NatCom, and 43% submitted the third NatCom

Figure 1. Percentage of Non-annex I Parties (n=155) meeting the various reporting cycles for NatComs



3 Data retrieved from UNFCCC website on 27 August 2019.

Figure 2. Percentage of non-annex I Parties (n=155) meeting the various reporting cycles for BURs



as well. As yet, however, only a very small number have actually submitted the fourth and following NatComs.

On average, the number of years between the submission of the first and second NatComs is ten years, and the number of years between the second and third NatComs is 5.8 years.[4] However, this average is expected to increase as more countries submit their third NatCom. The difficulties in keeping up with the NatCom reporting cycle may have been exacerbated by the introduction of the requirement to prepare biennial update reports (BURs), especially for countries that are already stretched in their capacity to prepare their NatComs.

The reporting cycle for the biennial update report (BUR) started in 2014 and has so far had three reporting rounds. Roughly, only a third of Non-annex I Parties submitted the first and second BUR, and only 2% (three countries) submitted the third BUR[5] (Figure 2).

Different factors contribute to the difficulty in implementing the UNFCCC reporting framework. A factor often mentioned is the lack of capacity on the part of these countries' governments to address the reporting requirements. Typically, the activities leading to the preparation of these reports are not budgeted nationally or have only very limited budgets, while the ministries engaged in the process of preparing the reports are often understaffed or have very limited staff resources to allocate. Developing countries can access funds from the Global Environment Facility for their NatCom and BUR projects, but there is an administrative process for obtaining this funding, which itself takes time and resources to complete. This dependence on project-based funding to prepare the NatCom and BUR results in weak continuity of the activities leading to the reporting of information to the UNFCCC, namely in the regular preparation of inventories of GHG emissions and the systematic collection of information about mitigation actions, adaptation actions, and existing financial, technical and capacity-building needs.

4 Data retrieved from UNFCCC website on 25 January 2019 and prepared by UNDP.

5 Data retrieved from UNFCCC website on 27 August 2019.

Besides the often limited capacity and resources a country has to implement the activities leading to the reporting of NatComs and BURs, another challenge relates to availability of the data needed to produce these reports. Constraints related to data have been mentioned by the majority of developing countries according to a report compiled by the UNFCCC Secretariat (UNFCCC Secretariat, 2017). These constraints on data affect not only national GHG inventories, but also mitigation assessments and adaptation and vulnerability assessments. In relation to the GHG inventory, the constraints often mentioned are the lack of a proper system for collecting, compiling, sharing and reporting data, and a lack of expertise in managing data. Echoing this, a number of developing countries surveyed for their needs with respect to a national inventory system have indicated the development of a data management system as a priority (Damassa, Blumenthal, and Elsayed, 2015). For mitigation assessments, the main data constraints are a lack of expertise to manage data or to use data to identify mitigation options, as well as data collection gaps across different sectors and data variables. The gaps in expertise are identical for adaptation and vulnerability assessments, as the collection of primary data is also constrained by a lack of infrastructure to support the collection and analysis of data at different governance levels (national, subnational, sectoral) (UNFCCC Secretariat, 2017).

2.2. The Enhanced Transparency Framework and information systems

Addressing data-related constraints requires not only capacity-building to acquire the necessary expertise, but also that countries have in place systematic data management[6] procedures. The tool best suited for systematic data management is an information system. An information system combines people, processes and information technology to collect, store and process data with the aim of facilitating the dissemination of information. The main advantage of such systems is that they respond efficiently to the information needs of different stakeholders. A well-designed information system addresses needs such as customizing data to help with specific tasks or decision-making and archiving data for analysis, reporting and planning purposes. Information systems contribute to a higher level of efficiency and productivity, better availability of information and better communication among stakeholders (if they all have access to the same information), and in general create a platform for exploring various alternatives and seeing the possible results before making decisions.

The need for systematic data management appears to become even greater as countries start to implement the enhanced transparency framework of the Paris Agreement. The ETF requires developing countries to establish or improve existing processes to collect data regularly and systematically about the following:

6 Data management is the practice of acquiring, validating, storing and processing data securely, efficiently and cost-effectively.

- National GHG emissions estimates and projections
- Progress made in implementing and achieving the country's nationally determined contribution (NDC) to the Paris Agreement
- Climate change impacts and adaptation
- Adaptation actions with mitigation co-benefits
- Impacts of implementation of response measures
- Financial support, technology transfer and capacity-building support needed and received
- Use of internationally transferred mitigation outcomes.

The possible uses of these data are many. For example, this information is extremely useful for purposes of policy planning and research, as well as in increasing awareness of climate change and climate action in the country concerned. In terms of policy planning, data that have been systematically collected and verified through quality assurance and control procedures can be used with a high level of confidence to support decision-making nationally and sub-nationally, to inform the analysis of the impacts of actions and projects, to track progress with the implementation of NDCs, and to identify gaps and areas where support is needed.

In a similar vein, this good quality data can be used for research purposes and for awareness-raising and educational efforts within the country, engaging various stakeholders, including investors and financiers, and inspiring action and further ambitions in terms of climate goals. As a corollary, the quest for good-quality data will stimulate national and local-level research, development and deployment, strengthening the nexus between policy and research. Arguably, good national climate data will be a stimulus for ensuring national as well as local-level policy coherence, as well as contributing significantly to the attainment of many of the sustainable development goals.

2.3. Potential barriers to the development of an information system project

Before embarking on a project to develop an information system for managing climate action and climate support data, project developers[7] need to have a good understanding of what they are trying to achieve and how to get there. For the project to succeed, it is important to be aware of the barriers that can hamper project development and to address them. The project developers of this sort of project are typically part of the national ministry that has the role of being the focal point for the UNFCCC.

7 In this publication, we define project developers as government staff working in the climate change area who embark on projects aiming to build or further develop systems that support systematic data management procedures for climate action and climate support data.

Reporting on GHG emissions is complex, and many developing countries lack the experience and capacity to do it themselves. In many cases, countries have relied on consultants to meet the reporting requirements, and this has had mixed results. In some cases capacity-building is delivered as part of the consultancy's services, but in others the outcome is little or no internal capacity-building. As such, project developers may have an insufficient understanding of the reporting requirements, including an overview of the data needs, data sources and the stakeholders that need to be engaged.

It is also difficult to determine which data need to be collected, from whom, and how to do it when countries are in the early stages of policy implementation. This is the case when tracking the implementation of NDCs under the ETF of the Paris Agreement, which countries are about to start. This is a risk to the project because the scoping of the system may prove inadequate.

Project developers may lack knowledge about how to implement an information system or may have no previous experience with software development projects. This can be a significant risk for the project because of the complexities of information systems, which require a good understanding of software design. If the project developer does not have the skills to understand the actions of the software development team, bringing in an independent technical auditor can be quite helpful in mitigating this risk.

Moreover, there is often a lack of evidence, such as feasibility studies, to inform decision-makers and project developers about the benefits and costs of different options for developing an information system, such as whether to build independent or integrated information systems, or what to prioritize if funds are limited.

In addition, there may be pressure to make short-term decisions that can compromise long-term objectives. For example, if countries are receiving funding for developing a system to track the implementation of their NDC and the funds are to be spent in a certain period to achieve specific related outcomes, this may result in the development of a system that is not entirely aligned with the country priorities.

Another issue is unclear or non-existent legal and institutional frameworks for reporting the necessary data (World Bank, 2016). It is important that legal frameworks be defined in advance, or at least during the development of an information system. Where this is not possible, the system should be designed with the flexibility to respond to an evolving regulatory environment. A clear institutional framework facilitates governance and oversight of the information system, supports project development, and helps in the system's future adoption and use. As such, establishing formal institutional arrangements with clearly defined roles and responsibilities is beneficial to the success of the project.

CHAPTER 3

Information systems for climate action and support

Information systems support the key aspects of managing information in all kinds of governing structures (e.g. organizations, municipalities, ministries), such as record-keeping, decision-making, data analysis, and internal and external communication. The core functions of an information system are to collect, store, share, process and present data. The elements of an information system are computer hardware, computer software, manual procedures by humans and databases. Technically this combination of elements can be either rudimentary or more sophisticated, and hence information systems can vary significantly in terms of their features, configuration, system access arrangements, and the resources and capacities needed to develop and maintain the information system over time.

For example, a basic information system to support the elaboration of the national GHG inventory can combine widely used productivity software[8] with other specialized software,[9] such as IPCC 2006 GHG inventory software. Typically, this consists of a set of spreadsheets and word-processing documents, shared through email or through a cloud-based storage service (e.g. Dropbox, OneDrive, GoogleDrive) in order to receive data inputs from different data providers, and the processing of this data with the IPCC inventory software. This arrangement is a minimally viable system for a country to produce GHG inventory reports, but it has fragilities when it comes to data validation, data integrity, data security and the long-term storage of data due to the intrinsic properties of spreadsheets.

Storing vast amounts of tabular data in spreadsheets is possible and actually very common, but it has limitations and is not considered good practice. Databases are ideal for storing raw data for the following reasons. A database ensures data validation – that is, it ensures that only data with a certain format can be stored in a certain field. This prevents inadvertent mistakes, which are very common in spreadsheets, given that a cell in a spreadsheet can store formulas and data in any format (a date, a number, text, etc.). Databases ensure data integrity because all data processing is done after data retrieval, and data processing is completely separated from data records. This is not the case with spreadsheets, where formulas, functions and raw

8 Productivity software is software that allows people to create documents, presentations, data lists and charts. Historically, when this software was introduced into offices, the productivity of workers increased, hence the name. Productivity software is generic in use, meaning that it has many uses. Examples include Microsoft Office, the Google Office Suite (Docs, Sheets, and Slides), and LibreOffice.

9 Specialized software is software created for a specific task rather than for a generic task like writing a text. This software has very few uses, possibly only one. Examples include accounting software, geographic information systems, 3D animation software and software to control a pacemaker.

Table 1. Possible setups of information systems for MRV of GHG emissions

	Collect data	Store data	Share data	Process data	Present data
Basic IS for MRV of GHG emissions	Spreadsheets Word processors	Spreadsheets Word processors	Email Cloud services	IPCC inventory software	Spreadsheets Word processors
Specialized IS for MRV of GHG emissions	Web-based form or interface	Relational database	Relational database	Integrated calculation engine	Webpage Exported data in different formats

data are all stored in cells and can become mixed up. Unlike spreadsheets, databases provide a stable structure with the ability to control access and user role permissions, therefore guaranteeing data security. This is not possible with a shared spreadsheet, where it is impossible to track which user changes what and when. There are also limitations in terms of the volume of data (number of rows) that spreadsheets can handle, as well as performance limitations when working with multiple linked spreadsheets.

A more sophisticated information system may consist of dedicated web-based specialized software,[10] accessible through an internet browser (there might be an offline version as well), allowing multiple users with different types of permissions to insert data into a database, to manipulate that data and to extract the transformed data into different reports. This ensures a stable data structure, data integrity, data consistency, data accessibility and proper security and storage, while avoiding data redundancy and preventing and signalling accidental data errors. Such an information system allows multiple users, with different roles and permissions, to access data concurrently and to extract data into customized reports. Moreover, it enables the standardization of data submissions, automated sense checks on data entry and the cross-checking of different datasets, contributing to better data quality and data integrity.

Table 1 shows possible arrangements of information systems for the MRV of GHG emissions. According to Damassa et al., (2015), the information systems used for GHG inventories by Austria and Hungary are spreadsheet-based, while, for example, Germany uses specialized software developed and maintained by a German company.

Information systems supporting the national processes to achieve transparency regarding climate action and support can also vary in terms of how they integrate or

10 Web-based specialized software is software that people access and use through the internet using an internet browser (e.g. Internet Explorer, Firefox, Chrome). It does not require the downloading or local installation of the software. Examples are the UNFCCC’s NAIIS software for GHG inventory, the customer relations manager software Salesforce and the social networking software Facebook.

separate different data flows. Developing countries must collect data and report regularly to UNFCCC on the following:

1) National inventory of GHG emissions
2) Information to track implementation of NDCs
3) Information on climate change impacts and adaptation
4) Information on support needed and received
5) The impacts of implementing response measures
6) Adaptation actions with mitigation co-benefits
7) Use of internationally transferred mitigation outcomes
8) Support needed and received.

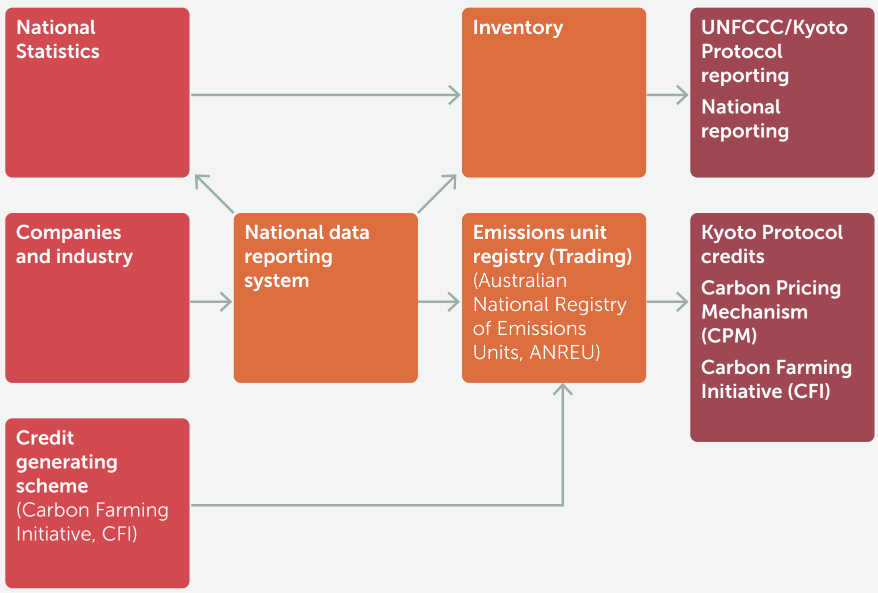
A completely integrated national information system would combine these data flows, adopting common definitions and features, and serving multiple uses. Conversely, a non-integrated information system would have separate information systems for some or all of the above data flows, each with own definitions, features and uses, and possibly with each system responding to separate mandates.

To examine the importance of integrated information systems for climate action and support, section 3.1 looks at the experience of Annex I countries with national GHG inventories. Annex I countries have been submitting GHG inventories annually to the UNFCCC since 2003, and as such they have had to build and continuously improve the information systems that support the regular elaboration of their national GHG inventories. As the experiences of these countries are not very thoroughly documented, section 3.1 draws mainly on technical notes from the World Bank's Partnership for Market Readiness (World Bank, 2013, 2016) and on a working paper on data management systems from Damassa et al., (2015).

3.1. Integrated information systems

Reporting on climate action is complex because it involves large quantities of data coming from different sources, communicated through diverse means and involving a huge range of stakeholders. Integrated information systems for climate action are able to combine datasets collected for different purposes, use common definitions for their data structures and typically provide a single point of entry for different types of user. For example, Australia's integrated information system collects data about multiple mitigation policies through the National Greenhouse and Energy Reporting System (NGERS) and integrates this data flow with others in drawing up the GHG inventory (Vignette 1). In preparing the inventory, the Australian Greenhouse Gas Emissions Information System (AGEIS) collates data from the NGERS, national statistics from the Australian Bureau of Statistics and processed satellite image data from the land-use sector (World Bank, 2013).

Vignette 1. Australian information system for national GHG inventory (based on World Bank, (2013), (2016))



Source: World Bank (2013)

Australia's information system was designed to be a single reporting framework for GHG emissions. A key feature is that facility-level data can inform the national inventory. Moreover, the system provides aggregated and anonymized data through a public online platform. The system was built using a combination of in-house and outsourced developers (Microsoft). Estimated development costs were USD 11 million over three years.

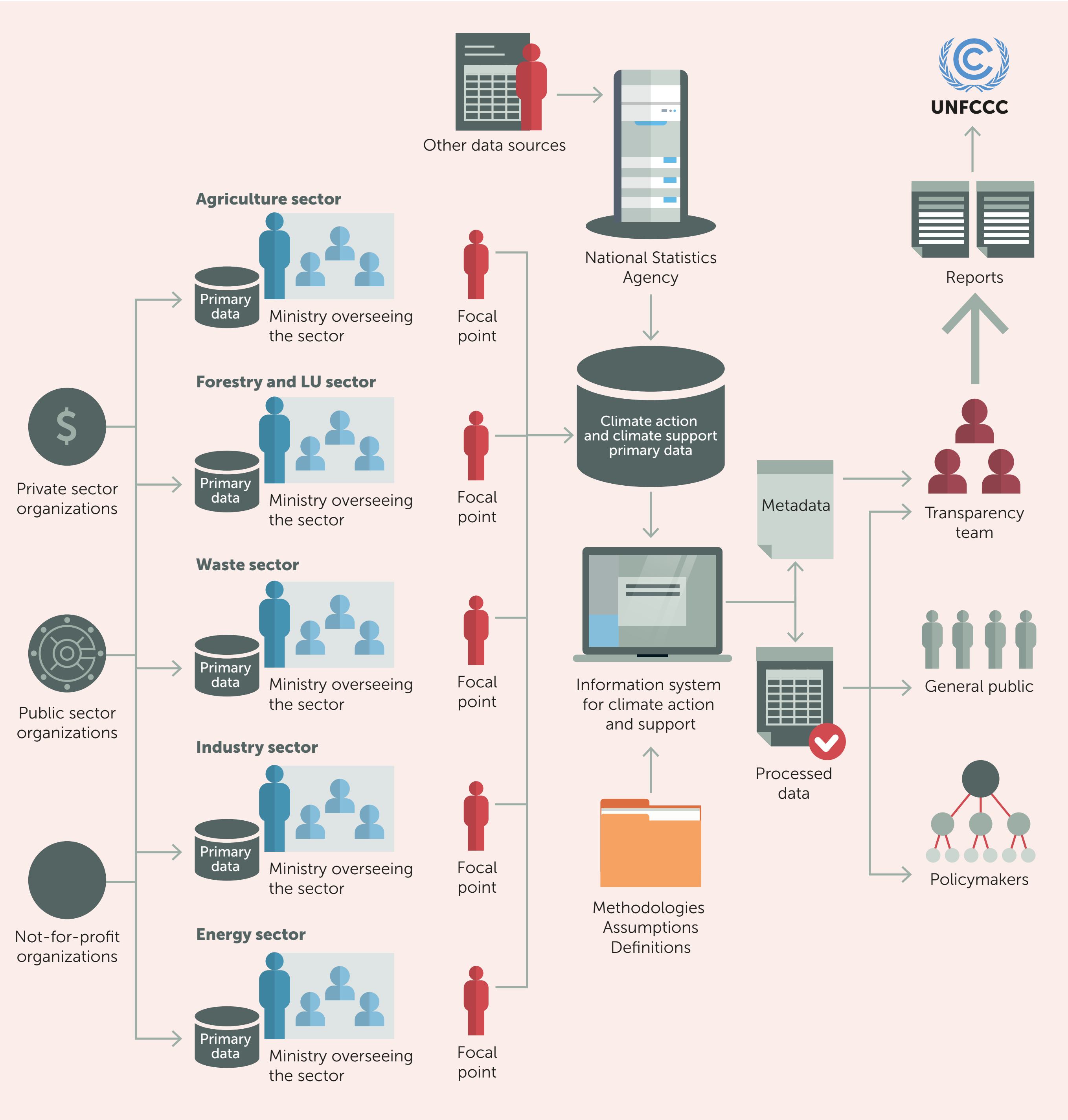
Some lessons learned through the development process were:

- Creating a one-stop-shop reduces duplication of effort and the burden on data providers
- It is beneficial to empower data providers through e.g. stakeholder engagement and user testing
- Designing the system to be configurable reduces maintenance costs.

Figure 3 depicts a possible architecture for an integrated information system for climate action and support.[11] Raw data from the different actors that generate emissions and implement climate projects, such as private-sector organizations, public-sector organizations and not-for-profit organizations, flow to the respective sectors, which are under the control of a ministry. Sectoral data are aggregated at the national level and combined with data from the National Statistics Agency into a national database that contains the relevant primary data on climate action. This national database, the methodologies to process the raw data and the assumptions, data definitions and software that processes raw data (including automated quality control operations) are all part of the information system. Data are processed by the information system and are provided to different stakeholders, for example, to the team responsible for preparing the national reports to the UNFCCC, to policy-makers wanting to track the implementation and effects of mitigation actions, and to the general public wanting to know about the country's efforts to mitigate climate change. It is important to ensure at the outset of the development of the information system for climate action and support that the information system itself is sufficiently transparent to build trust and confidence.

[11] This figure was developed based on discussions and previous work done with Miriam Hinostroza.

Figure 3: An integrated information system for climate action and support



There are clear advantages in establishing an integrated and transparent information system for climate action and support, from the possibility of comparing and aggregating different data sources to the ability to share consistent information with a wide number of stakeholders. However, the implementation of such a system is not straightforward. An integrated system requires more time to identify requirements and engage with a greater number of stakeholders. There are sometimes multiple mandates in a country to collect and manage data on climate action and support. This is problematic and can result in difficulties ahead in the establishment of an integrated and transparent information system. It is thus recommended that the institutional framework for the information system is clearly defined upfront, with clear roles and responsibilities agreed upon by drawing on existing legal or regulatory mandates, and that the system is designed by incorporating the early and continued engagement of stakeholders.

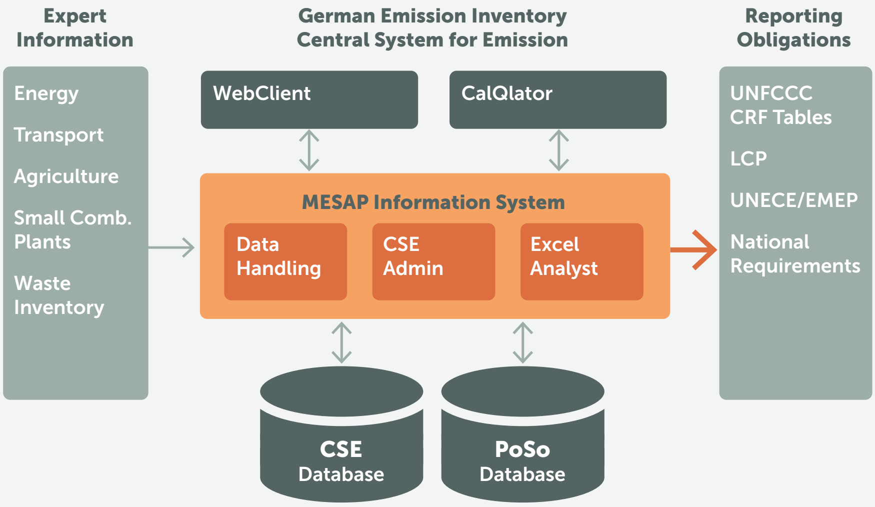
3.2. Independent information systems

Germany developed separate information systems to implement the European Union Emissions Trade System (EU ETS) and to prepare the national GHG inventory. This is an example of independent information systems, that is, separate information systems that address specific objectives (e.g. national inventory of GHG, registry of carbon allowances) but have very limited or no direct links between them and hence do not allow different datasets to be compared. The decision to develop an information system for GHG inventories goes back to 1997, and the EU ETS was launched in January 2005 (Schlenzig, 2002). The German central system for GHG inventory was designed to support different data types and different aggregation levels, and to meet the quality criteria principles that apply to GHG inventories: transparency, accuracy, consistency, completeness and comparability of the reported data (Vignette 2). The EU ETS registry is a web-based system specifically developed for the objectives of the ETS, which protects the confidentiality of data about EU ETS participants and allows verifiers' access. Because the GHG inventory system and the EU ETS registry are run separately, the datasets of the national GHG inventory and EU ETS are not entirely comparable (World Bank, 2013).

Independent information systems are faster to implement and can be developed as needs emerge, for example, in tandem with the development of sectoral mitigation actions or policies, which makes them quite flexible. However, the lack of coordination between systems is a serious obstacle to cross-checking different datasets or to aggregating, comparing and combining different data flows.

Adopting consistent and comparable data definitions is key to ensuring that data are consistent and that policy discussions will be well informed. As such, data structures need to be designed flexibly in order to accommodate present and future policy needs. If data labelling is done in a manner that responds to multiple reporting purposes, then datasets are comparable and adaptable to likely changes in scope. First

Vignette 2. German information system for national GHG inventory (based on (Schlenzig, 2002))



Source: (Schlenzig, 2002)

The requirements of Germany's information system for GHG inventory were to store time series with different time resolutions, to retrieve data quickly and to allow user-defined data views. Reports in MS Excel can be extracted from the system. The data consist of a database of emissions in accordance with UNFCCC categories (CSE) and a database of emissions from power plants and large industries (PoSo). The database is combined with MESAP modules for data management, data retrieval and generating reports. The system is maintained by a private company and uses proprietary software, which limits the bargaining power in contracting improvements.

Some lessons learned through the development process were:
- It is efficient to combine systems for GHG and air pollutant data
- Training data providers is beneficial for better data management procedures.

and foremost, there should be clarity on the scope of the data (what is needed), the sources of the data (who provides what) and the processing and eventual use of data (the beneficiaries of the data). Underlying all these is the engagement of stakeholders in every aspect of data management.

Figure 4 shows an example of independent information systems for the MRV of national GHG inventory (in blue) and the MRV of mitigation policies in the energy sector (in grey). As depicted in the figure, the two information systems have their own data definitions, assumptions and methodologies, and accumulate data in separate databases. The energy policy reporting system collects data on specific policies in the energy sector and is governed by the ministry overseeing that sector. Although this allows the ministry to monitor the implementation of energy policies, the data collected by this system may not be comparable to the data collected by the national inventory information system. For example, the definitions of sectors, the emissions calculation method, the emission factors, the data types and format, and the procedures for data verification used in the energy policy reporting information system may be different from those used in the national inventory.

Figure 4. Independent information systems for the MRV of national GHG inventory and of mitigation policies

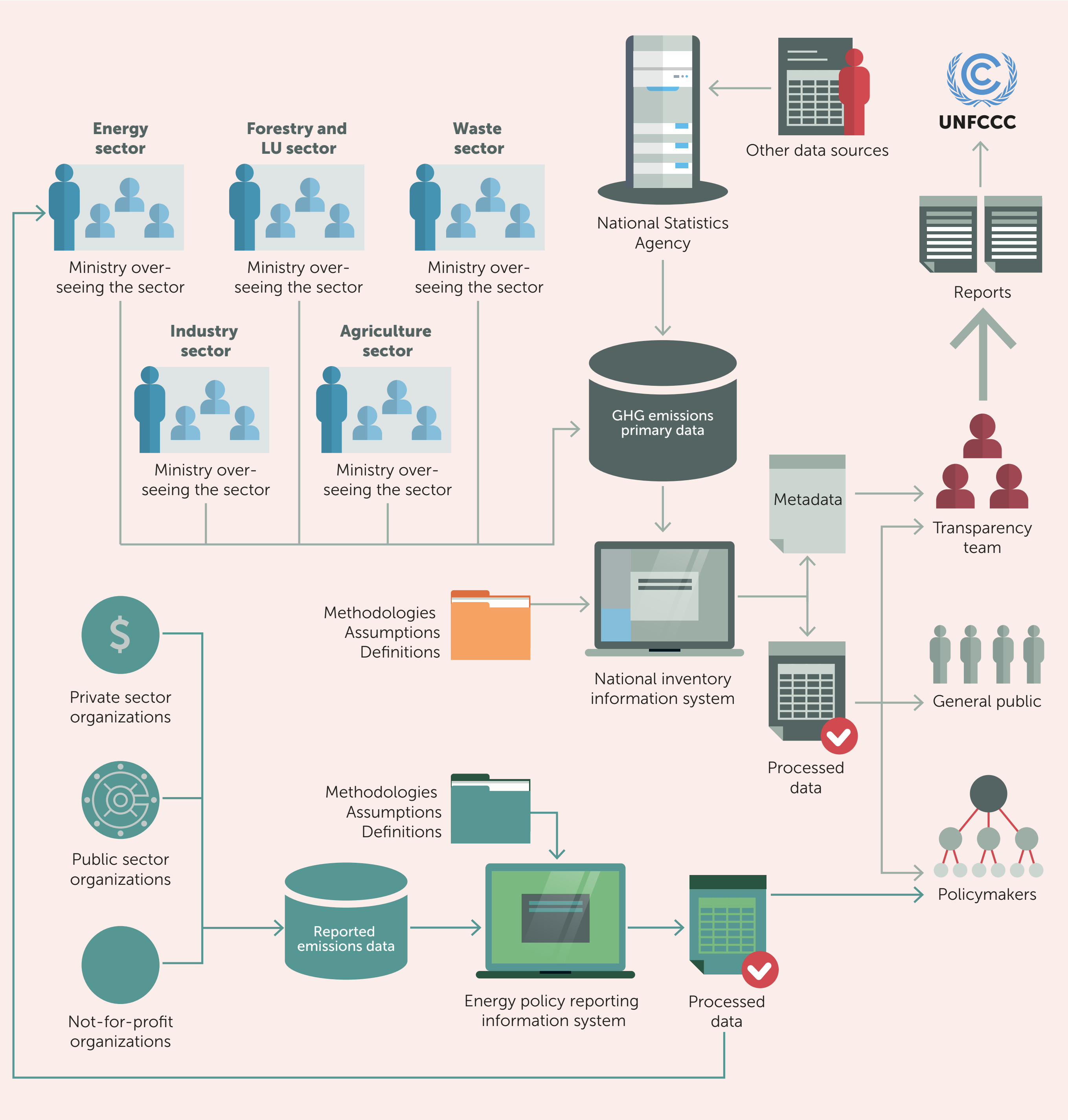


Table 2. Advantages and disadvantages of integrated and independent information systems

Type of information system	Advantages	Disadvantages
Integrated information systems	• Lower reporting burden for data providers • Comparability of datasets and consistency in definitions	• Higher set-up costs • Greater complexity of project
Independent information systems	• Lower set-up costs • Less time to build	• Possibly higher costs of maintenance • Difficult to aggregate and compare data from multiple systems • Multiple reporting re-quirements for data pro-viders

Transitioning from independent to integrated information systems is complex and consumes significant resources in data validation and reconciliation. Provided there is an appropriate internet infrastructure in the country, it is advantageous to begin with the end in mind and aim to build an integrated national information system that responds to multiple reporting requirements (e.g. reporting on national climate policies, reporting to UNFCCC, reporting on the implementation of 2030 Agenda and SDGs). Table 2 summarizes the advantages and drawbacks of each type of system.

In sum, an integrated national information system is valuable for various reasons. First, it reduces the reporting burden for data providers because it is only necessary to report to one system. Second, it ensures comparability and consistency between data flows for different reporting obligations. Third, although the set-up costs and the time taken to build the system are lower in independent systems, operating multiple independent information systems is very likely to be more costly in the long run.

CHAPTER 4

A road map for establishing information systems for climate action and support

This section provides a plan to guide project developers[12] in navigating the uncharted area of development of information systems for climate action and support. There are different aspects that need to be taken into consideration, namely the scoping of the system, the approach to its design and development, the need for testing and quality assurance, and the deployment of the information system and its maintenance.

An information system is not the typical project commissioned by an Environmental Agency or a Ministry of Environment. It taps into specific skills and expertise that are often not found in these organizations and normally requires external consultants to be brought in to develop the work. These professionals typically originate in a different subject domain (software development) and are not familiar with the domain knowledge of the transparency of climate action and the Convention. As such, there may be difficulties in working together due to different professional languages, different work methodologies and asymmetrical domain knowledge. With the road map presented in this section, this publication hopes to provide project developers with an overview of key aspects to consider in information system projects, thus contributing to the success of the projects they are developing.

4.1. Scoping the information system

Not all information systems are the same. They can vary significantly in terms of their functionality, their interface with users, who can use them, and the way they can be accessed, whether through a web-browser or through specific software installed in a specific computer. Understanding what is required from an information system is critical in ensuring its usefulness and relevance to all stakeholder groups. A good definition of the scope and functionality of the system needs to be supported by a thorough investigation of a number of aspects, inter alia the relevant legislation, the objectives of the system and the stakeholders it will serve. This assessment is usually done before contracting the development of the information system to consultants or to a software development company. The list below is a reminder of key aspects to consider in this scoping stage.

12 In this publication, we define project developers as government staff working in the climate change area who embark on projects aiming to build or further develop systems that support systematic data management procedures for climate action and climate support data.

4.1.1. Mapping and documentation of existing systems

In many countries there are already some MRV systems in place that are collecting relevant data on climate action and support. Possibly these systems were developed independently, have different objectives, respond to different mandates and serve different stakeholders. There is likely to be a diversity of approaches and procedures both within and between sectors. Some of the existing MRV systems may be very basic and mainly involve the use of spreadsheet templates to collect data from data providers, which is then sent by email to a regulator or inventory coordinator. These existing systems may need to be integrated with the new information system, or they may continue to exist independently but send data regularly to the new information system. Therefore, existing systems need to be inventoried and documented in terms of the data they produce, the methodologies they use and the stakeholders involved.

4.1.2. Stakeholder engagement

It is very difficult, if not impossible, to develop an information system that meets the information needs of different stakeholder groups without consulting and engaging them. The complete mapping of stakeholders depends on the scope of each particular information system, but typically the stakeholders of an information system for climate action and support include data providers, data verifiers, governmental entities, accreditation bodies, technical experts, non-governmental organizations, trade associations, consumer associations, academia and research institutions.

Consulting stakeholders is useful throughout the entire project development. Their early involvement improves the design of the information system by incorporating their needs into the functional requirements. They should also be involved in the testing stage because they can provide feedback that will improve the quality of the information system. After the information system has been deployed and launched, they can provide input for improvements and report technical difficulties. Through continuous engagement, stakeholders are familiarized with the new information system, which contributes to acceptance and buy-in, which are critical factors in the success of any information system.

4.1.3. The regulatory framework

Regulatory frameworks related to GHG data management and GHG data reporting or related to specific sectoral policies on GHG are inputs for taking decisions on the design of the information system. Important design aspects of the information system are determined by the applicable regulation and legislation (World Bank, 2016). For example, greenhouse gas reporting programmes are typically based on specific laws or regulations, which define key aspects of the system, such as: sectors covered, thresholds of reporting, data types and formats, methodologies that are applied, emission factors to be used, frequency of reporting, data verification, data confidentiality and data security requirements.

4.1.4. Data requirements

The core functions of an information system are related to the management of data. Consistent and comparable data definitions are crucial to ensure data integrity and confidence in the information system. Most countries already have some datasets from existing MRV systems, as well as previous reports that have been created. Therefore, it is useful to make an inventory of existing datasets and assess the need for data transformation before inserting these in the database of the new system. One aspect to consider is how data will be inserted into the new system. This can be done in different ways: manual insertion in a web interface, manual insertion in a template document (typically, a spreadsheet) followed by uploading to a web interface, and insertion from another database through a data communication interface (especially useful when the data is already being collected by another system).

It is also important to consider the levels of access to data, that is, who will have access to which data. Some data may be classified as confidential and hence need to be anonymized and aggregated before being made public. Another aspect is how adaptable is the database structure.[13] It is advantageous to develop structures that are flexible and that can adapt to the evolving needs of policy and to changing needs and priorities. For example, it is important to keep in mind possible changes in reporting thresholds, sectors and the need for data aggregation sub-nationally. In addition, labelling the data in ways that ensure multiple purposes enables a good level of data granularity.[14]

4.1.5. Functional requirements

Identifying what the information system will do – that is, the functionality it will provide to users – is a necessary prior step in the development of the system. Any project involving the development of a software-based system needs to have its requirements specified. The functions of the system will vary depending on stakeholder needs and the regulatory framework. Stakeholders have multiple needs and typically require the information system to support them in different objectives. Examples of such objectives are:

- Storing and displaying data in different formats, including maps
- Repository of articles and country reports
- Centralized data collection and validation
- Transformation of data and calculation of indicators to track mitigation actions
- Collaborative work on documents
- Integration of sectoral information systems into a national information system

13 The database structure (or the logical structure of a database) is a model that shows the entities (tables) that exist in a database, the relationships between them and the attributes (fields) they contain.

14 Data granularity is the level of data detail in the database structure. For example, a field storing data on the energy consumption of a facility can store these data at different levels of granularity: days, weeks, months, quarters, or years. In this example, the lowest level of granularity is the day.

- Integration with other reporting requirements established under other multilateral mechanisms, such as the Montreal Protocol, the Convention to Combat Desertification or the Convention on Biodiversity.

To a certain extent, there are functions that almost any information system for climate action and support needs to have. Below, we provide a list of data- and user-related functions, which are exemplary and non-exhaustive.

- Insert, edit, view and delete data
- Validate data entry
- Check data consistency (range check, compare with previously reported data)
- Transform data (e.g. convert activity data into emissions data, change data formats)
- Data aggregation and data analytics
- Create data reports to visualize data and export them to different file formats
- Insert, edit, view and delete data definitions (data dictionary)
- Label data as confidential
- Create, edit, view and delete users
- Configure user permissions
- Securely authenticate users
- Send notifications to users

A key lesson from countries that have developed their own information systems, such as Australia, is that it is advantageous to build a configurable system. That is, providing users with special roles (e.g. system administrator) the ability to update emission factors and global warming potentials (World Bank, 2016), instead of requiring changes in software to do this. This will ensure that the system can stay consistent with updated IPCC guidelines and the most up-to-date values of standard data such as country emission factors. It does not require specialized intervention by a software developer to make those updates.

4.1.6. Non-functional requirements

While the functional requirements describe what an information system should do, the non-functional (sometimes also called technical) requirements specify how an information system is supposed to perform. That consists of the specification of conditions or criteria under which the system should operate, and includes aspects such as:

- Availability: the days and times the system will be available to use, and when it will require planned maintenance downtime
- Fault tolerance: the ability of a system to continue to operate when some of its components fail
- Interoperability: the ability of the system to exchange data and processes with other systems
- Response time: how much time the system takes to respond to a user request

- Back-up and disaster recovery: procedures for back-up and the amount of time required for the system to be working again after a natural or human-caused disaster.
- Security: what is expected from the system when its vulnerabilities are exploited

4.1.7. Hardware and software architecture

Specifying the requirements can also include considerations about the system's software and hardware architecture, that is, that a certain programming language will be used to develop the system, or that the server should run a certain operating system. These aspects actually depend on the functional and non-functional requirements. Moreover, because hardware and software evolves so quickly, there is no advantage in imposing constraints at this level while at the scoping stage. An exception would be where the software is to be developed by an existing team with skills and competences in certain programming languages, or when there are software licenses and financial resources already committed to specific hardware and software.

4.2. Development of the information system

When the scope of the information system is defined, a logical next step is to look for solutions that address the system's requirements as identified in the scoping stage. Analysing similar information systems can provide valuable insights, especially if combined with demonstrations and the collection of user feedback. It is important to bear in mind that there is no one-size-fits-all solution, as there may be different approaches to the development of an information system for climate action and support, while the country context and priorities are also unique. In addition, the external financing available and the budget that countries may have for developing and sustaining transparency capacities over time are also limited, posing a serious constraint over the resources available for the development of an information systems project.

4.2.1. Build or buy an information system

As a starting point, it is useful to raise awareness about stand-alone tools and software (some are free or low cost, other are commercial), which may be used not as an integrated information system, but in bits and pieces to respond to the requirements of data processing and reporting of information both nationally and internationally. Following this point, this section presents a decision tree with different options for the development of an integrated information system, before illustrating the different options with concrete examples from different countries.

Stand-alone tools and software

There is a large gap in terms of the tools and software that might be used to assist developing countries in meeting all their transparency requirements under the Paris Agreement. Although tools and software are available that can be used for specific tasks or objectives, it is not possible to combine them into an integrated information system. Despite some exceptions (e.g. the IPCC Inventory Software), the majority of

Table 3. Stand-alone software and tools that can assist in meeting transparency requirements

Tool or software name	Objective	More information	License
IPCC inventory software	Preparing national GHG inventories according to 2006 IPCC Guidelines	https://www.ipcc-nggip.iges.or.jp/software/index.html	Free to download and use
@Risk Add-in to Microsoft Excel	Uncertainty analysis	https://www.palisade.com/risk/default.asp	Commercial
Agriculture and land-use GHG inventory software	GHG inventory and mitigation analysis in agriculture and land use sectors	https://www.nrel.colostate.edu/projects/alusoftware/home	Free to download and use
Energy performance and carbon emissions assessment and monitoring tool	Mitigation analysis of urban water sector (online web-tool and offline downloadable)	https://github.com/icra/ecam and http://www.wacclim.org/ecam/	Free and open source *
Greenhouse gas Abatement Cost Model (GACMO)	Mitigation analysis and projections (Excel-based)	http://www.cdmpipeline.org/publications/GACMO.xlsm	Free to download and use
Long-range energy alternatives planning tool (LEAP)	Mitigation analysis and projections	https://www.energycommunity.org/	Commercial
Water evaluation and planning tool (WEAP)	Adaptation and resilience (water management policy scenarios)	https://www.weap21.org/	Commercial
Various tools listed in Climate Smart Planning Platform	Various: mitigation and adaptation analysis, projections	https://www.climatesmartplanning.org/tools9ba9.html?page=3	Various types
MediaWiki	Collaborate on writing documentation to retain knowledge	https://www.mediawiki.org/wiki/MediaWiki	Open source
Samvera	Repository of various types of digital assets	https://samvera.org/samvera-open-source-repository-framework/	Open source

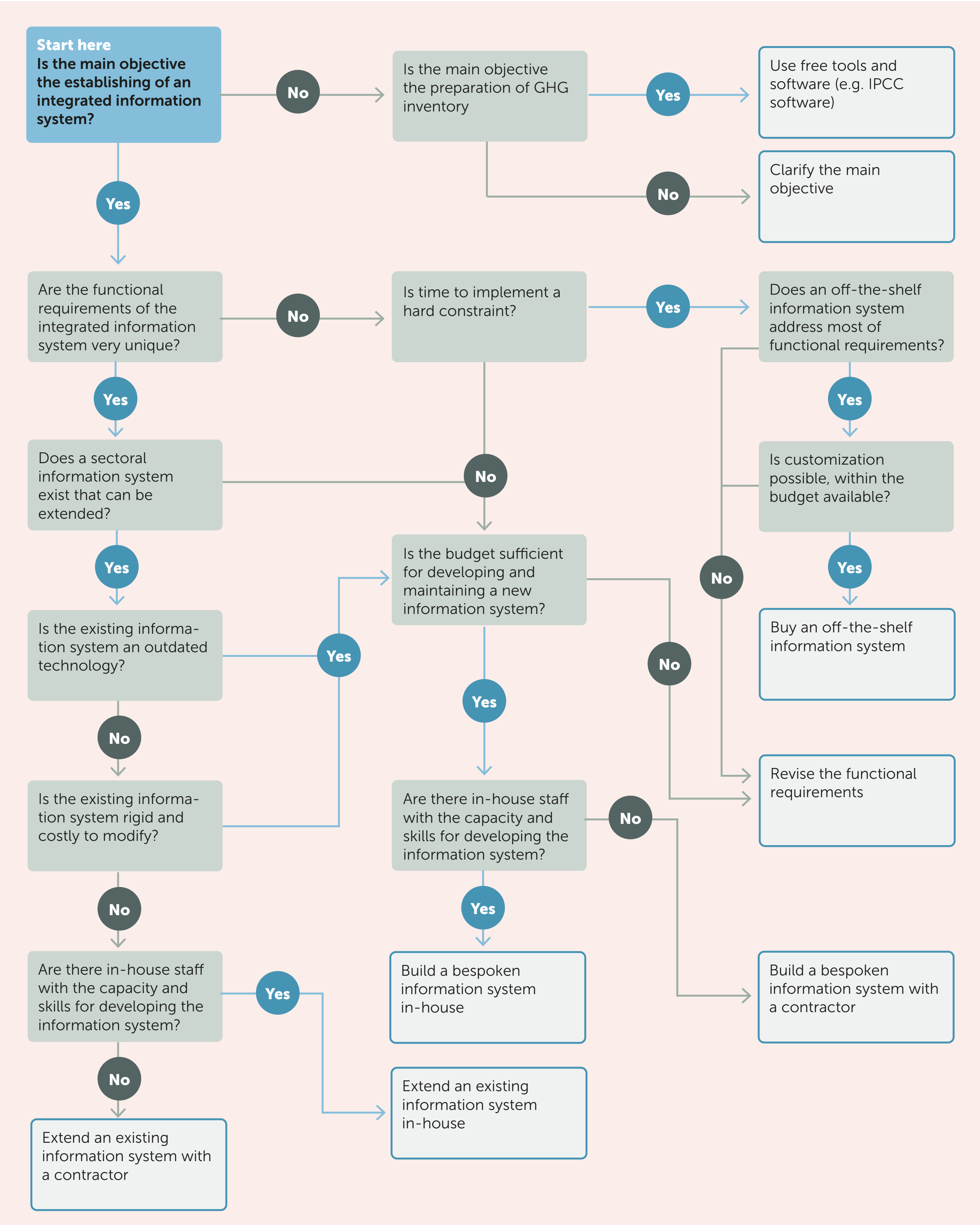
* Open source software license is software in which the source code is freely distributed, without fees, and which can be read and modified by others. Open source software licenses promote cooperation and col-laboration on developing software.

such tools have not been developed specifically for reporting under the Convention and hence may require customized technical training in order to be suitable for that purpose. Table 3 is a non-exhaustive list of the different tools and software available, linked to sources of information where more details can be found.

Decision tree: extend, build new, or buy an information system?

A key decision is whether to build an information system from scratch, to extend an existing one or to buy an existing off-the-shelf information system to customize. Building from scratch may be the preferred option if the system has especially unique requirements and the country has personnel in-house with the expertise in building information systems, including software development professionals. Building with in-house resources means that the country will have full control over the system's

Figure 5. Decision tree for evaluating different options for information systems projects



functionality, allowing the country to take ownership of the process of development and gain knowledge throughout. However, building with in-house resources puts less pressure on time and budget constraints than when contracting consultants with a fixed budget and schedule, and hence it requires very tight control on project management.

Figure 5 is a decision tree intended to assist project developers in evaluating possible options for information systems projects. The tree does not aim at providing a definitive, authoritative solution for each contextual case, but it can certainly help in making a decision by raising the issues that challenge different possibilities and their associated outcomes.

Build a bespoke information system

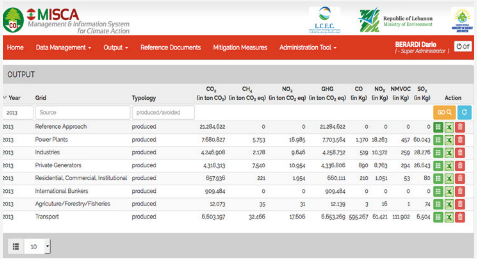
It is rarely the case that the in-house resources exist to build an information system for climate action and support because these projects are typically commissioned by the Ministry of Environment. Hence, in many cases, the development of a bespoke system is contracted to consultants or to a specialized provider. This is what, for example, Vanuatu, Lebanon, Montenegro and Costa Rica have done (Vignette 3).

When building a new system, it is crucial that an interdisciplinary team is assigned to the project. For the project to succeed, the solution development team[15] (this can be an in-house team, consultants contracted for this purpose or a combination of the two) needs to work in close collaboration with the national experts in MRV and transparency. A common challenge is that these two groups of people have different sorts of expertise, use different jargon, and lack a common working language to dialogue about the project they need to do together. It is therefore useful for the MRV and transparency technical people involved in the project to become sensitized regarding common terms and concepts used in information systems development.

The costs of building a system from scratch can be highly variable. For example, Damassa et al. (2015) report upfront costs ranging from USD 10 to 100 thousand, the developer of a system like Vanuatu's mentioned a budget ranging between USD 60 to 90 thousand, and the World Bank (2016) estimated that a system built with a combination of in-house and outsourced developers could cost between USD 1 and 3 million. Primarily, the costs depend on the scope of the system, its functionality and features. For example, if the system needs to receive and/or send data to existing databases, how this is done may inflate the costs depending on the technical complexities involved. Key cost drivers are the amount of hours of work needed to build the information system and the cost of working hours. The hourly rate for software development services is different depending on where in the world the workers are situated. For example, the hourly rate of software developers in India is lower than in Denmark. This may be an incentive for offshoring the development to certain

15 Those with expertise in software development who work to build the information system solution that addresses the specified functional and non-functional requirements.

Vignette 3. The examples of Lebanon, Vanuatu, Montenegro, and Costa Rica's information systems for climate action

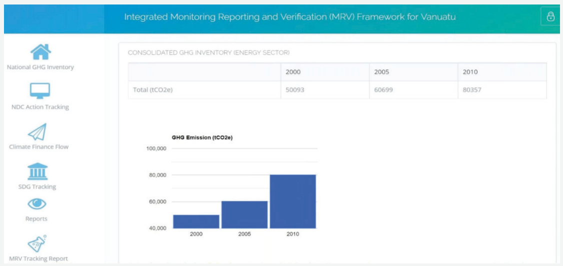


With support from ClimaSouth, **Lebanon**[1] developed an information system to track GHG emissions and mitigation actions, which was piloted in the energy sector.

The scope of MISCA is data management and the calculations of emissions and emission reductions. The system bridges different datasets and their owners, ensuring their different responsibilities and roles in terms of data management.

MISCA also includes a data validation feature (with links to data sheets), and a data release feature to make the data public only with the approval of sectoral data managers.

The system is built in Lucee[2] with a MySQL database, and its development was contracted to an Italian software development company called Dev4U[3].



Vanuatu[4] built an integrated information system for its MRV framework with support from UNDP's NDC Support Programme. The system is specifically designed for the requirements of the government of Vanuatu and includes modules for national GHG inventory, NDC action tracking, finance tracking, and SDG tracking. The SDG tracking module is based on UNDP's Climate Action Impact Assessment Tool[5]. It produces GHG reports and NDC MRV reports.

The system can be deployed as a stand-alone version (on a single computer), or as a web version with a central database hosted online in a server. It is built in Java[6], and its development was contracted to a New Zealand consulting company called Subbarao Consulting Services[7].

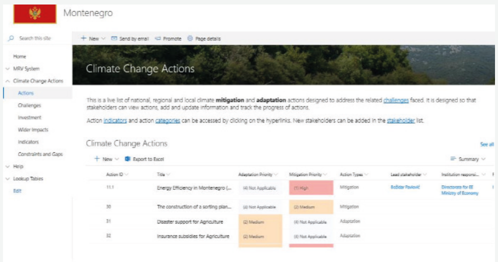
1 Illustration source: Climate change portal of Ministry of Environment of Lebanon, http://climatechange.moe.gov.lb/newsmisca
2 Lucee is an application platform based on the Java programming language that is used for the rapid development of client-server web applications.
3 https://dev4u.it/
4 Illustration source: Webinar "Integrated online tool for climate mitigation action tracking". Recording and details can be found on the NDC Support Programme website: https://www.ndcs.undp.org
5 https://climateimpact.undp.org
6 Java is an object-oriented programming language used to develop computer applications.
7 http://www.subbaraoconsulting.co.nz

countries, but, before making such decision, it is necessary to keep in mind the challenges of contracting to remote locations, such as struggling with different time zones, cultural differences and language barriers.

Buy a commercial information system

An alternative to building one's own bespoke information system is to buy an existing commercial off-the-shelf solution and customize it as much as possible to meet the project's requirements. An example of a commercial off-the-shelf solution to manage GHG inventory and integrated MRV is Atmo, a product developed by Spherical (Vignette 4). Commercial off-the-shelf solutions have the advantage that the time from project inception to deployment and use is shorter than a bespoke information system because all the development work has been done, leaving only

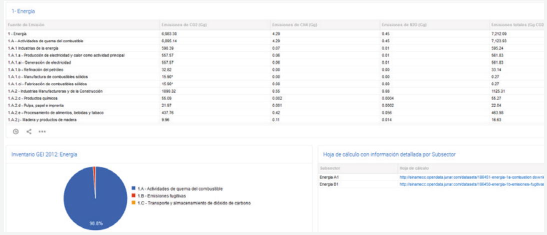
Vignette 3. The examples of Lebanon, Vanuatu, Montenegro, and Costa Rica's information systems for climate action



Montenegro[8] developed a conceptual framework for MRV in the context of the Second BUR project, which then led to it building a web-based information system for climate actions. The system aims to build and retain institutional capacity and memory and to maintain an active data archive for national and international reporting on climate action. It engages stakeholders in collecting data about mitigation actions, adaptation actions and climate finance, hence operationalizing sustainable institutional arrangements.

The system generates reports in different formats to inform decision-makers and climate reporting.

The system is web-based, completely bespoke, can be hosted in a dedicated server or in the cloud, and is built in SharePoint[9]. The development was contracted to a consultancy company called Aether[10], based in England (UK).



Costa Rica has been developing SINAMECC[11], the national information system for the climate change metrics, over the last 5 years. The system has three main functional areas: mitigation, adaption, and climate finance. It includes the following features: data collection and management, NDC tracking, mitigation actions registry, and linkage to modelling and visualization tools.

SINAMECC is open source software, meaning it can be used and modified by others, and has the explicit goal of collaborating with other countries, so that they can also use the software, modify it as needed, and work together to maintain and improve it, saving resources and enhancing South-South collaboration. SINAMECC has an important impact in two areas: enhancing capabilities for doing MRV, and improving the knowledge base for decision-making. It is built in Python[12] and was contracted to a consortium involving national and international consultants.

8 Illustration source: Webinar "MRV Systems and Database". http://www.un-gsp.org/event/webinar-mrv-systems-and-database

9 SharePoint is a browser-based document and content management platform from Microsoft.

10 Aether's website: https://www.aether-uk.com/

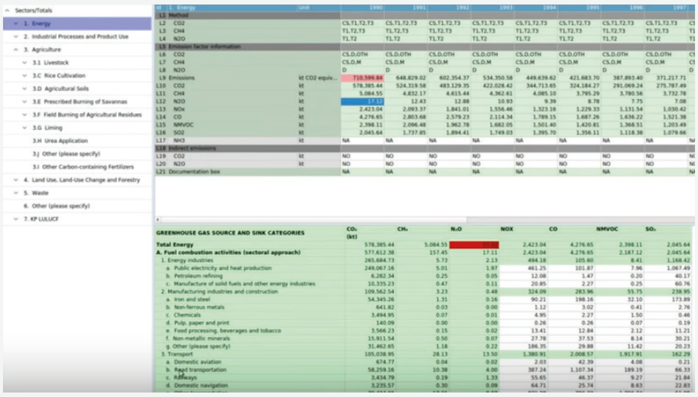
11 Illustration source: Sinamecc: http://www.sinamecc.go.cr

12 Python is a popular and versatile programming language that is widely used for web development and data analysis.

customization and deployment. The purchase agreement usually takes the form of a service-level agreement in which the buyer of the information system pays a software license fee, plus annual or monthly fees for software updates, and an additional fee for installing the software, customizing it and training the users. The original developer of the software typically does the customization, and the costs of customizing can vary, depending on the extent of the adjustments needed to meet the project's requirements.

However, as commercial off-the-shelf information systems are designed using a standard framework with a variety of uses in mind, they might not meet the more specific requirements of a particular country. The software may be a bit more sophisticated than the average user needs, and adjustments must usually be made. If

Vignette 4: An example of commercial off-the-shelf information system for climate action and support



Atmo's features include the following: management of data for GHG inventories; project and portfolio management for MRV of mitigation; generation of IPCC/UNFCCC common reporting format tables, and a financial process management tool for MRV of support. IT provides workflow management, automated quality assurance and control checks, customized data entry in different formats, and data visualization.

The software is web-based, and it can store all the data in the cloud or on a dedicated server. It can work offline and in environments with weak internet connectivity.

A software company called Spherical, based in Bonn, developed Atmo and provides services related to the software. Atmo is built in Python.

Source: Spherical Atmo Reporting System, https://www.spherical.pm/atmo/

adjustments are very costly on the side of the information system, then the users may need to change the way they work in order to adapt to the system's capabilities. For example, if a country requires the information system to print data tables with day granularity and the information system does not have this possibility and implementing it would be very costly, it may be more effective to extract the data with the granularity desired from the information system and to compose the data table using a spreadsheet. Nevertheless, these information systems are usually not overpriced because the cost of development is supposedly split among numerous buyers, who pay the license fees. Because a bespoke system is produced for just one customer, typically the upfront costs are higher.

Expand an existing information system

Yet another possible solution for developing an information system is to expand the scope of an existing in-house information system. Some countries have systems in place for monitoring other environmental information, for example, forest and land-use information systems to track the impact of policies in this area (Cheung, Austin, Utami, Bangoura, and Stolle, 2014). This existing infrastructure could be leveraged to develop an integrated information system. The benefits of this approach are using in-house expertise and capacity, possibly lower costs of development, and less time from project inception to deployment and use. However, it is crucial to have an in-depth investigation of the existing system during the scoping stage in order to determine whether the system is easy to modify and whether it is built on technology that is still current or easy to update.

Procurement

Building a new system, expanding an existing one and buying a commercial off-the-shelf solution typically require procurement processes. Each country has its own procurement rules, and it is difficult to make recommendations on this aspect. A common approach to procurement is competitive bidding, based on a request for proposals (RFP) sent to known qualified developers or announced publicly. Sometimes, this is preceded by a public request for information (RFI) to identify qualified service providers. Annex A lists and describes the common sections of a RFP and can be used as a template for preparing this kind of document.

It is necessary to identify and establish an in-house team, including the national MRV experts - the problem domain team[16] – with the responsibility not only for procuring a qualified solution provider, but also for managing the project and engaging with the selected provider throughout. National MRV experts have specialized knowledge and the insiders' view that are critical for the success of these projects. A balanced team that combines different levels of seniority and gender is beneficial for these projects, especially the engagement of younger officials from the Ministry who are more familiar with the use of information and communication technologies.

4.2.2. Best practices for information systems projects

Awareness of good practices in the area of information systems development is beneficial to proper project monitoring. While a thorough understanding of good practices in this area certainly requires deeper study, there is much to be gained just by implementing what is listed here. A key concern is that the country should have control over access to the source code,[17] passwords, configuration details and project documentation. This is to ensure that, for example, the project could continue if the specialized provider had to stop working on it tomorrow and there is a proper handover in any case.

It is good practice to use a source code repository[18] and version control software,[19] such as Git[20] or Mercurial.[21] Version control software enables multiple people working simultaneously on a single project to ensure seamless integration of their contributions and to maintain a historical back-up of the project as a safeguard against computer crashes and data losses. Version control software uses a source code repository, that is, a database of all the changes and historical versions of the software. The

16 The problem domain team is the group of people from the government side that is engaged in climate transparency work and in the development of the project. This team is spearheaded by the project developer.

17 The source code is the human-readable list of instructions that a programmer writes when building software.

18 A source code repository is a central file storage location that is used in tandem with version control software to keep back-up copies of source code.

19 Version control software is software that helps a team with multiple programmers to manage changes that they all do to the source code.

20 https://git-scm.com/

21 https://www.mercurial-scm.org/

repository can be deployed on a local server (government premises or data centre in national territory) or in the cloud.

For information systems that are web-based, it is recommended to set up a test (or stage) server and a production server. The test server allows the project to have a space where changes can be tested before they are deployed to the users. The test server runs in an environment similar to the production environment, and hence it is possible to perform quality assurance to detect mistakes, performance or usability issues before deployment in the production server. All the logins, passwords and configuration details for these servers need to be documented and transferred to the project owner (the team in the Ministry or in the governmental agency) in the handover.

Another good practice is to document and annotate source code. Documenting source code describes the functionality of the code and is done for both users and developers. Whereas users need "only" to understand what the source code does, developers need to know enough to be able to make it work. This includes a summary of the goal and approach, and instructions on how to install it and get it to work. Annotations in the source code make it easier for software developers to understand it and be able to maintain it, and they are also useful both for the developer who wrote it[22] and for others who may in the future need to change it. The goal of the annotation is to explain, in human terms, what the source code aims to instruct the computer to do and the rationale for choosing a certain method or approach.

4.2.3. Quality and testing

An information system that is free of mistakes and defects from the beginning is still to be invented. All information systems can have mistakes or issues in the software that powers them because software is written by humans. Hence, the importance of quality assurance and testing throughout the development of an information system cannot be overstated. This is especially important for bespoke systems because off-the-shelf information systems, once they are ready to deploy to customers, have typically gone through a variety of tests. This does not mean that off-the-shelf information systems are error-free. There may be mistakes (so-called bugs) in the software that have not been detected. Some software bugs are only detected when the system is put to use and some new scenario of use, not considered in the tests, is applied.

The benefits of testing and quality assurance in the process of developing an information system are:

- Testing helps to save money in the long term because mistakes and defects are detected and solved before they have consequences in the real world
- Testing enables the detection of security flaws which may result in leakage of sensitive information

22 It is not uncommon that the software developer who wrote the code will need to fiddle with it at some later point and cannot exactly remember the rationale behind it.

- Testing helps to bring the final product to the desired form, to ensure that the product is fit for purpose, and to ensure a good user experience
- Testing verifies that the system meets the functional and non-functional requirements defined at the scoping stage.

It is good practice to develop the test cases in tandem with the specification of each functional component (so-called use case[23]). When developing the test cases, it is necessary to engage with the stakeholders and the problem domain team to capture the information systems' scenarios of use. Test cases are collated in the test plan, which guides the testing work. The test plan is a blueprint of how the testing work is to be done and typically covers the scope of the testing – what will and will not be tested; the approach that will be taken (the types of tests); the criteria for pass and fail; the deliverables from the testing process; responsibilities and schedules; and eventual risks and risk mitigation strategies. The benefit of having a test plan is that it enables the effort needed to validate the quality of the information system to be determined, making it a useful project management tool. Most of the tests are carried out by the software development team, but the user acceptance tests are done by the project developer and end-users.

To facilitate the documentation of flaws in the software and the tracking of the corrections, it is recommended to use a software bug-tracking tool, such as Bugzilla,[24] Atlassian Jira[25] or Redmine.[26] It is also good practice to perform tests throughout the development process and to separate the roles of software development and software testing. This will ensure that the source code is tested by a different team member, and not only by the team member who created the source code.

Types of tests

In general, the testing approach considers multiple types of tests done at different levels. Some tests, such as unit testing and integration testing, are relevant only for the software development team because they are part of the development process. When the testing is at the system level, it becomes more relevant for the users of the information system and for the project developer. At the system level, the usual tests are:

- Functional tests: testing whether the system meets the functional requirements defined at the scoping stage
- Performance tests: testing how the system responds when the workload is increased momentarily, or during a continuous period, or even beyond the anticipated limits

23 A use case describes how a user will interact with the information system to achieve a goal.

24 https://www.bugzilla.org

25 https://www.atlassian.com/software/jira

26 https://www.redmine.org/

- User acceptance tests or beta tests: testing performed by the project owner (the team in the Ministry or governmental agency) to verify that the system delivers the features and functionality specified at the scoping stage
- Usability tests: testing with end-users to validate the interface of the system and determine the extent to which the system is easy to learn, easy to operate and easy to interpret its outputs. The objective of the test is to review the user interface with the people that will use the system.

Although a functional information system can seem like the ultimate desired result of a development process, it is nearly as important to build a system that scores well in usability. Especially for information systems that may not be used at all times, like an information system for climate action and support, it is important for an infrequent user to be able to operate the system and not require training every time. As such, it is important to pay attention to the development of interfaces at the front-end of the system that are easy to figure out and to operate. The design layout and sequence should allow the systems' functions to be executed in an easy and intuitive manner.

4.3. Deploying and launching the information system

In the deployment stage, the information system goes "live" and is populated with real data. Deployment in the production environment only happens when the system has been fully tested and signed off by the project developer at the ministry or governmental agency. Some of the key considerations for the deployment process include:

- The hardware and infrastructure needed (what hardware is needed, from computers to network devices? Where will the hardware be placed?)
- The data set-up in the new system (is data to be inserted by users, or migrated from existing databases?)
- The schedule and length of the deployment process (will the changeover be done overnight, or is there a transition period for users to get accustomed to the new system?)
- Training needs (what skills and training will the users need in order to use the system? How will the users be supported?)

4.3.1. Hardware and infrastructure

Prior to deploying the information system in the production environment, it will be necessary to install the hardware and infrastructure required for the system to run. For information systems that are web-based, there are different possibilities:

- The information system is hosted by a server located on the government's premises: this requires budget that ensures that the hardware and infrastructure equipment is state-of-the-art and that the staff have the expertise in the administration of systems to maintain the equipment, implement the security policy, run the physical back-ups, respond to problems and update the operating system

- The information system is hosted and managed by a commercial hosting service: the hardware and infrastructure equipment and partially the systems administrator function are provided by the hosting service provider, which charges a fee for the service; hardware for users and data are off-premises and accessed through an Internet connection[27]
- The information system is cloud-based: this is a special case in which the information system is so-called “cloud-native” and is provided as a service,[28] typically under a subscription model with prices varying depending on the number of users[29]

All the options above have advantages and disadvantages. The decision of which one to use needs to weigh factors such as budget, security and data sovereignty.

4.3.2. Data considerations

Any information system is useless if it does not have data to operate. For a new system it may be necessary to add data manually to the information system or to recreate it from existing reports like the NatCom or BUR. For a system that is replacing or upgrading an existing system, it will be necessary to migrate the data from the existing “old” database to the new information system. This might entail data needing to be converted to a different format. The process of data conversion may be automated, but it will still require a significant amount of time and resources, especially if the historical data are not of good quality (are incomplete, have errors) and will require corrections. Depending on the amount of historical data, in some cases it might be quicker and less expensive to insert these data manually into the new information system.

4.3.3. Schedule of the changeover process

An important aspect when planning the deployment of the new information system is how to achieve the switch-over. There are different possibilities, with advantages and disadvantages that need to be considered in the context of each project. The most common are:

- Overnight changeover: the new system is brought into operation straightaway, and all users start using it. This option allows some money to be saved because deployment does not take much time, but is high risk in terms of user acceptance and adoption if the changeover process is perceived as managed poorly. To minimize these risks, it is important to engage users sufficiently in the development process and ensure thorough testing for defects
- Parallel running: this is the usual approach when a legacy system exists that will be replaced by the new one; it has both the old and new information systems

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27 This is similar to renting a water tank that is located off your property but is connected to your house. Only you can use it, and you pay for the tank capacity whether you use it or not.

28 The term that is commonly used for this is “software as a service”.

29 This is similar to paying for the water supply service to the water utility company or municipality. You pay for what you use, and the infrastructure is shared with other customers.

operating in parallel until the users are acquainted with the new system, and then the old one is switched off. This approach is less risky than overnight changeover because users are exposed to a gradual transition, but it is more expensive, and users may resist having to abandon the old system

- Pilot implementation: the new information system is deployed for only a sector or ministry, experience with using it contributing to improvements and adjustments prior to deploying to the other ministries or governmental agencies. This is less risky and less expensive than direct changeover, but it requires good management of the pilot stage in order to make it successful and not undermine the confidence of other sectors in the new system
- Phased implementation: the functionality of the new information system is released in stages and not all at once; this approach reduces the risk and allows the user to become acquainted with the new system gradually, but it tends to be expensive because it requires simultaneous efforts on the development and maintenance of the system.

The decision about the timings of deployment of the new system and its introduction to its future users needs to be done in advance. Ideally, the introduction of the information system should synergize with existing efforts to prepare national reports. Perhaps the information system is ready to be deployed when the country already has an advanced draft of the NatCom. If the country team is very busy with an important project, it might be better to wait until they have received training on the new information system. It might be useful to delay the introduction to the new information system by taking in consideration, for example, the schedule for collecting data for the next BUR.

The data collected for the previous NatComs and BURs can already be inserted into the new information system, and when users start training on how to operate the information system and how to extract information, they will already have the system populated with data that is relevant for their work. The users will benefit more from training on data collection and on how to provide data to the system when the time for the next round of data collection approaches because they can immediately put into practice what they are receiving training on.

4.3.4. Training needs

There has been significant progress in terms of the usability of software, but the majority of new software-based systems still require users to be supported in how to operate the system. It is good practice to provide users with manuals and system documentation, and to couple this with training sessions. The extent of training can be sorted out through a mapping of the skills the users require and a comparison with staff competences. Once training needs are understood, a training strategy can be developed. It is useful to consider what methods of training will be more effective given that the regular activities of governmental organizations will be impacted by the trainings.

The main methods of delivering training are face-to-face, hands-on training sessions; webcasts or remote training sessions; and "train the trainers" or cascade training, in which a small group of "super-users" receive training and then train the other users. This last method is quite popular and is widely used, for example, with enterprise software applications. The main advantage is that cascade training ensures that a pool of capacity is retained in the organization, with the group of trainers being able to provide training and continuous support to their colleagues.

4.4. Maintenance of and improvements to the information system

The maintenance stage concerns not only the work that is done to keep the information system running and in good order, but also corrective actions and enhancements to functionality. In general the 80/20 rule applies, meaning that on average only 20% of the work carried out in this stage is corrective, the bulk of maintenance being related to improvements and refinements. This reflects two well-known facts. One is that most information systems improve with the engagement of users, though unfortunately in many cases their engagement is not sufficient in the development stage. The other is that users typically only operate a small percentage of the features in a system, rendering parts of the system useless and unnecessary.

The costs of maintenance may turn out to be significantly higher than expected depending on the extent of enhancement work. It is good practice to maintain a backlog of the system's new requirements or new features and to prioritize development work based on the available funds. Moreover, all information systems require maintenance and adjustments to respond to evolving reporting needs (e.g. the new MPGs of the enhanced transparency framework). Therefore, funds for improvements and maintenance have to be budgeted and sought out. It is also good practice to examine the enhancements of the system in a feasibility study, especially if they are numerous and could consist of a development project on their own.

Another reason why maintenance work is unavoidable is because software is in constant evolution and security flaws are uncovered regularly in data management systems. This requires the regular application of software patches to prevent security flaws from being exploited or the data and reputation of the organization being damaged. These software updates need to be regression-tested in order to check that the changes being introduced do not adversely affect the functioning of the system. As such, maintenance work requires technical skills that in many cases do not exist in the ministry or governmental agency overseeing the information system. Thus, it is often necessary to start a procurement process to contract a specialized provider.

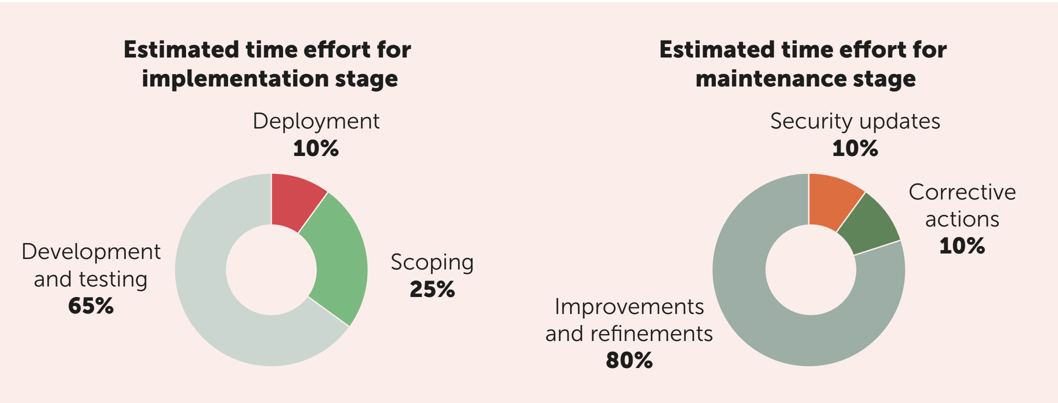
4.5. Indicative time estimate for the road map

Developing an information system for climate action and support that addresses the needs of different stakeholders is a complex project and requires a reasonable amount of time. As the experience of other countries demonstrates, the initial development is often followed by a longer period of maintenance in which many improvements are made. For example, Australia reported three years of development work and continued maintenance afterwards, even when the system was suitable for use (World Bank, 2016).

Generalizations in terms of the time needed to establish an information system are not quite possible because context variables vary significantly across geographies. Estimates improve with the analysis of actual data from other projects, namely by looking at experiences in completing a similarly complex project. Hence, the actual time spent on a previous project that used a similar development methodology is a good indicator for the country. Nonetheless, Figure 6 attempts to create a time perspective of the percentage of time spent in the major steps of the road map presented here.

The estimates in figure 6 below are based on heuristics extracted from project management discussions in various online outlets. The trends from projects of different sizes indicate that about 20 to 30 percent of the time is spent in scoping, but this number may be higher depending on the extent of unknowns in the project's goals. The underlying assumption in the estimates above is that the methodology for implementing the project follows the steps in the road map in a linear and sequential way.

Figure 6. Estimated percentages of time spent in the implementation and maintenance of information systems



CHAPTER 5

Methodologies and techniques used in the development of information system projects

In the early years of computing and software development, the technical aspects of developing information systems – that is, programming and building computer applications – were prioritized. People-oriented considerations, in the sense of the needs of the users, were often neglected. Most systems were developed without an explicit development methodology. Programmers used their own experience and heuristics, and a significant amount of time was spent correcting and improving a system after its deployment. Because many projects failed to meet the objectives of the users, and as the demand for information systems kept growing, the realization dawned that the development of these projects needed proper techniques and methodologies in order for them to succeed and meet the goals of their users. Hence, there are today well-proven techniques for the analysis and design of information systems and methodologies for their development. This section introduces well-known techniques for analysing information systems and methodologies for their development. A more thorough coverage of this topic would go beyond the scope of this publication, but may form the substance of another publication.

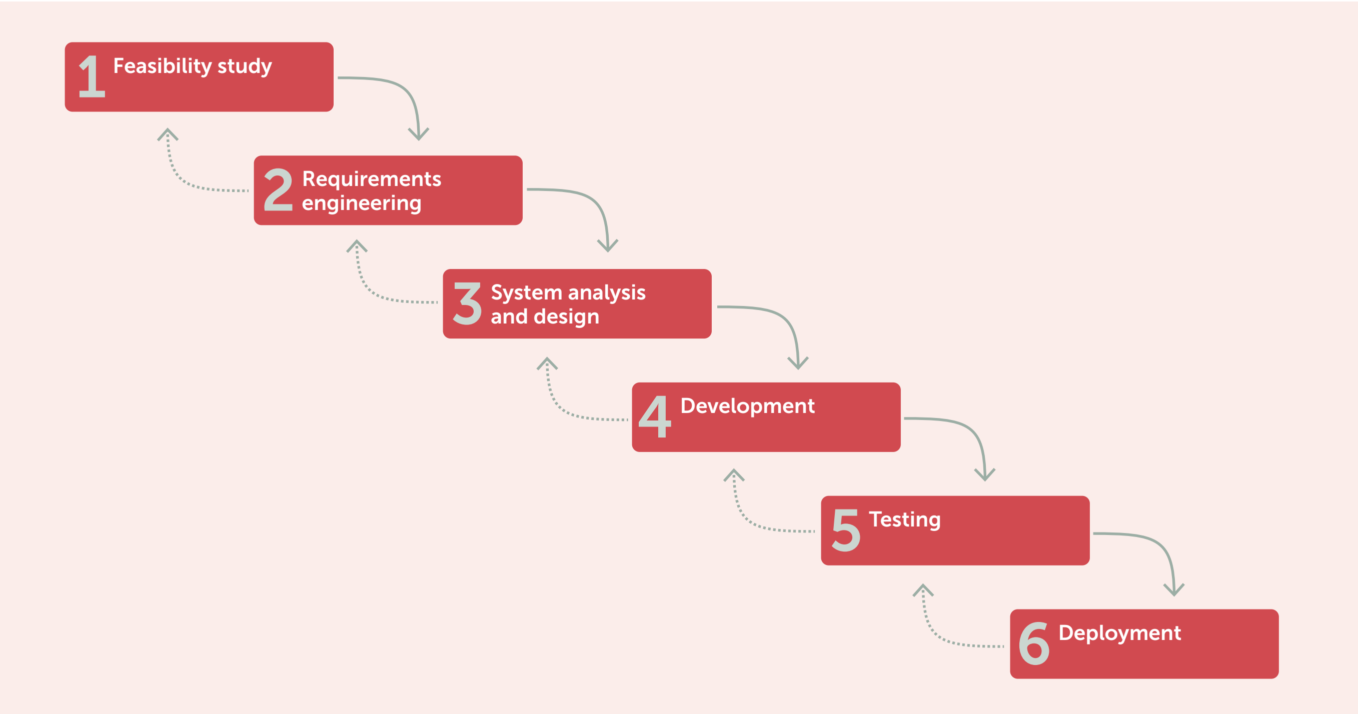
5.1. Methodologies for developing information systems

There are two main types of methodologies: linear methodologies and evolutionary methodologies. Linear methodologies are step-based and require that each step is completed, reviewed and signed-off before the next one is started. Evolutionary methodologies also ensure that the necessary steps for developing a functional information system are in place, though they do so in an iterative and incremental manner.

5.1.1. A linear methodology: Waterfall

The Waterfall methodology was one of the first structured methods introduced to make the process of developing information systems more standardized and controlled. The main principle behind this approach is that each step needs to be completed before the next one is started. For example, a feasibility study needs to be completed before the requirements engineering is initiated. Figure 7 shows the different steps in the Waterfall methodology. The solid arrows represent the sequence of the steps to be taken, and the dashed arrows show that the development process can flow back to correct any problem identified at later stage.

Figure 7. Steps of the Waterfall Methodology



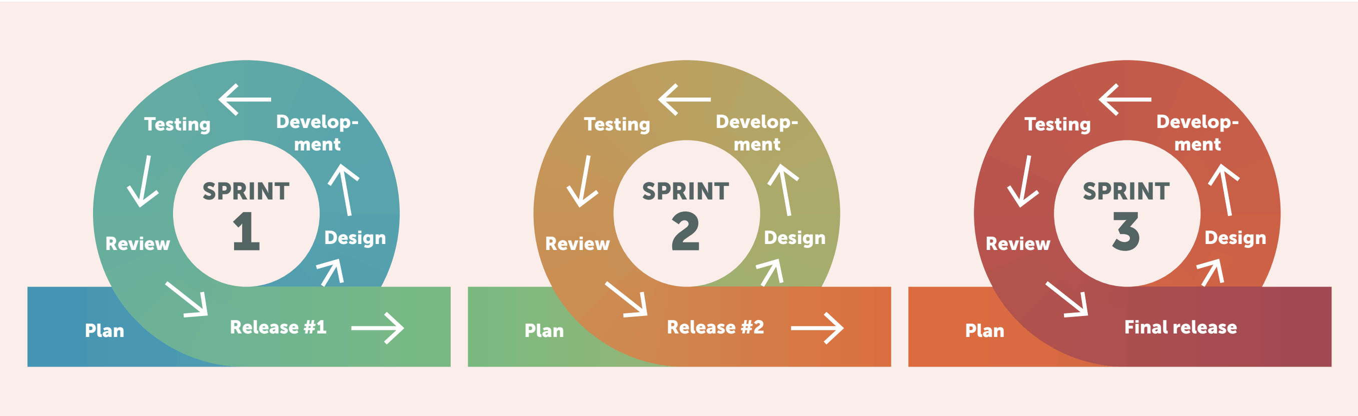
The success of projects developed using a Waterfall methodology hinges on a good understanding of the functional requirements, strong project management, accurate estimates of time and budgets, and sound design. The methodology is easy to understand and manage, especially for projects contracted to consultants, but is not very flexible, and changes of scope are very costly to implement.

5.1.2. An evolutionary methodology: Agile

Evolutionary methodologies address the lack of flexibility of linear ones. They are incremental and based on continuous improvements. A very popular evolutionary methodology is Agile. This is considered a lightweight approach to the development of information systems, focusing as it does on the rapid development of software (programming) in tandem with a continuous process of review, with input and feedback from users in order to improve it. Figure 8 gives a graphic depiction of the Agile methodology.

The Agile methodology partitions the project into time-boxed developments, called sprints. Sprints contain some of the stages of linear development, such as design, development, testing and deployment (release), but typically do not contain a conventional requirements stage. Instead the sprint starts with the planning stage, in which the features to be developed are evaluated and prioritized. Each sprint is incremental and develops a limited number of features that have been translated into user stories – that is, a description of what a user needs to do with the system and for what purpose.

Figure 8. Agile methodology



5.2. Techniques for analysing information systems

The design and conceptualization of an information system needs to analyse aspects such as the processes involving data and the different data elements that will be represented in the information system. This analysis provides a way to understand the essential elements of an information system, ensuring that the key ones are not forgotten, and is a tool for communication with the technical people (software developers and programmers) building the information system. Widely used analysis techniques are process-modelling and data-modelling.

Process-modelling techniques look at the flows of data and related processes. Data-flow diagrams are a well-established process-modelling technique that illustrates the data being processed by a system in terms of inputs and outputs. They produce an overall view of the complete system, its processes, data stores, data flows and boundaries. Figure 9 shows an example of a data-flow diagram for the process of reviewing GHG emissions.

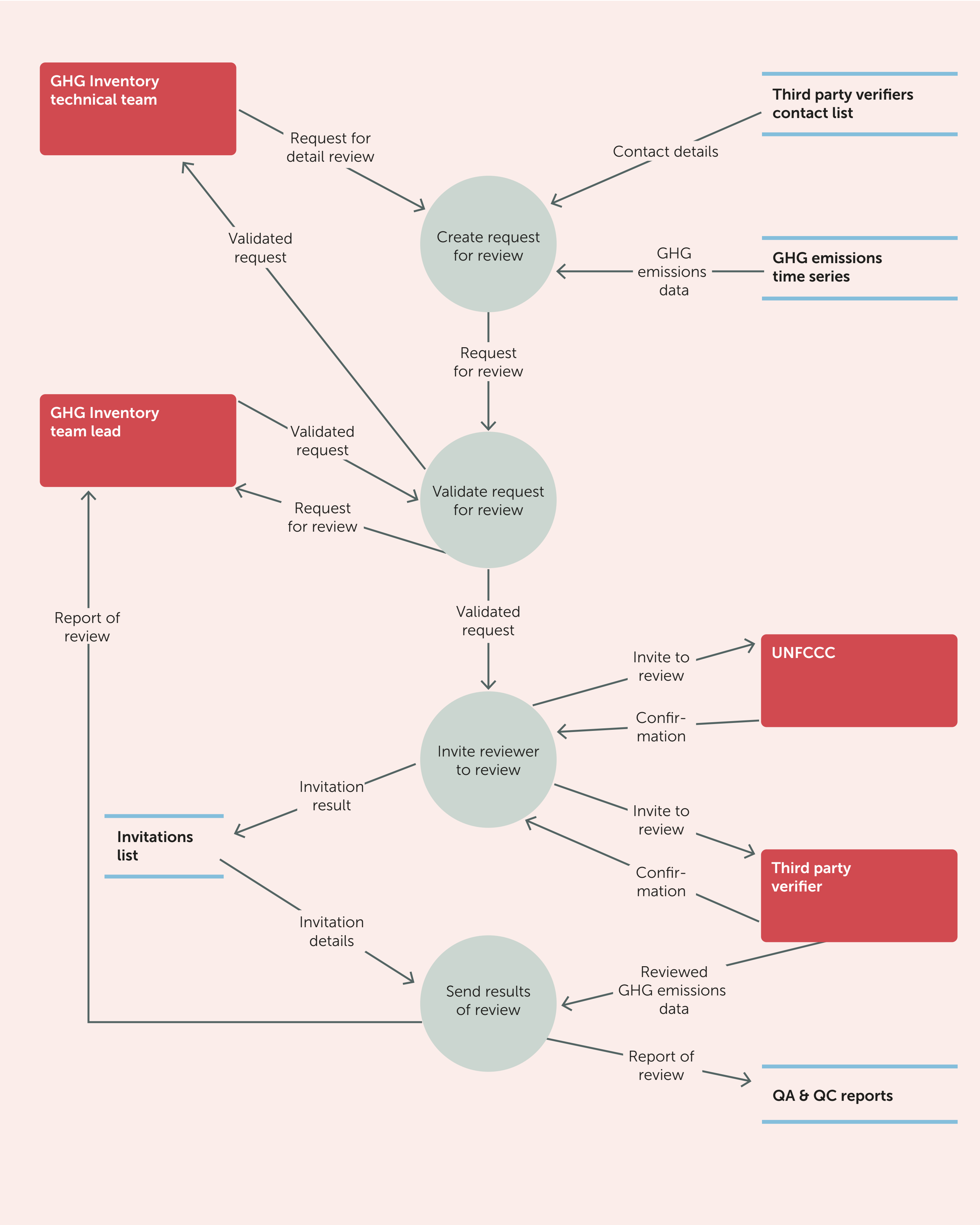
The data-flow diagram notation is quite simple, with only four symbols:

- Processes (circle shape): these are the activities performed by the system which use and transform data; they are usually expressed as active verbs
- Data stores (two parallel lines): where data is stored in the system
- External entity (rectangles): providers and receivers of data
- Data flow (arrows): inputs of data to processes, and outputs of data from processes.

The processes in the data-flow diagram can be decomposed to a higher level of detail for purposes of improved understanding.

Data-modelling techniques are useful for understanding and documenting the data within an information system. They provide a logical and graphical representa-

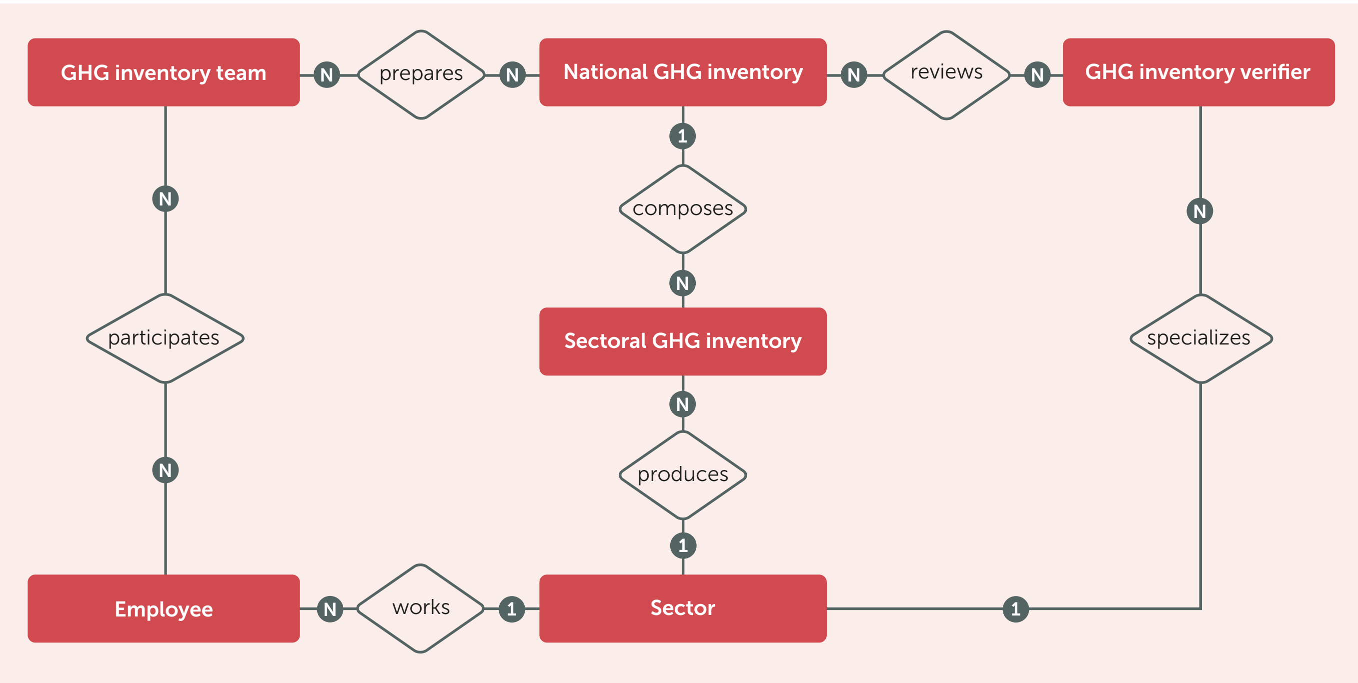
Figure 9. Level 1 data flow diagram for the process of review of GHG emissions data



tion of the data structures in the information system that can easily be interpreted by programmers and software developers. A widely used data-modelling technique is entity-relationship modelling, which shows the data elements of an information system, known as entities, and the relationships between them. An entity is simply a thing of interest in the information system about which we want to hold data. For example, among the entities related to GHG inventory are sectors, employees and verifiers. The entities have attributes (characteristics or properties, like name and date of birth for an employee entity), and have different types of relationships between them. Figure 10 shows a hypothetical entity-relationship diagram for a national GHG inventory system.

Entity-relationship models are easy to understand and are commonly used to validate the data model of the database before implementation. They work as a blueprint of the database and provide a snapshot of the various data structures within it. Like the data-flow diagram, the entity-relationship diagram produces a visual representation of the information system that is beneficial as a communication tool between the technical people from the climate change area and the technical people building the information system.

Figure 10. Entity relationship model of a national GHG inventory system



CHAPTER 6

Final remarks

The need for good-quality data to support the development of climate policies and actions in countries is generally acknowledged in the current climate regime. To implement the Paris Agreement, all countries need to improve the collection, transformation and presentation of data about their climate action and climate support. The systematic and regular collection, preparation and reporting of climate action and climate support data by a country to the UNFCCC is a resource-intensive process that involves a large number of national stakeholders. The use of computer-based information systems can make this process more efficient, reliable, systematic and traceable, and less expensive.

However, information systems are not the typical project commissioned by a country's Ministry of Environment or the Environmental Protection Agency. As such, there is often insufficient understanding of how to get from project idea to final product. If the ministry or the country agency wants to develop this information system, how should they go about it? The process of developing an information system is not simply "hire a computer programmer to build it". As when building a house, no one gets from the initial idea to the completed house without a detailed plan and a proven methodology for building it.

Developing an information system is, in some ways, like building a house. The house is designed with a view to who will live there and the special needs they may have. Before the actual construction starts, an architect makes a blueprint with detailed plans for the electricians, plumbers, carpenters and contractors so that they know what they are going to do. These plans are constantly reviewed, and each stage of construction is tested and inspected. The same needs to happen with an information system: there must be proper thought about the needs of who is going to use it, what is a good method of building it and what needs to be tested before people start using it. This publication has attempted to provide a road map to help project developers to establish an information system, with insights regarding relevant aspects to ponder for these projects.

Annex A.

Template Sections of Request for Proposal

The request for proposal (RFP) is normally used in a competitive bidding processes to engage an external services provider (suppliers) in the development of an information system. The RFP can be publicly announced or sent to a selected group of pre-qualified providers, depending on procurement rules. The main objective of the RFP is to state clearly what services are being requested, the terms and conditions governing the future contract and the information that is required from the submissions. Table 4 lists the common sections of a RFP and what is usually covered in each of them.

Table 4. Sections of a Request for Proposals

Section	Description
1. Summary	The objective of this section is to provide, in a condensed form, the key information that the suppliers need to know about the RFP. Typically, it contains a brief description of the organization issuing the RFP, the services it is looking for, the instructions for submitting proposals, the criteria for assessing proposals and the timeline for contracting. More detailed information and instructions are provided in other sections of the RFP, and hence references to these other sections should be included. The section can be structured with the following sub-headings: 1.1. About <*name of the organization*> 1.2. About this Request for Proposal 1.3. Submitting proposals 1.4. Proposal evaluation criteria 1.5. Contracting schedule
2. Statement of work	This section is where the contract work is thoroughly defined, namely what is expected from the supplier and the outcomes that must be met. This can be structured in the following way: • Project overview: a description of the project’s objectives and purpose, its context and origin, and the scope of the work • Project deliverables and tasks: the end products to be submitted by the supplier • Delivery schedule and milestones: due dates for deliverables and eventual milestone dates that are critical to the project’s schedule • Acceptance standards: the review and acceptance process for deliverables, including the objective criteria that will be used to assess whether the work meets the requirements • Estimated budget: an indication of the budget for the project • Support and maintenance: expectations regarding the supplier attending and resolving issues detected after the handover of the project.

Section	Description
3. Guidelines for proposals	This section specifies what the suppliers need to include in their proposal. The idea is to make the process of submitting a proposal simple and clear and ask only for the necessary information to assess competing proposals objectively. Usually this includes: • Legal name and address of supplier, and the name of the contact person who is authorized to deal with any lack of clarity in the proposal and to conduct negotiations • Brief history of the supplier and key financial figures • Supplier's qualifications and references: customers with whom the supplier has worked before, with contact information, cost and schedule of projects • Project plan: description of the development process to be used; proposed schedule; milestones and deliverables; project costs and payment details; description of project team and their qualifications; analysis of project risks; description of process for change management; assumptions made by the supplier in the proposal; any proposed trade-offs between functionality, quality, schedule and cost; and any terms or conditions that the supplier wishes to include in the contract.
4. Contracts and licenses	Use this section to clarify issues related to standard terms in the contract to be executed with the supplier, and aspects such as intellectual property ownership and licensing agreements.

Glossary

Term	Definition used
Data	The values of quantitative of qualitative variables. Example: '2017', '2018', '2019' are data for the variable 'Year'.
Data accessibility	Ensuring that users can access data according to pre-established access rights.
Data management	The practice of acquiring, validating, storing and processing data securely, efficiently and cost-effectively.
Data processing	Performing operations on data items in order to transform data into meaningful information. Examples are converting activity data into emissions equivalent data, performing automated quality control operations, aggregating data and presenting data in a graphical form.
Data reconciliation	In a data transfer or data migration process, data reconciliation verifies whether the migration of data from the source database to the target database transferred the data correctly. The data in the target database are compared with the data in the source database to detect errors.
Information	Data that are processed, organized and presented in a meaningful way to make it useful for the user of the information.
Information system	A combination of hardware, software, communication networks and manual procedures to collect, store, process and deliver relevant and useful information to users.
Problem domain team	Those people from the government's side who are engaged in climate transparency work and in developing the project. This team is spearheaded by the project developer.
Project developer	The government staff member working in the climate change area who embarks on projects aiming to build or further develop systems that support systematic data management processes for climate action and climate support data.
Productivity software	Software that allows people to create documents, presentations, data lists and charts. This software has many use cases. Examples include Microsoft Office, Google Office Suite (Docs, Sheets, and Slides) and LibreOffice.
Solution development team	The group of people with expertise in software development who work to build the information system solution that addresses the specified functional and non-functional requirements.

Term	Definition used
Source code	Human-readable list of instructions that a programmer writes when building software.
Source code repository	A central file-storage location that is used in tandem with version control software to keep back-up copies of source code.
Specialized software	Software created for a specific task rather than a generic task like writing a text. This software has very few use cases, possibly only one. Examples include accounting software, geographic information systems, 3D animation software and software to control a pacemaker.
Use case	A description of how a user will interact with the information system to achieve a specific goal. Example: the description of the interaction of the user with the information system in order to print a data table.
Version control software	Software that helps a team with multiple programmers to manage changes that they all do to the source code.
Web-based specialized software	Software that people access and use through the internet using an internet browser (e.g. Internet Explorer, Firefox, Chrome). It does not require the downloading or local installation of the software on a device (computer, tablet or smartphone).

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