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PMR PARTNERSHIP FOR MARKET READINESS

Developing Emissions Quantification Protocols for Carbon Pricing

A Guide to Options and Choices for Policy Makers

WORLD BANK GROUP

PARTNERSHIP FOR MARKET READINESS

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This work is a product of the staff of The World Bank with external contributions, including from the Partnership for Market Readiness. The Partnership for Market Readiness supports collective innovation and action by providing a platform for countries to share lessons and work together to shape the future of cost-effective greenhouse gas mitigation. It also funds capacity building to scale up climate change mitigation efforts.

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Abbreviations

AFOLU	Agriculture, Forestry and Other Land Use
BTU	British Thermal Unit
CDM	Clean Development Mechanism
CEMS	Continuous Emissions Monitoring System
CO_2e	CO_2 equivalent: the emissions from all Greenhouse Gases (GHGs) converted to a common base expressed in CO_2e using an agreed-upon Global Warming Potential (GWP) for each gas
CT	Carbon Tax
ETS	Emissions Trading System
EU ETS	EU Emissions Trading System
EUROSTAT	EU Statistical Office
GHG	Greenhouse Gas
GWP	Global Warming Potential
IEA	International Energy Agency
IPCC 2006	*The IPPC 2006 Guidelines for National Greenhouse Gas Inventories*[1]
LULUCF	Land use; Land Use Change; and Forestry
MP	Monitoring Plan
M&R	Monitoring and Reporting
MRR	Monitoring and Reporting Regulation
MRV	Monitoring, Reporting and Verification
MRVA	Monitoring, Reporting, Verification and Accreditation
MS	Member State
Nm^3	Normal meters cubed[2]
OEM	Original Equipment Manufacturer
PMR	Partnership for Market Readiness
PMR A&V Guide	Partnership for Market Readiness (2019): *Designing Accreditation and Verification Systems: A Guide to Ensuring Credibility for Carbon Pricing Instruments*
PMR MRV Guide	Partnership for Market Readiness (2015): *Guide for Designing Mandatory Greenhouse Gas Reporting Programs*
QA/QC	Quality Assurance and Quality Control
REDD	Reducing Emissions from Deforestation and Forest Degradation
RGGI	Regional Greenhouse Gas Initiative
GHG Protocol	GHG accounting protocol published by the World Resources Institute and the World Business Council for Sustainable Development[3]
tC	Tonne of carbon
tCO_2	Tonne of CO_2
UNFCCC	United Nations Framework Convention on Climate Change

1 The Intergovernmental Panel on Climate Change, *2006 IPCC Guidelines for National Greenhouse Gas Inventories*, (2006): https://www.ipcc-nggip.iges.or.jp/public/2006gl/.

2 Nm^3 = Normal meters cubed. For gases, volumes need to be standardized back to known temperature and pressure conditions to allow comparability and consistency in the data calculation process.

3 World Resources Institute and the World Business Council for Sustainable Development, *GHG Protocol,* http://ghgprotocol.org/.

Glossary

The definitions given here are for terms related to quantification for carbon pricing instruments in this report. **Bolded** words indicate key terms defined elsewhere in this list.

Accuracy	A relative measure of the exactness of an emissions or removals estimate taking into account both random and systematic factors, and with uncertainties reduced as far as practicable. For emissions inventories, this measure means that they are neither systematically over-estimated nor under-estimated. See also appendix A.
Activity data	Data on a quantitative measure of human operations that result in greenhouse gas (GHG) emissions or removals occurring over a given period. Data on energy use, metal production, land areas, land management approaches, lime and fertilizer use, and amount of waste produced are examples of activity data. For many carbon pricing instruments, activity data are defined as data on the amount of fuels or materials consumed or produced by a process (such as output of a process [electricity, pulp, lime] or the number of hours equipment is operated). Activity data are used in a calculation-based methodology and are multiplied by an emissions factor to derive the GHG emissions associated with a process or an operation.
Base year	A specific year or multiple years when yearly average values are determined against which an entity's emissions are tracked over time. This may also be called a baseline or a **reference period**.
Bias	In measurement, a systematic error in one direction or the other (such as overstating or understating the true value).[4] In sampling, the result of a non-random approach, which means that not all of a sampled population has an equally likely chance of being selected for analysis.
Biomass	The non-fossilized and biodegradable fraction of products, by-products, wastes and residues of biological origin arising from agriculture,[5] forestry, and related industries, as well as the biodegradable fraction of industrial and municipal waste. It includes bio-liquids (non-transport liquid fuels) and bio-fuels (liquid or gaseous fuel for transport).
Biomass fraction	Amount of carbon stemming from biomass relative to the total carbon content of a fuel or material. The biomass fraction is expressed as a percentage and is used where quantification allows for the deduction of biomass-related emissions or the application of a zero emissions factor to biomass-related consumption that is allowable under the carbon pricing instrument.
Calculation factor	Any of the factors required to convert an input fuel/material to quantifiable emissions data. Calculation factors include gross/net calorific values, emissions factors, oxidation factors, conversion factors, purity fractions, carbon contents, and biomass fractions.
Calibration	A comparison of measurement values delivered by a device that is being tested with measurement values from a calibration standard[6] of known accuracy in order to allow instruments to maintain their designed accuracy.
Carbon content	The analyzed content of carbon in the fuel or material expressed as a percentage of the mass of fuel/material.[7]
Carbon tax (CT)	A charge on GHG emissions or the carbon content of fossil fuels/ materials.[8]

4 For example, as a result of drift in instruments; a formula error in calculation; application of an incorrect calculation factor.
5 Including vegetal and animal substances.
6 Such a standard could be another measurement device of known accuracy, a device generating the quantity to be measured (such as a *voltage, sound* tone, or a physical artefact such as a meter ruler). For laboratory work it is a reference material of known composition from a trustworthy (often accredited) source. Calibration standards are normally traceable to a reference standard held by a national or international metrological institute.
7 When converting carbon to CO_2, the factor of 3.664 tCO_2 / tC is used; this is the ratio of the full molecular weights of CO_2 and C [44.01 /12.0107].
8 The charge is applied at the point of regulation so any subsequent use to which the fuel or material is put is irrelevant for the purposes of the tax.

CO_2 equivalent (CO_2e)	A measure used to compare the emissions from various greenhouse gases on the basis of their global-warming potential (GWP), by converting amounts of other gases to the equivalent amount of carbon dioxide with the same global warming potential. The CO_2 equivalent for a gas is derived by multiplying tonnes of the gas by the associated GWP.
Continuous Emissions Monitoring System (CEMS)	A system of gas sampling units, gas analyzers, temperature, and flow monitors integrated with a data acquisition and calculation system to automatically generate data for process performance monitoring and to calculate the level of specified emissions to demonstrate environmental regulatory compliance. The precise set-up of a system will depend on the gas being monitored and the regulations to be complied with**.** CEMS are used in **direct measurement of emissions.**
Conversion factor	A measure of the amount of carbon emitted as CO_2 as a share of the total amount of carbon contained in the source stream before the emitting process takes place. The conversion factor is expressed as a fraction, taking account of carbon monoxide (CO) emitted to the atmosphere as being the molar equivalent amount of CO_2.
Data flow	The sequence in which the process of data generation, data transfer, data transformation (such as calculations), and data use or reporting is described in text or a diagram.
Data management system	A system for collecting and storing GHG emissions information from reporting entities. The system facilitates the reporting, organization, and analysis of GHG data (including associated inputs, calculation factor, and other parameters). It should also support quality assurance, quality control, and verification activities; track emissions over time; and facilitate analysis and sharing of data with stakeholders. Different data management systems can apply at the level of the carbon pricing instrument and at the individual obligated entity level.
De minimis source or source stream	Emission sources or source streams that generate a relatively very small amount of emissions. For these sources and source streams, alternative quantification methods such as estimation methods are used to reduce costs; these are usually defined in regulations**.**[9]
Direct GHG emissions	Emissions from sources that are owned or controlled by the obligated entity (Scope 1).
Direct measurement of emissions	Measurement of GHG emissions directly in the exhaust stream of a process using CEMS.
Downstream entities	Entities that are regulated at the point of consumption where emissions are released to the atmosphere through the combustion of a fuel, consumption of energy, or conversion of a material.
Emission factor	A coefficient that quantifies the emissions or removals per unit of activity. This factor is used to convert activity data into GHG emissions data.
Emission source	Any physical technical unit or process that releases GHGs into the atmosphere.
Emissions trading system (ETS)	A system that sets an overall emissions limit, allocates emissions allowances to participants, and requires them to surrender allowances equivalent to their reported emissions. Excess allowances can be traded.
Facility	An individual operating site with a clear boundary comprising the technical and process units for manufacturing or other operations.
Fiscal metering	Quality controlled metering used for invoicing of fuels such as oil and gas. The control process is usually part of legislation for **national metrological control**.
Fugitive emissions	Emissions that result from intentionally or unintentionally releasing GHGs without abatement controls. They commonly arise from the production, processing transmission, storage, and use of fuels and other chemicals, often through joints, seals, packing, or gaskets.
Global warming potential (GWP)	A factor describing the radiative forcing impact (degree of warming caused) of one unit of a given GHG relative to one unit of CO_2 over a defined period of time such as 100 years.
Greenhouse gases (GHGs)	For the purposes of this report, the seven gases covered by Annex A of the Kyoto Protocol to the United Nations Framework Convention on Climate Change: carbon dioxide (CO_2); methane (CH_4); nitrous oxide (N_2O); hydrofluorocarbons (HFCs); perfluorocarbons (PFCs); sulphur hexafluoride (SF_6), and nitrogen trifluoride (NF_3);[10] as well as relevant gases covered by the Montreal Protocol.

9 For example, a de minimis source stream in EU ETS is defined as the source streams selected by the operator for its installation that jointly correspond to less than 1, 000 tonnes of fossil CO_2 per year or to less than 2 percent, up to a total maximum contribution of 20, 000 tonnes of fossil CO_2 per year, whichever is the highest in terms of absolute value. In California, ETS de minimis sources represent less than or equal to 3 percent of facility's total CO_{2e} emissions, not exceeding 20kt of CO_{2e}.

10 Although some carbon pricing instrumentshave included other fluorinated gases such as those subject to the Montreal protocol.

Gross calorific value (GCV)	A measure of the heating value of a fuel determined on the basis that all water component is in a liquid state at the end of combustion (in the product of combustion) and that all heat delivered at temperatures below 150°C (302' F) can be put to use. GCV is also called the Higher Heating Value (HHV).
Indirect GHG emissions	Emissions that are a consequence of the operations of the obligated entity but occur at sources owned or controlled by another entity. They are categorized as Scope 2 emissions (purchased energy) and Scope 3[11] emissions (other indirect emissions not included in Scope 2 that occur in the obligated entity's value chain), in contrast to **direct GHG emissions**.
Mass balance method	A method to calculate GHG emissions based on determining the balance of fuel, material, and gas flows entering and leaving the entire obligated entity or a specific unit or process within the obligated entity, expressed in units of mass. The input/output flows may be classified as **source streams.**
Materiality threshold	A quantitative concept employed in the process of verification and used by the verifier to determine whether an **error**, omission, non-conformance, or non-compliance gives rise to a significant discrepancy.
Midstream entities	Entities that are regulated at some point between where a fuel enters the economy and where its energy is consumed. This often occurs at the point of processing or conversion of a fuel or material (for example, refiners, distributers, or electricity generators).
Mobile combustion	Burning of fuels by transportation devices such as cars, trucks, trains, airplanes, ships, or other equipment[12] where the combustion is used to power the equipment's movement. Portable equipment on wheels[13] is not mobile unless it can use its own fuel to drive its own combustion engine to move itself.
Monitoring plan	A plan that outlines how an obligated entity will collect and control data used to quantify and report its emissions or emissions reductions. This plan usually contains quantification boundaries, quantification methodologies, and data collection and quality assurance procedures.
National metrological control	A national/regional network of laboratories, calibration facilities, and accreditation bodies that implement and maintain the metrology[14] infrastructure; this affects how measurements are made in a country[15] and how they are recognized by the international community. For the supply of commercial products such as gas or electricity, requirements for metrology are often subject to legislation for the specific types of measurement instruments required; for carbon pricing, these legal requirements can be used as part of the quality assurance processes for emissions quantification.
Net calorific value (NCV)	A measure of the heating value of a fuel determined after the subtraction of the heat of vaporization of water from the Gross Calorific Value. This approach treats any water formed as a vapor, so the energy required to vaporize the water is not released as heat. NCV is also called the Lower Heating Value (LHV).
Obligated entity	The entity, organization, facility, project developer, or person that is required by the CT or ETS legislation to participate or comply with regulatory quantification, monitoring, reporting, and compliance (for example, surrendering allowances or paying carbon tax). For voluntary programs, an obligated entity would be the one that has made a commitment to comply with the program's requirements.
Oxidation factor	A measure of the extent to which carbon is fully oxidized to CO_2 as a consequence of combustion expressed as a percentage of the total carbon contained in the fuel. The oxidation factor is usually expressed as a fraction taking account of carbon monoxide (CO) emitted to the atmosphere as being the molar equivalent amount of CO_2.
Precision	The closeness of results of repeated measurements of the same measured quantity under the same conditions. This outcome is often quantified as the standard deviation of the values around the average and reflects the fact that all measurements include some random error; this error can be reduced, but not completely eliminated.
Predictive emissions monitoring system (PEMS)	A software-based alternative to a CEMS, typically used as a backup system. This system uses software analysis to provide a real time estimation of emissions properties by using an advanced mathematical model of the emissions generating process based on real process values such as temperature, pressure, and flow. PEMs systems can be used in **direct measurement of emissions.**

11 Scope 3 is referenced here for completeness but this report does not cover scope 3 emissions. No carbon pricing instrument currently includes Scope 3 emissions; obligated entities have no control over the generation of these emissions and no accurate way to determine them. Scope 3 emissions are highly uncertain in the context of carbon pricing instruments.

12 Such as cranes, fork-lift trucks, and the like.

13 Such as a portable generator or pump that has wheels to move the equipment around by towing, but the fuel used is for its primary purpose.

14 Metrology is defined by the International Bureau of Weights and Measures (BIPM) as "the science of measurement, embracing both experimental and theoretical determinations at any level of uncertainty in any field of science and technology." It establishes a common understanding of units crucial to human activity.

15 Throughout this document, the term "country" has been used to mean country, state, region, or supra-national entity as appropriate to the carbon pricing instrument or local context.

Process emissions	Emissions generated from manufacturing processes not caused by the combustion of fuels but by (other) chemical processes, such as CO_2 that is emitted from the breakdown of calcium carbonate ($CaCO_3$) during cement clinker manufacturing.
Program of activities	The coordinated implementation of a policy, measure, or goal that leads to emissions reduction under the CDM (or other carbon pricing instrument, if specified in the rules), often combining dispersed activities or emission sources instead of one central (project) activity on one site.
Purity fraction	A measure of the amount of carbon contained in input material as a fraction of the total amount of input material. The purity fraction is expressed as a percentage and is used where quantification requires that the emission factor is related to the relevant quantity of carbon-containing material instead of the total quantity of input material (for example, the amount of pure calcium carbonate – $CaCO_3$ - in limestone used as an input material for cement manufacture).
Quantification protocol	A quantification protocol provides a framework for quantifying emissions. It comprises the rules, processes, and other requirements necessary for obligated entities to monitor data and quantify emissions for reporting; and for regulators to evaluate compliance.
Reference period	See **base year**.
Reporting period	The time frame over which quantification of emissions must occur. Typically, this is a calendar year (although it may also be the fiscal year or another twelve-month period).
Scope 1 emissions	Emissions from sources owned or controlled by the obligated entity (emitted directly at a facility they control).[16] Also called **direct GHG emissions.**
Scope 2 emissions	Emissions associated with the generation of energy (electricity, power, heating/cooling, or steam) purchased for the obligated entity's own consumption. Also called '**indirect GHG emissions.**
Scope 3 emissions	Indirect emissions except those covered under Scope 2[17], see also **indirect GHG emissions.**
Source streams	Specific fuel type, raw material, or product giving rise to GHG emissions at one or more emission sources as a result of its consumption or production.
Stationary combustion	Burning of fuels in stationary equipment such as boilers and furnaces. This includes portable equipment that is not considered a **mobile combustion** source.
Third-party verification	An independent assessment of the reliability, completeness, and accuracy of emissions-related information submitted by obligated entities to the carbon pricing instrument/reporting program regulator.
Transportation entities	In the context of carbon pricing instruments, transportation can mean different things depending on the scope of the carbon pricing instrument for transport activities. Each carbon pricing instrument defines what the obligated entity is for transportation. For example, for aviation this may be the aircraft or fleet owner, airline company, or airline operator; similar approaches apply to maritime and land transport.
Uncertainty	1) Quantitative definition: In metrology, uncertainty is the attribute that characterizes the range within which the true value is expected to lie with a specified level of confidence. It is the overarching concept that combines precision and assumed accuracy. (See appendix J-A for more details.) 2) Qualitative definition: A general term that refers to the lack of certainty in data and methodology choices, such as failure to apply the rules of the carbon pricing instrument; the application of non-representative factors or methods, incomplete data on sources and sinks, or lack of transparency.[18]
Upstream entities	Entities that are regulated under the carbon pricing instrument at the point of supply where the fuel or material is produced or enters the economy. The entities must pay tax or submit allowances at or near the point of supply of carbon-based fuels or materials, for example, at a coal mine entrance, a gas wellhead, or a port for imported fuels or materials.

16 Based on definitions in *the GHG Protocol*.

17 Such as extraction and production of purchased materials and fuels, transport-related activities in vehicles not owned or controlled by the obligated entity, outsourced activities, and waste disposal.

18 Section 3.1.5 of volume 1 of the *IPCC Reporting Guidelines 2006* provides a summary of the likely sources of uncertainty to be found in emissions quantification. See https://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/1_Volume1/V1_3_Ch3_Uncertainties.pdf.

1. Executive Summary

Carbon pricing is an important instrument in addressing climate change. However, a well-functioning carbon pricing instrument needs a robust framework to quantify GHG emissions (including removals) underpinned by high quality data. This data can help policy makers set the level of a carbon tax (CT) and help regulators track how many emissions allowances companies need to surrender under an Emissions Trading System (ETS). A robust framework will facilitate implementation and enforcement of the rules and increase compliance levels.

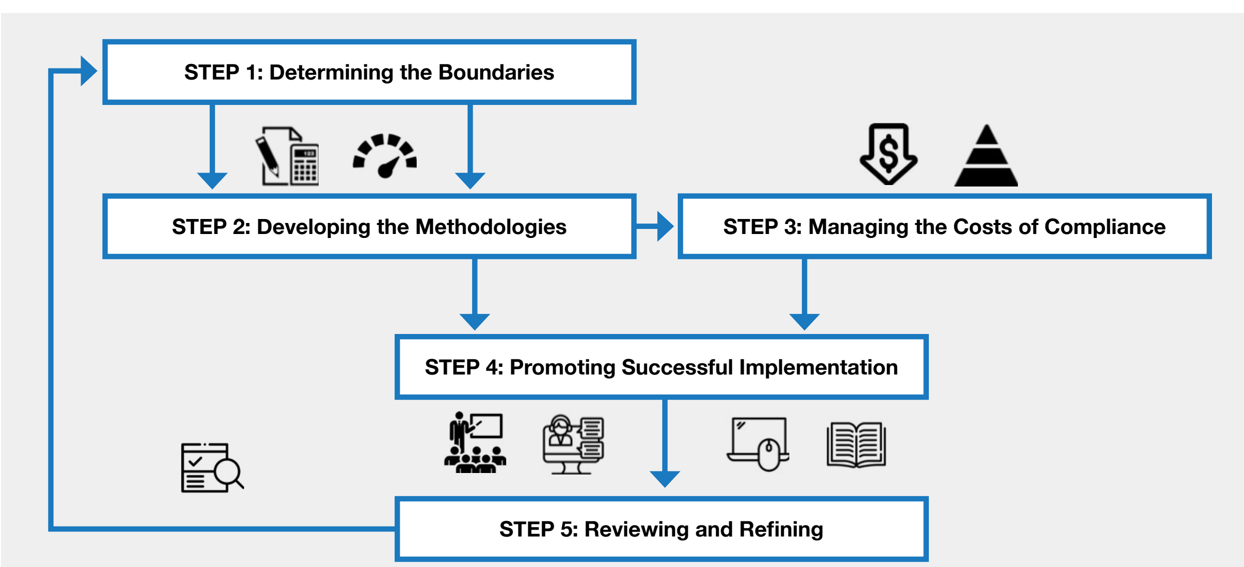
This report builds on the *PMR Guide for Designing Mandatory Greenhouse Gas Reporting Programs* (PMR MRV Guide), which provides a broader overview of establishing an MRV system. This report, *Developing Emissions Quantification Protocols for Carbon Pricing,* focuses on the technical detail of quantification protocols, that is, how in practice emissions data can be monitored and quantified for reporting.

This report is intended for policy makers and government officials responsible for setting up and implementing emissions quantification protocols as part of the emissions monitoring, reporting, and verification (MRV) systems that support carbon taxes and emissions trading systems.

A quantification protocol comprises the set of rules that are defined by policymakers to prescribe how obligated entities have to monitor data and quantify emissions for reporting. Such protocols help to ensure standardized approaches to quantifying emissions by all obligated entities, promoting consistency over time and equal treatment among entities. They define minimum requirements for how obligated entities can set up their internal quantification and reporting processes to meet the carbon pricing instrument rules. By setting standards for measurement and calculation accuracy, complete, consistent, and accurate data collection over time can be promoted.

The report outlines five steps to designing quantification protocols, as illustrated in figure 1.

FIGURE 1: The Report Structure - 5 Steps to Designing Quantification Protocols



Source: PMR Secretariat

1.1. Before You Begin

A robust quantification protocol is critical to the reporting of GHG emissions and, ultimately, the success of a carbon pricing instrument. Quantification protocols help generate a robust dataset that underpins the operation of carbon pricing instruments, as well as supports the development of national GHG inventories and reporting under the Paris Agreement. Aligning national and company level reporting, where practical, can improve the consistency of the data quantification process. Over time, key principles have emerged to promote high quality quantification and reporting that can guide the protocol drafting process. These include concepts such as reliability, accuracy, completeness, consistency, transparency, and the need for continuous improvement.

Countries[15] do not need to start from scratch in developing quantification protocols, however. Existing reporting programs may be relied upon or adapted to the needs of the carbon pricing instrument. Equally, international standards such as the *2006 IPCC Guidelines for National Greenhouse Gas Inventories* (IPCC 2006), standards from the International Organization for Standardization (ISO), and industry-led guidance can also facilitate the development of quantification protocols.

Quantification protocols are normally established in legislation to enable enforcement[19]. Such legislation outlines how the protocol work and the steps that obligated entities must follow to quantify emissions. It also provides the basis for regulators to check and enforce compliance. Further details are then outlined in supporting documents and guidance. The rules must provide certainty, predictability, and enforceability, while containing enough flexibility to ensure that quantification rules reflect the latest standards, technological developments, best practices, and are implementable on the ground. Consultation with sector experts and obligated entities can help to ensure such protocols are fit for purpose and workable.

1.2. Determining the Boundaries[20]

When designing quantification protocols, policy makers should ensure obligated entities report all emissions included in the carbon pricing instrument. Five broad areas of activity are identified by the IPCC (energy, industrial processes and product use, agriculture, forestry and other land use, waste and other), each of which can be broken down into discrete sectors, emission sources, and source streams. The sectors covered by the carbon pricing instrument will influence which emission sources and source streams need to be quantified. Emissions quantification is easier in sectors where data are readily available and/or easier to collect. Conversely, some sectors have additional methodological challenges, making quantification and data collection more complex. Complicated sectors will require more detailed data collection. In addition, the gases and point of regulation of the carbon pricing instrument, along with a decision to include indirect emissions (or not), will affect the scope of the quantification protocol.

19 Voluntary programs may not include quantification approaches in legislation; or may reference a choice of available standards that support quantification
20 Geographic boundaries are part of the framework of the carbon pricing instrument itself so are outside the scope of this document

1.3. Developing the Methodologies

There are two main methodologies for quantification: calculation-based and direct measurement-based. A combination of the two methodologies can also be used by any one obligated entity depending on its circumstances.

Calculation-based methodologies are often applied to simpler situations such as defining fuel combustion emissions or situations in which it is not possible or is too expensive to directly measure emissions from an emission source (for example, when there is no appropriate location for measurement equipment, there are too many emission points, or the obligation to report is applied upstream). Calculations can be made using a standard calculation approach, which requires only a few specific inputs such as activity data and emission factors, or using a mass balance approach based on the carbon content of fuels, materials, and products across all or a defined part of the obligated entity. Policy makers will need to ensure sufficient rules and guidance on when and how to apply a particular methodology (such as whether factors like calorific values and emission factors need to be defined through sampling and analysis or whether appropriate default values can be applied).

Direct measurement-based methodologies may be applied where there is one – or only a few – emission points that are suitable for the necessary measurement equipment (for example a single flue stack at a power plant). When setting up direct measurement methodologies, policy makers need to make decisions on the type of approach to allow (continuous monitoring versus predictive emissions software); while it is accurate and yields frequent data points, continuous monitoring can be expensive, and policy makers may allow alternative approaches. For either methodology, quality assurance guidelines are also needed – to ensure quality data collection and control and to ensure instruments are of sufficient quality and in good working order.

For both calculation and direct-measurement methodologies, as obligated entities often have multiple emission sources or source streams, requirements should also be put in place to ensure data are aggregated appropriately from individual source or source stream up to obligated entity level, for example, without early rounding of primary or intermediate data.

1.4. Managing the Costs of Compliance

While in an ideal world, quantification protocols should aim to generate the most accurate data possible, achieving this may sometimes be cost prohibitive or not technically feasible. There are three main ways to help balance accuracy against cost concerns[21]. The first is a tiered approach, which creates a hierarchy of increasing levels of sophistication and data accuracy when it comes to quantification. Policy makers can also encourage or build in transition periods that move entities or source streams to more accurate quantification methodologies over a defined period of time. A second way is to establish simplified approaches for smaller emitters (entities) that may not have the capacity and resources to implement more stringent quantification requirements. Thirdly, simplified approaches may also be allowed for small or very small emission sources.

21 Going forwards digital technology and software may make it easier to generate accurate data; however, installing equipment such as higher accuracy meters, analysers and CEMS may still impose significant costs on obligated entities.

1.5. Promoting Successful Implementation and Compliance

Equally as important as designing the quantification protocol is ensuring that a protocol is consistently and correctly applied by the regulators and obligated entities. Early and frequent communication with key stakeholders to make them aware of the resource requirements can help them plan in advance for the rollout of the quantification protocol. Tools, guidance documents and especially IT software can also make compliance with a protocol significantly easier.

1.6. Reviewing and Refining

The need for consistent data over time is balanced by the need to continually refine and improve the emissions quantification process. There is an onus on governments to regularly review and refine quantification protocols to ensure they reflect changes in science, technology and industry practices, as well as improve quantification methods over time. However, quantification protocols should not change arbitrarily or without justification. Nevertheless, there may be situations in which amendments to the application of specified methodologies by obligated entities are necessary or encouraged. Examples include if an obligated entity has new emission sources or source streams, or if they require a temporary deviation due to equipment failure. In these situations, clear rules are required on how, when, and why obligated entities can or must change their application of specified methodologies.

Changes to the quantification protocol itself may also be required if there are changes to the broader carbon pricing instrument. If, for instance, new sectors are included or coverage thresholds are lowered, this may necessitate additional methodologies or simplified approaches for those new entities. Finally, change can come about as a result of a formal review process. Stakeholder involvement and clear communication on the type of changes and the timelines for their implementation will ensure protocols are updated smoothly and implemented properly. These changes should also be reflected in any supporting documents, tools, and IT systems.

2. Introduction

Carbon pricing is an important instrument in addressing climate change. Putting a price on carbon allows markets to adequately price emissions that occur as a result of economic activity. Implementing a carbon pricing instrument creates a financial incentive for organizations and consumers to make lower carbon choices, thereby reducing the economy's GHG emissions; and a properly designed carbon pricing instrument encourages abatement to occur where it is least costly. Underpinning carbon pricing is the need for high quality, credible, and robust data on the quantity of GHG emitted (or taken up) by different activities. High quality data:

- Provide transparency on whether emissions targets and climate mitigation goals are being reached
- Enhance trust that the carbon pricing instrument is fair and has environmental integrity, allowing parties to determine how much tax must be paid or how many emissions allowances must be surrendered
- Provide information to policy makers for designing and evolving the carbon pricing instrument
- Facilitate the development of other policies and programs for climate mitigation and adaptation, and improvement of national emissions inventories

High quality data can be generated through a monitoring, reporting, and verification (MRV) system (for more information see the PMR MRV Guide). Part of a robust MRV system includes the design and implementation of quantification methodologies for GHG emissions[22] so that they can be accurately monitored and reported. Quantification protocols outline the accepted methodologies and calculation factors that obligated entities under the carbon pricing instrument need to apply to their individual circumstances. Independently verified data obtained through these procedures will result in more accurate reporting, providing a better reflection of actual GHG emissions than general estimates from top-down economy level statistical information, which is often used for United Nations (UN) reporting.

When implemented appropriately, the data generated may provide countries with an excellent source of granular information to compile GHG national inventories and parties' specific reporting requirements under the Paris Agreement.[23] The generated data can also help policy makers design complementary policies, monitor the effectiveness of the jurisdiction's carbon pricing policy and can also inform future revisions of a government's Nationally Determined Contribution. **A quantification protocol provides the framework for quantifying emissions. It comprises the rules, processes, and other requirements necessary for obligated entities to quantify emissions data for reporting. Regulators will also use it as a basis for assessing compliance with the carbon pricing instrument's reporting requirements.** The protocol helps to ensure that standardized approaches are applied by all obligated entities, promoting consistency over time and equal treatment among entities.

A quantification protocol is established by policy makers to set the framework of acceptable methodologies for an obligated entity to apply within the context of its operational activities; and for regulators to use for assessing compliance with the carbon pricing instruments reporting requirements.

22 In the context of this report, the term "GHG emissions" should be understood as including removals where relevant to a policy maker's carbon pricing instrument.

23 Paris Agreement, Dec 1/CD 21, Annex UNDOC FCCC/CD/2015/10 Add.1, January 29, 2016.

2.1. Objectives of the Report

This report is intended for policy makers and government officials responsible for setting up and applying emissions quantification protocols to support carbon pricing and other climate action programs. Building on their experience with UN inventory reports and other climate action programs they may apply, it aims to help them understand their options in designing a quantification protocol tailored to the specific needs and circumstances of the carbon pricing instrument they have selected. This report builds on the third step in the PMR MRV Guide for developing an MRV system (See figure 2).

FIGURE 2: Steps in Establishing a GHG Emissions Reporting Program and the Role of Quantification Methodologies

Source: PMR Guide For Designing Mandatory Greenhouse Gas Reporting Programs.[24]

Where the PMR MRV Guide provides a broader overview of establishing an MRV system (essentially, what to include), this report gives more **in-depth technical guidance on the development of rules, methodologies, and tools for the quantification of GHG emissions** for mandatory carbon pricing instruments (essentially, how to achieve quantification). It draws on both academic literature and practical experiences from countries that have implemented carbon pricing instruments.

2.2. Structure of the report

A quantification protocol for any reporting mechanism (whether mandatory or voluntary) has common key concepts and principles for quantifying emissions and emissions reductions that will influence the design of the quantification protocol, as outlined in chapter 3. Before policy makers start designing protocols, they need

24 Partnership for Market Readiness. Guide For Designing Mandatory Greenhouse Gas Reporting Programs. Washington DC: World Bank Group, 2015

to consider the legal framework, including existing legislation and international standards, and consult with key stakeholders in order to facilitate the drafting process. Following this section the report is divided into the five steps that cover the key issues in quantification protocols (see figure 3) as follows:

Step 1: Determining the boundaries. Policy makers need a clear understanding of the type of sectors, activities, emission sources, and source streams that will need to be accounted for through a quantification protocol. Boundary decisions will be influenced by decisions on the scope of the carbon pricing instrument.

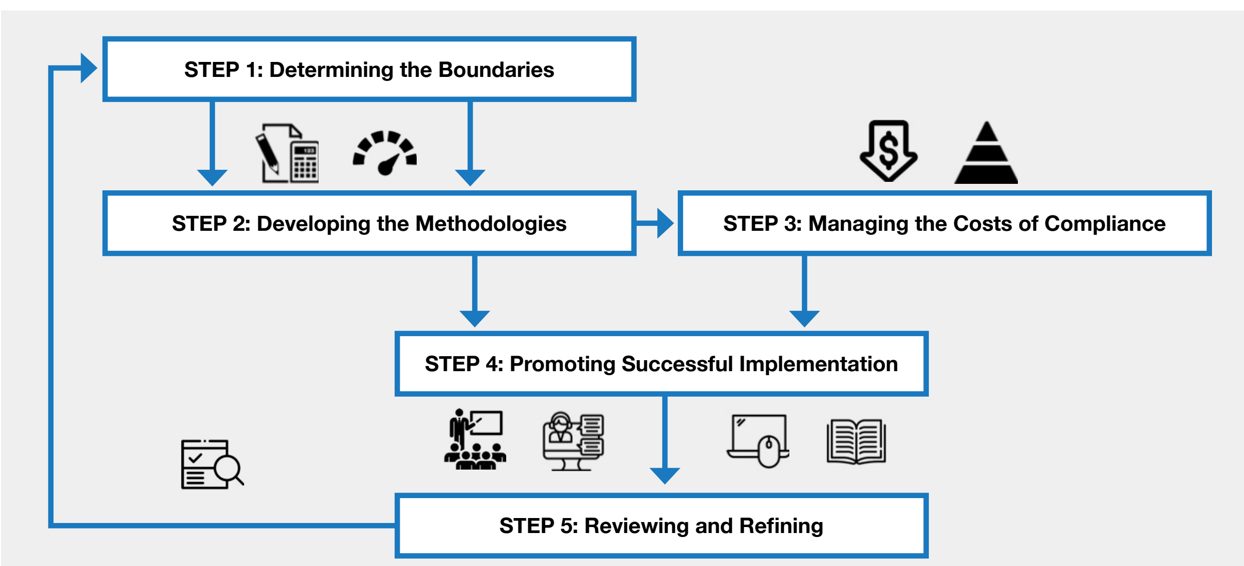
Step 2: Developing the methodologies. There are two main ways emissions can be quantified – calculation and direct measurement. This chapter analyzes these two methodologies to aid decision making; it describes requirements and offers guidance on when one methodology may apply over another. At the same time, alternative methods must be put in place to deal with situations like data gaps. Regardless of which methodology applies, policy makers also need to ensure consistent and accurate data are generated. Outlining acceptable levels of uncertainty can help ensure this. Finally, the chapter discusses other factors affecting methodology choice, including the design of the carbon pricing instrument.

Step 3: Managing costs of compliance. The need for accurate data should be considered in light of the costs and capacity of obligated entities to generate such data. A simplified or tiered approach can help smaller emitters manage the compliance burden.

Step 4: Promoting successful implementation and compliance. Tools, templates, additional guidance, and training can help to improve compliance and build capacity.

Step 5: Reviewing and refining. Quantification protocols may need to be refined over time to keep pace with technological innovations or changes to the scope of the carbon pricing instrument, for instance. Equally, as obligated entities become more experienced, they may be able to implement more rigorous requirements.

FIGURE 3: The Report Structure - 5 Steps to Designing Quantification Protocols



Source: PMR Secretariat

2.3. Scope of the Report

As highlighted in section 2.1, this report covers a subset of the information included in the PMR MRV Guide, which is referenced throughout. This report focuses on the **development** of a quantification protocol; **implementation** of a protocol is not covered except where implementation aspects relate to protocol design and development (for example, see chapter 7). Equally, other MRV aspects, such as auditing, accreditation and verification systems[25] and registries, are important aspects to consider when developing quantification protocols. However, detailed guidance on these topics is addressed in other PMR documents and they are therefore not covered in this report (references are given in the chapter Additional Readings).

While this report notes the broader application and benefits[26] of quantification protocols, it focuses on developing a protocol for the purposes of implementing a carbon pricing instrument. In this regard, the quantification protocol is primarily aimed at supporting implementation of a carbon tax (CT) or an emissions trading system (ETS). While elements of this report may have relevance for a crediting or offset program, issues relating to developing baselines and quantification methodologies for the purposes of crediting are not considered here.[27] Similarly, design issues related to carbon pricing instruments (such as sector coverage) are beyond the scope of this report, except where those design issues influence the scope of and approach to GHG emissions quantification (see section 4.2).

25 Information on verification of quantified emissions and associated accreditation/approval can be found in the *PMR A&V Guide, Designing Accreditation and Verification Systems,* (World Bank Group, Washington, DC, 2019), https://openknowledge.worldbank.org/handle/10986/31324.

26 The information provided in this report can also support practitioners setting up GHG emissions reporting programs for other purposes.

27 The PMR is in the process of preparing guidance on crediting systems.

3. Key Principles and Legal Frameworks

AT A GLANCE

This chapter introduces you to the main principles of emissions quantification and how they are applied in the design and operation of quantification protocols. Guidance on how you can set up the legal framework is also outlined, including the extent to which you can draw on existing domestic legislation and/or international standards.

- A quantification protocol underpins the integrity of a carbon pricing instrument and any broader GHG reporting system.
- A quantification protocol must have a strong legal framework underpinned by the key principles of reliability, completeness, consistency, accuracy, transparency, and continuous improvement.
- Incorporating key aspects of quantification in legislation, as opposed to in guidance documents, helps ensure the framework is robust, durable, and enforceable. The rules need to be clear while flexible enough to keep pace with improvements in international reporting requirements and guidelines, as well as changes in science, technology, and industry practices.
- Where appropriate, your quantification protocol should build on existing frameworks such as those established for reporting other pollutants. This can support alignment with other reporting programs (potentially reducing burdens on obligated entities), expedite development of the protocol more broadly, and promote credibility and integrity. Policy makers can also draw from international standards and industry best practices.
- Early stakeholder involvement can improve acceptance of the proposed rules and help ensure the quantification protocol works in practice

A robust quantification protocol is critical to the reporting of GHG emissions and, ultimately, the success of the carbon pricing instrument. This chapter highlights the key aspects to consider when developing a quantification protocol. Policy makers should consider the purpose of the protocol (section 3.1) and bear the key principles in mind during its development (section 3.3). Promoting these principles within the protocol's rules will promote compliance with the carbon pricing instrument, facilitate delivery of robust and useful data and support broader international reporting requirements. When drafting legislation and regulatory guidance for quantifying emissions, policy makers may be able to draw on pre-existing domestic legislation, international standards, and industry best practices (section 3.4). Early outreach to industry, regulators, and verifiers can help ensure protocols are practical and consistent.

3.1. Purpose of a Quantification Protocol

A good practice quantification protocol provides the rules, tools, and guidance necessary for obligated entities to collect and report consistent and reliable data. Accordingly, **developing a high-quality quantification protocol is critical for delivering on broader GHG reporting objectives**, as identified in the PMR MRV Guide, including:

- Supporting policies and regulations, such as CT and ETSs, which require detailed source-level data
- Facilitating policymaking by analyzing emissions data at different resolutions (source, facility, entity, sector, or economy-wide)
- Providing policy makers with a robust dataset that can help inform evaluation of existing policies and/or development of new policies

- Providing information to stakeholders to facilitate their involvement, including helping organizations to identify opportunities to reduce their GHG emissions

- Supporting international reporting requirements, including preparation of national GHG inventories under the United Nations Framework Convention on Climate Change (UNFCCC)) and the development of Nationally Determined Contributions

- Helping obligated entities assess their climate risks and opportunities as well as their compliance obligations

Given the link between how emissions are calculated for carbon pricing instruments and for government's national objectives, promoting consistency – where possible – across company and national reporting practices will ensure policy efficiency and alignment. However, it should be noted that quantification for carbon pricing instruments is much more tailored than national emissions reporting as it is focused on a bottom up approach, determining more precisely emissions at the level of the obligated entity itself.

The carbon pricing instrument should have clear policy objectives and the quantification protocol should be designed to support these. In addition, as a quantification protocol can help deliver on a range of different objectives, the objectives themselves should be considered when designing the protocol. For example, including reporting requirements and data collection that extends beyond the requirements of the carbon pricing instrument can be helpful. See chapter 2 of the PMR MRV Guide for detail on determining program objectives. However, when developing a quantification protocol for a carbon pricing instrument, policy makers need to keep in mind that the protocol should be sufficiently robust to ensure accurate data because these data determine how much tax will be paid in a CT system or how many emissions allowances have to be surrendered in an ETS.

3.2. Roadmap for Developing Quantification Protocols

Quantification protocols are usually developed over several stages, which can overlap each other in time. figure 4 below shows how these stages interact; further considerations at each stage include:

- **Stage 1 –Framework design and legislation for the carbon pricing instrument**: Policy makers decide on the framework and type of legislation suitable to cover different elements of the carbon pricing instrument. These choices affect how the quantification protocol is developed in the second stage.

- **Stage 2 – Protocol design:** Policy makers make decisions on the design of quantification methodologies, including requirements for quantification elements, mandatory plans, QA/QC, and verification. They also analyze the costs of different quantification elements; this stage is closely related to stage 3.

- **Stage 3 – Protocol framework and legislation:** Details of primary and subordinate legislation are developed and consulted upon. Development of primary legislation usually needs a longer legislative process than subordinate legislation, so policy makers need to consider the timings carefully when developing a roadmap for the quantification protocol; they must also consider need for capacity building.

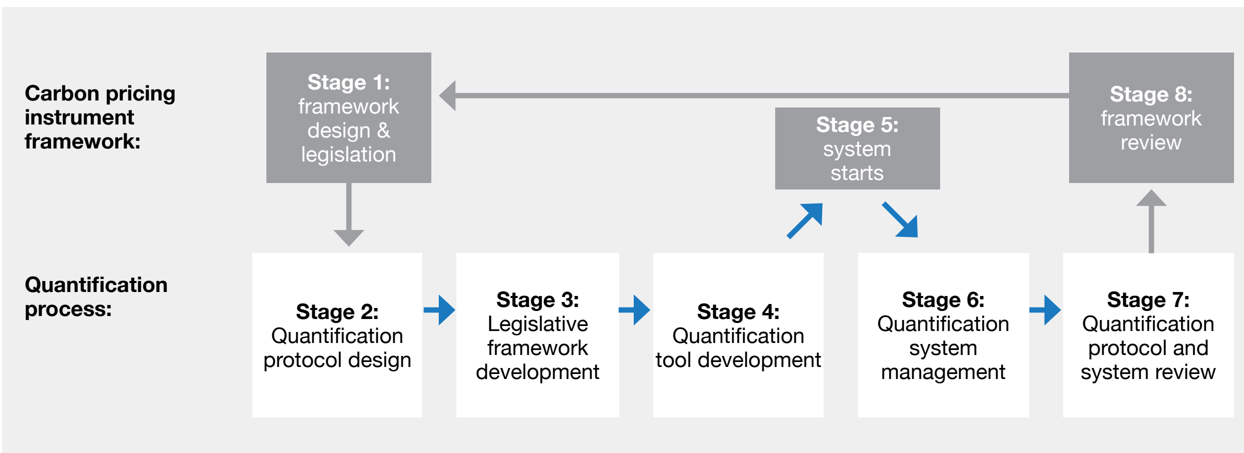
- **Stage 4 – Quantification support tools:** This stage usually overlaps with stage 3. Policy makers and regulators develop tools that facilitate the implementation of the quantification protocol: developing guidance, arranging for helpdesks, and designing IT systems. Ideally, the rules and tools to facilitate implementation should be in place before the carbon pricing instrument starts and before obligated entities are required to quantify their emissions. This timing should be considered when setting deadlines for obligated entities to submit required documents and defining a timeline for approving or validating such documents, if required.

- **Stages 5 & 6 – Quantification system management:** Once the carbon pricing instrument is up and running, the quantification management phase starts: ongoing quantification (including for allocation baselines, as necessary) and regular reporting (and verification) of emissions, maintenance of tools, updating of baselines, and other aspects of the carbon pricing instrument.

- **Stages 7 & 8 – Protocol and system review:** The whole quantification protocol is usually under frequent review, feeding into regular planned programs of evaluation of the carbon pricing instrument. During such an evaluation stage, policy makers and regulators will assess how the quantification protocol is functioning and whether there is a need to update its rules and framework.

The steps outlined in the rest of this report feed into these stages of the quantification process.

FIGURE 4: Context and Roadmap for Developing and Implementing Quantification Protocols



Source: SQ Consult

3.3. Key Principles of Emissions Quantification

Considerable efforts have been made over the last few decades to help promote the quality of emissions quantification and reporting. These efforts include:

- *ISO 14064-1 - Specification with guidance at the organization level for quantification and reporting of greenhouse gas emissions and removals,* outlines a regime neutral framework, principles, and requirements for quantifying an organization's GHG emissions.

- The *Greenhouse Gas Protocol - A Corporate Accounting and Reporting Standard*, developed by the World Resources Institute (WRI) and World Business Council for Sustainable Development (WBCSD), has helped establish many of the concepts used in GHG accounting and quantification today.

- The *2006 IPCC Guidelines for National Greenhouse Gas Inventories* sets out the approaches for countries to use when preparing their national inventories, along with contextual information for different sectors.

- The Paris Agreement also supports the principles of transparency, accuracy, completeness, comparability, and consistency for the purpose of emissions accounting.

Based on these documents and the experience of obligated entities and verifiers in applying quantification protocols, Table 1 provides a summary of the key principles underpinning quantification protocols. Further explanation is provided in appendix A. These principles should be referred to when preparing a quantification protocol and can be embedded within the enabling framework. **Promoting these principles will support compliance with the carbon pricing instrument by providing clear and consistent rules for GHG data quantification and reporting and will help to deliver a robust dataset for multiple purposes**. They will also help to ensure that quantification methodologies are consistent within and across industries and across time.

TABLE 1: Key Quantification and Reporting Principles and How They Impact Design Requirements

Principle	Meaning	Impact on design, need for clear rules on
Completeness	All sources and emissions covered by the program are quantified.	The scope of the carbon pricing instrument and its quantification boundaries[28]
Consistency	Overtime the same approaches, methodologies and data sets should be used without any arbitrary changes.	When to update the quantification protocol or individual methodologies to improve accuracy and coverage of the carbon pricing instrument over time; changes to be based on a clear rationale.
Accuracy	There is no systematic over- or under-estimation of emissions.	Balance between level of accuracy and costs when designing quantification methodologies.
Transparency	Primary data can be traced back from reported emissions.	Quantification, data collection, and recording and retention of data.
Verifiable	Quantification should ensure that data can be fully checked and confirmed as being reliable for the use to which it will be put.	Transparency, data retention and documentation to facilitate auditing of data and data management systems.
Comparable	Emissions estimates for similar entities in the same sector should follow the same approaches. Where possible, quantification approaches should be aligned across sectors.	Harmonization of methodologies and approaches across sectors and similar entities for common or cross-cutting elements.
Continuous improvement	Quantification methodologies, approaches to implementing them and their robustness are improved over time.	How and when to improve methodologies and implementation approaches.

3.4. Setting the Legal Framework

As highlighted in the PMR MRV Guide, establishing a strong legal architecture is important to providing a robust carbon pricing framework. This is also true for developing quantification protocols. The following sections outline the main issues to be considered when developing a framework for quantification. These considerations include:

- The potential to build on existing domestic or international frameworks (sections 3.4.2 and 3.4.3)
- The most appropriate legal structures, noting that some elements may need to be updated more frequently (section 3.4.1)
- Broad consultation with stakeholders (section 3.4.4)

28 It is not necessary for policy makers to justify exceptions (for example, of sectors or GHGs) in the quantification protocol as completeness in this context covers only what they have determined is included within the carbon pricing instrument, for which all relevant information should be included in reporting.

3.4.1. Consider legislative structure

The rules and requirements for GHG quantification need to be clear and enforceable. Accordingly, it is essential to embed key elements of the MRV framework, including quantification, in legislation (see PMR MRV Guide). In addition to helping with enforceability and compliance, legislating key elements provides obligated entities and stakeholders with a degree of regulatory certainty and predictability. Lessons learned from various CTs and ETSs show that the legislation needs to be of a sufficiently high status to enforce compliance and to ensure good quality data is provided by obligated entities in line with the requirements. Compared to other elements of the carbon pricing instrument and MRV frameworks (such as cap setting, baselines for allocation, or penalties), **there is a greater need to more frequently assess, update, and improve quantification methods in order to keep pace with new technology, scientific developments, and international standards** (chapter 8 provides detail on processes for reviewing and updating methodologies). To help balance these two objectives, the legal structure[29] should be considered when designing the framework for quantification protocols.

Importantly, policy makers should consider which elements of the quantification protocol are more likely to change. Some fundamental aspects (such as key definitions, main responsibilities of various stakeholders, and penalties) are unlikely to need frequent update. Accordingly, it may be appropriate for these elements to be fixed in primary legislation (such as Acts of Parliament). In addition, some elements that require greater clarity and enforceability may be better suited to primary legislation. However, **it may be more appropriate for elements that likely need frequent updates to be included in documents that can be more easily amended**, such as subordinate legislation (regulations and decrees). Lessons learned from various CTs and ETSs show that requirements should be included in legislation to give a mandatory effect, while guidance material can best be used to explain rules laid out in primary or subordinate legislation. Without the ability to enforce rules, it may be difficult to get obligated entities to comply with them and to get good quality data across sectors and obligated entities.

The process for determining the appropriate level of legislation, rules, and guidance will be highly influenced by the country's constitutional structure, legal frameworks, and political processes. Table 2 provides examples of different quantification elements and their likely frequency of change.

TABLE 2: Examples of Frequency of Change of Quantification Protocol Elements

Key - Frequency of change:	LOW	MEDIUM	HIGH

Examples of quantification protocol elements	Appropriate enabling mechanism
– Key definitions – Principles of quantification – Key responsibilities of various stakeholders (such as which regulator enforces rules, whether obligated entities must submit a monitoring plan, notifications to regulators on changes, and so on) – Activities and sectors covered by the carbon pricing instrument – Legal basis for further subordinate legislation on quantification and key elements to be regulated – Timeframes and deadlines for things such as submission of monitoring plans and emissions reports.	Primary Legislation (such as Acts of Parliament), which is updated infrequently

29 Such as constitution, primary legislation, secondary (implementing) legislation, and customs applied by courts based on traditional or recognized practices or codes of law.

Key - Frequency of change:	LOW	MEDIUM	HIGH

Examples of quantification protocol elements	Appropriate enabling mechanism
– Calculation formulae – Broad types of technical units that should be included for applicable sectors as a minimum (such as fired heaters, specialist processes, or flares) – What type of default values to apply and when – Main sampling and analysis requirements, including minimum frequencies – Applicable GWPs – Acceptable levels of uncertainty (for example, for measurement instruments) and minimum requirements for calibration and maintenance of measurement equipment – Methodology eligibility requirements – Tier requirements – Definition of biomass (See appendix B) – Minimum contents of reports and monitoring plans	Subordinate legislation (such as regulations or Ministerial decrees), which may be updated more frequently or more easily
– Some default values (such as those based on standardized datasets including electricity grid emissions intensity factors and factors updated annually and reported in national) inventories[30]) – Automated processes such as IT systems for reporting or workflow management – Examples of applying legislation, interpretations of rules and their application – Responses to frequently asked questions	Guidelines, tools, templates, and IT (see section 7.3), which can be regularly updated by policy makers or regulators

Stating clearly in the rules which elements will be updated and at what frequency also gives clarity to the obligated entities. If, for instance, some emission factors will require annual updating, the updated value can be stated in technical guidance with an indication of its date of applicability. Other amendments and refinements may arise as a result of stakeholder consultation, formal reviews, and international developments.

Appendix C provides examples of international legislation and guidance that countries have relied upon to establish their quantification protocols.

3.4.2. Build on existing domestic frameworks

Using existing frameworks, particularly existing legislation, can expedite development of a quantification protocol; it can also ease the drafting process for governments as well as the compliance burden (for both governments and obligated entities). Prior to developing a quantification protocol, policy makers should **undertake a comprehensive review of existing frameworks** that may relate to GHG quantification (for more, see step 2 of the PMR MRV Guide). Such a review will help identify opportunities and potential areas of overlap, including existing legislation or programs that can be used as a basis for developing GHG

30 However, the legal basis should be included in secondary legislation. This legislation should specify what type of default value to apply in what situation. The actual value could be published on a website or in guidelines that are regularly updated.

quantification methodologies. For example, many countries have already established reporting programs for GHG emissions and/or other pollutants. In some cases, existing legislation, reporting frameworks, and tools can be used as the foundations for developing quantification protocols. For example, there may already be established sampling, measurement, or calibration standards that may also be applicable for reporting under the carbon pricing instrument.

In addition to expediting protocol development, using existing frameworks also allows obligated entities to build on their existing knowledge, which can reduce the regulatory burden. **However, the existence of previously established systems also presents the potential for overlap and duplication of effort**. To avoid overlaps and to ensure obligated entities do not have to report the same data twice, some countries have taken measures to streamline reporting programs. In Mexico, the National Emissions Registry is built on the local pollutant release and transfer registry; it uses the same online reporting tool. This approach has reduced any overlaps between reporting requirements and so reduced costs for business.

When building on existing frameworks, policy makers should ensure that these frameworks (such as those for rules and standards) can be appropriately tailored to the specifications of the carbon pricing instrument. An important consideration when tailoring existing frameworks is the ability and capacity to amend existing legislation to ensure the framework can be fit-for-purpose for the carbon pricing instrument. In any case, it is important to realize that a carbon pricing instrument can require more specific and strict quantification rules as the objectives for quantification and the level of reporting and accuracy required can be different from that of a standard GHG reporting mechanism. In a downstream ETS, quantification is done at facility level, and the level of accuracy required can be high, depending on the sectors and type of facilities or entities involved. The options, including the advantages of each for building on existing legislation, are summarized in table 3 and examples of using existing legislation are provided in box 1 to box 3. The PMR MRV Guide has additional detail on establishing an enabling environment for quantification and reporting.

BOX 1. Examples of Adding Quantification Rules to Existing Legislation in Switzerland

In **Switzerland**, quantification and reporting rules for the CO_2 carbon tax and ETS are included in general legislation on the reduction of CO_2 emissions. The same structures and principles, therefore, apply to the carbon tax, offset mechanisms, and ETSs. This reduces overlap among the different systems.

TABLE 3: Summary of Options for Using Existing Legislation

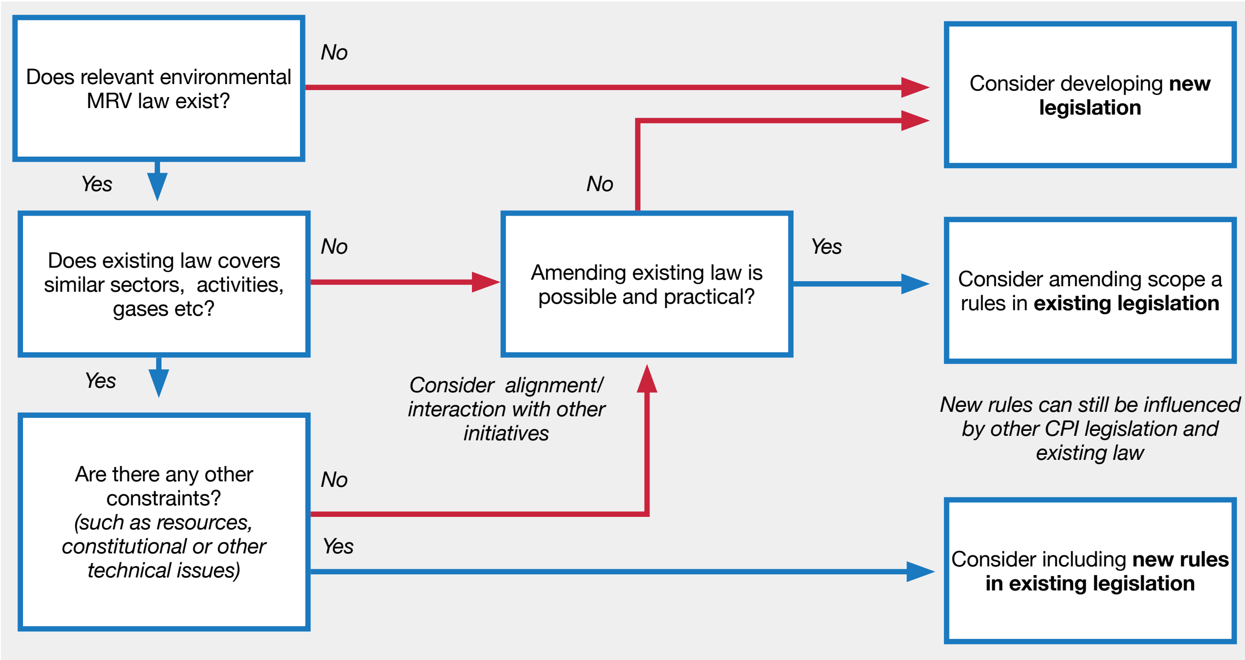
Option	Advantage	Disadvantage
1. Include quantification rules within existing legislation	– Expedites development. – Obligated entities should be familiar with existing rules and framework, lowering regulatory burden and costs. – Administration costs (such as to regulate/ enforce) may be lower if existing infrastructure can be used. – Consistency of approach across GHG reporting mechanisms can be achieved by including common requirements (such as those for institutional, enforcement and penalties), as well as quantification responsibilities in overarching primary legislation.[31]	– Difficult to ensure rules are fit-for-purpose – Potential for confusion if two programs apply the same rules but quantification is not identical – Accuracy levels required for quantification under a carbon pricing instrument may be higher than is required for existing environmental law, so elements from existing legislation, such as penalties or enforcement, may not lead to sufficiently robust quantification.
2. Amend or use existing legislation to enable quantification[32]	– Can expedite development (but less so than option 1) – Obligated entities should be familiar with existing rules and framework, lowering regulatory burden and costs (but less so than option 1). – Administration costs (such as to regulate/ enforce) may be lower if existing infrastructure can be used.	– Potential limitations from using existing framework, although more flexible than option 1
3. Establish new legislation	– Rules are bespoke and fit-for-purpose. – Should result in better quality data	– Time and resources required to develop new legislation – Lack of operator data may hamper new rule development. – Introduces new reporting burden on obligated entities that need to learn and understand new legislation

There are several considerations for a policy maker to bear in mind for the legal framework. A survey of existing legislation, as well as consideration of resource and technical constraints can help decide whether new legislation is necessary and/or desirable. When developing new rules, it can still be necessary to align with existing legislation so as to remove overlaps between reporting requirements; and quantification requirements for carbon pricing instruments generally need to be stricter than for other policy instruments because the large direct financial stakes in carbon pricing instruments which require greater accuracy and robustness.

Figure 5 provides an indicative decision tree on whether to build on existing domestic legislation.

31 Some country's legislative structures may require this.
32 This can either lead to partially new rules based on existing legislation or the inclusion of carbon pricing instrument specific quantification elements in existing quantification rules.

FIGURE 5: Decision Tree on Existing Legislation.



Source: SQ Consult

BOX 2. Amending/Using Existing legislation

- In **South Africa** existing legislation on the national GHG emissions reporting scheme is used for quantification under the carbon tax system. The existing rules are based on IPCC 2006 (that is, the IPCC tier approach is applied). Some amendments were made to the GHG reporting scheme legislation to make the quantification rules applicable to the carbon tax system (such as application of certain default values). Specific guidelines were developed for the carbon tax system on how the rules should be applied in different sectors.
- **Chile** introduced a green tax system to address emissions from local pollutants such as NO_x and SO_2. Quantification rules were based on the rules for NO_x and SO_2 quantification in the US EPA reporting mechanism. Some rules are similar to those for US EPA reporting (such as the continuous emissions measurement approach and certain standards), while other rules were tailored to the local situation (such as when to apply a calculation-based methodology and how to address data gaps). More information can be found in appendix H, table H.2.
- **EU ETS** - When drafting the rules for the EU ETS, the European Commission considered existing legislation an?d took some elements into account. Elements included the following, for example:
    - Tier approach from IPCC 2006, which was fine-tuned to fit installation level quantification (see section 6.1).
    - Certain requirements on CEMS for facilities that were included in environmental legislation for large combustion plants (such as application of EN 14181 to quality assurance of measurement equipment). However, some elements were made EU ETS specific; including how to address data gaps and how to apply the tier approach to CEMs.
    - Use of IPCC 2006 factors for emission factors and net calorific values in the case of Tier 1 approaches.
    - Certain sector specific approaches that were applied in other environmental legislation, such as how to quantify emissions of installations carrying out combustion activities.
    - Industry specific approaches (such as those for the aluminium sector).
- **The Regional Greenhouse Gas Initiative** - The cap-and-trade program on the US East Coast builds on existing national US EPA reporting regulations for power plants.

BOX 3. Aligning Carbon Pricing Instrument Legislation with Existing Legislation in the EU

- Legislation on the **EU ETS** is aligned with the Renewable Energy Directive, which specifies renewable energy targets and includes sustainability requirements for biomass. The EU ETS legislation uses the same biomass definition as in the Directive. Furthermore, the emissions factor for biomass can be zero only if the biomass meets sustainability criteria or, if such criteria are not applicable. More information can be found in appendix B.
- Under the **EU ETS** legislation, emissions reports also have to list NACE codes, IPCC categories, location of sites, and, if waste is involved, identification of EU Waste categories. This requirement facilitates reporting under other environmental legislation and collection of data for UNFCCC reporting.

3.4.3. Consider using international standards and industry best practices

Policy makers need to determine whether and to what extent they should use international standards[33] when developing quantification protocols. Appendix D, table D.1 contains a list of international standards relevant to developing quantification protocols. Using international standards can expedite protocol development, increase the transparency and robustness of the protocol, and promote consistency with other countries adopting the same standards, which may facilitate linking in the future. Quantification protocols can draw from international standards for a range of elements, for example:

- **Industry standards:** Best practice standards such as those produced by the International Organization for Standardization (ISO) and industry sector bodies may provide valuable information for highly technical and complex quantification issues for certain sectors. However, care needs to be taken to ensure they meet a sufficient standard of environmental integrity and have appropriate review and acceptance frameworks. **ISO14064-1** provides frameworks for data accounting and quality control, and industry bodies such as the Petroleum Industry Association (IPIECA) provide information focused on the specifics of their sector.
- Specific elements from **standards such as the GHG Protocol** (for example, approaches for calculating indirect emissions) and sector specific elements in **IPCC 2006 (**for example, how to calculate methane emissions in agriculture) can influence the development of a quantification protocol.
- **Internationally agreed default values** for emission factors and calorific values given in IPCC 2006: Such factors may be appropriate if national inventory factors are not available,[34] but entity-specific factors will always be the most accurate.
- **General quantification approaches:** the tier approach outlined in IPCC 2006 has been adopted and adapted by countries to develop more fine-tuned approaches in national quantification methodologies (see section 6.1). However, it should be noted that **quantification for a carbon pricing instrument is generally carried out at entity and facility levels, which will usually require more detailed quantification approaches that are tailored to the specific context of the CT or ETS rather than those outlined in IPCC 2006.**

33 Relevant domestic standards are presumed to be used normally as part of a country's legislative processes. But international standards promote harmonized approaches between jurisdictions; facilitate linking; and may cover areas for which there are no domestic standards.
34 The default values for emission factors and calorific values in the guidelines from IPCC 2006 are global averages and are not always appropriate for a particular sector in a country. The use of national inventory factors, if available, can lead to more accurate results.

- When drafting specific and tailored quantification rules for a carbon pricing instrument, policy makers must **consider how data quantified for the instrument can most effectively be collected and collated** as input for international reporting requirements, such as annual GHG inventories submitted under the UNFCCC. Appendix E provides examples of how countries have tried to align with other reporting requirements.

Policy makers can determine the most appropriate way to adopt international standards within the quantification protocol. How these standards are adopted can have implications, particularly where standards are updated in the future. There are three main options:

1. **Importing the standard fully into domestic law and/or referencing the full standard in the quantification protocol as the basis for quantification.** The rules in the quantification protocol would require entities to quantify emissions (including data collection) in accordance with the specified standard. This option is simple and can be implemented quickly. However, this approach can result in standards not being specifically targeted for domestic purposes and may be less accurate than rules developed specifically for domestic CT or ETS quantification. In addition, policy makers have less control over when standards are updated. For example, if standards are adopted by reference to "the most recent version available", entities may be automatically required to use updated standards. Automatic update has benefits because it is done quickly and without the need for legislative amendments. However, it means governments are not able to deviate from those updates, without legislative changes, if they are not relevant and appropriate for their country.

2. **Using elements of standards in domestic rules and tailoring requirements to domestic specifications**. Under this option, elements of a standard are adopted by being written into domestic legislation. All elements of the standard are assessed and can be modified to ensure they are fit-for-purpose for domestic quantification requirements. While this option can be more time consuming, it ensures the quantification protocol is using only relevant elements of the standard and that it gives policy makers complete control over whether and how to incorporate future updates to the standard.

3. **Creating domestic quantification rules but referring in very specific areas to an international standard**. Under this option, domestic rules on a specific area include reference to specific international standard(s). For example, domestic rules detail how to quantify emissions but a specific sampling standard is referenced to determine a facility-specific emission factor; or for continuous measurement equipment reference is made to a specific quality assurance standard. This option is often applied by countries and can be used in combination with option two.

Countries should be cognizant of how to refer to a standard in legislation. If the reference is too general, a revision of an international standard could lead to an automatic application of the revised standard under domestic legislation without policy makers being involved in the revision. Policy makers should either reference a specific date/version number or monitor revisions of applicable international standards to ensure they are applicable to the intent of the county's carbon pricing rules.

Box 4 highlights examples of how countries have adopted international standards; table 4 outlines factors for policy makers to consider when deciding whether, and to what extent, to include international standards within a domestic quantification protocol.

BOX 4. EXAMPLES OF THE USE OF INTERNATIONAL STANDARDS

Option 1: Full reliance

Costa Rica: Organizations use ISO 14064-1 and the GHG Protocol corporate standard to meet the Carbon Neutrality Standard (norm INTECO B5/2016). International standards were used to facilitate the drafting process and to link with international structures.

Option 2: Adapted standards

Chile's rules are based on US rules for measurement-based quantification; therefore, they use US standards such as AP-42: Compilation of Air Emission Factors (US-EPA) for local pollutants and IPCC 2006 for CO_2. Chile wanted to address local pollutants such as NO_x and SO_2, so it looked at existing US quantification rules to measure these gases.

Singapore's MRV requirements are based on principles and elements defined in the GHG Protocol, EU ETS rules, IPCC 2006, and ISO140564/65/66. Other internationally recognized sector specific standards may also be used where the obligated entity can provide a justification to the regulator.

South Africa's quantification rules for its carbon tax system are based on IPCC 2006. South Africa used existing national emissions reporting regulations applied to collect data for national inventories as quantification rules for the carbon tax.

Option 3: Domestic rules with very specific, limited reference to international standards

The EU ETS Monitoring and Reporting Regulation requires installation operators to use an ISO17025 accredited laboratory to conduct analysis of fuel/materials composition in order to determine a facility-specific emission factor. Only under specific circumstances can a non-accredited laboratory be used. The same standards are prescribed in other legislation, such as that for large combustion plants, and on industrial emissions reporting. As similar installations fall under EU ETS, the same standards were also prescribed for the EU ETS.

TABLE 4: Considerations for Selecting and Including International Standards in a Protocol

Considerations	Factors
What are the **resources and capacity** in a country?	– Using international standards can be useful for countries with limited resources. – They can build on existing structures and rules that can reduce costs and facilitate development and implementation of quantification rules. – Depending on the standards adopted, some may contain more stringent requirements, which could mean costs of introducing the standard are higher during implementation. Whether this is worth the benefit of achieving higher environmental integrity and the advantages of applying recognized standards must be considered. – The risk of higher costs can be mitigated somewhat by only incorporating selected elements of chosen standards in legislation and not referencing the entire standard.
What are the carbon pricing instrument's short-term and long-term objectives?	– **Short-term objectives:** may include desire to harmonize requirements across sectors and obligated entities. International standards can support harmonization by providing recognized frameworks for specific elements such as sampling and analysis and instrument management. – **Long-term objectives:** countries intending to link to carbon pricing instruments in other countries in the future may want to apply international standards because this provides linking partners with confidence in the robustness of quantification underpinning the carbon pricing instrument.
Are international standards also used in **other domestic reporting frameworks**?	– Alignment with existing procedures and requirements[35] may make sense if environmental integrity and rigor can be maintained for the carbon pricing instrument.

35 For example, where mandatory reporting programs in the EU require use of CEMs, they also require use of EN 14181 for CEMs quality assurance. For that reason, the EC decided to prescribe the same standard for CEMs quality assurance for the EU ETS.

Considerations	Factors
Are the **sectors** under the CT or ETS **experienced** in using standards?	– Large-scale industry sectors (and international companies) are usually accustomed to international (and national) standards as these are often applied in environmental or reporting schemes in other countries. – Such standards are also often used by large companies as part of their product quality processes and to meet customer requirements.
Are any special considerations needed?	– **Intellectual property rights:** In some cases, there will be copyright issues; for example, text of ISO standards cannot be copied into legislation without formal permission. – **Review and updating:** International standards are periodically reviewed and can be amended. Updates may risk leaving out of date standards in legislation or having automatic updates that are not appropriate to the carbon pricing instrument. A close eye must be kept on UN, ISO, or national standards body revisions processes.

In addition to international standards, quantification protocols can refer to **industry-led technical documents**. Industry documents can be advantageous because **some complex activities, such as oil and gas extraction, are highly technical and it is impractical or impossible for governments to have the necessary expertise to develop methodologies that are fit-for-purpose**. The American Petroleum Institute's *Compendium of Greenhouse Gas Emissions Methodologies for the Oil and Gas Industry*[36] is an example of an industry-led technical quantification document that is used in some countries (including the United States and Australia) to quantify GHG emissions from the oil and gas sector. However, while drawing from industry-led technical documents has its benefits, it also presents risks.

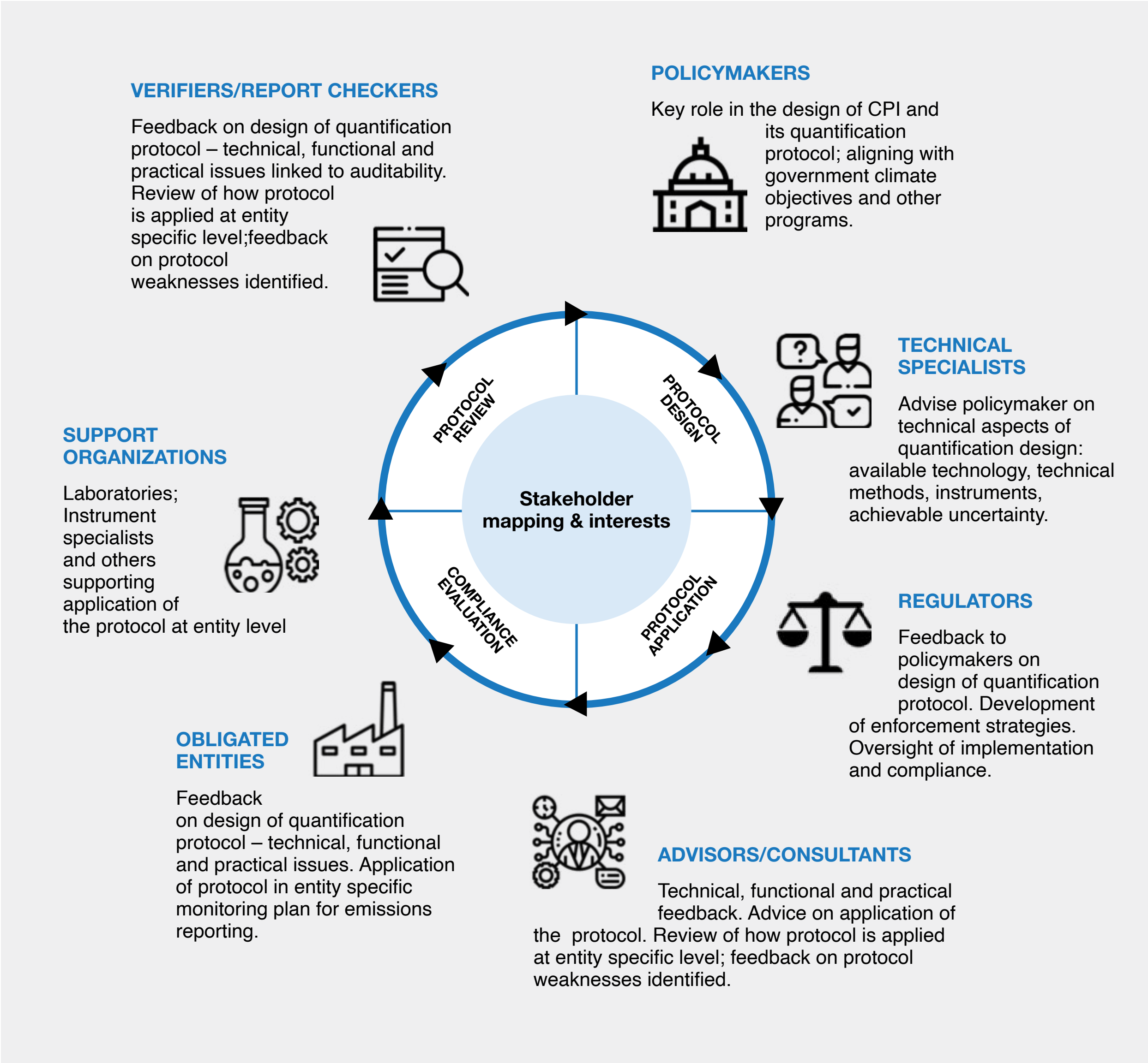
Importantly, policy makers need to be able to control which elements of the document are used by the quantification protocol and if updates are adopted (specifically, policy makers need to be able to assess and decide when and how updates are included). Using industry-led documents can create support for the protocol and add credibility that the right technical expertise has been sought; however, if not handled carefully, it could give rise to a challenge to confidence in the protocol because some may perceive that such an approach allows industry to develop its own rules. Consequently, where used as a basis for quantification, safeguards need to be put in place and communicated to maintain integrity and community support for the quantification protocol.

3.4.4. Consult stakeholders

Engaging stakeholders at an early stage when developing quantification protocols is essential to ensure protocols function effectively. Engagement applies not only to stakeholders that will play an active role in the implementation of the carbon pricing instrument but also to other interested parties. The PMR MRV Guide outlines the type of stakeholders that can facilitate development and implementation of mandatory reporting programs, as well as information on best practices, methods, and what steps need to be taken to organize stakeholder engagement. Figure 6 below identifies stakeholders involved in the implementation of quantification protocols and their potential interests. As quantification protocols should be designed alongside verification rules to ensure consistency and practicality, interacting with potential verifiers and industry experts will also be useful. Early and engaged contact with stakeholders can result in more tailored and practical quantification protocols.

36 American Petroleum Institute, *Compendium of Greenhouse Gas Emissions Methodologies for the Oil and Natural Gas Industry,* (August 2009), https://www.api.org/~/media/files/ehs/climate-change/2009_ghg_compendium.ashx.

FIGURE 6: Stakeholders and Their Roles and Interests in Quantification Protocols Tasks



Source: SQ Consult

4. Step 1: Determining the Boundaries

AT A GLANCE

When designing quantification protocols, you need to decide what will be quantified and what will be excluded. These boundaries will be largely determined by the design of your carbon pricing instrument. This chapter provides guidance on how to identify all the activities that need to be quantified by obligated entities, as well as specific quantification issues that sectors, GHGs, and activities might raise.

- The broader objectives and purposes of the carbon pricing instrument will determine the scope of your quantification protocol.
- Obligated entities can be complicated: they may undertake multiple activities across a number of sectors.
- Your quantification protocol must provide methodologies to quantify emissions from all activities consistently across sectors and types of entity. You can facilitate this by assessing the scope in terms of emission sources and source streams.
- Your carbon pricing instrument's scope (including the sectors, activities, and GHGs covered; the point of regulation; and whether indirect emissions are included) influences the scope of the protocol and the applicability of various quantification approaches.
- Some sectors and activities have specific issues and challenges that need to be considered.

The complexity and breadth of a quantification protocol is determined by its intended purpose, which is discussed in section 3.1. At a minimum, the protocol needs to cover all activities and emissions included in the carbon pricing instrument. The following sections outline the type of activities that should be considered for inclusion in a protocol, giving examples; they also discuss factors that influence the potential scope of a quantification protocol with the understanding that precise identification depends an individual carbon pricing instrument (see section 4.2).

4.1. Potential Emission Sources and Source Stream

Under a carbon pricing instrument, or any GHG reporting program, obligated entities must report all emissions from activities included in the scope of the program for which they are obligated. An obligated entity (such as an organization or facility) may have operations that include multiple activities. For example, a cement manufacturing facility may need to combust fuel to fire its kilns and operate vehicles as well as undertake core activities such as using carbonates to produce clinker. **Quantification methodologies need to have sufficient granularity to allow emissions from each of these activities to be quantified**.

The *IPCC 2006 Guidelines* identify five areas of activity for the purposes of preparing national GHG inventories (energy; industrial processes and product use; agriculture, forestry and other land use; waste; and other). However, more granularity is required for the purposes of preparing entity-based quantification methodologies. Two concepts are broadly used: emission source and source stream. These concepts are discussed in more detail in sections 4.1.1, 4.1.2 and 4.1.3 below.

4.1.1. Identification of emission sources and source streams

The quantification protocol should require obligated entities to ensure that all emissions from emission sources and source streams included within the carbon pricing instrument scope are quantified. Factors that play a role in identifying the correct emission sources and source streams include:

a. What **sectors, activities,** and **GHGs** are included in the carbon pricing instrument?

b. Whether **scope 2** emissions are included (from imported electricity, heat, or steam) as well as emissions **directly** generated from sources controlled by the obligated entity?

c. Which **specific technologies** are included or excluded from the carbon pricing instrument? For example, the EU ETS specifically excludes waste incinerators and combustion units below 20MW thermal input (in aggregate for an individual combustion-only entity).

d. How **broad the definition of combustion** is in terms of the technical units it incorporates (see box 5).

e. Whether **all technical units and emission sources are included if a sector activity has a certain eligibility threshold**. For example, if the carbon pricing instrument scope specifies that certain sector specific activities are included, are all associated combustion activities automatically included in quantification?[37] or is associated combustion included within the quantification boundary only if it exceeds a certain threshold for emissions from combustion? For example, in the EU ETS once a sector specific activity – such as production of ceramics - is included, the entity has the obligation to report all combustion activities for the obligated entity, regardless of whether they fall below the eligibility threshold of the ETS for an entity that has only combustion activities.

BOX 5. Impact of Unclear Activity Definitions

EU ETS: In the 2003 EU ETS Directive covering trading periods 1 (2005-2007) and 2 (2008-2012), “combustion installation” was not clearly defined, ultimately affecting the completeness of the reported data. This unclear definition led to some Member States (MS) following a narrow interpretation, defined as “combustion of fuels to produce energy delivered to third parties”. Other MS adopted broader interpretations that included the combustion of fuels for any purpose (for example, roasting of coffee beans, cookers in canteens, and burning of acetylene for welding). As a result, MS with the narrow definition excluded emission sources that had been covered by MS using the broader definition. In addition, often only part of an installation was included in the EU ETS. This meant that installations had to deduct emissions from sources not covered by the system, complicating the quantification approach. It required either reasonable estimates for non-eligible emissions to be made or additional measurement equipment to be installed to determine the eligible emissions. This influenced the accuracy of the installation’s overall reported data and, in many cases, it increased the administrative burden. In trading period 3, such problems were avoided by including a much clearer definition of combustion activities in legislation.

All these factors will influence what is included within the boundary of a carbon pricing instrument’s quantification protocol. Once these elements have been defined, policy makers will be able to review information held by government departments and agencies to determine:

37 For example, if an obligated entity is included in the carbon pricing instrument on the basis of its industrial process sources (such as aluminium production), then all combustion activities at the obligated entity are included, even if--for other entities that have only fuel combustion sources--some entities are excluded from the carbon pricing instrument if their combustion related emissions are below a certain threshold – meaning this threshold would not apply to process sector entities.

- What emission sources and source streams need to be considered
- Whether each type of source needs to be individually identified or whether rules can be written in a way that requires obligated entities to include everything that falls within a broader definition (for example, fired heaters or process fuel gas)

Available information for such a determination may include:

- The UNFCCC national inventory dataset
- Economy level energy and related data
- Statistical office data on the economy's sectors and sector entities
- Data on facilities and organizations that are permitted or regulated under, for example, other environmental or health and safety legislation

A review of such information can be supported by information on different sectors provided in IPCC 2006. In addition to national level data, engagement with stakeholders and sector trade associations operating within the country will provide more detailed information on what emission sources and source streams exist on the ground. Many carbon pricing instruments have relied on a combination of IPCC guidelines and national data as a route to identifying the appropriate sources and source streams (see box 6).

BOX 6. Examples of Identifying Emissions Sources and Source Streams

The EU ETS: The ETS scope determines which sources and source streams are included for quantification. Along with IPCC 2006, existing legislation and reporting mechanisms, such as that for industrial emissions and large combustion plants, were used to identify which source streams and emission sources could relate to a certain sector and activity. In addition, stakeholders were consulted to obtain further information. Information gathered enabled the specification of which emission sources operators should include in their monitoring plan as a minimum – within an identified installation boundary - and what methodologies to apply to a particular source stream in individual sectors when a calculation based methodology is applied or an emission source when a direct measurement based methodology is applied. **California ETS and other systems such as RGGI and the Tokyo ETS** also used similar information sources.

South Africa: As the carbon tax legislation was based on national reporting rules used to collect data for the UNFCCC inventory reporting, identification of emission sources and source streams was largely based on IPCC 2006.

Whatever approach is used, policy makers should include clear rules on the scope of the carbon pricing instrument so the quantification boundaries for an obligated entity can be clearly defined and the entity knows what emission sources and source streams it needs to identify and include in quantification of its emissions.

The same factors identifying sources and source streams also have an impact on the selection of the quantification methodology. Examples of such impacts are included in table 5 below.

TABLE 5: Examples of How Sector and Gas Influence the Quantification Methodology Selected

Sector	Gas	Quantification methodology
Aluminium production	CO_2	One or more mass balances are generally applied to site process activities, but a calculation method can be applied to fuel combustion where this can be segregated.
	PFC	Direct measurement of emissions in the stack is required, adjusted for the collection efficiency of associated extract duct(s). However, where data on anode effects or overvoltage are collected, a calculation can be used.
Electrical equipment	SF_6	The manufacturing, use, and disposal of electrical equipment may result in release of SF_6. Generally, a calculation methodology is used, based on how much SF_6 is put into or extracted from the equipment.
Fluorochemical production	HFC	A mass balance approach is generally used, although direct measurement can be applied where the facility has appropriate equipment in its vent stack (taking account of any gas recycled to feedstock).
Fuel Combustion[38]	CO_2	Generally, a calculation methodology is the simplest approach; however, for power generation entities, other legislation may require that they have direct measurement installed on one or all of their flue stacks.
	CH_4 and N_2O	The amount of these gases arising from combustion processes is generally very small, so a calculation approach can be used with default value applied to the activity data. When accounting for CH_4 in this way, consideration needs to be given to the Oxidation Factor used to ensure that there is no double count of emissions within the scope of the carbon pricing instrument (see section 5.1.1.4).
Magnesium production	SF_6	Used as a fire protection system in the production process, the gas escapes to atmosphere when the system is triggered. A calculation approach based on inputs to the system is required unless capture and abatement equipment is installed, which would allow direct measurement of emissions.
Nitric acid production	N_2O	N_2O emissions[39] are generally monitored by direct emissions measurement because there are too many variables to allow for accurate calculation. CEMS or PEMS equipment is applied to the flue stack(s) where there is abatement equipment in operation. A mass balance based on the maximum potential emissions rate of the process can be used for backup, but it would be potentially very conservative. In situations where there is no abatement (for example, equipment failure) a calculation approach could be used based on periodic stack monitoring to develop an emissions factor.
	CO_2	CO_2 emissions arise from fuel combustion and can either be calculated or continuously measured depending on the operational set up of the facility. Policy makers can allow obligated entities to select the appropriate methodologies unless other factors (see factors 5 to 8 in section 5.5) determine that there should be a preference for a specific methodology in certain situations.
Refining	CO_2	A combination of methodologies can be applied depending on the operational set up of the plant. For example: – Emissions from catalytic cracker regeneration, other catalyst regeneration, and flexi-cokers can be determined by standard calculation or mass balance, but direct measurement is possible if the process unit flue has the right type of measurement equipment. – Process emissions from flue gas scrubbing can be determined using a standard calculation or by including them in a mass balance calculation for the whole refinery. – A standard calculation is usually appropriate for emissions from dedicated hydrogen production units and from combustion units. Because operational set-up is context specific, policy makers need to include flexibility in the rules to allow the obligated entity to make these choices unless there are other factors that exclude the use of a particular methodology (see factors 5 to 8 in section 5.5).
	CH_4	CH_4 generally arises as fugitive emissions (uncontrolled release) so it would require engineering estimates and other studies/modelling-based estimation to determine emissions levels.

38 This will apply across most (if not all) sectors, so it is not included in each of the sector examples.
39 From each emission source. This should include emissions from oxidation reaction, any direct process venting and/or any emissions control equipment.

4.1.2. Emission source

Article 1 of the UNFCCC defines an emission source as "any process or activity which releases a greenhouse gas, an aerosol or a precursor of a greenhouse gas into the atmosphere." Other guidance, such as the GHG Protocol uses similar definitions.[40] Essentially, an emission source is **the combination of physical units or processes that lead to the production of emissions**. In some carbon pricing instruments more specific definitions have been included, but these are based on the same principle. Examples from different sectors are outlined in table 6 below.

TABLE 6: Examples of Emission Sources in Different Sectors

Cross-cutting:	Example of Emission Sources
Combustion[41, 42]	– CHP, turbines, boilers, process heaters, engines, dryers, furnaces, incinerators, oxidizers, reformers, flares, emergency/back-up generators, fire pumps, and other units which combust fuel or process/ waste gases and the like; additionally, flue gas scrubbers – Trucks, trains, cars, planes, barges, and other vehicles/vessels (if mobile equipment is included)

Fugitives (uncontrolled releases of gas)	– Process and equipment venting and leaks, maintenance activities, and the like.
	– Solid waste, including decomposition, biological treatment, and disposal on land
	– Waste-water treatment and handling
	– Uncontrolled releases of gases such as:
	  – CH_4 from coal mines, coal handling and stockpiles, oil and gas exploration, natural gas production, and processing and storage
	  – HFC from chemicals production, PFC from aluminium production, and SF_6 from electrical and transmission & distribution equipment, and magnesium production

Sector specific	**Example of Emission Sources**
Aluminium	– Combustion and fugitives – Waste gas scrubbers – Process emissions from electrode production, carbon anode oxidation, and electrolyzers (including PFCs)
Ammonia	– Combustion and fugitives – Reformers (catalytic or steam) – Waste gas scrubbers
Cement clinker, lime and ceramics	– Combustion and fugitives – Calciners, kilns, dryers, and other production process units – Waste gas scrubbers – Process emissions from conversion of limestone, shale, clay, or other input materials
Iron, steel and ferro-metals	– Combustion and fugitives – Calciners and coke ovens – Process emissions such as waste gases, crude iron oxidation, reducing agents, carbonate fluxes, graphite electrodes, and the like

40 The WRI/WBCSD *GHG Protocol* defines GHG source as "any physical unit or process which releases GHG into the atmosphere." https://ghgprotocol.org/

41 Combustion includes energy generation as well as process equipment in a variety of sectors. Combustion is a source of emissions that is likely to be applicable to almost all sectors.

42 Fuel combustion is defined in *IPCC 2006* as "Emissions from the intentional oxidation of materials within an apparatus that is designed to raise heat and provide it either as heat or as mechanical work to a process or for use away from the apparatus" The EU ETS applies a broader definition that catches many sector processes and supporting activities: "combustion emissions mean greenhouse gas emissions occurring during the exothermic reaction of a fuel with oxygen."

Sector specific	Example of Emission Sources
Oil and gas	– Combustion and fugitives – (Catalytic) crackers, including catalyst regeneration – Oxidizers (thermal or catalytic) – Cokers
Chemicals (including nitric acid, adipic acid and urea)	– Combustion and fugitives – Crackers (catalytic and steam) – Catalytic oxidizers/converters and abatement equipment – Calciners – Process emissions such as N_2O by-products
Pulp and paper	– Combustion and fugitives – Calciners and lime kilns – Waste gas scrubbers
Glass	– Combustion and fugitives – Waste gas scrubbers – Process emissions from melting of input materials
Electronics	– Combustion – Processes using gases and liquids such as SF_6 and fluorinated compounds

The type and combination of emission sources play an important role in defining how an individual methodology is applied. Section 4.1.1 identifies different factors that play a role in helping to specify the correct emission sources and source streams that define the boundaries of quantification for an obligated entity.

4.1.3. Source stream

Associated with emission sources are source streams. **Source streams are the fuels, raw materials, and (by-)products that lead to emissions at one or more emission sources** as a result of their consumption or production. Source stream is a term used in the EU ETS Monitoring and Reporting Regulations and is designed to encompass all inputs and outputs that need to be monitored for the purposes of quantification.[43]

An example of a source stream is the fuel combusted in equipment under the fuel combustion emission sources listed in table 6 above. Each combustion emission source may have multiple source streams. For example, a power plant may have several fuel combustion emission sources consuming different source streams, including natural gas and/or heavy fuel oil consumed in turbines and boilers, propane for start-up fuels as well as diesel used in fire pumps, back-up generators, and on-site vehicles (if mobile emission sources are included in the carbon pricing instrument). Examples of materials source streams that lead to industrial process emissions include:

- For cement clinker production - the limestone used as input material in kilns to produce clinker, the intermediate product for cement manufacture
- For mineral oil refining – coke burned in regeneration of fluid catalytic cracker catalyst; CH_4 vented during glycol dehydration

43 Other GHG reporting systems use different terms (such as sub-source or source type) to describe similar concepts.

Depending on the individual obligated entity's activities and facility specific operations, different source streams may be used by an entity compared to any of its sector peers. It is important for the obligated entity to identify all its source streams that are within the scope of the quantification protocol and the carbon pricing instrument. Section 4.1.1 outlines criteria that play a role both in identifying emission sources and source streams and in how policy makers can ensure proper identification by obligated entities.

Identification of source streams is important because, for calculation-based methodologies, quantification of emissions is carried out for each individual source stream. **Where the protocol allows for – or prescribes – calculation-based methodologies, the quantification protocol should require obligated entities to quantify emissions for each individual source stream.** Individual quantification is important because, as highlighted above, entities may need to quantify multiple source streams for a single emission source within an individual entity. Each source stream will have different activity data and parameters (such as emission factors) to enable quantification. Using the power plant example, the total consumption of each fuel (individual source streams related to fuel combustion emission sources) will need to be quantified separately. Each fuel will be measured separately by different means (for example, coal by weighbridges; natural gas through gas meters; diesel through meters, fuel invoices, or by distance travelled for vehicles) and each will have different fuel attributes (such as energy and carbon content). How the quantification methodology is applied to emission sources and source streams is discussed in chapter 5.

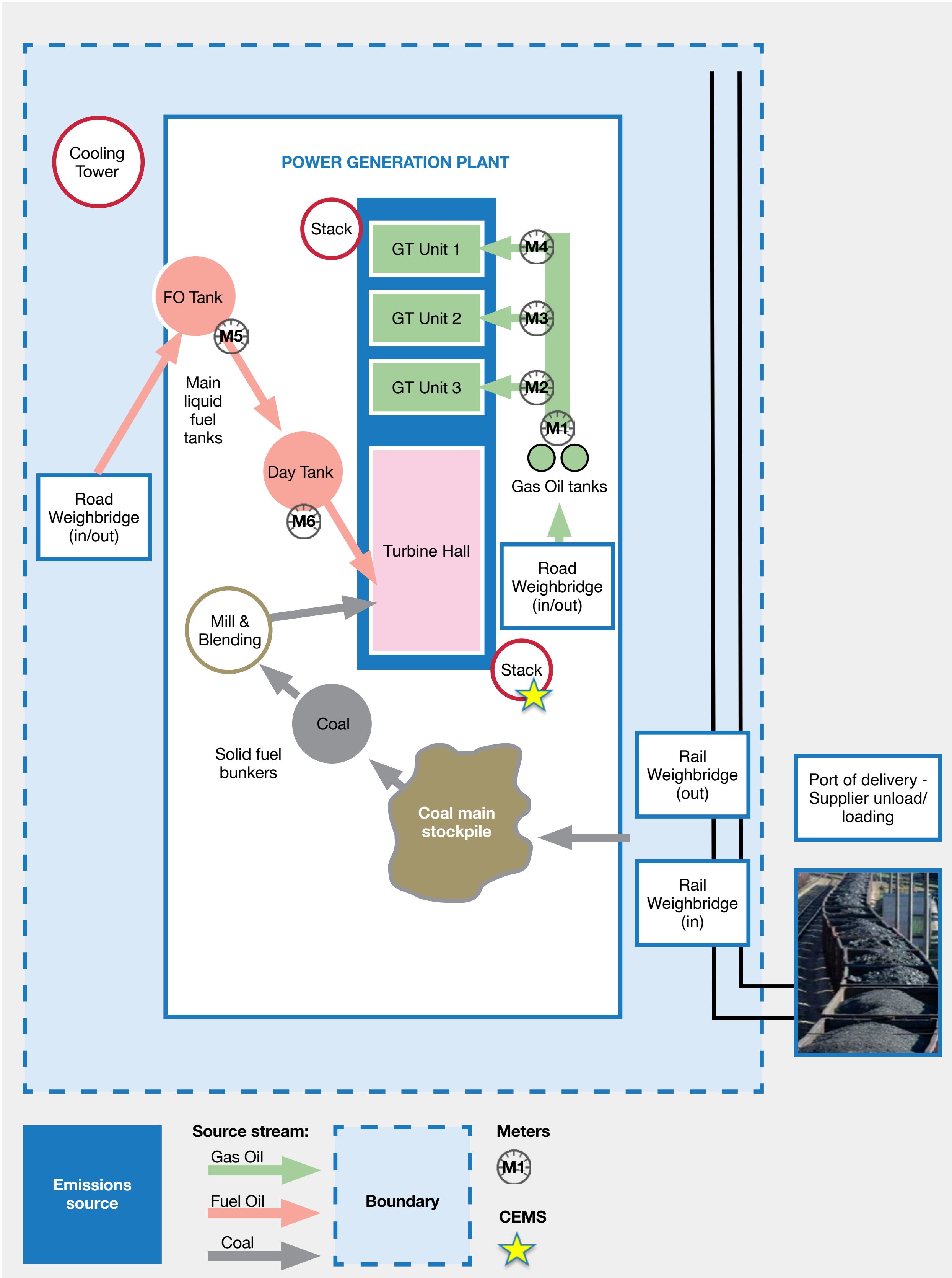
Figure 7 gives an example of a layout plan for a power station showing the emission sources and source stream that make up the facility. Box 7 gives an example of how the activities covered by the power generation entity can affect the sources and source streams that are included in quantification, and also the selection of quantification methodologies to be applied. The GHG gases to be covered will depend on the scope of the carbon pricing instrument.

BOX 7. Example of Direct Emission Sources and Source Streams at a Power Generation Facility Covered by a Downstream Carbon Pricing Instrument

Site Activity	Emission sources	Potential source streams	Methodology option
Power Generation	Fired turbines and boilers	Coal, fuel oil, gas, solid biomass, liquid biomass	D/C1
Flue gas stacks	Acid gas scrubbing	Carbonate/gypsum	D/C2
Support services	Fire pumps, emergency generators, workshop heaters	Diesel	C3
Electricity transmission	Electrical equipment	SF_6 inert safety gas	C4

D = Direct measurement of CO_2 via CEMS in the flue gas stack, if equipment installed
C1 = Calculation of CO_2 based on measurement of activity data via meter or invoice; determination of calculation factors by sampling and analysis
C2 = Calculation of CO_2 based on measurement of activity data using industry best practices and application of default calculation factors based on stoichiometric ratio of input material
C3 = Calculation of CO_2 based on measurement of activity data via meter or invoice and application of default calculation factors based on commercial standard fuel
C4 = Calculation of SF_6 based on measurement of the amount of SF_6 topped up into equipment during the reporting period

FIGURE 7: Example of Process Plan Showing Emission Sources and Source Streams for a Power Station



Source: SQ Consult, © 2018

4.2. Protocol Scope

In addition to the type of obligated entity,[44] the scope of the quantification protocol is influenced by a number of factors, in particular those influenced by the scope of the carbon pricing instrument. **These factors will also influence the type of quantification approach applied, as some gases, sectors, and activities require a specific calculation approach or direct measurement-based methodology**. Section 5.5 provides more information on selecting the most appropriate methodologies.

As highlighted in section 3.1, there may also be a need to extend the protocol's coverage beyond the scope of the carbon pricing instrument. For example, quantifying emissions from activities planned to be covered in the future will allow development of baseline data sets and allow relevant entities to gain experience. Policy makers may also consider acquiring other useful data that assists with compliance assessments for the CT or ETS as well as meeting other policy objectives (such as informing policy formulation).[45] Any additional quantification requirements need to be balanced against the additional regulatory and compliance costs imposed.

4.2.1. Covered Sectors and Activities

The sectors and activities covered by the carbon pricing instrument are one of the most significant factors influencing the scope and complexity of the associated quantification protocol. While a broader scope will require additional methodologies, the types of sectors and activities covered can also affect how the protocol is developed. For example, relatively straightforward methodologies exist to quantify emissions from fuel combustion, whereas methodologies to quantify process related emissions from oil and gas production, for example, are necessarily more complicated. Market structure can also play a role. For instance, most emissions from the power sector come from a small number of sources at large emitters meaning there is less complexity. Lower complexity makes quantification easier than for entities in sectors with a multitude of smaller and/or more diffuse emissions sources that can make quantification more challenging and expensive, such as in the agriculture sector.[46]

Policy makers should consider the following when determining how the quantification protocol will apply to specific sectors and activities:

- **The quantification protocol should clearly articulate which rules are applicable to which sectors and/or activities**. Definitions must be clear, unambiguous, and sufficiently broad to apply to all emission sources intended to be captured by the methodology. Box 5 provides an example of potential impacts when definitions used in a quantification protocol are insufficiently clear.
- **Completeness is important**. **All activities intended to be covered by the carbon pricing instrument need to be included in quantification, and the quantification protocol should be designed so that completeness is ensured**. There should be clarity on the extent to which emissions throughout the life-cycle of an industrial process are included, from construction, commissioning,[47] start-up and shut-down

44 Whether the quantification responsibilities apply to a reporting entity consisting of several facilities or an individual facility has an impact on how the quantification is carried out and how data are collected by the obligated entity. Monitoring at a facility level is more tailored and focused than at an organisational/ reporting entity level. Furthermore, data collection at an organisational level is more complex as it covers various facilities consisting of multiple units and source streams; and will require additional mechanisms for internal data aggregation, quality control and validation; as well as an increased number of people responsible for handling parts of the dataset.

45 Other information that may be specified within the quantification protocol scope includes data on energy consumption and generation as well as production data.

46 Most ETS and Carbon taxes do not include AFOLU emissions largely for this reason.

47 This will require an agreed definition of start of (normal) operations.

situations, or from back-up capacity (such as emergency generators). Choices on the accuracy requirements for quantification may dictate which activities can or cannot be included within the carbon pricing instrument; or which may require flexibility in accuracy requirements in order to be include (see section 6.1).

- **Independent of business structure**. An obligated entity's operations may include multiple activities and may span a range of sectors under the carbon pricing instrument; for example, a paper company may include pulping, lime manufacture, paper making, and power generation, but lime manufacture may also be part of companies in the minerals, ceramics, and cement sectors. **Methodologies need to be applied consistently across entities that have processes encompassing similar emissions sources**, regardless of their broader operations. Rules on quantification boundaries must be clear to ensure quantification methodologies are applied consistently.

- **Consistency across sectors. Rules should ensure that methodologies are consistently applied across sectors**. For example, rules for using default emission factors or calorific values should be the same across sectors. Where differentiation is necessary for sector specific activities, policy makers should clearly state the reasons why, and also which cross-cutting activities should apply to all sectors. (For example, all sectors should include energy conversion technologies, such as boilers and CHP.)

Policy makers should also bear in mind sector-specific issues and challenges, examples of which are outlined in table 7.

TABLE 7: Examples of Sector Specific Issues and Challenges To Be Considered When Developing Quantification Protocols[48]

Sector/activity	Examples of sector specific issues and challenges
Fuel combustion activities	This is the most common area of emissions quantification and applies to almost all obligated entities regulated by a carbon pricing instruments. Issues generally relate to the availability and quality of data at specific points of regulation (especially upstream) as well as the quality of measurement instruments and sampling regimes and the like used to derive activity data and emission factors. Policy makers need to: – Differentiate quantification requirements according to entity/technical unit size and different sources/source streams to accommodate technical feasibility and simplifications for smaller entities[49] – Recognize that data quality will vary depending on where it is sourced from – for example, the use of facility-level energy related data versus national/sub-national level data from other energy related statistics collected by government agencies and others for the development of inventories and defaults, for example.
Oil refining	– Identification of, and accounting for, fugitive (uncontrolled) emissions – Complexities associated with accounting for emissions from some processes, such as fluidized catalytic cracking; including non-uniformity of technologies, large data sets, and different accounting approaches – Linkages to other petrochemical operations (often in integrated complexes), meaning shared data accounting in some areas is required along with, potentially, a mass balance approach for some processes – Use of alternative fuels (biofuels, synthetic fuels) and fuels which are also input materials to processes so are not combusted

48 CHP has not been included in this table because emissions are relatively straightforward to quantify. However, which party claims emissions relates more to the way the carbon pricing instrument assigns responsibility to be the obligated entity and whether indirect emissions are included within the carbon pricing instrument scope (this can result in double counting of emissions if care is not taken in definitions and boundary determinations).

49 This is a cross-cutting element that could apply also to other sectors

Sector/activity	Examples of sector specific issues and challenges
Production of hydrogen	There are different hydrogen production technologies, some of which produce no GHG emissions. Other technologies produce emissions depending on the fuels used to provide heat into the process (such as solar or wind renewables, biomass, or fossil-based fuels). Where natural gas is imported to a facility for both fuel and production material use purposes, careful accounting is required to ensure there is no overstatement (double counting) of emissions. New methodologies for accounting for hydrogen production have been included in the 2019 Refinement of IPCC 2006, but they may need to be tailored to meet the specific requirements of a carbon pricing instrument.
Waste	IPCC 2006 states that the best composition data can be obtained by routine monitoring - at the entrance to a solid waste disposal site, incineration plant, and other treatment facility - of the quantity and representative field sampling of the waste to determine its typical composition. Some waste sources are stable, but others – such as municipal solid waste - may vary significantly depending on its source (a city, for example) as well as time (from week to week over the seasons, for example). So, obtaining representative (or average) composition data means sampling at several typical cities on the same days of the week in each season and taking into account the weather, which will affect the moisture content of waste and resulting composition analysis. If the obligated entity is an individual site or incinerator, this makes the process of emissions estimation easier but more costly. The largest source of CH_4 emissions is typically solid waste disposal sites along with CH_4 emissions from wastewater treatment and discharge; unless a gas capture system is installed allowing measurement of gas produced (generally burned for conversion to CO_2), these emissions will be fugitive emissions for which an appropriate estimation method is needed, taking account of when the emission actually occurs – decay of the material could happen over decades. IPCC 2006 provides further information on applicable methods – including the application of a first order decay model, but these may need adapting for application at an individual obligated entity level. The main sources of CO_2 emissions for the sector are incineration and open burning of waste-containing fossil carbon (such as plastics). Where waste sources are mixed – such as municipal waste – it is necessary to measure or estimate the quantity of waste being incinerated and its quality in terms of combustible materials and whether those materials are fossil or may be considered biomass. Alternatively, a CEMS system is required on the flue stack to measure specified emissions. Determining the quantity and composition of waste is challenging since intermediate processes to treat waste can significantly change the physical and chemical properties of the waste; that is, the degradable organic carbon contained in the waste can change over time as it goes from the point of generation via treatment to the point of final disposal. Because of this, the point at which the obligation to report emissions occurs has an impact on quantity and composition.
Aviation	– Flexibility is required to accommodate different internal operations approaches of various aircraft operators. Rules must also clearly outline which flights are specified to ensure all flights covered by the carbon pricing instrument are included, especially the demarcation of international versus domestic flights to accommodate the CORSIA[50] program and links to other carbon pricing instruments.[51] – Ownership of aircraft and control of aircraft are not the same thing. Some aircraft are leased or lent/shared so the operator in control of the aircraft can vary over time, even within a reporting period. The methodology should be clear as to which is the operator responsible for reporting on which flights and for when within the reporting period. This means that a single aircraft could be reported in more than one entity's emissions report. – Identification of and access to corroborating information on flights, flight legs, and flight eligibility (for example, the EU ETS uses EuroControl flight data) to ensure that data from the obligated entity can be checked to an independent source of information.

50 The Carbon Offsetting and Reduction Scheme for International Aviation; CORSIA may have an impact on carbon pricing instrument rules if domestic airlines are included within a carbon pricing instrument as all aircraft operators are required to monitor and report their emissions associated with international flights.

51 For example, the Swiss ETS has specially defined scope for inclusion to avoid double counting of emissions due to its linkage to the EU ETS.

Sector/activity	Examples of sector specific issues and challenges
	– Rules need to take account of existing quantification methods for safety critical operations (for example, how fuel or baggage weight are accounted for in operational purposes) because aircraft operators cannot change these just for emissions quantification purposes. Otherwise, the process could end up in collecting two sets of data, one for the carbon pricing instrument and the other for transport safety purposes. – Access to some information may be challenging, including: – Quality of measurement instruments on board aircraft: manufacturers do not like to supply such information and instruments also vary across different aircraft types. – The actual density of fuel uplifted. This enables the conversion from volume to mass of fuel: this information is not available at some airports/fuel providers meaning a default density value would have to be used, or a volumetric based emissions factor.[52] – Access to and quantifying the use of aviation biofuels: where shared tankage is in operation at airports, it is not possible to directly link fuel purchased by an airline with fuel delivered to an individual aircraft. A 'book and claim' approach is most commonly used for determining activity data.
Road transport[53, 54]	Two options are available for quantification: fuel energy use and travel activity. The fuel use approach is generally in line with the methods used for national GHG inventories (such as fuel consumed versus fuel purchased/sold). However, there are potential distortions as a result of cross border activities. There are also difficulties in accounting for non-CO_2 emissions (such as CH_4 and N_2O), which are more dependent upon technology, fuel, and operating characteristics. The travel activity approach requires accurate recording of distance travelled and factors for different types of vehicles in terms of mass/volume of fuel per km travelled and tGHG per mass/volume of each type of fuel. For some aspects of emissions accounting more granular level emissions may be determined, such as values per passenger kilometer or per tonne kilometer. These could be country default values or more accurately determined factors.
Sea transport	– Ownership and control of vessels are not the same thing. Some vessels are leased, chartered, or shared so the operator in control of the vessel can vary over time – even within a reporting period. Because ownership and the flag under which a vessel operates can frequently change, the methodology should be clear as to which operator is responsible for reporting on which voyages and for when within the reporting period. If an operator is required to report all voyages by the vessel within a reporting period, this can make the method complex as it would require obtaining relevant information from other parties –which may be impossible where a vessel is bought/sold unless sale/transfer contracts require transfer of relevant data to the new owner/operator. Generally, the obligated entity is the one in control of the voyages within the reporting period (which is consistent with the IMO's DCS Fuel Oil Data Collection System), but this means that a single vessel could be reported in more than one entity's emissions report. – Clear definitions of what is considered an international voyage versus a domestic voyage (the latter could go into international waters, for example, but would not be an international voyage). The IPCC 2006 definitions should be considered, generally a carbon pricing instrument accounts for emissions within its jurisdiction (domestic shipping versus international shipping that falls under IMO regulations).

52 However, for accuracy, volumetric information would need to be converted back to a standard temperature to avoid inconsistencies in activity data at different geographic locations.

53 Further information can be found in: R*eference Document on Transparency in the Transport Sector - Measurement, Reporting and Verification of Greenhouse Gas Emissions* at https://www.changing-transport.org/wp-content/uploads/2018_Reference_Document_Transparency-in-Transport_2nd-ed.pdf and in *Compendium on Greenhouse Gas Baselines and Monitoring Passenger and Freight Transport* at https://unfccc.int/sites/default/files/resource/Transport_0.pdf.

54 In relation to construction for transport, equipment used, and manufacture of steel and other materials would be captured as direct emissions by the relevant obligated entity if included within the carbon pricing instrument. Emissions associated with changes in land use are likely to be covered by LULUCF monitoring and crediting instruments.

4.2.2. Included GHGs

As a minimum, the quantification protocol needs to include all GHGs covered by the carbon pricing instrument. Carbon dioxide (CO_2) is the most common gas requiring quantification. When it results from fuel combustion, quantification methodologies can be relatively straight forward. Other GHGs, depending on the source of emissions (such as fuel combustion, fugitive emissions, or industrial processes) can be more complicated, and their inclusion in quantification protocols varies across carbon pricing instruments. Appendix F provides an overview of the GHGs covered by various carbon pricing instruments internationally - all cover CO_2 emissions. Around half cover CO_2 only (53 percent), while most of the remaining systems cover all the original six GHGs under the Kyoto Protocol (42 percent).[55] Over time however, those covering only CO_2 may expand to cover other gases as entities become familiar with more sophisticated quantification and monitoring processes, if sector coverage expands, and/or policy makers consider that an extended scope of reported emissions warrants the additional quantification effort required. As international activity under the UNFCCC evolves, other substances may be considered including gases controlled under the Montreal Protocol and black carbon; where appropriate for an individual carbon pricing instrument, policy makers can choose to include them within its scope.

Importantly, **the GHGs covered do not have to be uniform across activities.** The EU ETS provides a practical example of this, where Nitrous Oxide (N_2O) resulting from the production of nitric acid, adipic acid, and glyoxal and glyoxylic acid is covered, but N_2O emissions from the combustion of fuels is not. Accordingly, quantification methodologies for the EU do not include an approach for quantifying the amount of N_2O emitted from fuel combustion.

If quantification is required for gases other than CO_2, rules should specify how those gases are converted into common units, namely carbon dioxide equivalent (CO_2e). Rules need to specify the accepted Global Warming Potential (GWP) values to be used for each GHG. GWP values are updated from time to time, reflecting the most up-to-date scientific opinion (particularly the IPCC Assessment Reports[56]) on the radiative forcing properties of each gas over specified time period. (See section 4.2.3 of the PMR MRV Guide for more information)

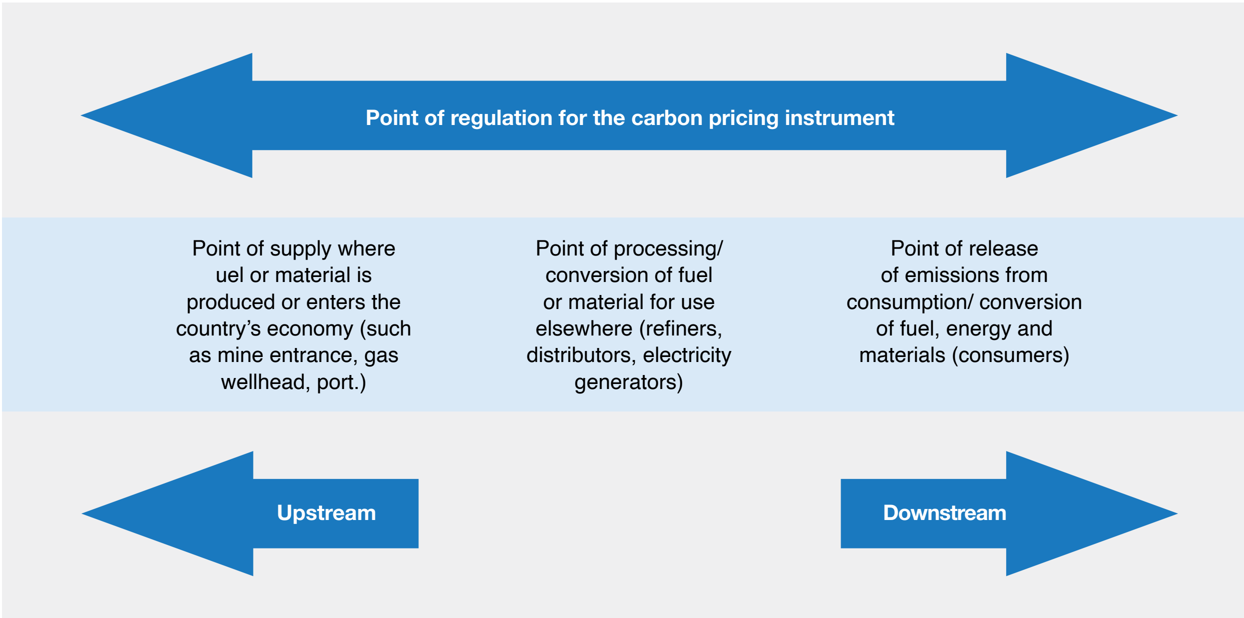
While decisions on which GHGs to cover under a carbon pricing instrument are beyond the scope of this document, policy makers should consider the costs associated with quantifying specific GHGs. Section 5.5 provides guidance on selecting methodological approaches suitable and/or necessary for quantifying different GHGs.

4.2.3. Point of regulation

Point of regulation (where to place the obligation to account for GHGs) is an important design consideration for carbon pricing instruments. Figure 8 below illustrates the different points of regulation for carbon pricing instruments and gives examples of typical locations or entities at each point.[57]

55 And of which 63 percent have also added the seventh recognized Kyoto gas - NF_3. Some jurisdictions such as California and Mexico also include other fluorinated gases within the scope of their carbon pricing instrument.
56 Information on this is in the PMR MRV Guide
57 Locations of entities will vary depending on the specific context of a carbon pricing instrument, so for example, where consumption of fuel is regulated an electricity generator may be in the downstream category, but where electricity is regulated, a generator would be midstream.

FIGURE 8: Point of Regulation for a Carbon Pricing Instrument – Upstream versus Downstream



Source: SQ Consult

The point of regulation can also affect the emissions quantification approach. Generally, the obligation can be applied to the import and supply of fossil fuels (referred to as upstream), at the point where the emissions occur (referred to as downstream), or a combination of both. A carbon pricing instrument does not have to rely on one point of regulation and it may be appropriate for approaches to vary by sector.[58] Table 8 summarizes how the point of regulation can affect which quantification methodologies are applicable.

TABLE 8: Characteristics for Quantification at Different Points of Regulation

Point of regulation	Characteristics
Upstream/ Midstream	– Obligation to report applied to fuels at the point of supply/distribution (either initial importer/ supplier or intermediate distributor); applied, for example by **Mexico** and **Iceland** in their carbon tax systems. **France** and **Denmark** apply a hybrid midstream system where taxes are paid at the point of use by either the supplier or user. – Emissions quantification requires an estimation of emissions that will occur downstream (at the point of regulation before the fuel is combusted). – Direct measurement is not possible, only calculation-based methodologies can be used (see chapter 5). – Quantification of emissions requires a number of assumptions (such as the amount of embodied carbon in an amount of fuel, and how this amount can be determined). – Emissions are determined by multiplying the amount of fuel sold (based on invoices or fiscal metering) by a standard emission factor (based on default values or samples by each supplier). In such cases, quantification is relatively simple.[59]

58 Some, such as California's ETS have a combination of all points of regulation for different sectors: downstream (stationary combustion facilities), midstream (transportation and natural gas fuel suppliers and imported electricity), and upstream (certain fuel producers).
59 See chapter 9 of the PMR Carbon Tax Guide: *Partnership for Market Readiness, Carbon Tax Guide: A Handbook for Policy Makers,* (World Bank, Washington, DC: 2017), https://openknowledge.worldbank.org/handle/10986/26300.

Point of regulation	Characteristics
Downstream	– Obligation to report is applied at the point emissions occur. – Can use either a direct measurement or a calculation-based methodology (see chapter 5). – Allows for more accurate quantification (such as accounting for a range of different (non-standard) fuels and/or other inputs that are used in process(es)). – Quantification can be simpler (although still more complex compared to upstream or midstream) when using a calculation-based methodology in the transport sector[60] or for fuel combustion; on the other hand, it can be more complex, such as requiring CEMS at the point emissions occur or applying a mass balance covering inputs and outputs. – Many carbon pricing instruments are downstream. For example, **California**[58] allows for calculation and CEMS, **The EU** allows for calculation and CEMS, **Tokyo** allows calculation only, and **South Africa** allows calculation only.

4.2.4. Indirect emissions

Generally, coverage of carbon pricing instruments and, therefore, the quantification and reporting of emissions, focuses on direct emissions (Scope 1). In these cases, quantification protocols need to include methodologies to quantify emissions resulting only from activities controlled by the obligated entity.

Scope 2 (indirect[62]) emissions occur as a result of consuming electricity (or heat/steam) that was produced elsewhere (such as by a third-party power station). Examples of programs that include such indirect emissions are China's National ETS (and most pilot ETS); Colombia's MRV (included in voluntary corporate reporting); Costa Rica's MRV (excludes power generators from the carbon pricing instrument); South Korea's ETS; Québec's ETS; Thailand's voluntary ETS; Tokyo's ETS; and the US EPA's mandatory reporting program.

The quantification protocol will need to include methodologies for scope 2 emissions if they are covered by the carbon pricing instrument as well as rules to prevent the double counting of emissions at both the power generation facility (as direct emissions) and the consuming facility (as scope 2 emissions) if both sets of facilities are included within the scope of the carbon pricing instrument.[63]

Scope 2 emissions are determined by a calculation-based methodology: multiplying electricity/heat/steam consumption by the national/local emission factor, in line with the standard calculation-based approach (see section 5.1.1). The GHG Protocol provides guidance on developing methodologies to quantify indirect emissions; methodologies may also include forms of life-cycle analysis data with high uncertainties.

60 For example, where fuel data are not available, quantifying transport fuel consumption can be as simple as measuring the number of miles travelled by different types of vehicles multiplied by a standard factor.

62 Scope 3 emissions have not, to date, been included in carbon pricing instruments. They are complex to calculate; highly uncertain and obligated entities have no control over the emissions nor any primary data associated with them.

63 Policy makers should be aware of this issue because it is different to GHG reporting programs where an individual entity's emissions footprint is being declared; this is because inclusion of Scope 2 is not deemed to be a double count for the purposes of reporting an entity footprint. Where entity GHG inventory reports are used as the basis for other national GHG quantification, account needs to be taken of the potential for double counting of emissions associated with Scope 2.

5. Step 2: Developing the Methodologies

AT A GLANCE

The core of a quantification protocol is the methodologies that obligated entities have to apply: calculation, direct measurement, or a combination of the two. The selection of these will be affected by factors including the type and scope of the carbon pricing instrument, the point of regulation and any existing quantification rules.

This chapter introduces you to the various components of these methodologies. You will also find provisions on quality assurance and control, including instrument calibration and other oversight measures. Guidance on how you can address data gaps and uncertainties in the two methodologies is given.

- Calculation methodologies are used where the fuel/material consumed can be related to emissions and activity data, as well as cases where direct measurement is not possible, or is too expensive, or individual emissions factors cannot be determined. Data for calculation methodologies can be derived in a number of ways including measurement, engineering or other estimates and proxies, for example.
- Measurement of activity data, sampling and analysis of fuels and materials in calculation-based methodologies, and direct emissions measurement, are the more accurate quantification approaches. However, in some cases one or other of these approaches may not be possible due to unreasonable costs or technical infeasibility. In such cases, the use of default values may be appropriate. Clear rules are needed for what conditions determine when a particular type of methodology is applied.
- Quality assurance and control (QA/QC) are important measures to reduce uncertainty and ensure data is accurately quantified and reported. QA/QC is an inherent part of quantification for both calculation and direct measurement methodologies.

Two different quantification methodologies are usually distinguished:

1. **Calculation-based methodologies: using measured quantities of fuel/materials, emission factors, and other parameters to determine emissions**[64]
2. **Direct measurement-based methodologies: using instruments to directly measure emissions released to the atmosphere**

This chapter outlines the two methodologies before discussing how measurement and calculation uncertainties can be reduced. It also discusses the potential need for alternative methodologies where circumstances such as equipment failures result in data gaps. In the context of these elements, section 5.5 then guides policy makers through the process for selecting the most appropriate methodology to quantify emissions covered by their carbon pricing instrument.

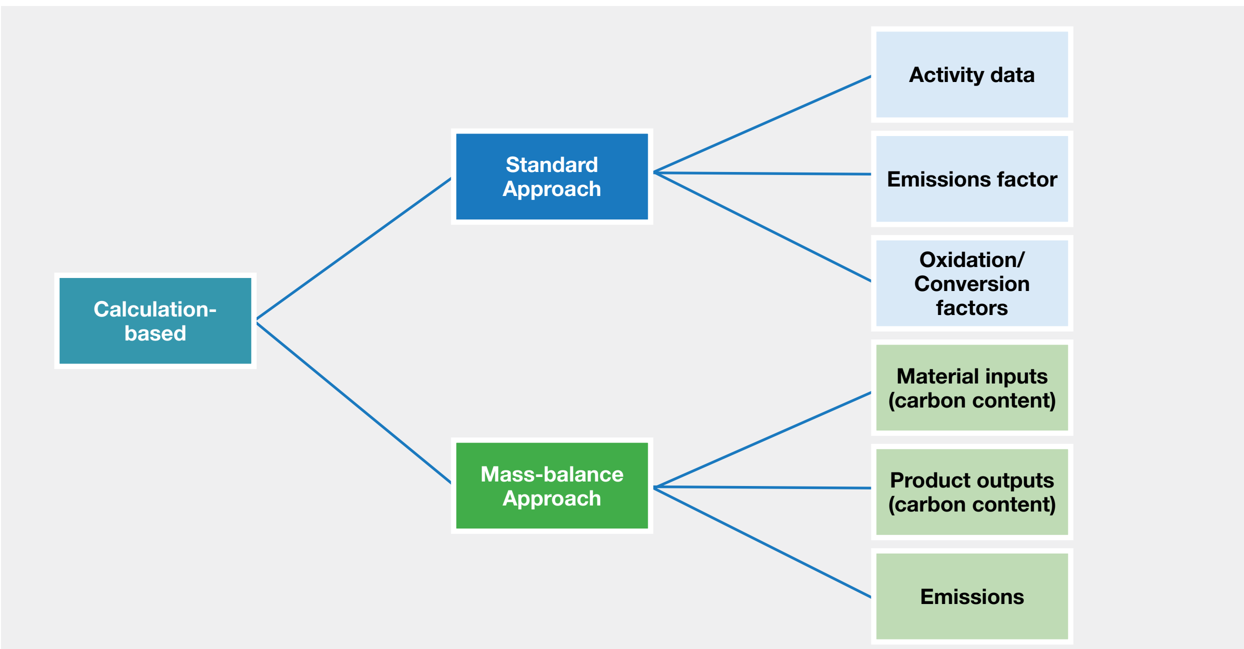
5.1. Calculation-Based Methodologies

Calculation-based methodologies estimate total emissions based on metrics like fuel consumption and other activity data. These methodologies can be broken down into two sub-categories: a standard approach and a mass-balance approach (see figure 9). The preferred approach will depend on the sectors and gases involved, and also how the emission source and source stream are configured at an individual

64 Note: calculation-based methodologies may use input data from measurement instruments such as weigh scales and flow meters, but they are not directly measuring the GHG output from the emissions source.

obligated entity (see section 4.1). The standard approach is often applied to fuel combustion and calcination processes where the fuel or material is directly related to emissions, and activity data and/or emission factors can be determined. Conversely, a mass-balance approach is often used for process emissions in sectors like petrochemical production or iron/steel manufacturing, where it may not be possible to measure the activity data associated with each individual source stream or to determine individual emission factors (see the PMR MRV Guide for more information). The choice often needs to be made by the obligated entity based on what is operationally possible on its site so flexibility needs to be built into the quantification protocol to allow obligated entities to select an appropriate approach for their operational conditions. That choice should then be approved by the regulator as being in line with the quantification requirements in the legislation. Section 7.3.2 explains how such individual choices and associated approval can be organized effectively (for example, by using a pre-approved monitoring plan).

FIGURE 9: Parameters to be Considered in the Two Calculation-based Approaches



Source: PMR Secretariat

For the standard approach to calculation-based methodology, the activity data, emission factor, and oxidation or conversion factors are the most relevant parameters. In a mass-balance approach, other parameters such as material inputs and product outputs and their carbon content are important. In most cases, the final result of quantification is expressed in metric tonnes of CO_2e (see section 4.2.2). In any case, it is important to use units of measurement consistently when designing quantification protocols.

5.1.1. Standard calculation approach

Emissions are typically determined by multiplying activity level data[65] with emission factors.[66] Additional detail is sometimes required or can be included; this detail may include oxidation factors or conversion factors. IPCC 2006 is a good starting place for identifying appropriate equations, but they may need to be adapted to accommodate entity-level quantification as opposed to country-level quantification.

65 Such as GJ/t fuel consumed or a sector specific value such as anode effect minutes/cell day for aluminium manufacture (AEM).
66 Such as kg CO_2/GJ of fuel consumed or kg CF_4 produced/t product.

The following examples of equations are for quantifying CO_2 emissions for combustion and process emissions respectively. For other areas of quantification, such as forestry or transport, and for other gases, the equations may be different. Depending on the number of different gases being accounted for, the formula below could be applied to each individual gas and the results summed to give the total emissions. Further sub-sections below go into elements of the example equations to provide more information.

For combustion related emissions:

Combustion emissions = activity data * emission factor * oxidation factor * GWP

Where the following measurement units are used:[67]

- Emissions [t CO_2e]
- Activity data [for example, TJ of energy; t or Nm^3 of fuel consumed]
- Emission factor [for example, t CO_2/TJ, t CO_2/t or t CO_2/Nm^3]
- Oxidation factor [for example, percent of fuel oxidized in the combustion process][68]
- GWP [dimensionless] for the relevant gas emitted

Where default values are used that already take account of things such as oxidation and the type of GHG, this is sometimes expressed more simply as:

Combustion emissions = activity data * emission factor

For process related emissions:

Process emissions= activity data * emission factor * conversion factor * GWP

Where the following measurement units are used:

- Emissions [t CO_2e]
- Activity data [for example, t or Nm^3 of materials input; or sector specific values such as AEM[69]]
- Emission factor [for example, t CO_2/TJ, t CO_2/Nm^3 or sector specific values such as SEF][70]
- Conversion factor [for example, percent of the input material converted to a GHG in the process][71]
- GWP [dimensionless] for the relevant emission(s)

67 Typical units of measurement are given here, but, depending on the carbon pricing instrument, these could differ.
68 Where the carbon pricing instrument takes account of both CO_2 and CH_4, the calculation will need to account for any un-oxidized carbon - CH_4 in natural gas, for example – in order to ensure that the correct total emissions are accounted for. Where only CO_2 is being accounted for, generally 100 percent oxidation is assumed, as this is conservative for CO_2 accounting.
69 Anode Effect Minutes/cell day for the aluminium sector.
70 Slope Emission Factor [(kgCF_4/t aluminium produced)/(anode effect minutes/cell day)] is an activity in the manufacture of aluminium. CF_4 (carbon tetra fluoride) is a product of aluminium manufacture.
71 For example, how much of the pure material is actually converted in the process; for example, in lime manufacture, is all the calcium carbonate converted or does some end up in the waste output from the process? This result is usually expressed as a percentage.

The quantification protocol should specify the units of measurement the data are to be reported in. In many cases, primary data will be measured according to the operational capability of an entity and then converted to the specified units; each conversion gives rise to a potential risk for error or early rounding of data.

The following sections discuss each of these parameters in more detail, including how each can be determined and quantified.

5.1.1.1. Activity data

The term activity data describes the **amount of relevant activity taking place within the relevant boundary of the obligated entity.**[72] Generally, **activity data are calculated by looking at input and output data for different types of fuels and materials used**. For inputs, two types of data are considered:

- Input fuels that result in combustion emissions where:
  - **Activity data** (energy based [TJ]) **= amount of fuel consumed** (volume or mass[73]) *** calorific value**[74] ([kcal/kg, kJ/kg, J/mol, Btu/m³ etc.])
- Input raw materials that are converted in a process that results in process emissions or the destruction of which results in avoided emissions[75] where:
  - **Activity data** (quantity of material [t]) = **amount of material consumed** (volume or mass[65]) *** purity fraction** (a measure of any contamination contained in the material, not consumed in the conversion process and so not resulting in GHG emissions [percent][76])

The consumption of fuel or materials can be determined by means of continual measurement (ongoing through a flow meter, for example) **or batch measurement** (on a weighbridge, for example) and may be determined by the entity using instruments that it controls or from third party supplier data that is included on invoices or other delivery documents. All instruments used for determining activity data need to have appropriate quality controls including calibration (see section 5.1.4).

Which approach to fuel or materials measurement is used by an individual entity will depend on their operational and technical context, so flexibility should be provided in the rules (appendix G gives more information on the two measurement approaches that may be used by different entities[77]). In some cases, quantification protocols allow fuel consumption or material input/production to be derived from purchase or sales invoices with stock change adjustments. Such an approach is usually the case when lower tiers are applicable or simpler methods apply (see chapter 6), as stock change adjustments may have relatively lower accuracy depending on how it is determined. Figure 10 below provides an example of a decision tree to help policymakers determine when these approaches are generally appropriate. When developing rules, policy makers should consider whether to:

STEP 2: DEVELOPING THE METHODOLOGIES

72 Depending on the scope and boundary for obligated entities specified by the carbon pricing instrument, not all fuels or materials at a facility may be included in the accounting process. However, it is important to include emissions from all fuels and materials that are included in the scope of the carbon pricing instrument.
73 If gas, adjusted for normalized or standardized conditions
74 Some programs use the Gross Calorific Value [higher heating value], but typically it is Net Calorific Value [Lower Heating Value] that is used to convert consumption data to energy data
75 Where a material is being destroyed to avoid emissions (such as the destruction of mine methane or HFCs), the calculation would take account of both the material input to the destruction process and the fuel or other material required to complete destruction.
76 For example, how pure the input material may be where only the pure form is converted in the process and the remainder is waste output from the process, such as the proportion of dolomite rock used for cement manufacture that is pure calcium magnesium carbonate ($CaMg(CO_3)_2$) from which emissions arise.
77 More information can also be found in EU MRR Guidance Document for installations 1: https://ec.europa.eu/clima/sites/clima/files/ets/monitoring/docs/gd1_guidance_installations_en.pdf

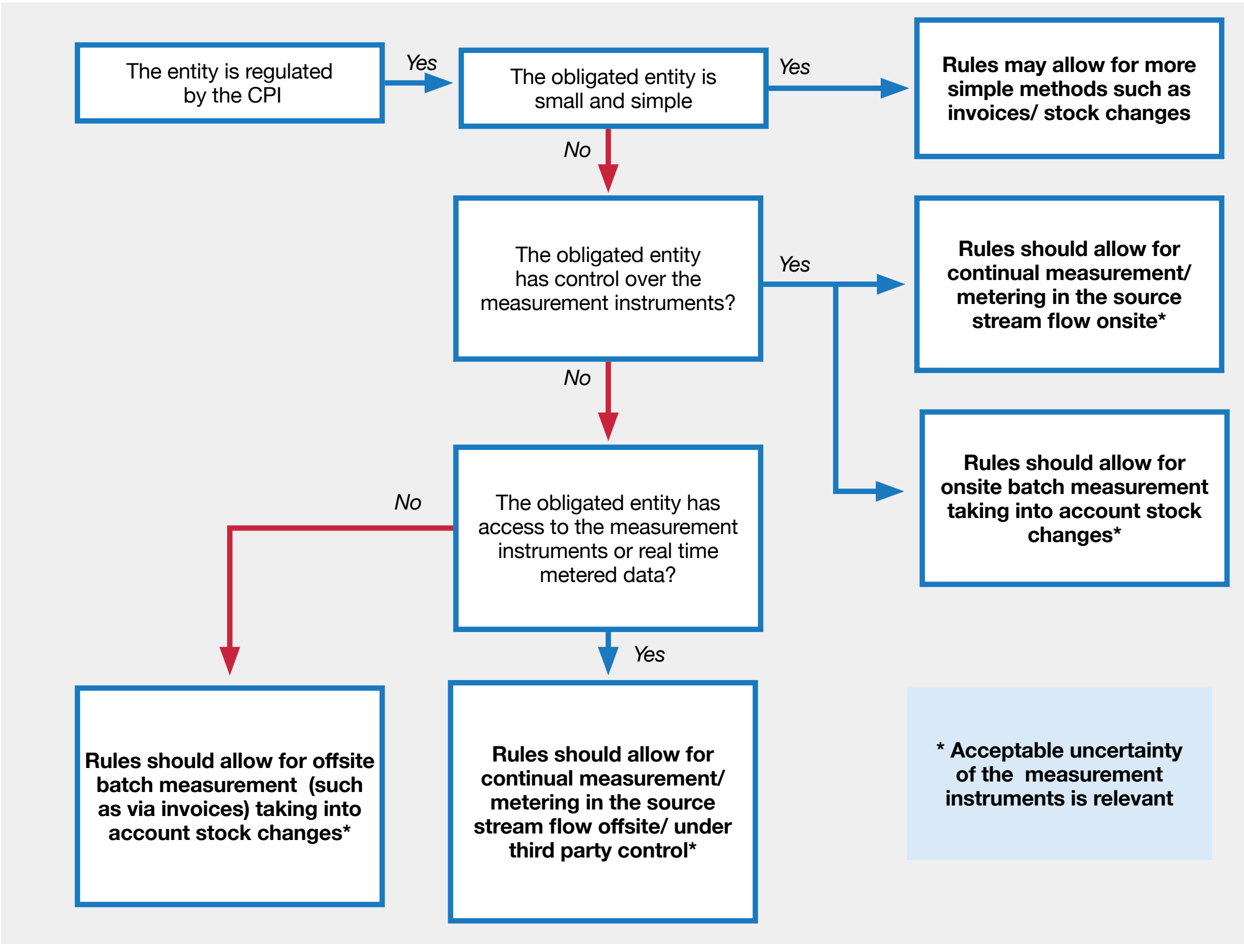
- Specify in legislation when obligated entities can apply simplified approaches (such as using invoices) (see chapter 6).
- Allow obligated entities to apply different approaches to measurement of activity data as outlined in figure 10 but regulate that they should request approval from the regulator for applying a specific approach. Approaches can, for example, be specified in a monitoring plan submitted for approval (see section 7.3.2). Such approval would ensure that the specific approach selected by the obligated entity is recorded and cannot be changed indiscriminately.
- Specify minimum uncertainty levels for measurement instruments and minimum requirements to maintain the defined threshold, for example meter calibration requirements. A range of threshold could be defined and is sometimes applied as part of a tier approach (see section 6.1)
- Specify in legislation how the obligated entity determines the activity data per source stream and subsequently aggregates the data for all source streams for the emissions report. Such processes should be detailed by the obligated entity in the monitoring plans or other instruments to be approved by the regulator for context specific situations (section 7.3.2). How an entity must determine its activity data is also closely connected to how quality assurance is regulated (see section 5.1.4).
- Specify standard units for reporting data in (mass, volume or energy)[78] and what is considered to be a primary record of data generated and that is to be retained for a specified period (for example a plant information system data base or spreadsheets that contain output from that database).

The quality of sales invoice data will depend on the country's controls over commercial supply (especially metering control arrangements). Where invoices are based on fiscal metering that is legally controlled to specified levels of uncertainty, and these specified levels are consistent with the carbon pricing instruments requirements, invoiced data may give better accuracy than the obligated entity's own meters. The quality of data occurs despite the fact that the operator has no control over those meters – it depends on what instruments are installed on an individual facility. However, for fuels such as natural gas, sales invoices are sometimes based on estimates or they run over the end of a reporting period, which means that there is potential inaccuracy in the activity data if the total invoice data is used. Operators may also wish to use instruments that they have control over and can ensure that appropriate maintenance and calibration is done to meet required uncertainty levels. Policy makers should build in flexibility for operators to use the best available data that meets the carbon pricing instrument's requirements.

Exceptions to the approach outlined in figure 10 will apply for certain sectors such as agriculture, forestry, and some industrial processes such as aluminium production. Specific methodologies apply for agriculture and forestry, and their activity data may relate to biomass quantity change or soil carbon content change, for example. For emissions due to leakages from industrial processes or storage or fuels and materials, activity data may need to be based on engineering analyses, estimates, or leak detection processes. In the case of aluminium production, process specific activity data may be defined. For example, activity data may be the "anode effect minutes/cell day" or "anode effect overvoltage per cell" where PFCs are being accounted for. In many cases default values are used; IPCC 2006[80] provides further information on formulae and approaches that apply to different process and AFOLU emissions.

78 Where rules are rigid, this may result in entities having to convert from what they are operationally capable of (depending on how meters etc are set up) to the required metric. Each conversion gives rise to the risk of mis-statement in that part of the data set.
79 Fossil or biomass based.
80 The Intergovernmental Panel on Climate Change, *2006 IPCC Guidelines for National Greenhouse Gas Inventories,* (2006): https://www.ipcc-nggip.iges.or.jp/public/2006gl/.

FIGURE 10: Setting Rules for Determination of Fuel[79] Consumption and Material Production in the Calculation Methodology



Source: SQ Consult

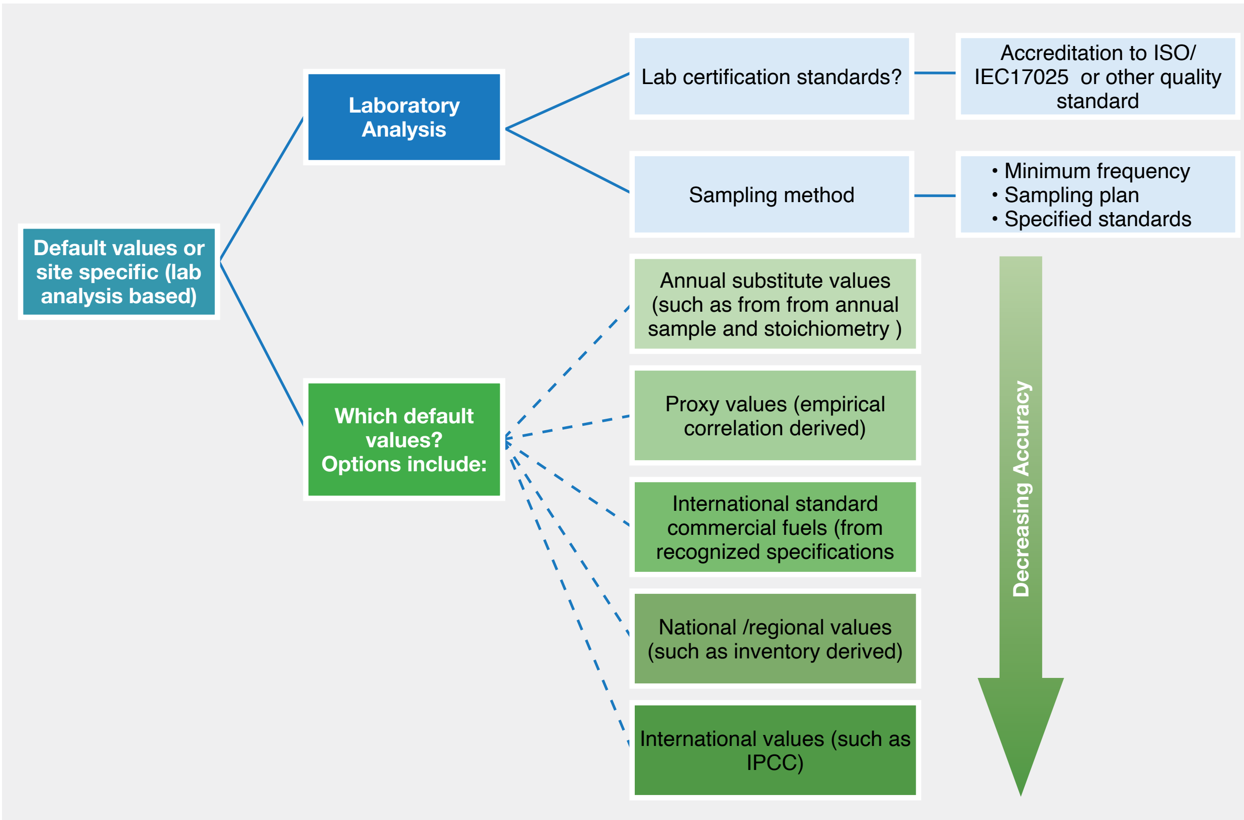
5.1.1.2. Emission factors and calorific values

Emission factors are values that outline the GHG emissions that result from undertaking a certain activity. The calorific value defines the energy contained in a fuel. For quantification of these parameters, there are four issues policy makers need to consider (see figure 11):

- The use of default values versus laboratory analysis of samplings to determine facility-specific factors
- If default values are prescribed for a specific situation, what type of default values are used
- Laboratory certification standards in the case of sampling and analysis for factors
- The sampling method in the case of sampling for factor determination

For all four issues, policy makers may also want to distinguish requirements using thresholds or a tier approach so that entities with higher emissions are subject to more stringent standards (at least for their more significant source streams) while entities with lower emissions may be subject to less demanding (lower cost) requirements (see also figure 19 in chapter 6).

FIGURE 11: Elements to Consider for Calculation Factors



Source: PMR Secretariat

Generally, the most accurate way of determining emission factors and calorific values is by analyzing fuel/material samples in a recognized laboratory. Country-specific or international default values can also be used. However, because these default values reflect a country-wide or global average, they are unlikely to provide highly accurate results for any specific facility or organization. Nevertheless, default values may be applied if the costs of facility-level values are too high or are not technically feasible, and so less accurate approaches are appropriate (see chapter 6). Where facility-specific factors are allowed, robust ex post verification provisions will help to ensure that there is no gaming by the obligated entity and reliable data is used for development of calculation factors. Guidance on such verification is given in the PMR A&V Guide.

For default values, policy makers can choose from:

- **Annual values-based on evidence** or derived from accepted sources that the entity uses as a substitute for calculation factors when it is not possible to generate all the required data in an accurate way. Analysis to derive such values are usually carried out at least once a year by a recognized laboratory.[81]

- **Proxy values** established on the basis of empirical correlations that show a relationship between two different measured attributes--for example, the amount of output power generated and the amount of fuel used for generation.

- **The calorific value of internationally standardized commercial fuels** such as diesel and kerosene can be taken from purchasing records from the fuel supplier, provided that the calorific value has been derived

81 Many carbon pricing instruments require that laboratories recognized under the program are accredited to ISO17025.

based on accepted national or international standards. In these cases, a definition of commercial standard fuels is usually included in legislation.

- **National or regional factors** that are used for fuels or materials either in the country's national inventory or approved for use by its regulators. These are more accurate than IPCC 2006 factors as they are country or region specific. In tier approaches, these default values are generally used at medium tier levels. This category would include national/regional grid emission factors[82] for quantifying scope 2 emissions.
- **International IPCC standard factors** for emission factors and calorific values.[83] These global averages will be less accurate than national or facility-specific metrics but are generally applied when there is no possibility of establishing national factors or when national factors are not sufficiently accurate. In tier approaches or simplified approaches, policy makers may choose to allow the use of international standard factors in the lowest tiers.

When establishing default values, it is important to ensure that there are no inconsistencies in the default values across sectors and industries: the same factor value should be used for the same fuel, for example, in every sector that it applies to, and the same rigor of approach to determining default factors should apply. If discrepancies arise, there will be differences in data accuracy, making it difficult to compare GHG emissions across and between sectors and to use the data for GHG emissions inventories.

Section 5.1.1.3 describes the approach to sampling and analysis for the determination of facility-specific factors.

5.1.1.3. Sampling and analysis

If policy makers require facility-specific parameters, material or fuel samples will have to be taken and analyzed by a laboratory recognized by regulators for the purpose. **When defining analysis requirements, policy makers need to outline standards for the competency of the laboratory**. One means of doing this is for the lab to be accredited against ISO/IEC 17025.[84] In carbon pricing instruments such as the EU ETS, Chile green tax, and New Zealand ETS, accreditation of the laboratory is in principle required when a facility-specific factor needs to analyzed.

In the early phases of implementing a CT or ETS, policy makers may want to allow an obligated entity to use both accredited and non-accredited laboratories (either internal or third party). As the carbon pricing instrument progresses, situations and conditions under which a non-accredited laboratory can be used may be narrowed. Such was the case in EU ETS. Currently non-accredited laboratories can be used only if the operator of the installation demonstrates that using accredited labs would lead to unreasonable costs or technical infeasibility. Non-accredited laboratories have to meet requirements that are equivalent to ISO 17025. The EU's MRR guidance[85] provides examples of the type of requirements that could be appropriate for these situations.

82 Further information can be found on : (a) IFI WG default grid emission factors - https://unfccc.int/climate-action/sectoral-engagement/ifis-harmonization-of-standards-for-ghg-accounting/ifi-twg-list-of-methodologies ; (b) https://emissionfactors.com/ and https://iges.or.jp/en/pub/list-grid-emission-factor ; and (c) *IFI Dataset of Default Grid Factors v.2.0* (July 2019), https://unfccc.int/sites/default/files/resource/Harmonized_Grid_Emission_factor_data_set.pdf.

83 Intergovernmental Panel on Climate Change, Emission Factor Data Base operated by the Task Force on National Greenhouse Gas Inventories, (2020), https://www.ipcc-nggip.iges.or.jp/EFDB/main.php.

84 An international standard that contains general requirements for the competence of laboratories carrying out analytical tests or calibrations, including sampling. It is applicable to all laboratories that perform testing or calibrations as part of inspection and product certification. When companies have their own laboratories, they can have these laboratories accredited, provided their activities fall within the scope of the standard. An alternative is a lab with a quality management system certified to ISO9001 that is consistent with the key requirements of ISO17025.

85 EU Commission, *MRR GD 5 on Sampling and Analysis*, https://ec.europa.eu/clima/policies/ets/monitoring_en#tab-0-1.

Sampling and analysis should be carried out at a legally specified minimum frequency to ensure representative results. Where fuel or material composition does not vary much over time, frequency can be lower than with a highly variable composition (such as for refinery fuel gas). Policy makers should also be prepared to address situations where minimum frequencies are not achievable for certain fuels or materials, or where it leads to unreasonable costs—for instance, when dealing with plant shutdowns or other situations that interrupt the schedule of sampling. Approaches to deal with such situations include regulator approval of an analysis frequency proposed by the obligated entity or mandating acceptable levels of variation in analytical results.

The laboratory will need to be provided with representative samples to carry out its analysis in compliance with the rules of the carbon pricing instrument. Uncertainty in analysis is reduced by the use of accepted testing methodologies such as those defined by ISO or national standards bodies. It is **important for obligated entities to develop a sound sampling methodology** so that it is clear what will be sampled, how it will be sampled, what sample will be analyzed,[86] and by whom. **Sampling needs to be representative of the whole delivery period or the fuel or material batch. It also needs to be free from bias** so the rules need to specify that this is required as well as specifying the level of confidence and precision required in the results which determines the size of a sample taken from an individual population of fuel or material.[87] The obligated entity then needs to demonstrate how they achieve this in practice, for example, through implementation of standards and procedures recorded in a monitoring plan and sampling plan (see figure 12), and verifiers (if used) need to check and confirm that there is no bias in the results.

The complexity of the sampling approach is dependent on the heterogeneity of the fuel or material. The more variable the fuel or material, the more complex and sophisticated the sampling methodology needs to be. Policy makers can take several approaches to ensure that obligated entities carry out sampling in an appropriate manner, including:

- Requiring obligated entities to submit **sampling plans**[88] to the regulator for advance approval. Such a plan would describe sampling approaches, sampling frequency, application of relevant sampling and analysis standards; and the laboratory selected to conduct analysis. Obligated entities must then carry out sampling according to the approved sampling plan. In addition, entities should also be mandated to update/amend the sampling plan to ensure that any changes in the source streams are properly reflected and accounted for.
- Embedding sampling principles in legislation, such as requirements that sampling be representative and free from bias.
- Prescribing (national or international) sampling standards. Examples of sampling standards can be found in appendix D, table D.2, including approaches such as ISO 18283 on the manual sampling of hard coal and coke or GPA Standard 2166-05 on obtaining Natural Gas Samples for Analysis by Gas Chromatography.
- Requiring a combination of the above options.

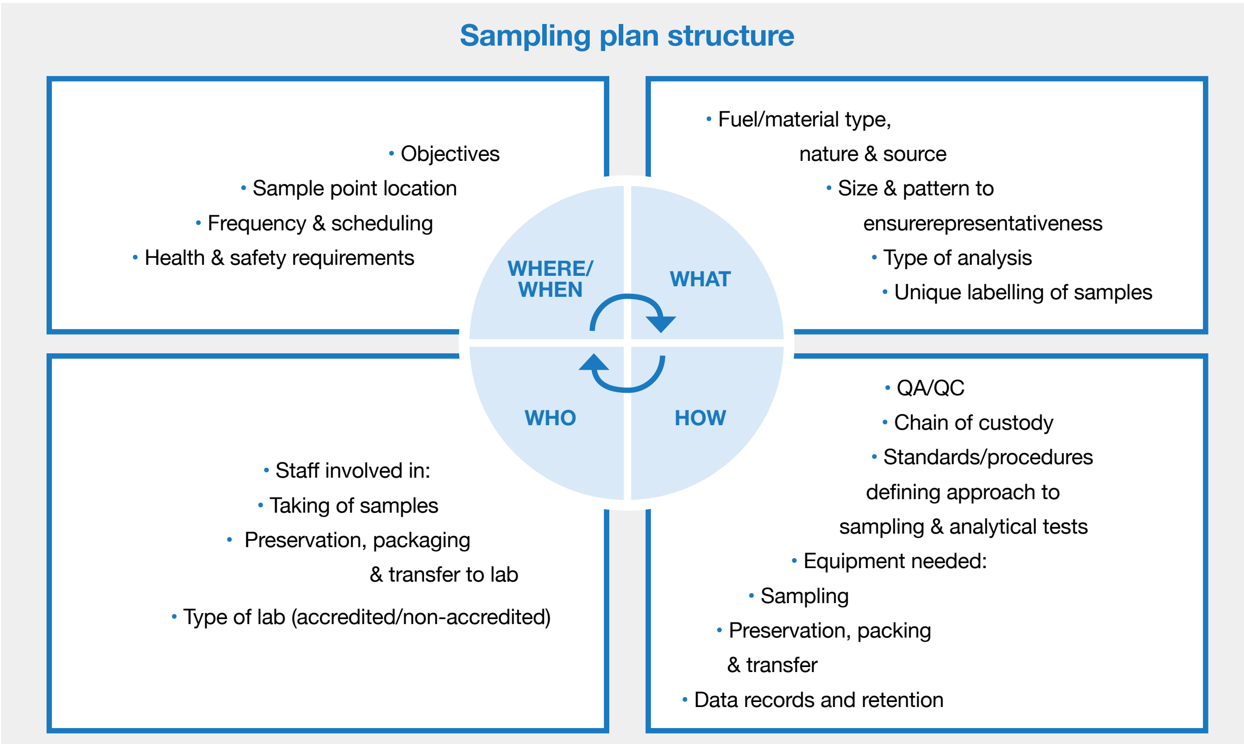
Nearly all carbon pricing instruments that require analysis for calculation factors include requirements on sampling in legislation, including Singapore, Alberta, and California. Typically, rules cover sampling frequency and how sampling is carried out. Under the EU ETS rules include not only requirements on representativeness

86 For example, a single sample or a composite sample made up of a number of samples taken over a period of time.
87 Further information is available in the CDM Standard on Sampling and surveys for *CDM project activities and programmes of activities : (a) CDM-EB50-A30-STAN* - https://cdm.unfccc.int/filestorage/e/x/t/extfile-20191129115244333-Meth_stan05.pdf/Meth_stan05.pdf?t=Ull8cWF3MmpvfDB3Uthx1qwBMQ8zoc5fsTm5 and (b) CDM-EB67-A06-GUID - https://cdm.unfccc.int/filestorage/e/x/t/extfile-20151023152925164-Meth_GC48_-ver04.0-.pdf/Meth_GC48_%28ver04.0%29?t=WVZ8cWF3Mm9yfDAIpzSKWjEkdUB8lQLxehiY
88 The sampling plan can be incorporated into a monitoring plan or be a separate but referenced document.

of sampling and references to certain sampling standards, but also a requirement for installations to have a sampling plan approved by the regulator.

Figure 12 below shows an example of a sampling plan structure. For simple obligated entities, the plan is straightforward, but for complex facilities (such as a refinery) a sampling plan can be much more detailed, possibly distributed across different documents and departments. In complex cases there could be multiple plans, depending on the number of source streams to be tested.

FIGURE 12: Indicative Sampling Plan Structure



Source: SQ Consult

5.1.1.4. Oxidation and conversion factors

In combustion and other conversion processes, not all the carbon inherent in fuels and materials is emitted to the atmosphere as a GHG (such as CO_2 or CH_4). For example, carbon can end up in ash or soot when combustion takes place, especially when solid fuels such as coal are burned. Oxidation and conversion factors account for the incomplete reaction of carbon with oxygen in the combustion or chemical process. **The oxidation factor refers to the ratio of the amount of carbon oxidized to CO_2 as a result of combustion to the total carbon contained in the fuel. If no oxidation is involved, such as for process emissions, this is called a conversion factor**. A conversion factor is the ratio of the amount of carbon emitted as CO_2 (or other relevant gas) to the total amount of carbon (or GHG) in the input material(s) of the conversion process. For oxidation and conversion factors, both default values and facility-specific factors can be used. It is up to policy makers to specify the conditions under which default values can be used.

When the carbon pricing instrument accounts only for CO_2 emissions, policy makers often prescribe or allow a default oxidation or conversion factor of 1[89]. A factor of 1 assumes that 100 percent of input

89 This is the approach for IPCC Tier 1 for combustion which presumes full oxidation of fuels.

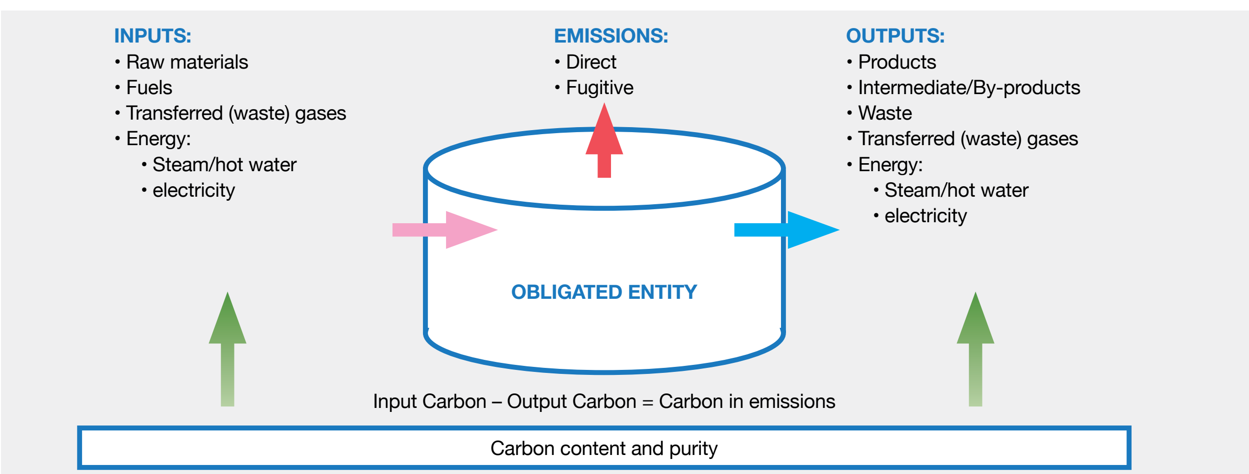
carbon is converted to CO_2, providing a conservative (higher) estimate of actual emissions. However, this assumption cannot be applied in the case when other carbon-based GHGs are included in a carbon pricing instrument as they have higher GWPs[90] and, therefore, assuming that all carbon is converted to CO_2 in a combustion process could underestimate emissions.[91] When tiered approaches are applied, default values for oxidation and conversion factors are generally applied for lower tiers (see section 6.1). When using IPCC 2006 as a basis for developing a quantification protocol, policy makers should be aware that the guidance generally applies an oxidation factor of 1 for a conservative approach, introducing inaccuracies for carbon pricing instruments covering multiple GHGs.

When oxidation factors and conversion factors are determined on a facility-specific basis, sampling and analysis are required. Where multiple fuels/materials are used by an obligated entity, policy makers may allow the entity to determine one average oxidation/conversion factor for the whole combustion or production process (applied to all fuels/materials used).[92] An alternative option is to attribute the incomplete oxidation to one source stream and use default values for the rest.

5.1.2. Mass balance approach

Mass balances can be applied where directly measuring changes in GHG emissions is not possible, for instance, changes in the HFC or PFC inventory. **They can also be applied where output emissions cannot be easily connected to individual input materials, such as in some chemical processes or if carbon is not released as CO_2 emissions but is incorporated in the final product**. An integrated steelworks is an example of this case where emissions in each part of the production process are difficult to identify and part of the carbon is embedded in the final product (iron or steel).[93] Other examples where the mass balance approach is used include facilities in the (petro)chemicals industry such as those producing bulk organic chemicals, hydrogen and synthesis gas or soda ash, and refineries. In such cases, emissions are determined from the activity as a whole by determining the difference in carbon content of inputs and outputs (see figure 13).

FIGURE 13: Example of the Mass Balance Approach



Source: SQ Consult

90 Basis for GWP is the value specified in the latest IPCC Assessment Report (AR) or the value in the AR specified in the carbon pricing instrument rules. The IPCC's sixth AR will become available in 2022.
91 For example, if methane (CH_4) is covered by the carbon price, a default oxidation factor of 1 (100 percent oxidation) for combustion of natural gas (that is, assuming all CH_4 is converted to CO_2) would not be conservative since the GWP applied for CO_2 is less than would be applied to the small proportion of CH_4 that had not been converted in the combustion process. This would result in understating CO_2e resulting from the combustion process.
92 For example, when a mix of solid fuels is combusted in a power station, it is not possible to determine the oxidation fraction of each fuel individually since the ash resulting from the burn is a mix of the remains of all the fuels.
93 In EU ETS and the Western Climate Initiative, a mass balance can be prescribed for this sector.

Whether a mass balance approach is applied may depend on the operational configuration of an obligated entity's facility; for example, it may depend upon the way in which the process is set up or whether there are measurement instruments installed at key points in source stream flows to enable activity data and the like to be determined. So, policy makers need to ensure there is flexibility in the rules to accommodate what is practical at facility level. Input from stakeholders can help to determine this for different sectors.

The mass balance approach is based on determining the balance of substances entering and leaving the entire facility or a specific process within the facility.[94] It calculates the difference between the amount of substances entering the process through feedstocks and the amount exiting the process in products. This difference is the basis for calculating the amount of GHGs released into the atmosphere.

Under a mass balance approach, the following example calculation is typically used for carbon-based accounting:

Emissions [t CO_{2e}] **=** $\sum_n$**[(Input activity data** [e.g. t or Nm^3] *** carbon content** [percent] *** conversion factor** [C:CO_2[95]]**)] - $\sum_n$[(Output activity data * carbon content * conversion factor) * GWP]**

The carbon content for fuels and materials is determined by sampling and analysis of the inputs and outputs of the mass balance. Alternatively, it can be back calculated from a default emission factor (either country specific or IPCC) as follows (see box 8 for a worked example):

- For fuels:
  - Using an energy-based emission factor:
    carbon content = [(emission factor * calorific value) / conversion factor: C:CO_2[95]]
  - For a mass-based emission factor:
    carbon content = (emission factor / conversion factor: C:CO_2[95])
- For materials:
  - **carbon content** = (emission factor / conversion factor: C:CO_2[95])

BOX 8. Worked Example – Back Calculation of Carbon Content from an IPCC Factor

Anthracite Coal: EF = 98.3 tCO_2/TJ; NCV = 26.7 TJ/Gg [0.0267 TJ/t]

tCO_2/t = 2.62461 = [98.3 * 0.0267]

C =0.87t/t = [2.62462 tCO_2/0.334]

Policy makers need to specify the situations when a mass balance approach can or should be used. Legislation should also specify that the mass balance should be complete, covering all materials entering and leaving the obligated entity or the relevant process within the entity. There may be difficulties when the amounts of carbon inherent in an individual material are very small as it could make it difficult for an obligated entity to account for some elements in the mass balance. In such cases, policy makers should consider allowing entities to use simplified methods or estimations (see chapter 6). However, policy makers should still clarify

94 Mass balances are not generally done on an organization-wide basis due to the complexities of obtaining consistent high-quality data for a whole organization.

95 0.334 tCO_2/tC. This is the ratio of the full molecular weight (MWt) of each component – Carbon/Carbon Dioxide. Policy makers should consider defining this in legislation to avoid early rounding of the factor and subsequent distortion of the emissions calculation.

in the prescribed methodology that the carbon is accounted for from all input and output materials covered by the mass balance.

5.1.3. Recording and retaining supporting data

Information required for calculations needs to be retained so that regulators as well as verifiers can assess the proper functioning of the data collection system. Legislation should specify what data needs to be recorded and for how long it should be retained. Typically, carbon pricing instruments apply the same retention period that the country requires for financial accounting or tax information, for example, 7 years. However, some such as California's ETS and the EU ETS require up to 10 years from the date the verified report is submitted to the regulator. The type of data to be retained may include:

- Activity data and other parameters used for calculation of emissions such as metering readings
- Default values used
- Full set of sampling and analysis results, if these are used for determining calculation factors
- Corrective actions taken where data anomalies are identified during internal validation
- Results of calibration and maintenance of measurement instruments
- An issues log for tracking instances of erroneous or missing data, stating periods for which data is affected, problems encountered, and how and when the issue was resolved

The PMR MRV Guide has additional information on record keeping requirements.

5.1.4. Quality assurance and control

Quality assurance and control (QA/QC) is intrinsically linked to the management of uncertainty associated with quantification. Each obligated entity has its own specific data flow consisting of the different activities (and databases, spreadsheets, and the like) that are needed to collect data from primary sources and aggregate it to quantify the entity's overall emissions. The larger and more complex the obligated entity is, the more sources of data are likely to be involved in the quantification process, and the more complex the data flow can be. Each activity and transfer of data along the data flow is prone to the risk of creating errors and non-compliance. These risks can be mitigated by implementing a system of QA/QC measures – this system could be within one to a recognized standard such as an ISO9001 quality management system, or a system designed by the operator to meet the requirements of the carbon pricing instrument.

When emissions for an obligated entity are calculated, QA/QC measures might include, for example, calibration of equipment used to measure fuel consumption or materials consumption and production, regular internal review and validation of data (including internal checks by the entity on its compliance with its monitoring plan (if relevant) and the rules of the carbon pricing instrument), procedures to ensure errors are corrected and data gaps are conservatively filled (see section 5.3), and documentation of measurement results. The type of QA/QC measures and the robustness of these measures highly depends on the nature of the inherent and control risks involved. For calculation-based methodologies, risks may be different than for direct emissions measurement, impacting the type of QA/QC measures to be implemented.

When defining rules on QA/QC, policy makers may want to consider the following:

- Require in legislation that obligated entities establish and implement an effective internal quality control system with measures that mitigate their inherent and control risks; this legislation should outline the minimum expected QA/QC measures. In, for example, EU ETS, California's ETS, US EPA reporting program, Chile green tax, and Singapore carbon tax, such minimum requirements are included in law.
- Some elements in QA/QC may need specific attention in the rules. These elements may include the retention period required for documented data, the frequency of equipment calibration and what to do in case equipment cannot be calibrated, or the frequency of sampling and analysis.
- A robust QA/QC system can facilitate the quantification process and will mitigate the risks of errors in the data. QA/QC will ultimately reduce uncertainty and make verification and compliance assessments by the regulator or other third parties easier.

5.2. Direct Measurement-Based Methodologies

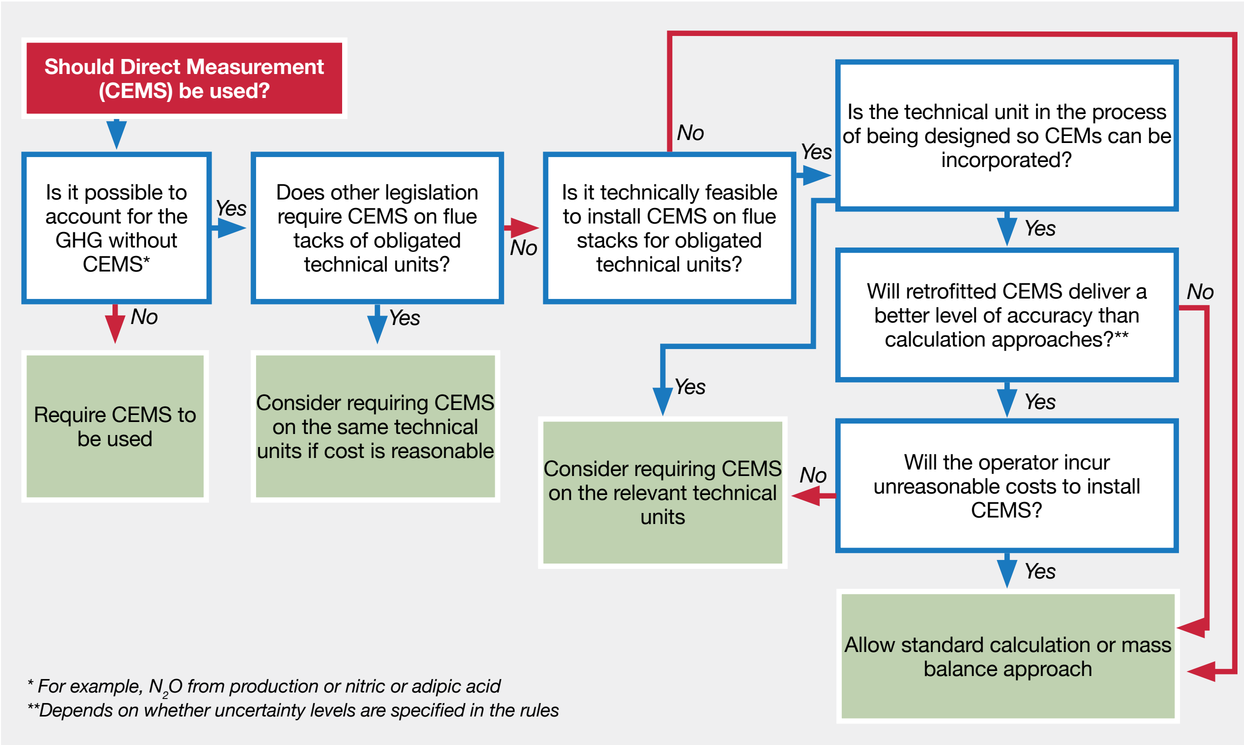
Direct measurement of emissions involves **measuring the GHG concentration and the volumetric flow of a gas stream in a flue stack and automatically determining the amount of GHG emissions, typically using a continuous emissions monitoring (CEMS) system**. Measurements are carried out at a defined frequency[96] and then averaged to provide an hourly mean of concentration and flow rate. All averaged hourly values for the reporting period are summed up to establish total emissions for the relevant process sources. If there are multiple emission sources that feed into one flue stack, the emissions from all those sources are accounted for in the total emissions of the processes that feed into that stack measurement point. In some mandatory reporting mechanisms, alternative approaches can be used to directly measure emissions, for example, by using predictive emissions monitoring (PEMS). Policy makers must consider a number of factors when determining if direct measurement is appropriate; these are outlined in figure 14.

Direct measurement-based methodologies are generally applied in cases where:

- It is not possible to quantify emissions any other way - for example, N_2O from production of certain acids such as nitric acid and adipic acid.
- Other environmental legislation mandates that the equipment is installed in flue stacks (and it can be adapted to the relevant GHGs); such is often the case for the power generation sector.
- Emissions accounting is done at a process/facility level and where instruments can be applied to specific technical units.
- It can (or is required to) be incorporated into designs for new built facilities.

96 For example, every 0.5, 1, 5, 10, 15, or 30 minutes (and so on), depending upon instrument capabilities and any legal requirements.

FIGURE 14: Considerations for Determining if Direct Measurement Can Be Applied



Source: SQ Consult

In most cases technical feasibility and unreasonable costs play a role in determining whether it is possible to install CEMS and to allow or require the application of direct emissions measurement. Where retrofitted CEMS do not deliver a better level of accuracy than calculation methodologies, it is not recommended to require CEMS or to allow it only under specified conditions. Where these conditions are not met, a standard calculation or mass balance approach would be more appropriate.

Policy makers also need to consider a number of other issues when designing measurement-based methodologies. These include:

- When to use CEMS vs PEMS (see section 5.2.1);
- Data flow, transfer and aggregation (see section 5.2.2);
- Missing data (see section 5.2.3); and
- Quality assurance (see section 5.2.5).

Direct measurement can be an onerous methodology to apply for obligated entities as it requires additional instrumentation and quality controls. One of the main challenges is to tailor the measurement-based methodology to the specific GHG or other gases to be measured. The requirements for N_2O measurements are different from CO_2 measurement. For example, unabated N_2O (such as when abatement equipment[97] fails) may need a mass balance calculation of emissions for the unabated period in addition to direct measurement during periods with abatement. Policy makers need to be aware of specific characteristics when measuring these gases so that rules can be tailored to appropriate methodologies. Early stakeholder engagement with industries and research institutes can support policy makers in getting a clear picture of what is achievable.

97 Equipment for the abatement of pollution including, for example, any equipment (including parts and accessories) used to eliminate, prevent, or reduce air pollutants emitted resulting from the manufacturing process.

Furthermore, there can be situations where the input gas streams contain very high CO_2 concentrations. In such situations it may be more accurate for obligated entities to determine CO_2 concentration indirectly by first measuring the concentrations of other constituents of the gas, and then subtracting them from the total. This approach is how CO_2 is determined in the EU ETS when it is permanently stored in a carbon capture storage facility.

5.2.1. CEMS vs. PEMS

Primarily, carbon pricing instruments that allow direct measurement of emissions use a CEMS. However, PEMS, a predictive software tool that estimates emissions based on mathematical models, is allowed by regulators in some countries where it can be demonstrated that it produces as robust data as a CEMS, and so it is considered equivalent. Most commonly, though, PEMS is used as a backup for traditional analyzers. Although PEMS can be complex to set up initially,[98] it also has lower capital and ongoing maintenance costs, contains auto-calibration software, and is at lower risk of drifting from calibrated settings unless there are problems with underlying operational instruments. PEMS can be applied to complex process units such as fluidic catalytic crackers or sulphur recovery units, but the most typical applications are on units such as turbines, boilers, and furnaces.

Some quantification protocols, like those for Chile's green tax and the US EPA federal regulations on emissions monitoring, allow PEMS under certain conditions including the demonstration by the facility that the PEMS has the same or better precision, reliability, accessibility, and timeliness as an approved CEMS. Appendix H-A provides more information on the differences between the two system types. Examples of different direct measurement approaches used by carbon pricing instruments are shown in appendix H-B, table H.2.

5.2.2. Data flow, transfer, and aggregation

In some MRV systems, the obligated entity aggregates the collected measurement data into a report that is verified by a third-party verifier. In other systems, data may be electronically reported from the CEMS to the regulator using a software tool. In the latter case, certification of the data may be carried out by the obligated entity before the data is transmitted to the regulator.

To ensure completeness of data, emissions monitoring systems may need to be installed in more than one flue stack or duct, as is required for the EU ETS and the US EPA. This approach can cause issues, particularly where there are interconnected stacks. Mexico and Chile have adopted alternative approaches to ensure completeness, for instance, through the application of default or average values.

Data aggregation and maintenance can be particularly challenging and expensive if the quantity of data is large and a sophisticated plant information system with robust back-up and storage capability is needed to collect and retain the data.

5.2.3. Missing data

The quantification protocol should specify how to deal with missing data in case of equipment malfunction or a failed calibration/ recalibration, for instance. In most cases filling data gaps is done by using **alternative or**

98 A bespoke model of the facility needs to be constructed from a full data set of relevant process parameters, meaning that the process plant needs to have a full set of instruments on all relevant processes and to be automated through a Distributed Control System, for example.

substitute values. Which values to use depends on what data are missing. In the EU ETS, different substitute value calculations are outlined for missing concentration versus other parameters. The procedure for dealing with missing data may also be different if the equipment was out of operation for several days rather than just a few hours. In the United States, for instance, backup monitors can be used to generate data; alternatively, values calculated using an EPA reference method may be reported. If neither option is feasible, missing data substitution procedures are outlined in US EPA federal legislation.

If a direct emissions measurement system is out of operation for more than a few days, it is important that the **regulator is notified within a specific timeframe to ensure a return to compliance can be enforced**. Such a requirement should, therefore, be included in legislation. As part of quality assurance, it is also good practice to require obligated entities to establish and implement procedures to prevent data gaps from occurring and to define specific alternative methods to close gaps when they occur.

There may be circumstances where additional calculation is required for some GHGs even though the direct measurement equipment is functioning for example, for quantification of N_2O that is released without going through abatement equipment or when the abatement equipment fails. A conservative mass balance calculation may be required in such cases.

If conventional metering is not feasible, policy makers should outline a process for obligated entities to propose alternative methods that meet any specified accuracy requirements (such as +/-5 percent). Chapter 8 contains further information on temporary changes to the methodology.

5.2.4. Recording and retaining supporting data

Legislation should specify the **information that needs to be recorded for direct measurement systems and for how long that information is to be retained**. The type of data to be retained depends on how the direct measurement system is designed and what requirements apply. Typically records include, for example:

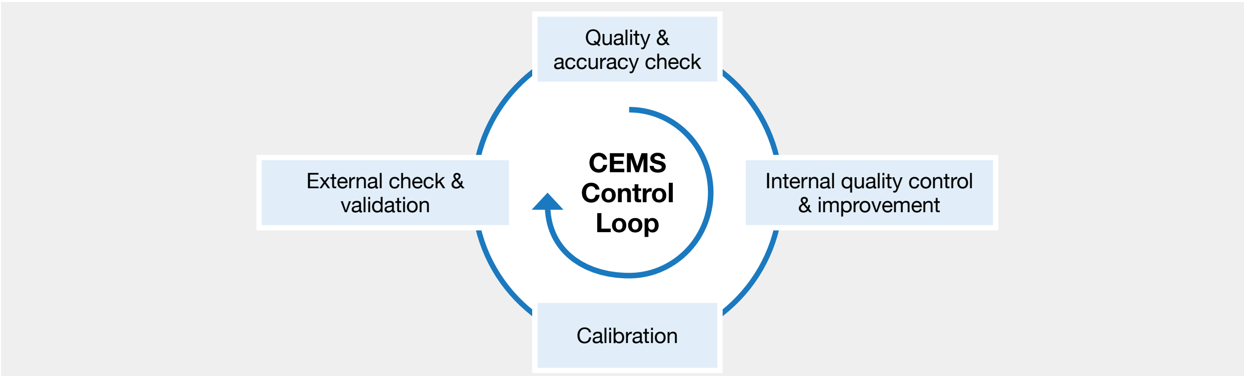
- Documents justifying the selection of the methodology to ensure the most accurate one is applied
- Description of the direct measurement system and documentation of any changes to it over time
- Data used for uncertainty analysis if required or if tier approaches apply
- Data used for corroborating calculations if these are required to support measurement results
- Raw and aggregated data from direct measurement systems, including documentation of changes over time, the log book on tests, down-times, calibrations, servicing, and maintenance
- Results of calibration and maintenance of the associated measurement instruments
- Procedures on how missing data are addressed, and what substitution values are used

This information is essential for regulators (and verifiers) to assess the proper functioning of the direct measurement system.

5.2.5. Quality assurance

Strict QA/QC mechanisms are necessary for a direct measurement-based methodology in order to **ensure the measurement equipment used is certified, validated, calibrated, and regularly tested** as outlined in figure 15.

FIGURE 15: CEMS Control Loop



Source: SQ Consult

Most carbon pricing instruments that allow direct measurement use international or national standards; for example, they may use EN14181 on the quality assurance of automated measuring systems and EN 15267-1 on the certification of automated measuring systems. For the United States, though, requirements are written into the federal air quality legislation,[99] and carbon pricing instruments that adopt US approaches also often use these CEMS requirements. Appendix D, table D.3 gives examples of standards that can be used for direct measurement-based methodologies. Whatever standard and requirements are applied, they all require obligated entities to:

- Test whether the CEMS / PEMS is meeting specified requirements and accuracy
- Calibrate and validate the CEMS / PEMS
- Establish internal controls such as data validation and instrument checks
- Undergo ongoing quality assurance activities such as annual surveillance testing

Some of these required activities - for example, the calibration and validation of the CEMS and annual surveillance testing - **may be carried out by an accredited testing laboratory**. Alternatively, the regulator may certify tests conducted by manufacturers/operators as meeting legal requirements. This is the case for the US federal mandatory reporting regulations. Further specifications for CEMS of specific gases and concentrations are given in international and national standards.

In addition, mandating obligated entities to undertake **corroboration calculations** can provide an additional layer of quality assurance and confirm no data gaps exist. Different approaches can be selected. In general, a calculation using the standard methodology with default values or a mass balance is applied. Obligated entities can use these corroboration calculations to ensure that there have not been any problems with the CEMS system. In other cases, a corroboration by calculation is not possible, such as when CEMS is used to determine N_2O emissions, so really effective QA/QC control of the CEMS is required.

99 US EPA Air Emission Measurement Center, *EMC: Quality Assurance Procedures for Performance Specifications*, (Washington, DC: US Environmental Protection Agency, 2018), https://www.epa.gov/emc/emc-quality-assurance-procedures-performance-specifications.

Because corroboration may use less accurate data, there is unlikely to be an exact match between the data sets. A significant deviation between the primary CEMS measurement and the corroborating calculations outside a reasonable tolerance band for the CEMS and the calculation approach selected indicates that:

- Data could be missing
- Quantification rules for missing data may need to be applied following an investigation (see section 5.2.3)

As part of its internal QA/QC procedures, the obligated entity would then have to take action (such as to correct data or use an alternative approach to fill gaps of missing data). Appendix H-B, table H.2 shows how several countries have approached missing data.

Quality assurance and corroboration of measured values are the strongest quality assurance measures an obligated entity can take. However, the obligated entity may be required to undertake additional measures depending on the risk of errors in the data flow, the accounting activities from direct emissions measurement through to the compilation of the emission report (such as internal review of data and other, procedures to ensure data is corrected). As with a calculation-based methodology (see section 5.1.4), the type of QA/QC measures and their robustness highly depend on the nature of the inherent and control risks involved.

5.3. Data Gaps

There are situations in which the obligated entity's standard calculation-based or direct measurement-based methodologies cannot be (or have not been) applied. Such situations include cases where data gaps are identified, for example, due to failure of measurement instruments, failure to undertake sampling or other operational issues, or where it is not possible to apply the quantification methodology due to a temporary shutdown of the facility. Most carbon pricing instruments have developed approaches for addressing data gaps that arise in such situations where approved approaches cannot or have not been maintained.

Data gaps are not the same as data errors. A data gap refers to any situation where the data cannot be retrieved from another primary source and cannot be reconstructed or recreated in another way. Different causes for data gaps can be identified, and they include:

- Measurement equipment used may be out of order or delivering erroneous data that cannot be rectified.
- Measurement systems may not be delivering/transferring data up the chain to critical data bases; and this may not be discovered before it is too late to re-gather data from earlier in the chain.[100]
- Information is recorded manually, and the responsible person failed to take required readings.
- Information taken from paper records (such as delivery notes or meter logs) or stored electronically without a back-up copy is lost.
- The required frequency of sampling and laboratory analysis is not followed, resulting in incomplete or invalid analyses.
- Samples have been contaminated and so have become invalid, or they may have been lost during storage or transfer to the laboratory.

100 For example, flow computers may retain data only for a short period of time and, if not transferred onto the plant control system, data may be over-written.

The risk of data gaps occurring can be mitigated, for example, by implementing regular internal QA/QC measures and procedures that ensure that problems are picked up in a timely way. However, the chance of data gaps occurring cannot be fully excluded. In most cases, **data gaps are filled by applying methods that aim to conservatively estimate appropriate surrogate/substitution data or estimate emissions based on the obligated entity's circumstances and what data parameter is missing.** Alternative methods could be simple (for example, reverting to sales invoices if a site instrument measuring natural gas consumption has failed); or they could be more complex involving other process parameters to create a correlation or proxy that can be applied to fill a gap. For instance, the quantification rules for Alberta's ETS mandate certain simplified calculation methodologies with proxy values in cases of data gaps,[101] whereas in California, missing CEMS data are replaced by the last prior quality assured data.[102] In Singapore, regulated entities must outline a conservative alternative approach to cover data gaps in their monitoring plans submitted to the regulator for approval (for more see appendix I).

When developing rules on dealing with data gaps, policy makers need to make decisions on the following:

- Whether rules will (ex ante) mandate specific approaches to filling data gaps, or whether the obligated entity can propose conservative approaches for approval by the regulator
- Whether obligated entities should have a documented procedure for addressing data gaps. Such procedures describe how an obligated entity plans to address foreseeable data gaps, and what measures they would take to correct and prevent reoccurrence. These procedures can be described in a monitoring plan if one is required for the carbon pricing instrument.
- What should happen if the obligated entity temporarily cannot meet the required (or approved) methodology. For example, should a temporary deviation be allowed (and for how long)? Should such a deviation be only as part of a short transition period before returning to the required method?
- Whether to allow alternative methods if tier approaches are applied and the specified tier cannot be met. Under what conditions would such methods be allowed (for example, because of unreasonable costs or technical infeasibility)?
- When entities can apply a conservative estimate.

Alternative approaches depend on the context of an obligated entity's activities and the nature of the data gap that arises. Therefore, policy makers should consider including the flexibility to allow entities to propose alternative approaches to fill the gap based on their best available data, provided that these alternatives do not underestimate normal emissions; for example, policy makers can require the inclusion of a safety factor based on standard deviations in the data used.

5.4. Dealing with Uncertainty

Key questions that are asked about the quality of emissions quantification include "How good are the data?" or "To what extent can we trust the measurements that produce the emissions data?" The answer to these questions can be determined by the level of uncertainty accepted in the quantification protocol. There are two aspects of uncertainty: quantitative, in relation to the accuracy of instrumentation and sampling/analytical methods, and qualitative, in relation to the overall framework of control on the emissions data accounting processes.

101 Alberta Climate Change Office, *Quantification Methodologies for the Carbon Competitiveness Incentive Regulation and the Specified Gas Reporting Regulation*, (Alberta, Canada: Alberta Government, November 2018), https://open.alberta.ca/dataset/61542074-8233-4f6c-a351-1454d57c0a32/resource/28cd6f46-ff55-4304-a863-dd8b193dfff1/download/cci-quantification-methodologies.pdf.

102 Full details are given in 40 CFR §75.31 and §75.33.

Uncertainty plays a specific role in the determination of activity data through the quality of measurement instruments used in both calculation-based and direct measurement methodologies. Underpinning factors for policy makers to remember include**:**

- **Maintenance and calibration of appropriate instruments is key to reducing the level of uncertainty in primary data** used for GHG emissions determination.
- **QA/QC play an important role in reducing the overall uncertainty of an emissions report**. At the same time, policy makers should bear in mind that QA/QC measures will potentially increase the cost and complexity of applying a quantification protocol.

Uncertainty associated with the determination of facility-specific calculation factors is minimized by use of recognized sampling and analytical standards.

This section provides an overview of quantitative measurement uncertainty (further details are in appendix J), while qualitative aspects of uncertainty are covered in sections 5.1.4 and 5.2.5 on QA/QC for calculation and direct measurement methodologies, respectively. The use of a tiered approach when mandating acceptable quantitative uncertainty levels, as well as instrument maintenance and calibration standards for obligated entities is discussed in section 6.1. 'The GHG Protocol' provides useful guidance on managing qualitative uncertainty through an effective quality management system as well as a working tool for calculating the aggregate statistical uncertainty due to random errors associated with an overall emissions report.[103] Examples of how different carbon pricing instruments deal with uncertainty are given in box 9**.**

BOX 9. Examples of How CPIs Deal with Uncertainty

California ETS defines uncertainty as the degree to which data or a data system is deemed to be indefinite or unreliable. The ETS rules (§ 95103(k)) require obligated major sources to meet quantitative measurement accuracy levels by regular calibration and maintenance of instruments taking account of 40 CFR 98 (US mandatory reporting rules) and to meet a field accuracy of ±5 percent, with methods to be documented in the monitoring plan and verified. The rules specify details of calibration expected for different types of instruments. Where instruments fail to meet the ±5 percent requirement on calibration, the operator must demonstrate to the verifier by other means that the emissions data meets the accuracy requirements back to the last successful calibration. If, for example, the instrument is determined to meet ±6 percent uncertainty, verifiers need to identify the 'excess' 1 percent instrument uncertainty as an error when analysing the totality of errors identified in the dataset for a material mis-statement

EU ETS – Defines specific acceptable quantitative uncertainty thresholds as part of the tier structure for Activity Data quantification applicable to each source stream. For example, for most combustion activities, the field accuracy of the measured amount of fuel at top tier is ±1.5 percent, and ±7.5 percent at the lowest. For instruments they control, operators must do an annual uncertainty assessment (in accordance with JCGM100:2008* or equivalent accepted standard) to demonstrate that permitted tiers are met – taking account of the instruments, their installation, maintenance, and calibration, and uncertainty of any stock changes. However, in some cases a simplified uncertainty assessment is possible.** For sampling and analysis, evidence must be provided of the uncertainty estimation associated with the lab results. The monitoring plan must contain information on procedures for assessing compliance with permitted uncertainty thresholds. Qualitative aspects of uncertainty are controlled via a risk assessment and management procedures. Uncertainty analysis, results, and application of QA/QC procedures are evaluated as part of the external verification.

Singapore - The uncertainty associated with the quantification approach outlined in the monitoring plan must be assessed to determine the source streams with the highest relative uncertainty, but there is no limit or threshold that must be met. The plan template includes a quantitative assessment with default uncertainty values for different instrument types (that can be overwritten by facility-specific values) and a calculation to support the simplified uncertainty assessment. Instruments must be maintained and calibrated in accordance with manufacturer's instructions to achieve tier 4.

103 "Measurement and Estimation Uncertainty of GHG Emissions, Guidance and Worksheet," (Greenhouse Gas Protocol: 2003), https://ghgprotocol.org/calculation-tools#cross_sector_tools_id.

IPCC – provides guidance on quantifying national inventory uncertainties in practice. This guidance largely covers a hierarchy of qualitative QA/QC of procedures covering Tier 1 checks at the national inventory level and Tier 2 checks on the country's key source category data - including checks such as applicability of IPCC and country default factors; historic data and order of magnitude comparisons; and evaluation of QA/QC activities associated with data sources being repurposed for the inventory. Finally, it outlines quality assessment (QA) procedures, which include expert peer review of calculations and assumptions and audits of compliance against the quality compliance (QC) plan specifications. More information can be found in the "IPCC Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories".***

* ISO Guide to the Expression of Uncertainty in Measurement96

**Guidance is available from the European Commission Directorate of General Climate Action at: https://ec.europa.eu/clima/sites/clima/files/ets/monitoring/docs/gd4_guidance_uncertainty_en.pdf; and https://ec.europa.eu/clima/sites/clima/files/ets/monitoring/docs/gd7_cems_en.pdf

*** Intergovernmental Panel on Climate Change, "Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories, (2000), https://www.ipcc.ch/publication/good-practice-guidance-and-uncertainty-management-in-national-greenhouse-gas-inventories/.

5.4.1. Uncertainty in calculation-based methodologies

Measurement instruments used to determine fuel or materials consumption have inherent quantitative uncertainties as a result of their design or from the way that they are installed, used, maintained, and calibrated. With batch measurement, uncertainties from determining stock levels at the start (opening) and end (closing) of the reporting period also need to be considered. Appendix J provides more information.

In calculation-based methodologies, uncertainties are generally associated with:

- **Determination of activity data: uncertainty about the amount of fuel/material consumed or material produced**
- **Determination of calculation factors:**[104] **uncertainties inherent to sampling and analysis activities.** Such uncertainties are usually covered in sampling and analysis methodologies described in recognized national or international standards. If default values are used for calculation factors, uncertainty is not relevant as it has already been accounted for in the method to determine the default value accepted by the regulator.

5.4.1.1. Specifying uncertainty levels for quantifying activity data

Uncertainty levels define the achievable level of accuracy for an instrument when it is fit for purpose and installed as recommended by the manufacturer.[105] This achievable level is true, regardless of whether the measurement instrument is under the obligated entity's control or that of a third party (such as a gas supplier). In order to obtain consistent, high accuracy data across all obligated entities, **acceptable levels of uncertainty should be defined by policy makers in rules or guidance**. The acceptable uncertainty for lower tiers can be higher than the acceptable uncertainty for higher tiers (see section 6.1). Defining uncertainty levels for a carbon pricing instrument can be done by referencing existing uncertainty levels in other environmental legislation or by specifying precise minimum accuracy requirements, as well as instrument maintenance and calibration requirements in carbon pricing instrument legislation.[106] If this information is unclear or not available,

104 Emission factors, calorific value, biomass fraction, and the like.
105 Uncertainty is associated with each of the components of a measurement system - for example, the individual instrument, associated temperature and pressure compensation instruments, flow computers, or communication lines between the instrument and the process control software system (such as a Distributed Control System and a Plant Information System). For the purposes of defining accuracy of measurement, the entire measurement system needs to be taken into account, not just the primary instrument.
106 For example, California ETS: § 95103(k)(6) of Regulation for the mandatory reporting of greenhouse gas emissions.

policy makers can also identify sensible uncertainty levels in discussion with instrument manufacturers and metrological institutes.

5.4.1.2. Demonstrating acceptable uncertainty is achieved for determination of activity data

Generally, uncertainty assessments are used to demonstrate compliance with required uncertainty levels. Where such levels are specified, policy makers should require obligated entities to demonstrate that levels are not exceeded during the reporting period to ensure compliance.

The same approach to uncertainty assessments will apply to instruments that the obligated entities control, as well as to ones that they do not control. However, there are some differences in the specifics as the information available to the obligated entity for the uncertainty assessment is different in those two circumstances.

Where the entity controls the instrument, it can access information on its make, model, and installation along with its history of maintenance, calibration, and validation. This information provides sufficient data to conduct an uncertainty analysis. Such an analysis may be based, for example, on the *ISO Guide to Uncertainty in Measurement*[107] - “Evaluation of measurement data – Guide to the expression of uncertainty in measurement” (GUM).

Measurement instruments not under the control of an obligated entity are usually those that are for the commercial supply of a fuel or material. These are generally meters that are used for commercial contracts and may be of fiscal quality standard when used for invoicing. ‘Fiscal’ meters are often regulated under national metrological control legislation. In such cases, obligated entities may not have access to the same level of information as for meters under their own control. Unless the carbon pricing instrument or other national legislation requires that the supplier conducts and provides the results of a formal uncertainty assessment to the obligated entity, the entity will be reliant upon general information[108] from the supplier or from national legal metrological specifications for fiscal instruments. Policy makers need to take account of this likely discrepancy of data when specifying that entities must prove they meet acceptable uncertainty levels. The EU provides extensive guidance and examples on how obligated entities should deal with ETS specified acceptable uncertainty levels and uncertainty assessment.[109]

When drafting requirements for uncertainty assessments, policy makers should be aware of the following:

- If instruments are already subject to robust national uncertainty requirements,[110] additional control requirements may not be necessary. Obligated entities would still have to demonstrate for the purposes of the carbon pricing instrument that the instruments are appropriately maintained and calibrated.
- Uncertainty assessments are more complex for measuring instruments that are not operating in an environment appropriate to their use specification, for instance, if the instrument is older or conditions

107 Bureau International des Poids et Mesurs, ISO/IEC Guide 98-3:2008 (JCGM/WG1/100), *Uncertainty of Measurement -- Part 3: Guide to the Expression of Uncertainty in Measurement*, (BIPM:1995), http://www.bipm.org/en/publications/guides/gum.html.
108 Such as statements of compliance.
109 European Commission, *Monitoring, Reporting and Verification of EU ETS Emissions*, https://ec.europa.eu/clima/policies/ets/monitoring_en#tab-0-1, in particular the European Commission’s Guidance on uncertainty assessment: https://ec.europa.eu/clima/sites/clima/files/ets/monitoring/docs/gd4_guidance_uncertainty_en.pdf
110 Instruments under national legal metrological control.

have changed since it was installed.[111] A full uncertainty assessment and extensive evidence may be needed to ensure that acceptable uncertainty thresholds are not exceeded.[112]

- Where instruments within and without the obligated entity's control are both available, policy makers should confine the use of instruments outside an entity's control to situations where risks to quality control[113] (such as instruments breaking down) are minimized and where the use of third party instruments would provide a more reliable and accurate data source than using an entity's own measurement instruments. This decision depends on the regulator's confidence in the quality of the third-party supplier's measurement equipment.[114]

- Acceptable uncertainty levels relate to instruments in a specific reporting period or for a specific source stream. Where the activity data associated with a source stream is derived from multiple measurement instruments, a flow weighted uncertainty assessment[115] will be needed to demonstrate that the acceptable uncertainty for the individual source stream has not been exceeded during the reporting period.

5.4.2. Uncertainty in direct measurement-based methodologies

Uncertainty in direct emissions measurement is related to the determination of the gas concentration and the flue gas flow. **Uncertainty levels are generally prescribed in the carbon pricing instrument's rules or applicable measurement standards that are recognized by the carbon pricing instrument** (see appendix D, table D.3 for examples). These standards also state what requirements and specifications measurement systems must meet and how obligated entities can demonstrate that they do not exceed uncertainty levels. Consultation with relevant stakeholders such as metrological institutes and instrument manufacturers may be required in order to determine what levels of uncertainty are achievable and what can be reasonably included in rule making.

A tier approach can also be applied in direct measurement-based methodologies (explained in section 6.1). In that case, the uncertainty associated with tiers relates to the sources of different gases being emitted, so it may differ from one gas to another (for example CO_2 versus N_2O). The larger the quantity of emissions, the higher the tier, the lower the acceptable uncertainty level, and the more stringent the requirements are.

A key element in demonstrating compliance with uncertainty levels for direct measurement is that **obligated entities should perform regular tests on whether the measurement system is meeting specified requirements**. These are usually based on internationally recognized standards typically from the **United States or the EU** including US EPA - Procedure 1 on Quality Assurance Requirements for Gas Continuous Emissions Monitoring Systems Used for Compliance Determination and EN 14181 on Quality assurance of automated measuring systems.

Policy makers should include requirements for measurement systems in legislation or refer to specific measurement standards to ensure direct measurement is carried out properly and is sufficiently robust to generate accurate data. The need to specify standards is especially important where the system is retrofitted,

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111 Manufacturer specifications will define what environmental conditions are appropriate for a measurement instrument and how instruments should be installed and maintained.

112 This is the uncertainty assessment defined in the *Guide to the Expression of Uncertainty in Measurement,* http://www.bipm.org/en/publications/guides/gum.html.

113 That is, that there will be a breakdown in the control, management, and maintenance of the instrument that could compromise the quality of the data that it produces.

114 Such as if it is subject to national legal meteorological control and the necessary data can be retrieved from the owner of the measurement equipment in a sufficiently detailed and timely manner.

115 The final uncertainty is proportional to the uncertainty of individual meters adjusted for their individual flow through each meter as a percentage of the overall total flow.

as probes and other components may not be able to be placed in the ideal positions to meet the system manufacturers' specifications and stated achievable uncertainties.

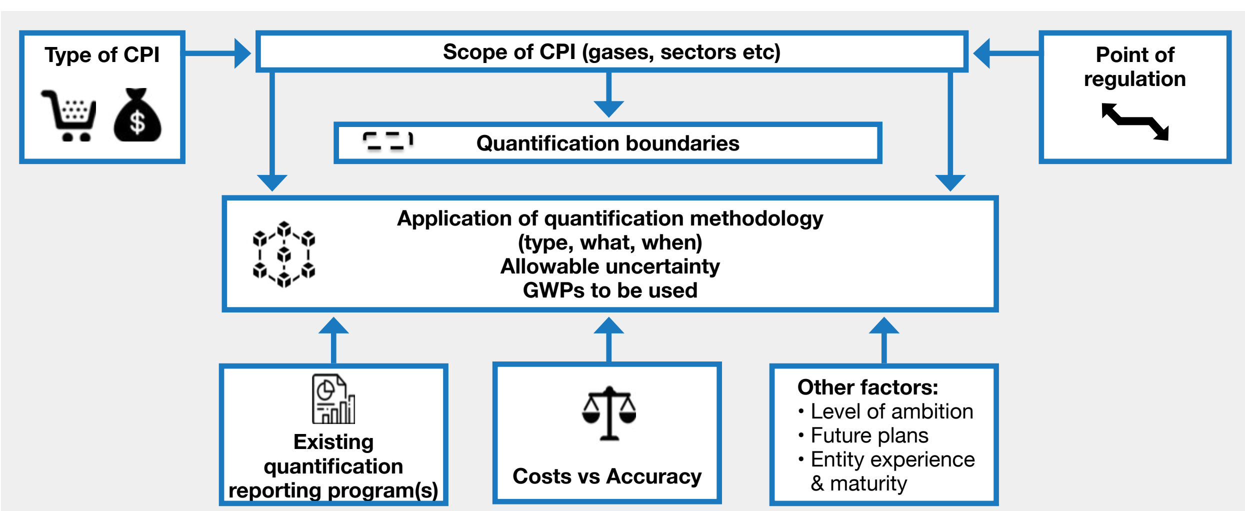
5.5. Selecting the Most Appropriate Quantification Methodologies

AT A GLANCE
A number of different factors determine which type of quantification methodologies you prescribe for obligated entities and under which conditions you should allow them to apply these methodologies. This chapter summarizes the key factors and outlines how these factors can influence the selection of the most appropriate methodologies. However, when considering which methodologies to prescribe, you should also be aware of the following points:

- Decisions on the scope of the carbon pricing instrument and its point of regulation will influence what is practicable, along with how ready entities in your jurisdiction are for robust emissions monitoring.
- It is not always possible to prescribe a specific quantification methodology as being appropriate in all cases as this choice is often context specific. The factors outlined in this chapter help you to narrow this choice down and provide an overview of when and under what conditions to allow a specific quantification methodology.
- Many details of quantification methodologies are context specific and depend on industrial sector and the operational conditions of the obligated entity that cannot be foreseen in legislation. So, in addition to quantification rules, it is important to consider legislative structures to approve methodologies as they are applied in individual situations (see section 7.3.2).
- Some elements of emissions determination apply across all or most sectors and obligated entities. Cross cutting elements include for example combustion, the tier approach (section 6.1), application of simplified approaches (sections 6.2 and 6.3), general aspects of calculation- or measurement-based methodologies such as quality assurance, sampling etc. (chapter 5), addressing data gaps and uncertainty (sections 5.3 and 5.4).

As outlined in step 2 (chapter 5), policy makers can make different choices in designing quantification protocols, including the type of methodologies to prescribe, when to apply different methodologies, and how to apply them. This chapter boils down the decision-making process for policy makers to key factors (questions) on for example scope, accuracy, and capacity. Figure 16 below shows how these factors are interrelated. For each of these factors, the implications that need to be considered for your quantification methodologies are outlined below.

FIGURE 16: Key Factors Impacting Design Choices for the Development of Quantification Methodologies



Source: SQ Consult

STEP 2: DEVELOPING THE METHODOLOGIES

Policy makers should consider the following questions to identify which type of methodologies are most appropriate for quantification of emissions in their carbon pricing instrument, and under what conditions methodologies should be applied:

- Factor 1: What is the type of carbon pricing instrument and point of regulation?
- Factor 2: Are Scope 2 emissions covered?
- Factor 3: What GHGS are covered by the carbon pricing instrument?
- Factor 4: What sectors/activities are included in the carbon pricing instrument?
- Factor 5: Will existing legislation or international standards be used for the design of quantification rules?
- Factor 6: What is the level of accuracy required for the carbon pricing instrument?
- Factor 7: What costs are involved in applying quantification methodologies at the operational level?
- Factor 8: What is the industry capability and maturity in the jurisdiction, and what are the available resources?

These factors are interrelated and can impact each other. Furthermore, future plans of a country can have an effect on how these factors influence the selection of the most appropriate methodologies. If there are plans to link with carbon pricing instruments from other countries, aligning or having compatible quantification rules may make future linking easier.

Factors 1 to 4 will give you a first indication on which quantification methodologies are most appropriate and under which conditions these must be applied. When there is a choice between calculation- and direct measurement-based methodologies factors 5 to 8 can give you further insight to guide your decision.

Factor 1: What is the type of carbon pricing instrument and the point of regulation?

- Policy makers should design the quantification methodology to reflect the scope of the carbon pricing instrument, as well as align it with any future plans for the CT or ETS (see chapter 5)
- If the carbon pricing instrument places the point of regulation upstream or midstream, quantification of emissions is relatively simple and a calculation-based methodology is the most appropriate methodology (see section 4.2.3).
- If the point of regulation is downstream, both calculation- and direct measurement-based methodologies can be applied.

Factor 2: Are Scope 2 emissions covered by the carbon pricing instrument??

- If Scope 2 indirect emissions are included, a calculation-based methodology should be applied to this element (see section 4.2.4).
- Direct emissions will be covered by all carbon pricing instruments and either a calculation- or direct measurement-based methodology can be applied, depending on the obligated entity's circumstances. Other factors then become relevant in selecting appropriate methodologies (see factors 3 to 8).

Factor 3: What GHGs are covered by the carbon pricing instrument?

- Some gases can be quantified using a range of approaches. For example, GHGs such as CO_2 from combustion can be determined using either calculation[116] or direct measurement methodologies.[117]
- Other gases have more limited options. For example, PFC must be quantified using sector specific approaches[118] while GHGs resulting from equipment leakage (such as SF_6 and HFCs) are generally quantified using a calculated mass balance approach (see table 5 in section 4.1.1).
- If N_2O is used, the most likely quantification methodology is direct measurement, although in some exceptional cases calculation can be applied (see section 4.1.1 and 4.1.2).
- This factor is closely linked to the type of sector and process activities involved.[119]

Factor 4: What sectors/activities are included in the carbon pricing instrument?

The sectors and process activities, and hence the gases, covered by the carbon pricing instrument affect the selection of quantification methodologies by policy makers, including:

- The choice between calculation-based and direct measurement-based methodologies (see sections 5.1 and 5.2). Table 5 in section 4.1.1 shows how the sector/activity together with the gas covered by the carbon pricing instrument can impact the selection of the quantification methodology.
- When to apply the standard calculation or the mass balance calculation approach (see section 5.1).
- Whether to apply a tier approach to allow flexibility over the accuracy required and the methodology to be used (see section 6.1).

For sectors and entities that undertake multiple activities, a combination of different approaches may be required (see section 4.1); and for certain sector activities, a mass balance is more likely to be appropriate than a standard calculation-based methodology (see section 5.1.2), particularly where:

- Levels of, and changes in, GHG emissions cannot be directly measured.
- Output emissions cannot be connected to individual input materials (such as in some chemical processes).
- Carbon is not released as CO_2 but is incorporated in the final product, such as steel.
- Entity processes produce bulk organic chemicals, hydrogen and synthesis gas, soda ash and refined petroleum.

Trade associations and other industry bodies can help policy makers identify different calculation approaches for activities in their sectors as many have identified industry best practices that can be adopted or adapted.

116 A calculation methodology for CO_2, CH_4 and N_2O might include measurement of the fuel input (activity data); application of a default or facility-specific emissions factor for CO_2; and a default factor for the tiny proportion of CH_4 and N_2O in the flue gas from combustion.
117 If there is appropriate instrumentation in the flue stack to analyze the three output GHGs.
118 For example, aluminium processes needs a calculation methodology while magnesium casting processes may be able to use direct measurement, depending on operational configuration.
119 *IPCC 2006* volume 3, chapter 1 provides an indicative table of sector processes and potential gases associated with them, available at https://www.ipcc-nggip.iges.or.jp/public/2006gl/vol3.html.

Factor 5: Will existing legislation or international standards be used to design quantification rules?

- If existing quantification and reporting legislation is used, this can have an impact on the rules for quantification methodologies for the carbon pricing instrument (see section 3.4.1).
- If quantification methodologies and rules from international standards are used as a basis for quantification in the carbon pricing instrument, this can have an impact on the selection of the most appropriate methodology (see section 3.4.3).

Factor 6: What is the level of accuracy required for the carbon pricing instrument?

- The level of accuracy required is closely linked to the level of ambition and environmental targets of the carbon pricing instrument.
- Level of accuracy can influence the type of quantification methodology, the type of associated quality assurance and the conditions under which quantification methodologies are applied. The higher the level of accuracy, the more robust quantification methodologies are needed.
- A tier approach can be applied to give flexibility over the acceptable accuracy for different obligated entities, emission sources and source streams (see section 6.1).

Factor 7: What costs are involved in applying quantification methodologies at operational level?

- This factor is closely linked to factors 6 and 8. The higher the costs, the more resources and technical capability are needed to apply quantification methodologies. This can influence the selection process (see chapters 5 and 6).
- In general, the costs of applying CEMS or PEMS are higher than applying calculation-based methodologies, in particular if facilities are not already fitted with an appropriate CEMS or PEMS instruments.
- It is important to have a good overview of the costs involved; early stakeholder involvement and cost studies can facilitate the decision-making process.

Factor 8: What is industry capability and maturity in the jurisdiction, and what are the available resources?

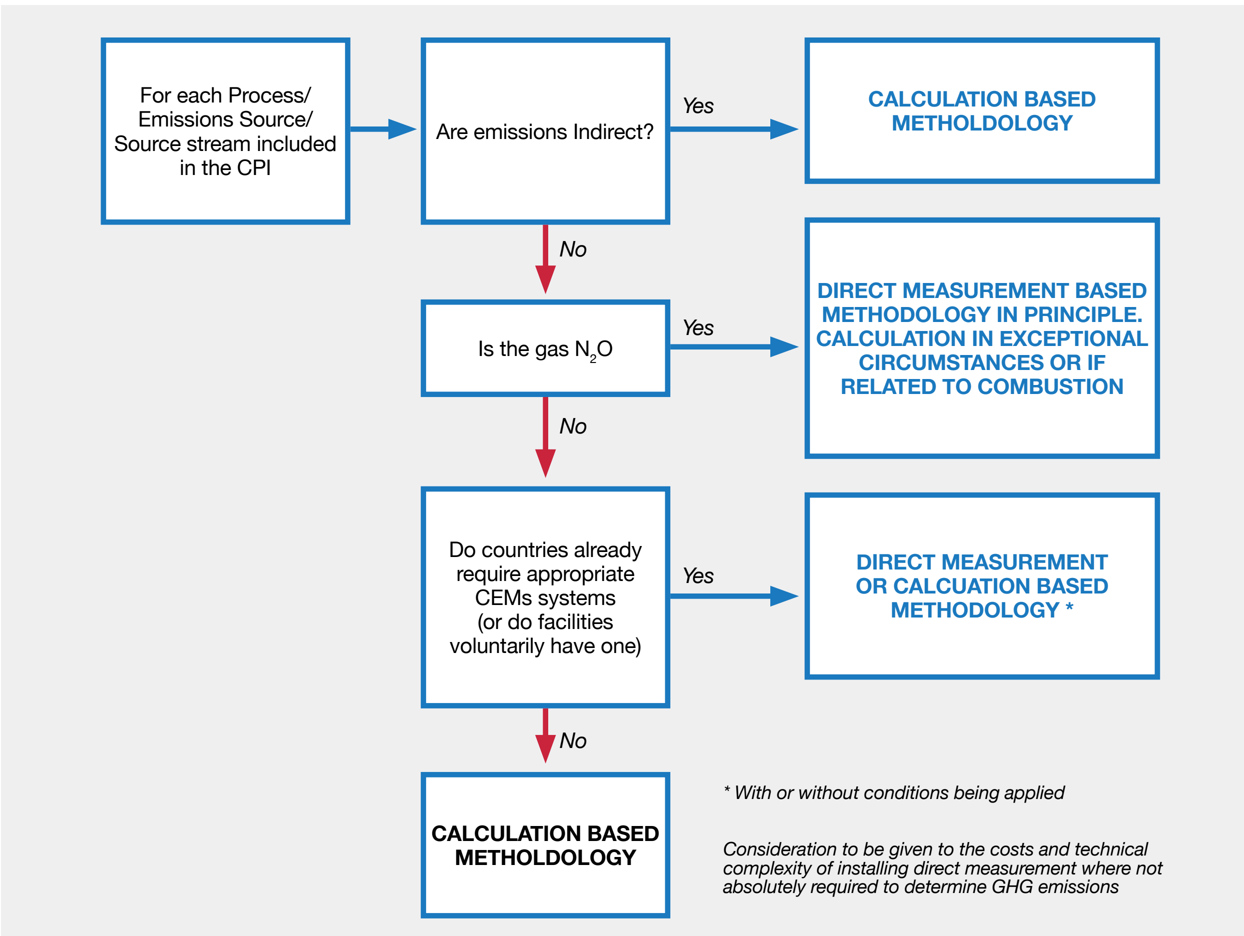
- The more mature and experienced obligated entities are in quantifying emissions, the more prepared they will be for implementing methodologies, and so the more robust quantification methodologies can be at the start (regardless of whether a methodology is simple or complex). Industry capability and maturity can also be a factor determining how fast a quantification protocol can evolve over time and whether elements such as tiers and simplifications need to be applied.[120]
- If facilities are not fitted with CEMS or PEMS (either when constructed or retrofitted) and industry is not technically prepared to do direct measurement, it is not recommended to require obligated entities to apply these methodologies unless there is no other choice. Policy makers should consider either not allowing the application of CEMS or only allowing it only under specific conditions (such as demonstration that the data are more accurate than from a calculation).

120 Industry capability and maturity can vary between emerging, developing, and developed economies as well as between international and local companies. For example, entities in developing countries may not have the resources or capability to install CEMs

- Constrained resources in a country can limit the operation of more advanced quantification protocols, especially if these are contingent on specific technical requirements. A balance is needed between the level of accuracy required and the effort needed to achieve that level.

Figure 17 provides an example of an indicative decision tree; because of the scale of potential activities included within carbon pricing instruments and the contextual issues associated with implementation on the ground this figure cannot cover methodologies for all possible contexts.

FIGURE 17: Indicative Decision Tree to Support Choices on Quantification Methodologies



Source: SQ Consult

6. Step 3: Managing the Costs of Compliance

AT A GLANCE
Emissions quantification protocols are a balancing act between accuracy and cost of compliance. This chapter gives guidance on how you can manage this trade off, including through tiered and simplified approaches to quantification. Simpler approaches for smaller emitters and/or emission sources have been implemented in several jurisdictions with a carbon price. However, you need to ensure that environmental integrity is not compromised as a result.

- Designing quantification protocols is a balance between ensuring the highest possible level of data accuracy while also avoiding unreasonable costs on the obligated entities.
- A tiered approach can assist in balancing these two objectives of accuracy and cost.
- Other cost-management elements can be considered, such as simplified approaches for smaller entities or smaller emission sources.
- Offering simplified approaches risks compromising the integrity of the quantification protocol. Such approaches need to be carefully considered and well-defined to limit any potential legal loopholes that allow non-targeted entities or sources to use them.
- As with other aspects of quantification, continued availability of, and eligibility to, simplified approaches needs to be regularly reviewed.

The quantification protocol should, in principle, aim to ensure quantified emissions are as accurate as possible. However, the most accurate method of quantification may not be technically feasible (for example, measurement instruments cannot be installed) and/or may impose unreasonable costs. **When designing quantification methodologies, therefore, policy makers need to be aware of the trade-off between accuracy and the cost of compliance**[121]. Several measures can be taken to ensure that costs of quantification and the need for accurate data are reasonably balanced. This chapter outlines three options to minimize the costs imposed on obligated entities:

1. Apply a tiered approach in which different levels of acceptable uncertainty in emissions accuracy represent different tiers of stringency in requirements (see section 6.1).

2. Apply a simplified approach to smaller facilities or organizations. Eligibility can be established by setting different thresholds, for example, in terms of operational capacity or annual emissions (see section 6.2). A tiered approach (option 1 above) can be applied in combination with a simplified approach for smaller emitters, as is done in the EU ETS.

Apply a simplified approach to smaller emission sources and source streams. This approach can allow entities to exclude or use simplified approaches for immaterial emission sources and source streams (see section 6.3).

Other ways of reducing costs related to quantification for obligated entities include the development of tools, templates, and guidance, all of which are discussed in section 7.3. In addition, regular reviews of quantification

121 Going forwards digital technology and software may make it easier to generate accurate data; however, installing equipment such as higher accuracy meters, analysers and CEMS may still impose significant costs on obligated entities.

methodologies can determine whether methodologies work in practice or whether revision may be needed to control costs or to facilitate implementation (see chapter 8 on reviewing the protocol).

6.1. Tiered Approach

A tiered approach represents a **hierarchy of requirements, stringency, and accuracy when it comes to quantifying and reporting data**. This is the approach taken by IPCC 2006, which gives guidance to countries developing national inventories and which has been adapted by different carbon pricing instruments to suit a more bottom-up approach. Tiers establish a transparent framework that can help ensure the burden of emissions quantification is proportionate to, for instance, the size of the obligated entity or the scale of its emissions from different source streams. IPCC 2006 (and the 2019 Refinement) identifies three tiers. Some jurisdictions (such as California and the EU) have a more nuanced approach, identifying four tiers for activity data measurement[122] and three tiers for other parameters (see figure 18). An example of a three-tiered (less nuanced) system[123] could comprise the following:

- **Tier 1** encompasses the most basic quantification methods with the least stringent requirements. Methods in this tier often use IPCC default emission factors and require lesser accuracy in the determination of activity data; where estimates are used, these may be classified as No Tier by some carbon pricing instruments. As a result, these methods are generally less accurate but also less costly to implement than methods in higher order tiers.
- **Tier 2** includes methods with intermediate complexity. Methods in this tier tend to use more activity and technology specific inputs than Tier 1 – for example, specifying acceptable levels of uncertainty for measurement of activity data in different sector activities/source streams. Default calculation factors[124] may be used where it is not possible or where it is too costly to determine facility-specific characteristics of fuels/materials, but the values will generally be country-specific factors based on data from UNFCCC inventory reports.
- **Tier 3** represents the most accurate methods and includes those that require more complex (and potentially expensive) quantification and data control requirements. Building on the approach in Tier 2, these methods generally involve facility-specific measurement of activity data and development of source-specific calculation factors. Where instruments are used for measurement, higher tiers generally involve lower acceptable levels of uncertainty for measurement equipment and are considered to be more accurate. For carbon pricing instruments that specify more than three tiers, the differentiation is generally in a greater gradation in the maximum uncertainty allowed for instruments.

Where higher Tiers are selected that require facility-specific data, robust ex post verification provisions will help to ensure that data used by obligated entities are reliable.

Tiers are not static, and policy makers can also specify conditions or time periods that encourage obligated entities to move up the tier hierarchy to apply more accurate and stringent quantification approaches. In the EU ETS, for instance, the largest facilities may deviate from the highest tier only if they can demonstrate it would not be technically feasible or would create unreasonable costs for them to use the highest tier. Should these

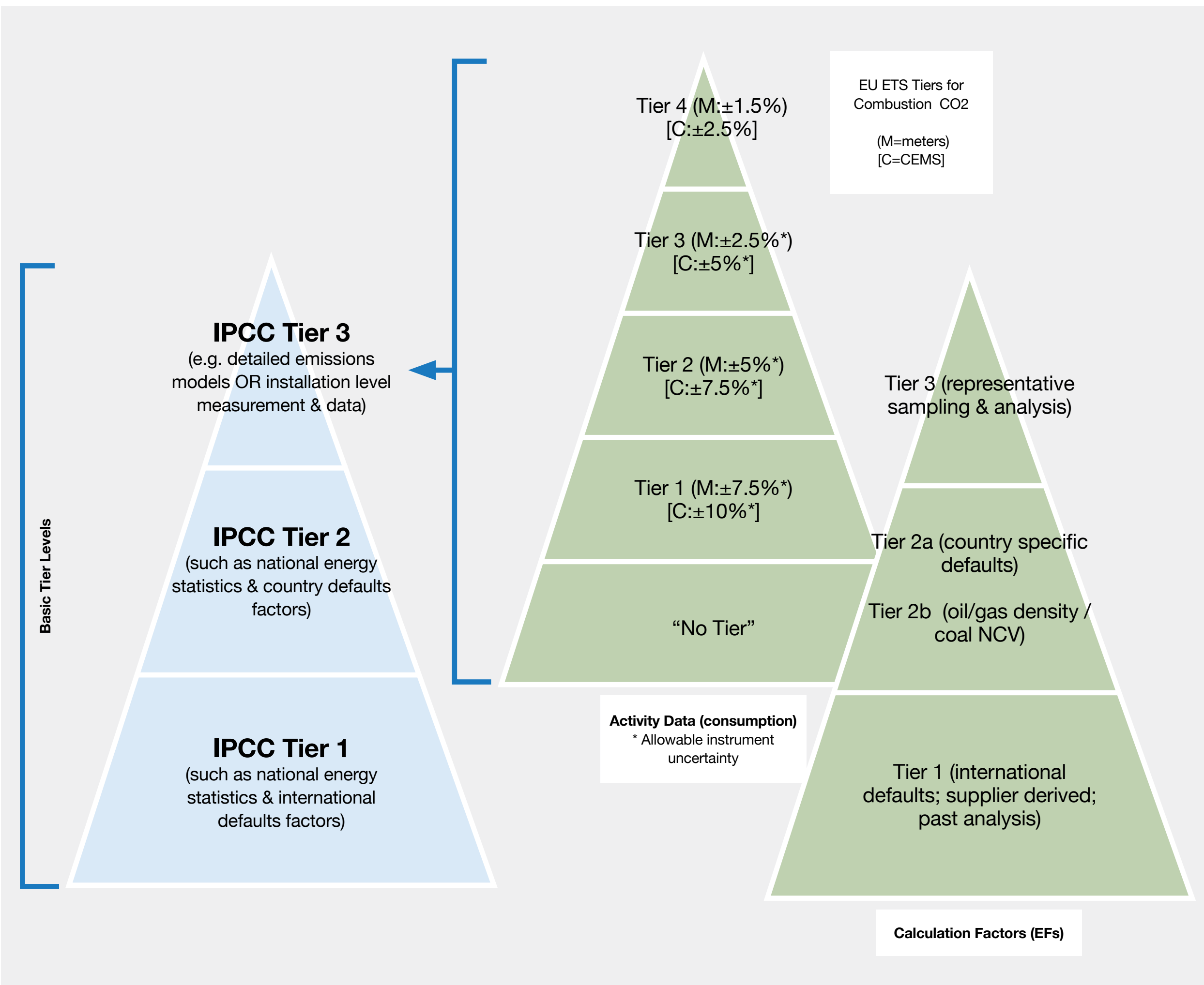
122 For the EU, different acceptable uncertainty is assigned to specific tiers; these values can be different for meters and CEMs at the same tier (see figure 16).
123 This less nuanced tier system reflects the IPCC2006 tier approach. In some carbon pricing instruments this has been more fined tuned (see table 9).
124 Calorific value, emission factor, biomass fraction, carbon content, depending on the applicable parameter.

conditions not apply, then action must be taken to improve the accuracy of the quantification approach and the obligated entity must update its monitoring plan. Over time, there has been a trend in the EU of facilities gradually moving to the highest applicable tier. Section 8.1 discusses the process for encouraging use of more accurate methods over time.

A tier is applied to the parameter (such as consumption of fuel, emission factor, calorific value, and the like) of each source stream in a calculation-based methodology and to each emission source in the measurement-based methodology.

While the IPCC's tiered approach can be adopted and/or modified for domestic carbon pricing instrument application, there is a need to ensure the domestic application is fit-for-purpose. IPCC 2006 tiers are designed for reporting national inventories and are applicable to a broad set of sectors and activities. Accordingly, implementing them for a bottom-up domestic carbon pricing instrument requires a more fine-tuned approach such as that shown for the EU ETS in figure 18.

FIGURE 18: Example of Tiers Associated with Determination of Emissions from Fuel Combustion



Source: SQ Consult, © 2018

Other jurisdictions have adopted different approaches to using tiers, as outlined in table 9.

TABLE 9: Examples of Different Approaches to Using Tiers

Approach	Country example
IPPC 2006	**South African carbon tax:** the IPCC 2006 tier approach is applied because the carbon tax methodology is based on national regulation that aims to collect data for the national inventory.
Expanded	**Alberta** (Canada): has adopted a tiered approach for its quantification methods based on specified gases and emission source types/activities rather than on acceptable uncertainties for measurement and the like. **Singapore carbon tax:** expands the IPPC Tier 3 approach by specifying options for: – Facility-specific measurement of activity data ranging from engineering estimates (lowest accuracy), use of invoices, to measurement instruments meeting specific standards (highest accuracy). – Conversion factors ranging from defaults values (lowest frequency) to representative analysis (highest frequencies) for facility-specific conversion factors. **USA Federal GHG reporting:** under 40 CFR 98 expands the approach to four tiers for general stationary combustion,[125] with quantification ranging from the use of billing and internal records (Tier 1) through metered mass flow (Tier 2) to CEMS (Tier 4). Each of those approaches has associated approaches to sampling related to calculation factors.
Fine-tuned	**California ETS:** for stationary combustion further, fine-tuned tiers are applied in relation to factors: – Tier 1: default calorific value (CV) and emission factors – Tier 2: default emission factors and measured CV – Tier 3: measured carbon content to generate an emissions estimate – Tier 4: continuous emissions monitoring system Restrictions on tiers used are applied in relation to fuel types and size of units. For activity data, all instruments are to be selected, installed, operated, and maintained in a manner to ensure an accuracy within ±5 percent; in accordance with OEM[126] or 40 CFR §98.3(i)(2)-(3) legal requirements. In addition, specific requirements are in place for pressure differential device inspection and the nature and frequency of checks on temperature and pressure devices. **EU ETS:** also fine tunes its approach by applying four tiers for activity data: the higher the tier, the lower the level of quantitative uncertainty allowed in measuring activity data (see figure 18). For calculation factors, the lower tiers - Tier 1 and Tier 2 - allow application of default values, whereas Tier 3 requires facility specific sampling and analysis to derive factors. The applicable sector, activity carried out, and the size of the source stream determine which tier must be applied. For direct emissions measurement different tiers can be applied depending on the size of the emissions source. The higher the tier the lower the uncertainty level required. Further fine tuning is applied by size category of installation (see example in figure 19). Large installations have to meet the highest tier whereas small installations can meet lower tiers under conditions. More information on tiers can be found in MRR Guidance Documents on EU ETS monitoring and reporting.[127]

There are several elements policy makers need to consider when developing a tiered approach. These include:

- How to apply the tiers, such as whether to apply them separately to each source stream activity data and calculation factor and to each emission source for direct measurement methodologies.
- What parameters will be subject to tiers. For example, entity size (see section 6.2) or size of a specific emission source for direct measurement or source stream for calculation (see section 6.3).
- The number of tiers, which can differ for activity data and for calculation factors.
- What are acceptable uncertainty levels for each applicable tier for activity data in the case of a calculation-based methodology or for measuring equipment in the case of direct measurement-based methodologies.

125 "Calculating GHG Emissions," (Cornell Law School Legal Information Institute), https://www.law.cornell.edu/cfr/text/40/98.33.
126 Original Equipment Manufacturer
127 *EU ETS MRR Guidance Document I: The Monitoring and Reporting Regulation – General Guidance for Installations* at https://ec.europa.eu/clima/sites/clima/files/ets/monitoring/docs/gd1_guidance_installations_en.pdf.

- Approved methods for determining calculation factors used in calculation-based methodologies.

- Whether obligated entities should be required to achieve the highest tier and the conditions under which obligated entities transition to higher tiers, to improve the accuracy of emissions measurement over time (see section 8.1 for more information).

- Whether deviations from a tier are allowed. Good practice suggests that deviation from approved tiers should be allowed only in very specific circumstances, such as proven temporary inability to apply the tier, unreasonable costs, or technical infeasibility.[128] In these instances, the rules should define unreasonable costs and technical infeasibility. Sector-specific and/or country-specific guidance may be needed on how unreasonable cost or technical infeasibility can be assessed.

- Any situations when no tier approaches apply (for example, where a basic estimation is allowed). This approach may be the case for very small source streams (see discussion on de minimis in section 6.3) or in situations when it is not possible for an obligated entity to meet even the lowest tier specified. The latter situation can occur, for example, at the start of a carbon pricing instrument when obligated entities have to get accustomed to new rules and may need to make technical changes to meet new requirements.

6.2. Simplified Approach for Smaller Emitters

Establishing categories of emitters with different reporting requirements can ensure that only larger, more sophisticated emitters are required to use the most stringent methodologies for emissions quantification. These larger emitters have the capacity and capabilities to comply with more stringent, and potentially more costly, requirements. Less stringent requirements apply to smaller and/or simpler obligated entities, which would reduce their administrative burden. A similar approach can be taken for smaller source streams or emission sources within a facility (see section 6.3).

Implementing such simplification measures requires the following steps:

1. Determine categories and the corresponding thresholds to apply.
2. Determine the quantification approach for each category.
3. Decide on any additional rules to apply.

For step 1, policy makers can use criteria like the entity's annual emissions levels, capacity, or production. Information on the number of entities and total emissions covered by each category and how these would change by altering the thresholds can help policy makers decide where category boundaries are set.[129] Other information, like administrative cost estimates for different types of obligated entities, might help policy makers decide what threshold to apply. That said, defining categories of obligated entities does not have to be a complicated exercise. Policy makers can implement very simple approaches that make a distinction for only small-scale entities; for example, in situations where the only emissions arising for an obligated entity are a very small amount from high capacity[130] backup generation where, say, a threshold of <1000tCO_2e could be applied.

128 The EU ETS Tier approach is an example of this. For more information, please see the E*U ETS MRR Guidance Document I: The Monitoring and Reporting Regulation – General Guidance for Installations* at https://ec.europa.eu/clima/sites/clima/files/ets/monitoring/docs/gd1_guidance_installations_en.pdf.

129 For example, if 25 percent of the smallest obligated entities produced less than 10 percent of the total emissions under a carbon pricing instrument, it would be reasonable to consider them as low emitters and set a threshold in such a way as to enable them to apply less stringent quantification approaches.

130 For example, a facility may be included in a carbon pricing instrument on the basis of the **capacity** of its back-up generators but these generators normally only run during testing which results in very low emissions levels.

Under step 2, policy makers have flexibility on how to determine the different quantification approaches for each category. **Usually small and/or simple obligated entities will be subject to simpler and less stringent quantification requirements.** For instance, they may be allowed to use estimations, default values for calculation factors, or invoices for determining fuel consumption, whereas **more stringent requirements for larger obligated entities** might include sampling and analysis to create facility-specific calculation factors and measurement of fuel/materials consumption according to specific uncertainty levels. A relatively straight forward way of differentiating between categories is to use the tiered approach outlined in section 6.1 where the smaller emitters can apply lower tiers or have derogations from normal rules, as is outlined in figure 19.

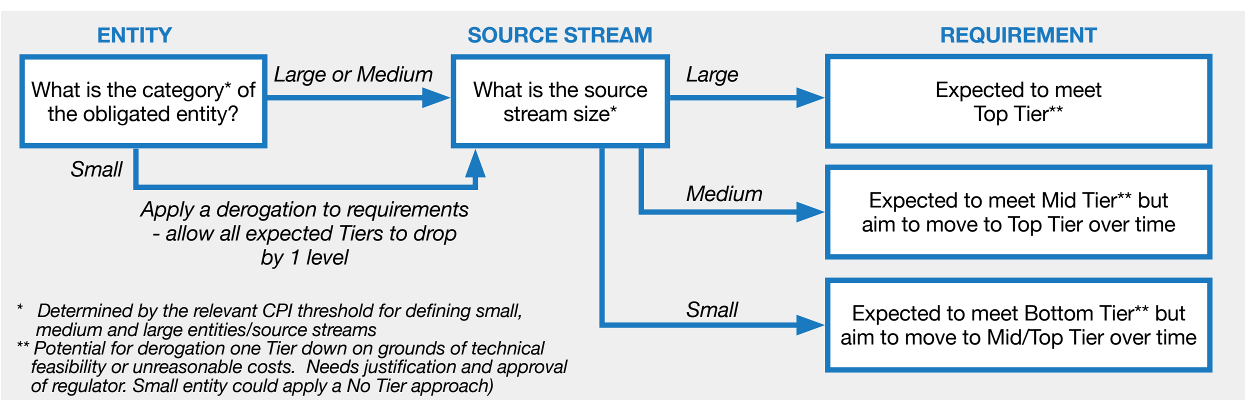
Finally, in step 3, policy makers may want to impose additional rules on different categories, such as exempting small entities from preparing and submitting certain documents or allowing small entities to use simplified reporting templates.

When implementing these types of measures, policy makers should consider the following:

- **Define in the rules the consequences for a change in category**. An obligated entity may be initially defined as a small emitter with streamlined quantification requirements. However, it is possible that an entity may later exceed the predetermined threshold to be classified as small. The consequence of exceeding such thresholds (temporarily or permanently) should be stated. Generally, if an entity can demonstrate the change is temporary, they may be able to stay in their existing category.[131]
- **Inclusion of mandatory notification requirements**. Regulators need sufficient information to know when an obligated entity moves into a different category (for example, due to an increase in its production and/or emissions level). Specific requirements for entities to notify the regulator in a timely way of its changed circumstances may be useful.
- **Assess correlation between emitter size and the risk of data error**. Policy makers need to have confidence that there is no correlation between entity size and the risk of data error when allowing simplified rules for smaller entities. For smaller entities, policy makers have generally chosen to institute an approach to tiers that allows derogations from specified rules under certain circumstances (see section 6.1). However, smaller obligated entities may have a higher risk of data error, especially if the data flow is complex, the internal control system is weak, or they have few resources to dedicate to regular emissions reporting.

Figure 19 below illustrates how thresholds and tiers can be combined.

FIGURE 19: Example of How Thresholds and Tiers Can Be Combined



Source: SQ Consult, © 2018 as adapted

131 For example, this can occur if the threshold is exceeded only once and the obligated entity can prove that this threshold has not been exceeded in previous years and will not be exceeded in the coming years. Such an approach is adopted in the EU ETS.

6.3. Simplified Approach for Small Emission Sources & Source Streams

To help reduce the cost of quantification, policy makers can consider alternative approaches for small emission sources and source streams. Policy makers could consider allowing obligated entities to exclude specified small or very small emission sources or source streams from the entity's overall data set (see section 4.1). However, exclusion can be complex in practice because an entity would need, for example, to demonstrate that a specific emission source meets a definition of "small." Such a demonstration would likely require a similar level of effort to quantifying emissions using a standard calculation approach. Excluding sources can also affect the uncertainty associated with quantifying emissions of other sources that remain included. Furthermore, exclusions of emission sources would mean an entity is not reporting a complete dataset, which is contrary to the completeness principle.

An alternative and better way of approaching this issue is to require the inclusion of all emission sources and source streams falling under the scope of the carbon pricing instrument, but that simpler quantification approaches can be used for small or very small emission sources or source streams. In this way, less stringent calculation-based quantification methodologies, such as using a justifiable estimate rather than measured parameters, could be used to minimize the costs of emissions quantification for very small source streams; for carbon pricing instruments that use a tier approach, such estimates may be referred to as No Tier approaches since they do not meet the acceptable uncertainty associated with the lowest tier.

GHG reporting programs often refer to these very small sources and source streams as de minimis or incidental. This approach can be particularly useful for sources and source streams with data or records that are difficult to obtain. If simplified approaches are adopted, rules need to be clear and sufficiently restrictive to avoid the introduction of potential loopholes that can exploited.

When implementing these types of measures, policy makers should consider the following:

- **Small or very small source streams or sources should be clearly defined**, such as through the use of thresholds. Thresholds can be set on an absolute basis (such as 1000tCO_2e per annum), on a percentage basis (such as 2 percent of a facility's emissions), or a combination of both.
- It should be **clear to obligated entities how they can demonstrate that an emission source or source stream is very small,** and what alternative quantification approaches can be applied.
- It should also be **clear what will happen if the threshold for a very small source stream or source is exceeded**.

Several carbon pricing instruments use the types of measures outlined above to balance costs in an objective and consistent manner across sectors.[132] The carbon pricing instruments that use this approach usually **distinguish between very small, minor, and major source streams or sources** (see box 10).

132 EU ETS, Swiss ETS, California ETS, US RGGI.

BOX 10. Example of Carbon Pricing Instruments Applying Source Classification Approaches for Simplification:

California- De minimis sources represent ≤3 percent of a facility's total CO_2e emissions (including emissions from biomass derived fuels and feedstocks), not exceeding 20kt of CO_2e per calendar year. For these de minimis sources, the obligated entity operator may estimate emissions and is not subject to the 5 percent accuracy requirements.

The EU distinguishes between de minimis, minor, and major source streams. **De minimis source streams** are source streams that jointly amount to less than 1kt of fossil CO_2 or to less than 2 percent up to a maximum of 20kt/year of fossil CO_2, whichever is the higher in terms of absolute value. **Minor source streams** are defined as source streams that jointly amount to less than 5kt of fossil CO_2 or to less than 10 percent of total entity emissions up to a maximum of 100kt/year of fossil CO_2, whichever is the higher in terms of absolute value. **Major source streams** are all other source streams.

For de minimis source streams, tier approaches are not required (conservative estimation methods may be used). For minor source streams, a tier approach is required but lower tiers can be applied.

Singapore – Defines three types of emissions in its Act:

- Reckonable emissions that are reportable, count toward emissions thresholds, and are liable for the carbon tax
- Non-reckonable emissions that are ancillary to the facility's main business activity - such as fugitive emissions - and are reportable, do not count toward emissions thresholds and are not liable for the carbon tax
- Excluded emissions not covered in the carbon tax sectors such as transport, agriculture, and the like and that do not need to be reported nor count toward emissions thresholds

7. Step 4: Promoting Successful Implementation and Compliance

AT A GLANCE
Once you have designed your quantification protocol, it will be applied by the obligated entities. This chapter outlines a few strategies to help obligated entities correctly and consistently apply the protocol. Early and clear communication about what will be required can facilitate compliance. In addition, a list of possible tools and resources your jurisdiction can develop are also outlined.

- Communicate early with regulators and other stakeholders on the human resource and technical requirements.
- Guidance documents, tools, and IT systems can make compliance easier, minimize error and ensure consistency across facilities and sectors.
- Engage with stakeholders to gather information on an ongoing basis to evaluate compliance with the quantification protocol and identify potential weaknesses to be addressed.

This chapter looks at additional steps policy makers can take to ensure quantification methodologies are applied correctly and consistently across different sectors and obligated entities. Clear and early communication on the human and financial resources, and technical requirements, for all stakeholders will give all parties sufficient time to plan for the introduction of quantification and reporting requirements. Organizing capacity building activities, including online activities and materials, can also help fill any knowledge gaps. In addition, guidance documents, tools, and IT systems can provide clarity on how to implement and enforce the quantification protocol. Policy makers can draw from and adapt existing tools and guidance from international bodies and/or other carbon pricing instruments. Not only will these promote successful application of quantification methodologies, but they can also improve administrative efficiency and lower costs for obligated entities.

7.1. Communicate Resource Requirements

During the design stage, it is important that stakeholders are aware of the human resource and technical capacity needed to set up, implement, and manage the rules and guidance on quantification. Policy makers may also want to consider involving external experts to assist with certain stages of the design process. For instance, industry sector experts may highlight sector-specific challenges or concerns, while experts from meteorological institutes may provide input on uncertainty assessments for measurement instruments.

Section 3 of the PMR MRV Guide contains more guidance on capacity building and associated administrative costs. To help stakeholders prepare, it is important that policy makers ensure that all stakeholders are aware of their respective resource requirements. Table 10 gives examples of the type of costs that can occur in designing and implementing quantification protocols (for more see appendix K).

TABLE 10: Costs for Stakeholders in Designing and Implementing Quantification Protocols

Stakeholder	One-off cost	Recurring costs
Policy makers	– Setup of legislation – Studies/data to facilitate design of the quantification, monitoring, reporting and verification system, including potential impact/cost assessments – Establishing new or restructuring existing institutions to meet the needs of the carbon pricing instrument	– Protocol reviews, updates of quantification protocol, and the like – Consultation costs – Internal capacity building
Regulators	– Stakeholder engagement activities (such as staff, travel, or venues) – Internal capacity building – Development of guidance materials and tools – Setup of templates or IT systems, if relevant – Setting up a helpdesk – Approval processes for verifiers (if done by regulators)	– Approving methodologies and monitoring plans (if required) – Checking compliance of obligated entities (such as inspection and enforcement) – Staff for communication with obligated entities – Capacity building of obligated entities – Updating/enhancement of guidance documents and tools – Maintenance of IT systems – Staff for helpdesk (if applicable) – Costs for review of emissions reports and follow-up
Obligated entities	– Stakeholder engagement during design of the protocol – Set-up of M&R quantification processes, such as data management system, quality assurance, and procedures – New or upgraded measurement instruments or other systems needed for quantification, such as laboratories – Set-up of IT systems – Increased staffing to operate quantification and other monitoring requirements, if necessary	– Ongoing training of personnel & capacity building – Drafting of monitoring plans, if applicable – Operation of quantification M&R, including data corrections and updates to plans or methodologies, if applicable – Maintenance of data management system to record and retain appropriate data – Calibration/maintenance of instruments – Sampling & analysis of fuels and materials – Validation/quality assurance of CEMS.[133] – Commissioning internal/external M&R audits – Subcontracting of technical support for implementation and operation of MRV
Auditors/verifiers	– Costs for stakeholder engagement during design of protocol and the like – Staff training to understand rules – Increased staffing to conduct entity's internal/external M&R audits – Accreditation to ISO14065 or other carbon pricing instrument approval mechanism, if required	– Ongoing training requirements – Subcontracting of technical support – Maintenance of accredited/approved status
Laboratories	– Accreditation to ISO17025, if required	– Maintenance of accredited status

133 If not already covered under existing legal obligations.

There will also be costs and requirements for verification and auditors/verifiers. If this is the approach decided upon by countries, information on this topic can be found in the PMR A&V Guide.

7.2. Build Capacity

Section 3 of the PMR MRV Guide outlines the type of capacity building (institutional, human resources, and technical) required for policy makers, regulators, and obligated entities to design and run a robust MRV system. Regulators are advised to define the responsibilities and competencies that will be required by people managing the quantification and reporting of GHG emissions. Defined responsibilities and competencies can give an indication of the kind of capacity building that may be needed to manage and implement a quantification protocol. Until people are adequately trained, other experts or consultants may be a useful additional resource, provided there is sufficient oversight and management. Policy makers may also want to provide training or other forms of capacity building to obligated entities as well as government staff. Such training should be organized well before the quantification and reporting cycles begin and focus on practical implementation issues. Webinars and training handbooks, including case studies, can be developed to supplement in-person training.

7.3. Develop an Implementation Tool Box

Nearly all reporting mechanisms and carbon pricing instruments have developed tools that facilitate implementation of the associated quantification protocol. These can help promote a common understanding of the rules and ensure their consistent interpretation and application. These tools include guidance documents, templates, and IT systems. It is essential that tools and documents are updated to keep up with any changes in CT or ETS rules or the quantification protocol (see chapter 8 for more on the review and refinement process).

7.3.1. Guidance

Implementation guidance explains rules further and may outline how to quantify and report emissions, for instance, by providing more detailed instructions on calculation and conversion factors. These can take a multitude of forms - from online FAQs that respond to common questions or issues raised by stakeholders to supplementary guidance documents that may present examples on how the regulations are to be applied. Some countries, like California and individual EU member states, have also set up a helpdesk explicitly dedicated to GHG reporting issues to address questions that are not easily captured in FAQs. Brochures, primers, and presentations have been developed by a number of carbon pricing instruments[134] and international organizations, including supporting material for IPCC 2006,[135] the GHG Protocol,[136] and the European Commission for EU ETS monitoring and reporting.[137]

134 For information about the California ETS, see https://ww3.arb.ca.gov/cc/capandtrade/capandtrade.html.
135 Supporting material from IPCC is aavailable at https://www.ipcc-nggip.iges.or.jp/support/support.html.
136 For Greenhouse Gas Protocol Guidance, see http://ghgprotocol.org/guidance-0.
137 For supporting information from the EU ETS see https://ec.europa.eu/clima/policies/ets/monitoring_en#tab-0-1.

7.3.2. Monitoring Plans

Monitoring plans can improve the consistency and quality of quantification and the resulting reported data: plans are used to tailor rules to a specific obligated entity and outline how specific quantification rules are being applied at the individual obligated entity level. Such plans need to be well designed, properly structured, and transparent. Such plans will allow staff of the obligated entity as well as other relevant parties to understand how the obligated entity is configured and what its emission sources are, which fuels and materials are used, and what quantification methodology and QA/QC is applied. In ETSs and some downstream carbon tax systems, monitoring plans are often prescribed and generally require pre-approval by the regulator. In some cases, other mechanisms are used that are similar to approved monitoring plans. Box 11 provides some examples.

BOX 11. Examples of Structures for Approval

The EU – Quantification rules are included in the Monitoring and Reporting Regulation. In addition, operators of installations are required to obtain regulator approval of a mandatory monitoring plan detailing emission sources, source streams, measurement equipment, applicable quantification methodologies, quality assurance measures, and procedure summaries. The EC developed a monitoring plan template. MRR Guidance Document 1 on monitoring and reporting provides more information; the guidance and associated templates can be found on the European Commission's EU Climate Action website (https://ec.europa.eu/clima/policies/ets/monitoring_en#tab-0-1).

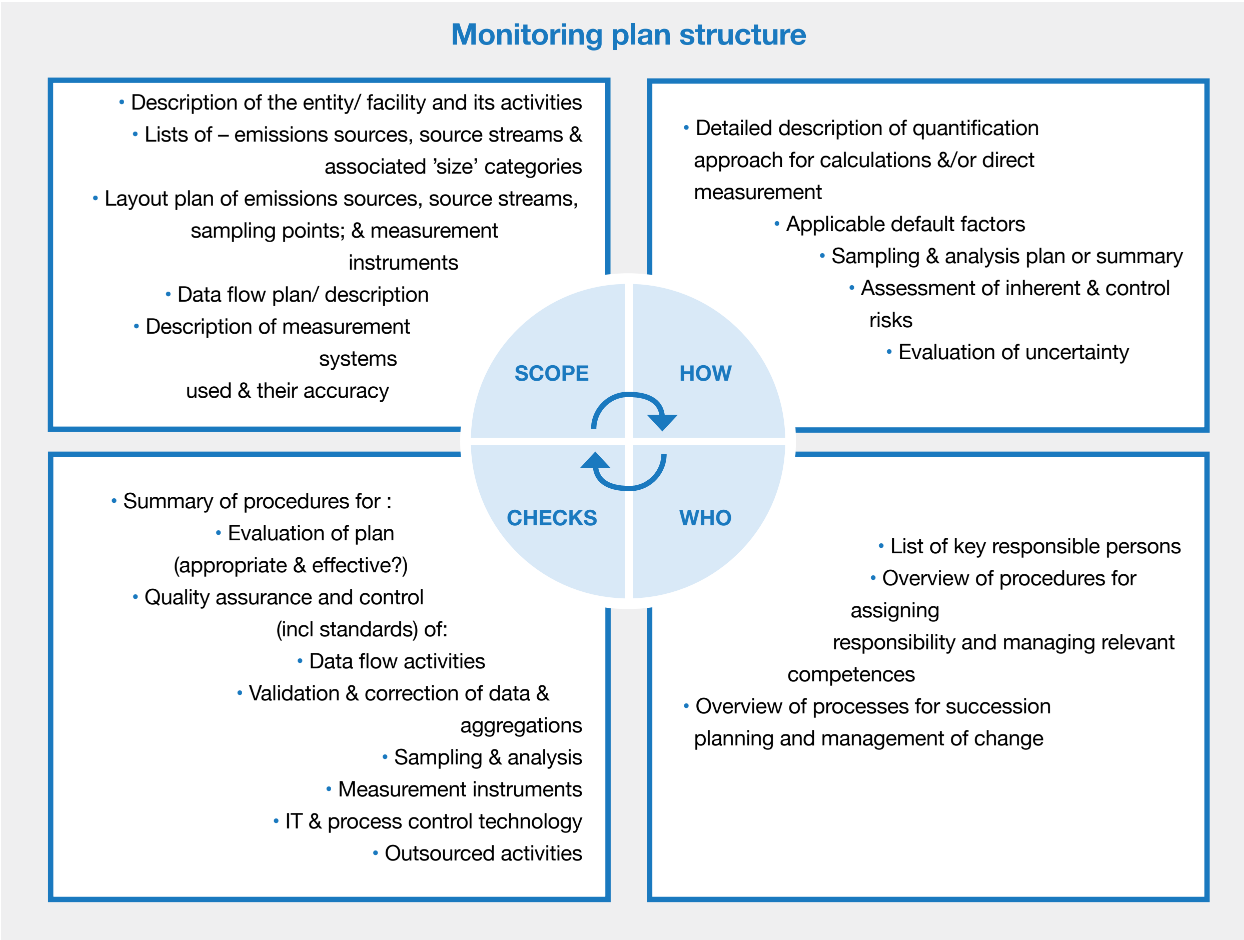
New Zealand – Generally emissions are determined by multiplying the activity data with a default emission factor. For each sector, default values are published. Quantification rules are stated in legislation. In some specified cases (non-forestry) ETS participants can use a facility-specific emission factor after they obtain regulator approval of their proposed method. More information can be found on the New Zealand government's emissions trading scheme website (https://www.mfe.govt.nz/ets).

Singapore – Mandatory monitoring plans have to be prepared and submitted by facilities using a standard template from the regulator. The plan must include description of emission sources, source streams, quantification methodologies, and quality assurance measures. Plans must then be approved by the regulator. More information can be found on Singapore's National Environment Agency website (https://www.nea.gov.sg/our-services/climate-change-energy-efficiency/climate-change/carbon-tax/measurement-and-reporting-requirements-for-greenhouse-gas-emissions).

When they require the use of a monitoring plan, as is the case in California, the EU, Singapore and Switzerland, it is important for policy makers to consider the following:

- Specifying in legislation the minimum content of the plan. A lack of such specification could lead to differences in the approach to and quality of monitoring plans between obligated entities and across sectors. Figure 20 provides an indication of the different elements that may be included in a monitoring plan.
- Arranging for approval of plans by the responsible regulator in advance of the start of regulated quantification, including establishing required procedures. Approval will help regulators to assess compliance of monitoring plans with the rules and define the tailored quantification approach for an obligated entity. (Where verification is used, the plan also forms the starting point for the verifier to check both rules compliance and conformance with the plan). Approval also provides more certainty to obligated entities that their application of the quantification protocol is acceptable to the regulator.
- Determining how to deal with changes to an entity's monitoring plan (such as when changes can or should happen, and what changes require approval by the regulator).
- Defining responsibilities of various stakeholders with respect to a monitoring plan.

FIGURE 20: Indicative Monitoring Plan Structure



Source: SQ Consult

7.3.3. Tools

Tools that can support the implementation of quantification protocols include checklists to assess the completeness of monitoring plans, software tools for data validation and error checking, tools that help obligated entities and regulators define what are unreasonable costs, and tools that help determine the frequency of analysis or carry out an uncertainty assessment. Box 12 contains further examples of tools developed by countries with carbon pricing instruments.

BOX 12. Examples of Useful Tools

California:

- California Electronic Greenhouse Gas Reporting Tool (including data validation)
- Calculation spreadsheets covering the emissions equations specified in different parts of the rules

The EU:

- Checklist for approval of monitoring plans and review of emissions reports
- Tool to determine and justify unreasonable costs and frequency of analysis
- Tool to help determine obligated entity risk of errors and non-compliance and to help assess which measures can be appropriate to mitigate risks
- Tool to determine the frequency of sampling and analysis for variable fuels and materials
- Templates for monitoring plan, sampling plan, and emissions report
- IT schema for electronic emissions reporting systems

Singapore:

- Monitoring plan Excel template (including simplified uncertainty analysis & guidance)

In addition, the GHG Protocol Corporate Accounting and Reporting Standard provides a range of online tools that may be a helpful starting point for calculating emissions from different sectors dealing with emissions uncertainty, global warming values, and more,[138] although these may need to be adapted to the specific circumstances of an individual carbon pricing instrument to ensure that they produce the intended outcomes.

7.3.4. Templates

Templates can be used for monitoring and sampling plans as well as emissions reporting. The European Commission, for instance, provides downloadable templates[139] for stationary installations and aircraft operators as well as templates for simplified installations; both California[140] and Singapore[141] provide online reporting templates. Templates help obligated entities to complete plans and reports in a structured and consistent manner, thereby mitigating differences between obligated entities and facilitating harmonized approaches. They also help regulators in evaluating monitoring plans, sampling plans, and reports. However, there is always a risk with any template that it may be inaccurate; consequently, when they establish templates, policy makers will need to ensure a rigorous QA/QC process to check that there are no errors built into templates. Early engagement with stakeholders to test templates using real life data and information can facilitate this process. Note that even with the introduction of templates there can still be differences across obligated entities, as they may complete the templates differently, particularly in terms of the level of detail included. Several carbon pricing instruments, such as the EU ETS, have developed exemplars of completed templates to ensure more harmonized approaches across sectors and entities.

138 "Calculation Tools," (Greenhouse Gas Protocol: 2003), http://ghgprotocol.org/calculation-tools.
139 Templates developed by the European Commission can be found on: "Monitoring, Reporting and Verification of EU ETS Emissions," https://ec.europa.eu/clima/policies/ets/monitoring_en#tab-0-1.
140 Compliance Instrument Tracking System Service (CITSS) Registration and Guidance, (California Air Resources Board, 2019), https://ww3.arb.ca.gov/cc/capandtrade/markettrackingsystem/markettrackingsystem.htm#guide.
141 "Emissions Data Monitoring and Analysis System," (Government of Singapore, 2020), https://www.edma.gov.sg/.

7.3.5. IT systems

IT systems can be used by obligated entities as internal systems to collect and monitor data, as well as by regulators who require a comprehensive database management system (for more, see appendix L). Section 4.4 of the PMR MRV Guide contains additional information on MRV data management systems that will also be applicable for quantification protocols. Examples include:

- ETSWAP, the UK's electronic workflow mechanism for the EU ETS, which is used to manage all interactions with the regulators (permitting, monitoring plans, notifications, and the like) as well as for reporting of emissions and submission of verification reports
- California's Electronic Greenhouse Gas Reporting Tool (Cal e-GGRT), which is used by all obligated entities to submit their GHG data reports. (This reporting tool was designed to mimic the US EPA's e-GGRT, given that the industry is familiar with this federal reporting tool).

Such IT systems are usually designed to ensure accurate implementation of legislation. However, in the process they may transfer risks from the obligated entity to the government if detailed QA/QC and testing of the system is not sufficient to identify all likely issues. In addition, systems may need updating as the carbon pricing instrument and its legislative basis evolve, so building in the flexibility for update at the start of system development is important.

Additional training and guidance should also be developed for obligated entities and those operating the system to ensure understanding and its proper application. These systems may build on existing platforms or connect with other reporting programs. Training and guidance can also encourage the generation of comparable data by incorporating templates like standardized reporting forms.

7.3.6. Additional measures

The PMR A&V Guide also contains guidance on measures policy makers can take to monitor obligated entities' compliance with the quantification protocol and to determine if the protocol needs any amendment. These include:

- Checking emissions quantification and emissions reports
- Inspections, including compliance with the monitoring plan (if required) and any associated documents
- Requiring obligated entities to self-certify the accuracy of their reports
- Independent, third-party verification

Appendix M provides more information on how regulators can gather information to evaluate compliance with the quantification protocol and assess any need for it to change.

7.4. Implementation Approach

As outlined in section 3.2, well-planned timing and sequencing when developing a quantification protocol can also assist with its successful implementation. The list below outlines some of the main timing considerations in developing and implementing a quantification protocol.

- Quantification requirements (such as the framework and potential approaches) should be considered while the rules of the carbon pricing instrument and broader MRV requirements are being developed.
- Guidance on emissions quantification and verification should ideally be developed before the legislation is completely finalized to allow feedback loops from one to the other. Guidance helps promote alignment and consistency, and it helps early identification of any technical issues that may need to be addressed in legislation. However, guidance is likely to require expansion and refinement over time.
- Quantification rules, guidance, and other tools need to be in place well before reporting commences in order to give obligated entities sufficient time to understand what is required and to prepare appropriately.
- Stakeholder engagement is required at each stage of implementation to ensure feedback on functionality can be taken into account (see section 3.4.4).
- The timing of adjustments after review of a quantification protocol during an operational period for the carbon pricing instrument need to be considered to prevent any market distortion. Upfront clarity on what changes will occur and from when they will be applied will facilitate entity preparedness and transition to the new version of the protocol.

8. Step 5: Reviewing and Refining

AT A GLANCE

Emissions quantification protocols will change and evolve over time. This chapter outlines guidance on the kind of changes you may want to consider and how you can make sure these changes can happen in a clear and systematic manner.

- Policymakers should encourage entities to continuously improve their application of methodologies over time to improve data accuracy.
- Changes by policy makers to the quantification protocol should not be done arbitrarily or without justification. Changes and the implementation timeline should be clearly communicated.
- Broader changes to the carbon pricing instrument or MRV framework may also affect the quantification protocol, which may require amendment or expansion.

According to the principles of consistency and comparability, obligated entities should use the same quantification methodologies and data sets over time. However, **over the long term, policy makers should strive to continuously improve the quantification protocol and its methodologies.** It may be difficult for obligated entities to implement a complex quantification approach in the beginning, but protocols and methodologies can evolve over time. In addition, policy makers can **encourage entities** to draft their monitoring plans in a manner that nudges entities over time to higher order tiers to **increase the accuracy of their data**. This chapter looks at instances in which methodologies may change temporarily or permanently as a result of certain conditions or through formal review processes. There are three different categories of change:

- **Category one** covers situations where a **temporary change to the methodology applied by the obligated entity** is permitted due to unforeseen changes to operations, such as a shutdown at a facility.
- **Category two** covers cases where an obligated entity makes a **permanent change to the methodology it applies as the obligated entity improves** its quantification capabilities[142] or where there are changes to its activities or quantification.
- **Category three covers amendments to and updates of the quantification protocol itself by policy makers and regulators,** which may arise out of updates to the carbon pricing instrument (such as when moving from a pilot phase to the next phase) or a formal review process. Review processes will be informed by stakeholder consultations (see section 3.4.4 and the PMR MRV Guide) as well as insights from regulatory review and enforcement of quantification rules. In addition, change may also be triggered by a broader review of the whole carbon pricing instrument, which is beyond the scope of this report.

For all three categories above, policy makers need clear rules for when and how changes to a methodology may occur, as well as rules governing review processes. **Whenever there are changes in quantification methodologies, it is important that they are not made arbitrarily and without justification**.

142 In terms of accuracy of quantification or robustness of the data accounting system.

8.1. When Entities Can Change Quantification Methods?

Outside of a formal protocol review process, there may be situations in which obligated entities may be required to, or may desire to, change the methodology applied to quantify emissions from their activities. In addition to permanent changes from changed operational set up, changes may also be temporary if, for instance, there is a failure of measuring instruments. Table 11 includes an overview of situations where the methodology may change:

TABLE 11: Situations Where Methodology May Change

Change type	Examples
Temporary	Deviations due to: – Shutdown of a process or facility for maintenance – Repair/ replacement/ calibration of measurement instruments – Loss of data (such as failure to read a meter or take a sample)
Permanent changes requested by obligated entity	– The entity demonstrates the current required method imposes an unreasonable cost and therefore seeks to change the methodology. – Changes to operational circumstances mean that it is no longer technically possible to apply the current approach.
Permanent changes that require a change in quantification	– Changes in operational circumstance (such as new instrumentation or reconfiguration of equipment) mean the entity is able to achieve a higher accuracy using a different methodology. – Changes in legislation mean the entity must install direct measurement equipment for other compliance purposes and which could be adapted to allow direct measurement for the purposes of the carbon pricing instrument. – Changes in the design or capacity of the obligated entity change the quantification boundaries. – New emissions as a result of new activities or source streams
Permanent changes requested by regulator or required by law	– Incorrect application of rules and/or protocol methodology – Misstatements or non-compliances with monitoring plans or quantification rules that are identified by regulators or in a verifier's report – Changes to the quantification protocol itself

Clear rules around changing methods and quantification requirements are important to maintain temporal consistency in emissions reporting. Requiring notification to, or approval of changes by, the responsible regulator is essential since it will inform regulators about changes in the application of quantification methodologies. In some carbon pricing instruments additional measures have been taken by regulators to ensure obligated entities do not switch from one method to another, resulting in reduced accuracy. These measures include prohibitions on adopting less accurate methodologies, allowing obligated entities to change between methodologies only after a certain period of time, or allowing obligated entities to change only under certain specific conditions or subject to approval by regulators.

When defining rules, policy makers need to outline their approach considering the following issues:

- **Whether and how an obligated entity can propose changes to its application of the quantification protocol**: If countries have opted to prescribe the use of a monitoring plan, specific rules are needed for updating these plans by obligated entities. If monitoring plans are not used, rules need to be developed on how and under what conditions methodologies can be changed.

- **What deadlines should apply for notifying changes:** Permanent and temporary changes to an entity's quantification methodology should be reported to the regulator as soon as possible.
- **When obligated entities should implement changes**: Changes should be implemented on the date from which it has been approved by the regulator, the date the change was applied for, or the date when the change actually happened in practice.The choice of date may depend on the legal system within a country. In some cases, it may be more appropriate to implement a change when it is approved by the regulator. But in other cases, it could be dictated by operational circumstances. For example, an entity may be able to anticipate a method change due to planned operational changes, but it would be reasonable for the carbon pricing instrument perspective to apply the changed method when the operational change actually happened.
- **When obligated entities are required to change their quantification methodology**: Such changes may occur when the carbon pricing instrument legislation changes or when there are new emission sources or source streams and the like.
- **Whether all changes to an obligated entity's quantification methodology must be approved by the responsible regulator or whether some can be deemed non-significant changes and just notified to the regulator without requiring approval**: Generally, changes to significant aspects of the quantification methodology itself should require approval by the regulator. Such approval will avoid gaming by the obligated entity. Such significant changes could include switching between calculation and direct measurement methodologies; changes or additions to emission sources; or changes between source stream categories, such as moving from a minor to a major source stream.
- **Whether changes are permanent or temporary**: Temporary deviations should be allowed only for specific cases. Care needs to be taken not to create loopholes. In addition to notifying regulators of such deviations, additional items to communicate include the reasons for deviating, an interim alternative methodology, measures being taken to restore the conditions for applying the normal quantification methodology, and the anticipated time when the normal methodology will be resumed.

In Alberta, for instance, facilities that cannot apply the specified methodologies have to apply for a time limited approval. The request must outline the alternative method, evidence that it would be conservative compared to the mandated method, and a plan outlining how the facility will return to the proscribed method in the future.

Appendix N provides further examples on how countries with carbon pricing instruments are addressing permanent changes to their quantification methodologies.

8.2. Continuous Improvement by Obligated Entities

From an environmental perspective, it is good practice for obligated entities to regularly evaluate the effectiveness and appropriateness of the methodologies they apply and to assess where they can improve their own performance in order to increase robustness of the quantification process and data accuracy. Policy makers can also consider mechanisms to entice or require obligated entities to continuously improve, particularly when changes would require no significant cost burden and are technically feasible. Several options are available:

- **Rewarding obligated entities by giving them more credits or tax incentives if they choose a more accurate quantification methodology**. In South Africa, for instance, companies are given a higher offset allowance if they apply a more accurate quantification methodology.

- **Requiring obligated entities to regularly assess whether they can improve** their quantification and update their methodologies and approaches as a result, for instance, to move from a lower to a higher tier. Such a requirement can impose an additional cost on obligated entities and will need clear guidelines on when and under what circumstances entities should improve their methodologies. In California's ETS and EU ETS, such requirements are included in law.

- **Requiring verifiers (if used) to transparently state any errors, non-compliance issues, or recommendations for improvement** that obligated entities are required to follow up on. Verifier reporting is an easy option to implement, but it will also require clear rules on the follow-up process as well as instructions on verifier impartiality to ensure they identify weaknesses and opportunities but do not provide consulting services.

- **Requiring obligated entities to submit improvement reports** or firm proposals to the regulator on how they will implement improvements to methodologies to address weaknesses identified (such as those identified by verifiers). The practice of improvement reporting is often implemented in more advanced carbon pricing instruments such as EU ETS, and guidance will be required on the content and frequency of such reports, as well as procedures to follow once issues are identified.

Appendix M provides further information on how regulators can obtain information to evaluate the compliance of obligated entities and how they can be encouraged to improve their application of quantification protocols.

8.3. Evolution of Carbon Pricing Instruments and Quantification Protocols

In line with the continuous improvement principle outlined in section 3.3 and appendix A, just as obligated entities should improve the methodologies they apply at operational level so should policymakers and regulators improve carbon pricing instruments and their quantification protocols. As these carbon pricing instruments and protocols go through a formal review process or move from one phase to the next, some aspects will likely change over time. Where changes are anticipated, such amendments should be developed with enough time for both regulators and obligated entities to prepare for the revised quantification requirements. Table 12 identifies some of the areas of evolution observed in different carbon pricing instruments around the world.

TABLE 12: General Trends in Evolution of Carbon Pricing Instruments and Quantification Protocols

Type of evolution	Examples and impact on quantification protocols
Moving from a voluntary to a mandatory system	– **Thailand:** There are plans to transform its voluntary ETS into a mandatory system which will require a more robust legal framework. – **The UK:** The UK established a voluntary ETS to help regulators and operators test out quantification and trading rules, as well as identify any challenges. – Generally, mandatory systems tend to be more stringent than voluntary systems. Policy makers should ensure data are being reported at a sufficient level of accuracy, which may be higher than that required under the voluntary system. In addition, lessons learned in the voluntary phases may lead to quantification amendments for the mandatory phase.

Type of evolution	Examples and impact on quantification protocols
Pilot system before commencement of the carbon pricing instrument	– **California** and **South Korea** both implemented a mandatory reporting program as a non-trading stage before formally starting up an ETS; this approach had the benefit of producing robust data on which caps and allowance baselines could be established. – **China:** Emissions trading was tested in seven pilots covering different regions and cities. Different MRV guidelines were developed by each pilot. Lessons learned from this phase were used in developing the national ETS. – **Thailand:** The country held a pilot phase in which MRV for an ETS was tested. – Like voluntary systems, pilots can be a useful way of building familiarity with quantification rules as well as testing out different guidelines and methodologies.
Transition period	– **The EU:** Several transition periods were built into quantification rules that allowed entities to use less stringent requirements, including lower tiers and deviations from the methodologies under specific conditions.[143] – **South Korea:** Based on a long-term master plan laid out in phases, South Korea started with annual mandatory emission reporting in 2012. This reporting formed the basis for cap-setting and allocation for the ETS, which commenced in 2015. It also formed the basis of training entities and helped build the necessary capacity for third-party verifiers, leading up to the adoption of ISO14065. – Countries may have an initial transition period with a lower level of quantification stringency and data accuracy to give entities time to adapt to the new obligations. When designing such transition rules, countries need to clearly specify the period for which the rules apply.
Sector expansion	– **China:** The national ETS will start with the power sector and add a further seven sectors over time. – **Chile:** The country plans to expand the green tax from power generation to other sectors such as health, mining, energy, and/or metals. – **Norway:** In 2005–2007 Norway established a separate ETS covering about 10 to 15 percent of Norwegian emissions. In 2008 Norway fully entered the EU ETS, which meant that its ETS expanded to more sectors. – **Switzerland:** The country linked its ETS with the EU ETS and therefore increased coverage to include aviation flights within both the EU and Switzerland; but this approach meant special rules were required to avoid double counting of emissions. – Sector expansion means that quantification methodologies must be designed for the new sectors.
Adapting threshold or eligibility criteria	– **South Africa:** The thresholds for eligible activities under the carbon tax are being evaluated and are likely to be changed. Amendments may be needed to any tiered or simplified approaches for smaller emitters. – **The EU:** In the first phase some EU Member States introduced specific rules for small emitters, as from 2008 the EU established a uniform threshold for small emitters (installations emitting less than 25 ktonnes of CO_2) and required specific quantification methodologies for these installations.

143 The competent authority may, for a transitional period agreed upon with the operator, allow an operator of an installation to apply tiers for major source streams that are lower than the highest tier (with a minimum of Tier 1), provided that the operator demonstrates to the competent authority that the tier required is technically not feasible or incurs unreasonable costs. In addition, an operator of an installation must provide an improvement plan indicating how and by when at least the tier required for that installation will be reached.

Type of evolution	Examples and impact on quantification protocols
Strengthening requirements	– **California:** The state holds regular public meetings[144] to review the ETS with all information published on its website. Recent review has led to clarifying procedures for changing calculation methods, adding a facility diagram with fuel flows and metering, updating the verification deadline, and establishing a price ceiling and rules on banking of allowances. – **Canada (Québec):** The mandatory MRV framework was reviewed and amended for the ETS. Quantification rules for the system are reviewed each year and, for example, rules for the fuel distribution sectors have been adjusted. Amendments following review and consultation are published by the regulator. – **The EU:** Over time, stricter requirements on tier compliance and QA/QC were put in place. More specifications were provided for sampling/analysis requirements and the content of monitoring plans and emissions reports. In addition, the opportunities for entities to deviate from quantification methodologies were reduced, while specific requirements on when to change monitoring plans were also introduced. – **South Africa:** The country is considering moving from IPCC default values to national values to increase accuracy of reporting. As entities become familiar with quantification methods and measuring instruments, the accuracy and stringency of these requirements can be improved.
Building in simplifications	– **The EU:** In 2008, ETS rules on quantification methodologies for stationary installations emitting less than 25,000 tonnes of CO_2 were simplified to reduce problems for "small emitters". Small aircraft operators[145] were also allowed to determine the fuel consumption using the tool implemented by EuroControl. Simplified rules for "small emitters" may be introduced if the quantification protocols prove to be overly complicated and/or impose unreasonable costs.
Developing national default factors	Many carbon pricing instruments develop national factors as part of their country's GHG emissions inventory reporting process. These are more accurate than the IPCC global averages and can also be incorporated by quantification protocols.

Generally, quantification protocols have gradually tightened their rules to generate more accurate data. At the same time, lessons learned from the application of protocols may also lead to greater flexibility and simplification of the rules should they prove overly onerous, particularly for smaller emitters.

8.4. Review Process

Regular evaluation by policy makers of quantification protocol rules and methodologies can help identify areas where quantification can be improved. There are different approaches for review and evaluation, which can be done through informal or formal stakeholder consultation processes (or a combination of), as well as an independent evaluation using empirical evidence. These types of evaluation usually cover all aspects of the carbon pricing instrument, not just quantification aspects. Selection of the evaluation approach often

144 California Air Resources Board, Public Meetings, https://ww3.arb.ca.gov/cc/capandtrade/meetings/meetings.htm and Mandatory Greenhouse Gas Reporting Regulation, https://ww2.arb.ca.gov/mrr-regulation.

145 Aircraft operators operating fewer than 243 flights per period for three consecutive four-month periods and aircraft operators operating flights with total annual emissions lower than 25 000 tonnes CO_2 per year (Article 55 (1) EU Monitoring and Reporting Regulation).

depends on the legal system and culture within a country. Whatever approach is selected, there are some key considerations:

- It is good practice to specify the frequency of evaluation upfront in legislation.[146] A specified frequency gives policy makers a firm opportunity to review rules and assess whether improvement is needed. It also gives obligated entities predictability about when changes might happen.
- Involving stakeholders in the process can generate useful input into the practical functioning of the system and the protocol.
- Clear communication lines should exist between the party running the review process and other authorities involved in quantification implementation and review. These could include, for instance, regional or local authorities, as well as accreditation authorities and verifiers.

For more information on the review process, see the PMR MRV Guide. The *PMR Carbon Tax Guide* (chapter 10 on evaluation) and the *PMR Emissions Trading in Practice* Handbook ("Step 10 implement, evaluate, and improve") also contain information on review process for carbon taxes and ETSs, respectively.

8.5. Process for Updating Quantification Protocols

While regulatory certainty is important, required changes and updates to quantification protocols may be identified as a result of the review process. Where these changes are significant, policy makers should ensure there is sufficient lead time so that obligated entities and regulators understand the requirements and have the capacity to implement them. Where new equipment is required, for instance, entities will have to purchase and install it. Major changes to quantification protocols may have a significant impact on the trading market and on how companies record information in financial accounts (which may affect their earnings), requiring policy makers to openly flag such changes potentially years in advance. For example, a quantification methodology may be updated in a certain year, but its mandatory adoption may be delayed for a number of years. Many of the recommendations for designing a quantification protocol are also relevant to the review process. This includes early consultation with stakeholders, transparent communication on what needs to be changed, the impact of such changes, and a timeline for the changed rules to take effect. Updates to guidance documents, tools, templates, and IT systems may also be required.

146 For example, the IPCC Guidelines for National GHG Inventories has been evaluated and refined about every ten years; the included GWP values are updated during each assessment cycle, which is about seven years. The EU ETS rules have been evaluated and updated for each Phase (originally every five years and now every ten years).

Additional Readings

1. American Petroleum Institute. Compendium of Greenhouse Gas Emissions Methodologies for the Oil and Gas Industry. Washington, DC, 2009. https://www.api.org/~/media/Files/EHS/climate-change/2009_GHG_COMPENDIUM.pdf.
2. European Commission. Monitoring, Reporting and Verification of EU ETS Emissions. https://ec.europa.eu/clima/policies/ets/monitoring_en#tab-0-1.
3. Gold Standard. Gold Standard for the Global Goals Documents. 2019. https://www.goldstandard.org/project-developers/standard-documents.
4. International Carbon Action Partnership (ICAP). ETS Library: reference database combines different sources of information on ETS. Berlin, 2020. https://icapcarbonaction.com/en/ets-library.
5. International Carbon Action Partnership (ICAP). Stakeholder Participation Guidance. (May 2018), http://www.climateactiontransparency.org/icat-guidance/stakeholder-participation/.
6. Petroleum Industry Guidelines for Reporting Greenhouse Gas Emissions. 2nd ed. IPIECA, 2011. https://www.api.org/~/media/Files/EHS/climate-change/GHG_industry-guidelines-IPIECA.pdf.
7. Partnership for Market Readiness. "The Nuts and Bolts of Baseline Setting: Why, What and How?" Washington, DC: World Bank Group, 2012. https://openknowledge.worldbank.org/handle/10986/21829?show=full.
8. Partnership for Market Readiness. Options and Guidance for the Development of Baselines. Washington, DC: World Bank Group, 2013. https://openknowledge.worldbank.org/handle/10986/21824.
9. Partnership for Market Readiness. Guide For Designing Mandatory Greenhouse Gas Reporting Programs. Washington, DC: World Bank Group, 2015. https://openknowledge.worldbank.org/handle/10986/21981.
10. Partnership for Market Readiness. Emissions Trading in Practice: A Handbook on Design and Implementation. Washington, DC: World Bank Group, 2016. https://openknowledge.worldbank.org/handle/10986/23874.
11. Partnership for Market Readiness. Greenhouse Gas Data Management: Building Systems for Corporate/ Facility-Level Reporting. Washington, DC: World Bank Group, 2016. https://openknowledge.worldbank.org/bitstream/handle/10986/23741/K8658.pdf?sequence=5&isAllowed=y.
12. Partnership for Market Readiness. Establishing Scaled-Up Crediting Program Baselines under the Paris Agreement: Issues and Options. Washington, DC: World Bank Group, 2017. https://openknowledge.worldbank.org/handle/10986/28785.
13. Partnership for Market Readiness. Carbon Tax Guide: A Handbook for Policy Makers. Washington, DC: World Bank Group, 2017. https://openknowledge.worldbank.org/handle/10986/26300.
14. Partnership for Market Readiness. Designing Verification and Approval Systems - A Guide to Designing Systems for Carbon Pricing Instruments. Washington, DC: World Bank Group, 2019. https://openknowledge.worldbank.org/handle/10986/31324.
15. Alberta Climate Change Office. Quantification Methodologies for the Carbon Competitiveness Incentive Regulation and the Specified Gas Reporting Program. Version 1.1. Alberta Government: Nov 2018. https://open.alberta.ca/dataset/61542074-8233-4f6c-a351-1454d57c0a32/resource/28cd6f46-ff55-4304-a863-dd8b193dfff1/download/cci-quantification-methodologies.pdf.

16. Deutsche Gesellschaft fuer Internationale Zusammenarbeit. Reference Document on Transparency in the Transport Sector: Measurement, Reporting and Verification of Greenhouse Gas Emissions. 2nd Ed. GIZ: May 2018. https://www.changing-transport.org/wp-content/uploads/2018_Reference_Document_Transparency-in-Transport_2nd-ed.pdf

17. Intergovernmental Panel on Climate Change. 2006 IPCC Guidelines for National Greenhouse Gas Inventories. Vols. 1-5. Japan: Institute for Global Environmental Strategies, 2006. https://www.ipcc-nggip.iges.or.jp/public/2006gl/. (see also box 13).[147]

18. Intergovernmental Panel on Climate Change. Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories. Japan: Institute for Global Environmental Strategies, 2000. https://www.ipcc.ch/publication/good-practice-guidance-and-uncertainty-management-in-national-greenhouse-gas-inventories/.

19. United Nations Framework Convention on Climate Change. CDM Rules and Reference. https://cdm.unfccc.int/Reference/Standards/index.html.

20. Verified Carbon Standard. Rules & Requirements. Washington, DC: Verra. http://verra.org/project/vcs-program/rules-and-requirements/.

21. Greenhouse Gas Protocol. Standard: https://ghgprotocol.org/standards.

BOX 13. Update and Refinement of IPCC Guidelines 2006

The *2006 IPCC Guidelines for National Greenhouse Gas Inventories* (IPCC 2006) provide methodologies for estimating national inventories of anthropogenic emissions by sources and removals by sinks of greenhouse gases. These have been updated and refined by the *IPCC Methodology Report (2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories)*, which aims to provide an updated and sound scientific basis to support ongoing preparation and continuous improvement of national greenhouse gas inventories.

The refinement updates, supplements, and/or elaborates IPCC 2006 where gaps or out-of-date science have been identified. In particular, the refinement:

- Provides supplementary methodologies for sources and sinks of greenhouse gases where there are gaps or where new technologies/production processes have emerged that require methodologies, or for sources and sinks that were not well covered by IPCC 2006
- Provides updated default values for calculation factors based on the latest available scientific information where significant differences from the current 2006 IPCC default values have been identified
- Provides additional or up-to-date alternative information and guidance as clarification or elaboration of existing guidance

The refinement should be used in conjunction with IPCC 2006 and the 2013 Wetlands Supplement.

(available at: https://www.ipcc.ch/report/2019-refinement-to-the-2006-ipcc-guidelines-for-national-greenhouse-gas-inventories/).

147 As amended by the 2019 refinement: E. Calvo Buendia, K Tanabe, A. Kranjc, J. Baasansuren, M. Fukuda, S. Ngarize, A. Osako, Y. Pyrozhenko, P Shermanau, and S. Federici, (eds),: IPCC 2019, 2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories (IPCC, Switzerland, 2019), https://www.ipcc.ch/report/2019-refinement-to-the-2006-ipcc-guidelines-for-national-greenhouse-gas-inventories/.

Appendices

Appendix A – Details on Key Principles of Quantification

Table A.1 shows the key principles in any quantification of emissions and further detail on how these principles can impact the design of a quantification protocol. These are synthesized from the application of principles in practice as well as guidance provided by the ISO14064 series of standards: ISAE3000, IPCC 2006, and The GHG Protocol.

TABLE A.1: Key Principles of Emissions Quantification

Key principle	Explanation of the key principle	Impact for the design of the quantification protocol
Completeness	All emissions from emission sources, gases, and activities within the quantification boundaries of the obligated entity need to be quantified and reported in accordance with the carbon pricing instrument scope and rules.	– Clear requirements are needed on quantification boundaries, eligibility, and inclusions/exclusions. (Requirements for mandatory reporting). – Quantification methodologies should avoid data gaps or overlaps that could give rise to double counting. Rules should be set for addressing data gaps.
Consistency	Quantification and reporting of emissions data should be applied in the same manner over time. Quantification should not be changed without grounds or arbitrarily. Changes to quantification to improve accuracy should be done transparently.	– Clear rules are needed on when update of an individual obligated entity's quantification methodology is allowed (within the framework of the quantification protocol) and to what extent regulator approval is required. – Updates to the quantification protocol itself should still allow a comparison of entities' emissions over time and be aimed at increased accuracy of reporting as a minimum. – Quantification protocol methodologies should ensure consistency over time, such as a consistent time series of default values.
Accuracy	Quantification of emissions must not be overestimated nor underestimated within agreed confidence levels. Uncertainty and bias in the quantification approach should be reduced as far as practicable.	– How to achieve accuracy depends on the type of quantification methodology. – Requirements may be needed to ensure minimum uncertainty requirements are met. – This principle should apply to all obligated entities covered by the carbon pricing instrument. However, policy makers may choose to apply less stringent quantification requirements to small and simple obligated entities or to smaller sources. – There is a balance between the benefits of greater accuracy and costs involved to achieve that accuracy. Policy makers need to decide whether and under what conditions obligated entities can deviate from applying specified quantification methodologies on the grounds of unreasonable costs or technical infeasibility.
Transparency	It should be possible for an informed third party to trace back to primary data to establish how the reported emissions have been arrived at.	– Rules are needed on how to control recording of data, quantification steps, the results of the quantification process, and what data and other information should be reported. A clear audit trail helps regulators and verifiers determine how reported data have been generated, collected, and calculated or measured. – Relevant information should be recorded, documented, retained, and securely managed by the obligated entity. – Lack of transparency does not imply inaccuracy; but for regulator checks or verification, it can impose additional work and, thus, costs for the entity to demonstrate the source and quality of its reported data.

Key principle	Explanation of the key principle	Impact for the design of the quantification protocol
Verifiable	This builds on the other principles referred to above whose application in quantification should ensure that the data can be fully checked and confirmed as being reliable for the use to which it will be put. Verifiable data is a credible and faithful account of the emissions the data set is reasonably expected to represent.	– The methodologies in the quantification protocol should be precise so a verifier can state whether or not they have been applied correctly in line with specified principles. – There is a link between quantification and verification. The higher the quality and robustness of internal control, documentation and data retention specified by the protocol for the obligated entity to implement, the better the verifiability of the data set will be.
Comparable	Emissions estimates produced by an entity should be comparable to those produced by similar entities within the same sector using the same methodology; and by entities in different sectors for cross-cutting elements (such as combustion)	– Methodologies prescribed for cross-cutting elements should be the same across all sectors included within the carbon pricing instrument – Flexibility to apply different calculation and/or direct measurement methodologies should still ensure that reported emissions can be compared within and across sectors – Methodologies used should allow for reported data to be comparable to estimates derived for the National Inventory
Continuous improvement	Quantification approach and procedures should improve over time so as to increase the accuracy and robustness of quantification and monitoring.	– Clear requirements are needed on how an obligated entity needs to improve its individual quantification approach to make it more robust over time. – The quantification protocol and its methodologies should be subject to periodic evaluation and improvement.

Appendix B – Treatment of Biomass

In the drive for decarbonization, the use of non-fossil biomass has been a prominent approach. However, not all types of biomass are acceptable in regulatory programs since its production can have adverse effects on the environment and society (such as biodiversity, soil and water quality impacts, as well as potential interaction with food production, mining, and traditional owner land rights). If a carbon pricing instrument restricts the use of specific types of biomass, policy makers need to consider whether to define eligibility criteria or definitions. Because an acceptable biomass source would be deemed to have a zero-emission factor, criteria are needed to ensure consistency and to confirm the accuracy of emissions reporting. An unacceptable source would be treated as a fossil source with a significant impact on the amount of emissions to be reported. The approach to quantification of biomass is the same as that outlined in chapter 5 in relation to fossil fuels, with the addition of rules on how to determine the biomass fraction of mixed fuels and materials (such as municipal or other wastes), as outlined below. Table B.1 below gives examples of acceptable biomass for different carbon pricing instruments.

Policy makers should consider the following basic principles[148] that may define acceptable biomass. The harvesting and use of the material should:

- Protect or enhance biodiversity, soils, and water quality

148 UK Committee on Climate Change Infographic “Biomass in a low carbon economy,” available at https://www.theccc.org.uk/publication/biomass-in-a-low-carbon-economy/.

- Minimize supply chain GHG emissions
- Not compete with food production and respect land rights
- Not come from virgin slow-growth, high diversity, or high carbon forests
- Not involve mining of carbon stocks in the landscape
- Not use residues needed for soil carbon quality or other existing uses
- Not produce harmful levels of air pollution when burned

TABLE B.1: Examples of Acceptable Biomass in Different Carbon Pricing Instruments

Country/program	Acceptable biomass
California ETS	The California ETS defines biomass as non-fossilized and biodegradable organic material originating from plants, animals, and microorganisms, including products, by-products, residues, and waste from agriculture, forestry, and related industries as well as the non-fossilized and biodegradable organic fractions of industrial and municipal wastes, including gases and liquids recovered from the decomposition of non-fossilized and biodegradable organic material. Detailed guidance on accounting for biomass-derived fuels is provided by CARB.[149]
EU ETS	The emission factor in the determination of biomass can be zero only if the biomass meets sustainability criteria[150] or if such criteria are not applicable. These criteria are included in the Renewable Energy Directive that defines biomass.[151] This is an example where the legislation on EU ETS (the carbon pricing instrument) is streamlined and linked with other environmental legislation. Detailed guidance on accounting for biomass (including mixed fuels and pure biomass) is provided by the EU.[152]
Québec (Canada)	Québec defines biomass[153] as a non-fossilized plant or part of a plant, an animal carcass or part of an animal, manure or liquid manure, a micro-organism, and any other product derived from such matters. The Québec ETS has set emission factors for certain types of biomass (such as wood waste, spent pulping liquor, and agricultural and biomass by-products).
Singapore Carbon Tax	Biomass and fuel derived from biomass[154] includes biodiesels, biogasoline, charcoal, landfill gas, sludge gas, sulphite lyes (black liquor), wood/wood waste, other biogas, other liquid biofuel, other primary solid biomass.

Rules related to determining the proportion of a fuel or material that is non-fossil will vary depending on the nature of the biomass. For solids, this can involve sampling and analysis for which the considerations outlined in section 5.1.1.3 are relevant. For liquids and gases, the approach relies on understanding the chain of custody from the source of the pure biomass to the point at which it was blended with a fossil-based fuel/

149 *Biomass-Derived Fuels Guidance for California's Mandatory Reporting GHG Program*, (California Air Resources Board, 2019), https://www.arb.ca.gov/cc/reporting/ghg-rep/guidance/biomass.pdf?_ga=2.36222560.1775044070.1557508454-1111296313.1557434350.

150 In the EU ETS, if the Renewable Energy Directive does not impose sustainability criteria on a type of biomass, the emission factor for that type of biomass under the EU ETS can also be zero. For more information see *MRR Guidance Document 3 on biomass in the EU ETS* at https://ec.europa.eu/clima/sites/clima/files/ets/monitoring/docs/gd3_biomass_issues_en.pdf.

151 "Biomass" means the biodegradable fraction of products, waste, and residues from biological origin from agriculture (including vegetal and animal substances); forestry and related industries including fisheries and aquaculture; as well as the biodegradable fraction of industrial and municipal waste. It includes bioliquids and biofuels.

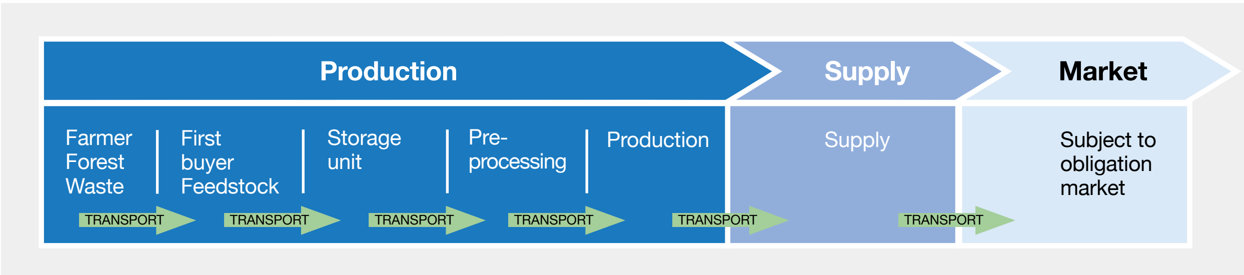
152 See EC Guidance Document 3, "Biomass Issues in the EUETS," (2017), at https://ec.europa.eu/clima/sites/clima/files/ets/monitoring/docs/gd3_biomass_issues_en.pdf.

153 Part 3(0.2) of the MRR at http://legisquebec.gouv.qc.ca/en/ShowDoc/cr/Q-2,%20r.%2015#se:3.

154 CO2 emissions from combustion of Biomass and Fuel Derived from Biomass are not subject to the carbon tax, but they are reportable.

material[155] as well as the proportions of that blend. The key aspect of this approach is traceability along the supply chain to ensure that all relevant data are verifiable and are passed along the chain from source to user via all intermediaries (see figure B.1).

FIGURE B.1: Typical Chain of Custody for a Biomass Supply Chain



Source: NL Agency – Sustainability Certification for Biomas[156]

For policy makers, key questions to consider at the development stage of a quantification protocol are whether to:

- Accept biomass as having an emission factor of zero in the quantification, and if so, for what sort of biomass, and under which conditions
- Apply a defined purity threshold for mixed materials above which all the material is considered biomass (such as less than 5 percent fossil content), and if so, what approaches are acceptable to determine purity
- Define categories of mixed biomass and apply default calculation factors for them (if a facility-specific factor cannot be developed)
- Define simplified rules for cases where determination of the biomass fraction is technically not feasible or leads to unreasonable costs
- Specify recognized standards for determining biomass fractions and the frequency with which sampling and analysis should be conducted

Appendix C - MRV Legislation, Guidance, and Tools in Carbon Pricing Instruments

Table C.1 provides an overview of legislation, guidance, and tools that are applicable in carbon pricing instruments that are currently operational. Where possible, reference is made to websites where such information can be found; these links are valid as of August 2019, when final research was completed.

155 For example, tall oil (a by-product of the Kraft process of wood pulp manufacture) blended with heavy fuel oil; or rape seed oil blended with gas oil.
156 *"Sustainability Certification for Biomass,"* (NL Agency, 2017), https://english.rvo.nl/sites/default/files/2013/12/Factsheet%20Sustainability%20Certification%20for%20biomass%20-%20november%202012.pdf.

TABLE C.1: Legislation, Guidance, and Tools for Carbon Pricing Instruments Currently Operating

Country	Type of carbon pricing instrument	Legislation, guidance, and tools
Australia	Mandatory reporting	**Enabling framework legislation** – National Greenhouse and Energy Reporting Act 2007 at https://www.legislation.gov.au/Details/C2007A00175. **Detailed quantification legislation** – National Greenhouse and Energy Reporting Regulations 2008 at https://www.legislation.gov.au/Details/F2017C00187. – National Greenhouse and Energy Reporting (Measurement) Determination 2008 at https://www.legislation.gov.au/Series/F2008L02309. **Guidance** – Guides and factsheets from the National Greenhouse and Energy Reporting scheme at http://www.cleanenergyregulator.gov.au/NGER/Forms-and-resources/Guides-and-factsheets.
Canada - federal	Mandatory reporting Carbon pricing	**Enabling framework legislation** – Canadian Environmental Protection Act, 1999 requires annual reporting of GHGs for certain emitters, available at https://www.canada.ca/en/environment-climate-change/services/canadian-environmental-protection-act-registry/related-documents.html. **Guidance** – PanCanadian Framework on Clean Growth and Climate Change (specifically section 7) at https://www.canada.ca/content/dam/themes/environment/documents/weather1/20170106-1-en.pdf. – Pan-Canadian Framework on Clean Growth and Climate Change, “Technical Paper on the Federal Carbon Pricing Backstop” at https://www.canada.ca/content/dam/eccc/documents/pdf/20170518-2-en.pdf. – Guidance on the Pan-Canadian Carbon Pollution Pricing Benchmark at https://www.canada.ca/en/services/environment/weather/climatechange/pan-canadian-framework/guidance-carbon-pollution-pricing-benchmark.html. – Supplemental Benchmark Guidance at https://www.canada.ca/en/services/environment/weather/climatechange/pan-canadian-framework/guidance-carbon-pollution-pricing-benchmark/supplemental-benchmark-guidance.html.
Canada - Alberta	Crediting mechanism (baseline & credit) Carbon Tax (repealed 06/19)	**Enabling framework legislation** – Climate Change and Emissions Management Act (including associated documents) at https://open.alberta.ca/publications/c16p7. **Detailed quantification legislation** – Specified Gas Emitters Regulation (SGER, repealed 2017) – Carbon Competitiveness Incentive Regulation (replaces SGER) at https://www.alberta.ca/carbon-competitiveness-incentive-regulation.aspx. **Guidance** – “Quantification Methodologies for the Carbon Competitiveness Incentive Regulation and the Specified Gas Reporting Program” at https://open.alberta.ca/publications/9781460140406.

Country	Type of carbon pricing instrument	Legislation, guidance, and tools
Canada – British Columbia	Carbon Tax	**Enabling framework legislation** – Climate Change Accountability Act (CCAA) (incorporates reduction targets) (SBC 2007, Chapter 42) at http://www.bclaws.ca/civix/document/id/complete/statreg/07042_01. – GHG Industrial Reporting and Control Act (SBC 2014, Chapter 29) (GGIRCA) -at http://www.bclaws.ca/civix/document/id/lc/statreg/14029_01. – Carbon Tax Act (SBC 2008, Chapter 40) at http://www.bclaws.ca/EPLibraries/bclaws_new/document/ID/freeside/00_08040_01. **Detailed quantification legislation** – Greenhouse Gas Emission Reporting Regulation at http://www.bclaws.ca/civix/document/id/lc/statreg/249_2015. – Greenhouse Gas Emission Control Regulation at http://www.bclaws.ca/civix/document/id/lc/statreg/250_2015 – CCAA Carbon Neutral Govt Regulation (B.C. Reg. 392/2008 as amended) at http://www.bclaws.ca/Recon/document/ID/freeside/392_2008. – British Columbia Climate Action Legislation at https://www2.gov.bc.ca/gov/content/environment/climate-change/planning-and-action/legislation.
Canada – Ontario	ETS (ended 2018)	**Enabling framework legislation** – Climate Change Mitigation & Low Carbon Economy Act (revoked 11/18) at https://www.ontario.ca/laws/statute/16c07. – Detailed quantification legislation – Regulation 144/16: The Cap and Trade Program (revoked 07/18) at https://www.ontario.ca/laws/regulation/160144. – Regulation 143/16: Quantification, Reporting and Verification of GHGs (revoked 08/18)- https://www.ontario.ca/laws/regulation/160143. **Guidance** – Guidelines for Quantification, Reporting and Verification of Greenhouse Gas Emissions at http://www.downloads.ene.gov.on.ca/envision/env_reg/er/documents/2017/013-0104_d_Guide.pdf.
Canada - Québec	ETS (with compliance offset crediting)	**Enabling framework legislation** – Environment Quality Act (EQA) (chapter Q-2) at http://legisquebec.gouv.qc.ca/en/ShowDoc/cs/Q-2/. **Detailed quantification legislation** – Regulation respecting mandatory reporting of certain emissions of contaminants into the atmosphere (chapter Q-2, r. 15) at http://legisquebec.gouv.qc.ca/en/ShowDoc/cr/Q-2,%20r.%2015/. – Regulation respecting a cap-and-trade system for GHG allowances (chapter Q-2, r. 46.1) at http://legisquebec.gouv.qc.ca/en/ShowDoc/cr/Q-2,%20r.%2046.1/. **Guidance** – Supporting information available at “Mandatory Reporting of Certain Emissions Contaminants into the Atmosphere,” at http://www.environnement.gouv.qc.ca/air/declar_contaminants/index-en.htm. – Information on compliance credits available at “The Carbon Market: Offset Credits,” http://www.environnement.gouv.qc.ca/changements/carbone/credits-compensatoires/index-en.htm. – Supporting information available at “The Carbon Market, a Green Economy Growth Tool!” http://www.environnement.gouv.qc.ca/changementsclimatiques/marche-carbone_en.asp.

Country	Type of carbon pricing instrument	Legislation, guidance, and tools
Chile	Carbon (Green) Tax	**Enabling framework legislation** – LEY-20780_29-SEP-2014 – “Reforma Tributaria que Modifica el Sistema de Tributación de la Renta e Introduce Diversos Ajustes en el Sistema Tributario (Law-20780_29-SEP-2014 – “Tax Reform that Modifies the Income Tax System and Introduces Different Adjustments in the Tax System”) at https://www.leychile.cl/Navegar?idNorma=1067194&idParte=. **Detailed quantification legislation** – Titulo I Medicion- Instructivo para la Cuantificación de las Emisiones de Fuentes Affects al Impuesto del Artículo 8 de la ley No. 20.780 (Title I Measurement - Instruction for the Quantification of Emissions from Sources Affects the Tax of Article 8 of Law No. 20,780) – Titulo I - Anexo 1: Instructivo para la Cuantificación de Emisones con Sistenas de Monitoreo Continuo de Emisiones (CEMS) y Métodos Alternativos- Alternativas 1, 2 y 3 (Title I - Annex 1: Instructions for Quantifying Emissions with Continuous Emission Monitoring Systems (CEMS) and Alternative Methods - Alternatives 1, 2 and 3) – Titulo I - Anexo 2: Instructivo para la Quantificación de Emisones a Través de Muestreos y Mediciones con Métodos de Referencia - Alternativas 4 y 5 (Title I - Annex 2: Instructions for Quantifying Emissions through Sampling and Measurements with Reference Methods - Alternatives 4 and 5) – Titulo I - Anexo 3: Instructivo para la Cuantificación de Emisones a Través de Factores de Emisón - Alternativas 6 y 7 (Title I - Annex 3: Instructions for Quantifying Emissions through Emission Factors -Alternatives 6 and 7) – Titulo II Reporte - Instructivo para el Reporte de las Emisiones de Fuentes Fijas Afectas al Impuesto del 8 de la Ley No. 20.780 (Title II Report - Instructions for the Reporting of Emissions from Fixed Sources Affected by the Rax of 8 of Law No. 20,780) – Titulo III Verificacion - Instructivo para la Verificación de las Emisiones de Fuentes Fijas Afectas al Impuesto del 8 de la Ley No. 20.780 (Title III Verification - Instructions for the Verification of Emissions from Fixed Sources Affected by the Tax of 8 of Law No. 20,780) The above documents are all available at https://portal.sma.gob.cl/index.php/portal-regulados/instructivos-y-guias/impuestos-verdes/ – Instructivo para la Cuantificación de las Emisiones de Fuentes Fijas Afectas al Impuesto del Artículo 8 de la Ley No. 20.780 (Instructions for the Quantification of Emissions from Fixed Sources Affected by the Tax under Article 8 of Law No. 20.780) at https://transparencia.sma.gob.cl/doc/resoluciones/RESOL_EXENTA_SMA_2016/RESOL%20EXENTA%20N%201156%20SMA.PDF **Guidance** – “Institutional Infrastructure for Chile’s Green Tax” at https://www.4echile.cl/4echile/wp-content/uploads/2018/05/2.-Institutional-infrastructure-for-Chile%C2%B4s-Green-Tax.pdf. – “Chile’s Green Tax: Creation and Implementation of a MRV System” at https://www.4echile.cl/4echile/wp-content/ uploads/2018/05/3.-Creation-and-implementation-of-a-Measurement-Reporting-and-Verification-MRV-System.-Chile%E2%80%99s-Green-Tax.pdf.

Country	Type of carbon pricing instrument	Legislation, guidance, and tools
Colombia	Mandatory reporting	**Detailed quantification legislation** – "Documento Nacional del Sistema de Monitoreo Reporte y Verificación MRV para Colombia V2 2017" ("National Document of the MRV Report and Verification Monitoring System for Colombia") at http://www.minambiente.gov.co/images/AsuntosMarinosCosterosyRecursosAcuatico/Documento_MRV_Nacional_Consolidado__Julio_2017_V_FINAL_2_0.pdf.
Costa Rica	Carbon Neutrality program	**Enabling framework legislation** – "Norma para Demostrar la Carbono Neutralidad. Requisitos. Norma INTE-B5" ("Standard to Demonstrate Carbon Neutrality. Requirements INTE-B5 Standard") at http://www.pgrweb.go.cr/scij/Busqueda/Normativa/Normas/nrm_texto_completo.aspx?param1=NRTC&nValor1=1&nValor2=86593&nValor3=112413&strTipM=TC. – Acuerdo -36-2012 – MINAET - Oficializa el PPCN (version 2012) – Decreto Nº 41122-MINAE - Oficializa el PPCN 2.0 **Detailed quantification legislation** – Programa País Carbono Neutralidad 2.0 - Categoria Organizacional (Country Carbon Neutrality Program 2.0 - Organizational Category). – Programa País Carbono Neutralidad 2.0 - Categoria Cantonal (Municipality Protocol) (Country Carbon Neutrality Program 2.0 - Cantonal Category (Municipality Protocol).
EU 28	ETS	**Enabling framework legislation** – Directive 2003/87/EC of the European Parliament and of the Council establishing a scheme for greenhouse gas emission allowance trading within the Community and amending Council Directive 96/61/EC at https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:02003L0087-20180408&qid=1581505369939&from=EN. **Detailed quantification legislation** – Commission Implementing Regulation (EU) 2018/2066 on the monitoring and reporting of greenhouse gas emissions amending Commission Regulation (EU) No 601/2012 at https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32018R2066&from=EN. – Supporting regulations, guidance, and tools for quantification and monitoring for phases 3 and 4 can be found at https://ec.europa.eu/clima/policies/ets/monitoring_en#tab-0-1. **Guidance** – Regulations and guidance for Phase 1 and 2 can be found at https://ec.europa.eu/clima/policies/ets/pre2013_en#tab-0-1.
France	Carbon Tax	**Guidance** – Explanation of the tax can be found at https://www.ecologique-solidaire.gouv.fr/fiscalite-carbone.
Ireland	Carbon Tax	**Guidance** – "Mineral Oil Tax Carbon Charge," details can be found at https://www.revenue.ie/en/companies-and-charities/excise-and-licences/mineral-oil-tax/carbon-tax/index.aspx. – "Solid Fuel Carbon Tax," details can be found at https://www.revenue.ie/en/companies-and-charities/excise-and-licences/energy-taxes/solid-fuel-carbon-tax/taxable-solid-fuels-and-liability.aspx.

Country	Type of carbon pricing instrument	Legislation, guidance, and tools
Japan - Tokyo	ETS	**Enabling framework legislation** – The Tokyo Metropolitan Environmental Security Ordinance – Detailed quantification legislation – Regulation for the Enforcement of the Tokyo Metropolitan Environmental Security Ordinance. **Guidance** – Tokyo Cap and Trade Program for Large Facilities details and guidance can be found at http://www.kankyo.metro.tokyo.jp/en/climate/cap_and_trade/index.files/TokyoCaT_detailed_documents.pdf. – Guideline for Monitoring and Reporting Energy Related CO_2 Emissions – Guideline for Verifying Energy Related CO_2 Emissions – Guideline for Monitoring and Reporting GHG Emission Other than Energy Related CO2 – Guideline for Monitoring and Reporting/Verifying GHG Emissions Reductions Other than Energy Related CO_2 – Guideline for Certifying/Verifying Operation Management in Facilities – Guideline for Monitoring and Reporting/Verifying Small and Midsize Facility Credits – Guideline for Monitoring and Reporting/Verifying Renewable Energy Credits – Guideline for Monitoring and Reporting/Verifying Outside Tokyo Credits – Guideline for Emissions Trading (How to Use the Registry) – Basic Approach on Accounting
Mexico	Carbon Tax	**Enabling framework legislation** – Ley del Impuesto Especial Sobre Producción y Servicios (Law on the Special Tax on Production and Services) - https://www.sat.gob.mx/ordenamiento/39956/ley-del-impuesto-especial-sobre-produccion-y-servicios.
Mexico	National Register of Emissions (RENE)	**Enabling framework legislation** – DO3452 Reglamento Registro Nac. Emissiones: Reglamento de la Ley General de Cambio Climático en Materia del Registro Nacional de Emisiones (DO3452 Regulations National Emissions Registry: Regulations of the General Law on Climate Change in the National Emissions Registry at http://biblioteca.semarnat.gob.mx/janium/Documentos/Ciga/agenda/DOFsr/DO3452.pdf. **Detailed quantification legislation** – Acuerdo que Establece las Particularidades Técnicas y las Fórmulas para la Aplicación de Metodologías para Elcálculo de Emisiones Degases o Compuestos de Efecto Invernadero (Agreement that Establishes the Technical Particularities and Formulas for the Application of Methodologies for the Calculation of Emissions of Greenhouse Gases or Compounds) at http://www.semarnat.gob.mx/sites/default/files/documentos/cicc/acuerdo_que_establece_las_particularidades_tecnicas_y_las_formulas_para_la_aplicacion_de_metodologias.pdf. – Acuerdo por el que se Establece la Metodología para la Medición Directa de Emisiones de Bióxido de Carbono (Agreement Establishing the Methodology for the Direct Measurement of Carbon Dioxide Emissions), at https://www.gob.mx/cms/uploads/attachment/file/195818/ACUERDO_metodologia_para_la_medicion_directa.pdf. **Guidance** – Guía de Usuario Registro Nacional de Emisiones (RENE) Versión 3.0 (User Guide National Emissions Registry (RENE) Version 3.0), at http://www.semarnat.gob.mx/sites/default/files/documentos/cicc/20160623_guia_rene.pdf. – Calculadora de Emisiones del Registro Nacional de Emisiones (RENE) versión 7.0 ¡Actualización! (06-06-2019) (Emissions Calculator of the National Emissions Registry (RENE) version 7.0 Update! (06-06-2019), at https://www.gob.mx/semarnat/acciones-y-programas/registro-nacional-de-emisiones-rene.

Country	Type of carbon pricing instrument	Legislation, guidance, and tools
New Zealand	ETS	**Enabling framework legislation** – Climate Change Response Act 2002 and the Climate Change Response (Emissions Trading) Amendment Act 2008 (as amended). Under these Acts there are several relevant implementing regulations: **Detailed quantification legislation** – Climate Change (Agriculture Sector) Regulations 2010 – Climate Change (Eligible Industrial Activities) Regulations 2010 – Climate Change (Emissions Rulings: Fees and Charges) Regulations 2010 – Climate Change (Forestry Sector) Regulations 2008 – Climate Change (Liquid Fossil Fuels) Regulations 2008 – Climate Change (Other Removal Activities) Regulations 2009 – Climate Change (Stationary Energy and Industrial Processes) Regulations 2009 – Climate Change (Synthetic Greenhouse Gas Levies) Regulations 2013 – Climate Change (Unique Emissions Factors) Regulations 2009 (as amended 2017) – Climate Change (Unit Register) Regulations 2008 – Climate Change (Waste) Regulations 2010 Legislation can be found at http://www.legislation.govt.nz/act/public/2002/0040/78.0/DLM158584.html. Relevant guidance can be found at https://www.mfe.govt.nz. **Guidance** – Guidance on emission factors at https://www.mfe.govt.nz/sites/default/files/unique-emissions-factors.pdf. – Guidance on New Zealand ETS at https://www.mfe.govt.nz/sites/default/files/media/Climate%20Change/A%20Guide%20to%20the%20New%20Zealand%20Emissions%20Trading%20Scheme.pdf.
Republic of Korea		**Enabling framework legislation** – Act No.11690, 23.03.13 – Allocation and Trading of Greenhouse Gas Emissions Permits, at http://www.law.go.kr/DRF/lawService.do?OC=jaa806&target=elaw&MST=137271&type=HTML&mobileYn=. **Detailed quantification legislation** – Decree No.24429, 23.03.13 – Decree on the Allocation and Trading of Greenhouse Gas Emissions Permits, at http://www.law.go.kr/DRF/lawService.do?OC=jaa806&target=elaw&MST=135892&type=HTML&mobileYn=.
Singapore	Carbon Tax	**Enabling framework legislation** – Energy Conservation Act 2012 (as amended), at https://sso.agc.gov.sg/Act/ECA2012. – Carbon Pricing Act 2018, at https://sso.agc.gov.sg/Acts-Supp/23-2018/Published/20180601?DocDate=20180601. **Detailed quantification legislation** – Energy Conservation (GHG Measurement & Reporting) Regulations 2017 – Carbon Pricing (Measurement, Reporting and Verification) Regulations 2018 **Guidance** – GHG Measurement and Reporting Guidelines, at https://www.nea.gov.sg/our-services/climate-change-energy-efficiency/climate-change/carbon-tax/measurement-and-reporting-requirements-for-greenhouse-gas-emissions.

Country	Type of carbon pricing instrument	Legislation, guidance, and tools
South Africa	Carbon Tax	**Enabling framework legislation** – Carbon Tax Act 2019, at https://www.gov.za/documents/carbon-tax-act-15-2019-english-afrikaans-23-may-2019-0000. **Detailed quantification legislation** – National GHG Reporting Regulations, at https://www.environment.gov.za/sites/default/files/legislations/nemaqa39of2004_nationalgreenhousegasemissionreporting_gn40762.pdf. – Draft Regulations on Carbon Offset, at http://www.treasury.gov.za/public%20comments/CarbonTaxBll2018/ **Guidance** – Technical guidelines for MRV of GHG by industry (TG-2016.1 April 2017), at https://www.environment.gov.za/sites/default/files/legislations/technicalguidelinesformrvofemissionsbyindustry_0.pdf.
Switzerland	ETS	**Enabling framework legislation** – Federal act on reduction of emissions (CO_2 Act), at https://www.admin.ch/opc/en/classified-compilation/20091310/index.html. **Detailed quantification legislation** – CO_2 ordinance (ordinance on the reduction of CO_2 emissions), at https://www.admin.ch/opc/en/classified-compilation/20120090/index.html#app6. **Guidance** – Communication on Swiss ETS at https://www.bafu.admin.ch/bafu/de/home/themen/klima/publikationen-studien/publikationen/emissionshandelssystem-ehs.html.
Switzerland	Carbon Tax	**Enabling framework legislation** – Federal act on reduction of emissions (CO_2 Act) at https://www.admin.ch/opc/en/classified-compilation/20091310/index.html **Detailed quantification legislation** – CO_2 ordinance (ordinance on the reduction of CO_2 emissions) at https://www.admin.ch/opc/en/classified-compilation/20120090/index.html#app6.
Thailand	ETS and offset mechanism	**Guidance** – ETS Guidebook, at http://carbonmarket.tgo.or.th/admin/uploadfiles/download/ts_10efb915e6.pdf. – Guidance on voluntary offset mechanism, at http://www.tgo.or.th/2015/english/content.php?s1=58.
Turkey	ETS	**Detailed quantification legislation** – Greenhouse Gas Emissions Monitoring Regulation; information can be found at https://carbon-turkey.org/en/regulation. **Guidance** – Annual emissions reporting guidelines and Monitoring Plan guidelines can be found at https://carbon-turkey.org/en/documentation.

Country	Type of carbon pricing instrument	Legislation, guidance, and tools
UK	Carbon Tax	**Enabling framework legislation** – FinanceAct2000(as amended) **Detailed quantification legislation** – Information on the levy can be found at https://www.gov.uk/green-taxes-and-reliefs/climate-change-levy. Information on levy exemptions (Climate change levy agreements) can be found at https://www.gov.uk/guidance/climate-change-levy-application-rates-and-exemptions#main-rates. **Guidance** – Excise Notice CCL1: A general guide to Climate Change Levy, at https://www.gov.uk/government/publications/excise-notice-ccl1-a-general-guide-to-climate-change-levy/excise-notice-ccl1-a-general-guide-to-climate-change-levy. – Climate change agreements guidance at https://www.gov.uk/guidance/climate-change-agreements--2. – Climate Change Agreements Operations Manual V8, December 2018, at https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/772721/Climate_Change_Agreements_Operations_Manual.pdf. – Managing your climate change agreement (CCA), at https://www.gov.uk/guidance/managing-your-climate-change-agreement-cca. – Climate change agreements: umbrella agreements, at https://www.gov.uk/government/collections/climate-change-agreements-umbrella-agreements. – Excise Notice CCL1/6: a guide to carbon price floor, at https://www.gov.uk/government/publications/excise-notice-ccl16-a-guide-to-carbon-price-floor/excise-notice-ccl16-a-guide-to-carbon-price-floor.
USA - Federal	Mandatory Reporting	**Detailed quantification legislation** – Part 98—Mandatory GHG Reporting Regulations, at https://www.ecfr.gov/cgi-bin/text-idx?c=ecfr&SID=be77ce6e756f0befaa0dd95743e3342e&tpl=/ecfrbrowse/Title40/40cfr98_main_02.tpl. **Guidance** – Part 75 Emissions Monitoring Policy Manual, at https://www.epa.gov/sites/production/files/2019-05/documents/part_75_emissions_monitoring_policy_manual_4-24-2019.pdf. – GHG Reporting Programme Implementation fact sheet, at https://www.epa.gov/sites/production/files/2014-09/documents/ghgrp-overview-factsheet.pdf.
USA – California	ETS Compliance offset crediting mechanism	**Enabling framework legislation** – AB 32, the Global Warming Solutions Act of 2006 (as amended) **Detailed quantification legislation** - Regulation for the Mandatory Reporting of Greenhouse Gas Emissions, at https://govt.westlaw.com/calregs/Browse/Home/California/CaliforniaCodeofRegulations?guid=IF29D06908B1711DF8121F57FB716B6E8&originationContext=documenttoc&transitionType=Default&contextData=(sc.Default)f. – Regulation on California Cap on Greenhouse Gas Emissions and Market-Based Compliance Mechanisms, at https://ovt.westlaw.com/calregs/Browse/Home/California/CaliforniaCodeofRegulations?guid=I47A831C02EBC11E194EACEFFB46E37D1&originationContext=documenttoc&transitionType=Default&contextData=(sc.Default) OR - https://ww3.arb.ca.gov/cc/capandtrade/capandtrade/ct_reg_unofficial.pdf. General information and legislation can be found at https://ww3.arb.ca.gov/cc/capandtrade/capandtrade.htm.

Country	Type of carbon pricing instrument	Legislation, guidance, and tools
USA - RGGI	ETS	**Enabling framework 'legislation'** – The RGGI Model Rule, at https://www.rggi.org/docs/ProgramReview/_FinalProgramReviewMaterials/Model_Rule_FINAL.pdf. **Guidance** – Part 75 Emissions Monitoring Policy Manual, at https://www.epa.gov/sites/production/files/2019-05/documents/part_75_emissions_monitoring_policy_manual_4-24-2019.pdf.
USA - The Climate Registry	Voluntary reporting	**Guidance** – General Reporting Protocol, at https://www.theclimateregistry.org/protocols/General-Reporting-ProtocolV3.pdf. Further information can be found at https://www.theclimateregistry.org/tools-resources/reporting-protocols/general-reporting-protocol/.

Appendix D - Internationally Recognized Standards Used in Carbon Pricing Instruments

Table D.1 below shows which internationally recognized standards are typically used for quantification of emissions in carbon pricing instruments (see section 3.4). In addition, Table D.2 shows examples of technical standards used for sampling and analysis (see section 5.1.1.3); table D.3 lists a selection of standards used in quality assurance of direct measurement systems (see sections 5.2.5 and 5.4.2); and table D.4 shows examples of technical standards used in biomass quantification (see appendix B).

Table D.1: Recognized Standards Used in Quantification[157]

Standard	What does the standard specify?
ISO 14064-1 and 14064-2	Frameworks for quantification and reporting of (1) organizational level GHG emissions and removals; and (2) project level emissions reductions or removal enhancements.
ISO 14064-3	Requirements for the validation and verification of GHG statements related to GHG inventories, GHG projects, and carbon footprint of products. It specifies the process of validation and verification including the planning phase, evaluation, and reporting on GHG statements.
ISO 17025	General requirements for the competence of testing and calibration laboratories. This standard is mostly used to accredit laboratories and to ensure they are technically competent.
CDM standards	Quantification methodologies for a wide range of offset crediting project and program types.
IPCC 2006	*IPCC Guidelines for National Greenhouse Gas Inventories*, 2006 version. These guidelines contain requirements on how data for relevant sectors have to be collected and what quality assurance have to be applied when compiling national GHG inventories.
EN 16214	A suite of standards on sustainability criteria for the production of biofuels and bioliquids for energy applications.
ISO/CD 22095	*Currently under development* - Chain of custody -- General terminology, concepts, requirements, and guidance. Aims to provide a good practice framework for harmonization of existing Chain of Custody programs.
'The GHG Protocol'	Corporate Accounting & Reporting Standard - A framework for businesses, governments, and other entities to measure and report their greenhouse gas emissions.

157 Standards that are used in validation and verification of emissions reports are included in the PMR A&V Guide.

Table D.2: Examples of Technical Standards Used in Quantification for Sampling & Analysis

Standard	What does the standard control?	Topic area
ISO13909	Hard coal and coke – Mechanical sampling	Sampling
ISO 3170	Petroleum liquids -- Manual sampling	Sampling
ISO 18283	Hard coal and coke -- Manual sampling	Sampling
GPA Standard 2166-05	Obtaining Natural Gas Samples for Analysis by Gas Chromatography	Sampling
ASTM E947-83	Standard Specification for Sampling Single-Phase Geothermal Liquid or Steam for Purposes of Chemical Analysis	Sampling
ASTM E1675-04	Standard Practice for Sampling Two-Phase Geothermal Fluid for Purposes of Chemical Analysis	Sampling
ASTM D4177-95	Standard Practice for Automatic Sampling of Petroleum and Petroleum Products	Sampling
ASTM D4057-06	Standard Practice for Manual Sampling of Petroleum and Petroleum Products	Sampling
ISO 5167-1	Measurement of Fluid Flow by Means of Pressure Differential Devices Inserted in Circular Cross-Section Conduits Running Full, Part 1: General Principles and Requirements	Analysis
ISO 5068-1	Brown Coals and Lignites -- Determination of Moisture Content, Part 1: Indirect Gravimetric Method for Total Moisture	Analysis
ISO 4259-1	Petroleum products -- Determination and application of precision data in relation to methods of test	Analysis
ISO 3675	Crude petroleum and liquid petroleum products - Laboratory determination of density - Hydrometer method	Analysis
ISO 29541	Solid mineral fuels - Determination of total carbon, hydrogen and nitrogen - Instrumental methods.	Analysis
ISO 1928	Solid mineral fuels - Determination of gross calorific value by the bomb calorimetric method, and calculation of net calorific value.	Analysis
ISO 1171	Solid mineral fuels - Determination of ash content.	Analysis
ISO 1170	Coal and coke - Calculation of analyses to different bases.	Analysis
ISO 11564	ISO 11564:1998 Stationary Source Emissions - Determination of the mass concentration of nitrogen oxides - Naphthylethylenediamine photometric method	Analysis
EN 15407	Solid recovered fuels. Methods for the determination of carbon (C), hydrogen (H), and nitrogen (N) content	Analysis
ASTM D6348 03	Standard Test Method for Determination of Gaseous Compounds by Extractive Direct Interface Fourier Transform Infrared (FTIR) Spectroscopy	Analysis
ASTM D5291-02	Standard Test Methods for Instrumental Determination of Carbon, Hydrogen, and Nitrogen in Petroleum Products and Lubricants	Analysis
ASTM D3174 04	Standard Test Method for Ash in the Analysis Sample of Coal and Coke from Coal	Analysis
ASTM D240-02	Standard Test Method for Heat of Combustion of Liquid Hydrocarbon Fuels by Bomb Calorimeter	Analysis
ASTM D1945-03	Standard Test Method for Analysis of Natural Gas by Gas Chromatography	Analysis
ASTM D1298-99	Standard Test Method for Density, Relative Density, or API Gravity of Crude Petroleum and Liquid Petroleum Products by Hydrometer Method	Analysis
ASTM D 3302	Standard Test Method for Total Moisture in Coal	Analysis
AS 1038.6.4	Coal and coke - Analysis and testing Part 6.4: Higher rank coal and coke - Ultimate analysis - Carbon, hydrogen and nitrogen - Instrumental method	Analysis
USEPA - Method 3C	Determination of Carbon Dioxide, Methane, Nitrogen, and Oxygen from Stationary Sources	Analysis

Standard	What does the standard control?	Topic area
USEPA - Method 3A	Determination of Oxygen and Carbon Dioxide Concentrations in Emissions from Stationary Sources (Instrumental Analyser Procedure)	Analysis
US EPA Method 3	Gas analysis for the determination of dry molecular weight	Analysis
VDI 2469-1	Gaseous emission measurement - Measurement of nitrous oxide - Manual gas chromatographic method	Analysis
ISO/TC 146/SC 1	This ISO technical committee is in the process of developing a range of sector standards for the determination of GHGs in energy intensive industries at https://www.iso.org/committee/52702/x/catalogue/.	General
USA Mandatory GHG Reporting – standards incorporated by reference	Other standards incorporated into USA Mandatory GHG Reporting rules are listed at https://www.ecfr.gov/cgi-bin/text-idx?SID=b0938db750f09b2af87de0d6559fcb33&mc=true&node=se40.23.98_17&rgn=div8.	General
ISO Guide 34	General requirements for the competence of reference material producers	Competence

TABLE D.3: Examples of Technical Standards Used in Quality Assurance of Automated Monitoring Systems

Standard	What does the standard control?
EN 14181	Stationary source emissions – Quality assurance of automated measuring systems
EN 14740	Stationary source emissions - Determination of the water vapour in ducts
EN 14789	Stationary source emission - Determination of volume concentration of oxygen (O2) - Reference method – Paramagnetism
EN 14791	Stationary source emissions - Determination of mass concentration of sulphur dioxide - reference method
EN 14792	Stationary source emissions - Determination of mass concentration of nitrogen oxides (NOx) - reference method: chemiluminescence
EN 15259	Air quality – Measurement of stationary source emissions – Requirements for measurement sections and sites and for the measurement objective, plan and report
EN 15267-1	Air quality. Certification of automated measuring systems. General principles.
EN 15267-2	Air quality. Certification of automated measuring systems. Part 2: Initial assessment of the AMS manufacturer's quality management system and post certification surveillance for the manufacturing process
EN 15267-3	Air quality. Certification of automated measuring systems. Performance criteria and test procedures for automated measuring systems for monitoring emissions from stationary sources
EN 15267-4	Air quality. Certification of automated measuring systems. Performance criteria and test procedures for automated measuring systems for periodic measurements of emissions from stationary sources.
EN 61207-1	Expression of performance of gas analysers. General.
ISO 10012	Measurement management systems - Requirements for measurement processes and measuring equipment
ISO 10396	Stationary source emissions -- Sampling for the automated determination of gas emission concentrations for permanently-installed monitoring systems
ISO 10780	Stationary source emissions - Measurement of velocity and volume flowrate of gas streams in ducts
ISO 10849	Stationary source emissions -- Determination of the mass concentration of nitrogen oxides -- Performance characteristics of automated measuring systems.

Standard	What does the standard control?
ISO 12039	Stationary source emissions -- Determination of carbon monoxide, carbon dioxide and oxygen -- Performance characteristics and calibration of automated measuring systems
ISO 12039	Stationary source emissions - Determination of carbon monoxide, carbon dioxide and oxygen - Automated methods
ISO 12039	Stationary source emissions - Determination of carbon monoxide, carbon dioxide and oxygen - Performance characteristics and calibration of automated measuring systems
ISO 14164	Stationary source emissions - Determination of the volume flowrate of gas streams in ducts - Automated method
ISO 14385-1	Stationary source emissions -- Greenhouse gases -- Part 1: Calibration of automated measuring systems
ISO 14385-2	Stationary source emissions -- Greenhouse gases -- Part 2: Ongoing quality control of automated measuring systems
ISO 14956	Evaluation of the suitability of a measurement procedure by comparison with a required measurement uncertainty
ISO 16911	Stationary source emissions - Manual and automatic de-termination of velocity and volume flow rate in ducts: Part 1: Manual reference method Part 2: Automated measuring systems (This applies EN 14181, EN 15267-3, ISO 14956, and EN 15259 as normative (mandatory) references.)
ISO 21528	Stationary source emissions - Determination of the mass concentration of dinitrogen monoxide (N_2O) - reference method: Non-dispersive infrared method
CEN/TS 17198	Stationary source emissions. Predictive Emission Monitoring Systems (PEMS). Applicability, execution, and quality assurance
US EPA - Performance Spec 3	For Oxygen and Carbon Dioxide at https://www.epa.gov/emc/performance-specification-3-oxygen-and-carbon-dioxide.
US EPA-Procedure 1	Quality Assurance Requirements For Gas Continuous Emissions Monitoring Systems Used For Compliance Determination at https://www.epa.gov/emc/procedure-1-quality-assurance-requirements-gas-continuous-emission-monitoring-systems-used.

TABLE D.4: Examples of Technical Standards Used in Quantification of Biomass

Standard	What does the standard control?
EN 15440	Solid recovered fuels -- Methods for the determination of biomass content
EN 15442	Solid recovered fuels -- Methods for Sampling.
EN 15443	Sampling, transport, storage of the solid recovered fuel and sample preparation in the field
EN 14778	Solid bio fuels --Sampling
EN 14918	Solid Bio fuels -- Method for the determination of calorific value
EN 16640	Bio-based products -- Bio-based carbon content – Determination of the bio-based carbon content using the radiocarbon method
ISO 13833	Stationary source emissions -- Determination of the ratio of biomass (biogenic) and fossil-derived carbon dioxide -- Radiocarbon sampling and determination
ISO 18466	Stationary source emissions -- Determination of the biogenic fraction in CO_2 in stack gas using the balance method
ASTM D6866 - 18	Standard Test Methods for Determining the Bio-based Content of Solid, Liquid, and Gaseous Samples Using Radiocarbon Analysis

Appendix E – Examples of Alignment between Emissions Reporting Systems

Table E.1 shows some examples of how countries have aligned:

- Quantification and reporting under the carbon pricing instrument with national inventory reporting; for example, how countries have used national inventory methodologies and concepts to ensure carbon pricing data can be used for UNFCCC purposes and systems are aligned
- Various GHG and pollutant reporting mechanisms to avoid overlap between systems and to reduce costs

TABLE E.1: Examples of Alignment

Approach	Examples
Use of IPCC 2006 default factor values	Nearly all carbon pricing instruments prescribe the use of IPCC 2006 default values in certain specified cases. These include, for most carbon pricing instruments, when more accurate values are not available or possible, or where obligated entities are simple and small and so methodologies can be less accurate. In countries[158] that use a tier approach, these values are usually prescribed for the lowest tier levels. Before prescribing IPCC 2006 default values, it is important to assess whether more appropriate default values exist for a sector, such as a national inventory default value.
Use of IPCC 2006 tier approach	See section 6.1 on how the IPCC tier approach can be used
Sector specific methodologies	– All carbon pricing instruments; GWP from the latest IPCC assessment report are used. – IPCC 2006 list measurement/ sampling standards that can be applied in different sectors. Most carbon pricing instruments use the same standards. – **EU ETS** - the aluminium sector GHG protocol is listed as one of the applicable standards for the primary aluminium sector. Installations have to use it when determining facility-specific factors. – **South Africa** – The carbon tax system methodologies applied are based on IPCC 2006 and the national GHG emissions reporting scheme. – **USA RGGI** -- The requirements of CEMS methodologies are based on methodologies that are applicable to US EPA GHG reporting.
Use of IPCC 2006 categories in carbon pricing reporting to facilitate collection of data for UNFCCC reporting	– In some carbon pricing instruments, such as the EU ETS, obligated entities have to use IPCC category codes when reporting activities emitting GHG emissions. This facilitates collection of data for UNFCCC reporting. However, policy makers should be aware that some facility data cannot automatically be used for UNFCCC reporting without checking consistency of the data (see Austrian example below). Austria - The national inventory uses the following CRF categories; pollutants, plant or boiler specific emissions declarations are considered: 1.A.1.a Public Electricity and Heat Production (55 boilers): CO, SO_2, NO_x 1.A.1.b Petroleum Refining (1 plant): SO_2, NO_x, CO, VOC (‘IE‘: reported under 1 B) 1.A.2.a Iron and Steel (2 integrated iron & steel plants): CO_2, CO, VOC, SO_2, NO_x 1.A.2.f Non-Metallic Minerals – Cement production (10 plants): CO_2, SO_2, NO_x, CO, VOC

158 EU ETS, South African carbon tax system, Singapore carbon tax system, Mexican National Emission Register (RENE).

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Approach	Examples
	To avoid double counting of point source and area source emissions (area source use national energy balance data), a check is done on consistency of the activity reported under the EU ETS with activity data from national energy statistics. Reported data must not be greater than statistics data for the relevant category (alignment of plant to the specific energy balance sector is determined by NACE[159] or ISIC-Codes). Only consistent and complete point source data are used for inventory preparation. If data are not consistent, then data from the national energy balance is used. Activity data and point source emissions declarations are checked by comparing implied emission factors against IPCC default values or by comparing emissions to those of a simple IPCC Tier 1 approach. This means activity data are taken either from national statistics or from the IEA/ EUROSTAT joint questionnaires. Calorific values used to convert fuel activity data [volume or mass into Terajoule] are country specific; these values are fuel and technology dependent and are based on information provided in data submitted by Austrian installations that are EU ETS obligated.
Evaluation on whether methodologies are consistent with IPCC	**Australia -** For the Emissions Reduction Fund, the Department of Industry, Science, Energy and Resources is responsible for actively ensuring each methodology is consistent with the estimation methods used to compile the National Greenhouse Gas Inventory in accordance with Australia's inventory reporting method.
Aligning with other reporting programs	In some countries there are existing GHG emissions and other pollutant registries or reporting programs. Existing programs can mean there is an overlap between emissions reporting for carbon pricing and the other reporting programs. To avoid overlaps and to ensure obligated entities do not have to report the same data twice, some countries have taken measures to streamline reporting programs: – **EU ETS** - Emissions reports have to list NACE codes, IPCC categories, location of sites, and if waste is involved identification of EU Waste categories. Adding codes facilitates reporting under other environmental legislation and collection of data for UNFCCC reporting. – **Mexico** - The National Emissions Registry has built on the existing local pollutant release and transfer registry. Overlap between reporting requirements has been reduced and the registry improved. Removing overlap was done to reduce costs for companies. An online reporting system is used to report the data. – **South Africa** - The carbon tax quantification rules use existing regulations on mandatory reporting of GHG emissions. This means that the methodology for collecting data for UNFCCC reporting is similar to quantification and reporting under the carbon tax system.
Using the same reporting format or system	In some countries a common online reporting tool is used to report any GHG emissions. Shared tools facilitate reporting processes, avoids overlap between reporting mechanisms, and enables efficient collection of data for UNFCCC reporting. – **Chile** - Green tax system reports have to be submitted through the Pollutant Release and Transfer Register, which is also used for other reporting mechanisms and is hosted by the Ministry of the Environment. Information is collected on a quarterly basis via an online platform, the Emissions Reporting System hosted by the Superintendent of the Environment. Reported information is stored in digital files and processed in a specialized database. – **Norway** requires operators of its EU ETS installations to submit their emissions reports through an online environmental reporting system that is also used for other types of GHG emissions and environmental reporting. – **South Africa** - Reporting is carried out via the online emissions reporting system, National Atmospheric Emissions Inventory System. This system is part of the South African Air Quality Information System, a national air quality information system established under the National Framework for Air Quality Management. – **USA** - The mandatory GHG reporting program uses a common online system to report data.

159 Codes to classify economic activities.

Appendix F – Overview of GHG Coverage by Carbon Pricing Instruments

TABLE F.1: GHG Coverage in Existing Carbon Pricing Instruments

Carbon pricing instrument	CO_2	N_2O	PFC	HFC	SF_6	CH_4	NF_3	Others included
Argentina carbon tax	✓							
USA: California ETS	✓	✓	✓	✓	✓	✓	✓	OFG[160]
Canada Alberta carbon tax	✓							
Canada British Columbia carbon tax	✓	✓	✓	✓	✓	✓	✓	
Canada: Newfoundland/Labrador carbon tax	✓	✓	✓	✓	✓	✓	✓	
Canada: North West Territories: carbon tax	✓							
Canada: Nova Scotia	✓	✓	✓	✓	✓	✓	✓	
Canada: Ontario ETS[161]	✓	✓	✓	✓	✓	✓	✓	
Canada: Québec ETS	✓	✓	✓	✓	✓	✓	✓	OFG, NO_x
Chile green tax	✓							NO_x, SO_2
China: Beijing - ETS pilot	✓							
China: Chongqing - ETS pilot	✓	✓	✓	✓	✓	✓		
China: Fujian - ETS Pilot *Not approved by National Authority.	✓							
China: Guangdong- ETS pilot	✓							
China: Hubei- ETS pilot	✓							
China: National ETS	✓							
China: Shanghai- ETS pilot	✓							
China: Shenzhen- ETS pilot	✓							
China: Tianjin- ETS pilot	✓							
Colombia MRV system for inventories & corporate reporting	✓	✓	✓	✓	✓	✓		
Colombia: carbon tax	✓	✓	✓	✓	✓	✓		
Costa Rica GHG voluntary reporting and carbon neutrality standard for organizations	✓	✓	✓	✓	✓	✓	✓	HCFCs & CFCs
Denmark: carbon tax	✓							
Estonia: carbon tax	✓							
Europe: EU ETS	✓	✓	✓					
Finland: carbon tax	✓							
France: carbon tax	✓							
Iceland: carbon tax	✓							
Ireland: carbon Tax	✓							
Japan: carbon tax	✓							
Japan: Saitama ETS	✓							

160 Other fluorinated gases.
161 Ended in 2018.

Carbon pricing instrument	CO_2	N_2O	PFC	HFC	SF_6	CH_4	NF_3	Others included
Japan: Tokyo ETS	✓	✓	✓	✓	✓	✓		
Kazakhstan: ETS	✓							
Latvia: carbon tax	✓							
Liechtenstein carbon tax	✓							
Mexico: carbon tax & national emissions registry	✓	✓	✓	✓	✓	✓	✓	OFG[162]
New Zealand: ETS	✓	✓	✓	✓	✓	✓	✓	
Norway: carbon tax	✓	✓	✓	✓	✓	✓	✓	
Poland carbon tax	✓	✓	✓	✓	✓	✓	✓	
Portugal: carbon tax								
Singapore: carbon tax	✓	✓	✓	✓	✓	✓		
Slovenia carbon tax	✓							
South Africa: carbon tax, and carbon budgets[163]	✓	✓	✓	✓	✓	✓		
South Korea: ETS	✓	✓	✓	✓	✓	✓		
Spain: carbon tax			✓	✓	✓			
Sweden: carbon tax	✓							
Switzerland: CO_2 tax and ETS	✓	✓	✓	✓	✓	✓	✓	
The Climate Registry (TCR) – a US voluntary reporting program[164]	✓	✓	✓	✓	✓	✓	✓	
Ukraine: carbon tax	✓							
UK: climate change levy	✓							
UK: carbon floor price	✓							
USA: Massachusetts ETS	✓							
USA: Mandatory reporting program	✓	✓	✓	✓	✓	✓		
USA: RGGI	✓				✓	✓		NO_x, SO_2
USA: Virginia ETS	✓							

Source: Literature research & survey for this report (see IETA Case Study Guide to Emissions Trading at https://www.ieta.org/The-Worlds-Carbon-Markets; ICAP ETS Map (2020) at https://icapcarbonaction.com/en/ets-map; and The World Bank Group (2020) Carbon Pricing Dashboard at https://carbonpricingdashboard.worldbank.org/)

Appendix G – Types of Measurement Used for Annual Activity Data

As explained in section 5.1.1, consumption of fuel or production of materials in activity data is generally determined by means of continual or batch measurement. Table G.1 below indicates how each of these measurements are carried out and what policy makers should take into account when setting rules.

162 HCFC, Halocarbon, halogenated ethers.
163 Due to commence in 2018 (in part).
164 This program is governed by U.S. states and Canadian provinces and territories; it designs and operates voluntary and compliance GHG reporting programs globally, and it assists organizations in measuring, verifying, and reporting the carbon in their operations so they can manage and reduce it. Although this is not a carbon pricing instrument, this program was part of the voluntary process that preceded and then provided input into the Californian ETS.

TABLE G.1: Considerations for Continual and Batch Measurement

Type	Description
Continual measurement related to the process that causes emissions	The placement of measurement instruments can be done as the source stream enters the facility (such as a natural gas meter at the facility boundary) or at some point in the flow before the fuel/material enters a processing unit (such as a flow meter or weigh-scale at the direct input point to the process unit)[165], or at the point the product leaves the process. The quantity consumed/produced can be determined by one or both of these actions: – Subtracting the quantity measured at the beginning of the reporting period from the quantity measured at the end of the reporting period[166] – Summing up meter readings taken periodically over the whole reporting period. The frequency of meter readings depends on the way the instrument system is set up and can be done over seconds, minutes, hours, days, weeks, months, and so on. The summation process can be manual or completed via an automated control and plant information system. Continual measurement is in general carried out when the obligated entity has control over its own instruments. However, in some cases continual measurement may also be done where the obligated entity is provided with direct access to instruments or real-time data by third party suppliers. The quantitative uncertainty relates to the type of measurement instrument used. Regulators should be aware that part of the fuel/material may not be used within the facility but is further exported to another facility; is consumed for an activity that does not fall under the scope of the carbon pricing instrument; or in the case of some fuels may be used as feedstock materials into a process. In those cases, the uncertainty of that amount of fuel or material deducted must also be taken into account[164]. Regulators need to consider this element when defining the rules on quantitative uncertainty assessments.
Batch measurement	The quantities of fuel or material consumed are measured in separate batches taking account of stock changes.[167] Quantities measured in batches are subsequently aggregated using a stock balance for the reporting period. Measurement can be done by different mechanisms including weighbridge, level gauge, flow measurement instruments, or qualified survey,[168] depending on the nature of the fuel/material. For example, Québec's (Canada) MRR[169] makes extensive provisions for use of flowmeters, including determining the eligible flow meter testing standards.[170] This approach is often applied when some or all of the measurement instruments are not under the control of the obligated entity (offsite), and invoices are the main source of delivery data. The following formula is used for the stock balance over a reporting period[171] (using fuel as an example): Quantify of fuel consumed = (Purchased quantity) – (exported quantity) + (Stock at start of reporting period) – (Stock at end of reporting period) The exported quantity is the amount that leaves the quantification boundary of the obligated entity.[172]

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165 See section 6.1.2 of the EU *ETS MRR Guidance Document I: The Monitoring and Reporting Regulation – General Guidance for Installations* at https://ec.europa.eu/clima/sites/clima/files/ets/monitoring/docs/gd1_guidance_installations_en.pdf., p. 60.
166 Typically, where totalizer meters are used.
167 For example, tanker deliveries of oil to a holding tank from which the fuel consumed is taken, rail/road delivery of coal to stockpiles, or materials weighed in on weighbridges. For further information, please see section 6.1.2 of *MRR Guidance Document I. The Monitoring and Reporting Regulation*.
168 For example, in the case of solid fuels/materials stored in stock piles, this may be done by quality controlled volumetric and density survey using approved or accredited surveyors.
169 *Regulation Respecting Mandatory Reporting of Certain Emissions of Contaminants into the Atmosphere,* (Légis Québec, Feb 2020), http://legisquebec.gouv.qc.ca/en/ShowDoc/cr/Q-2,%20r.%2015#se:3.
170 Table 1-9. Flow meter tests (QC.1.5.2(3) MRR.
171 Such as a calendar year.
172 Such as fuel that is delivered to parts of a facility that are not covered by the carbon pricing instrument or passed through to other facilities not covered by carbon pricing instrument.

Type	Description
	There are situations where determining stock levels by metering that meets specified quantitative uncertainty requirements is technically not feasible or is overly expensive. In such cases, policy makers may consider allowing estimation and/or correlation[173] methods. When using estimation, the quantity should be conservatively estimated, meaning that the resulting emissions should not be understated for annual emissions quantification nor overstated for baseline emissions quantification used for allowance determination and the like. **Considerations for policy makers:** When incorporating this approach into legislation, policy makers need to define: – What are unreasonable costs and the benchmark used to determine what is unreasonable in the context of the country or carbon pricing instrument? – What is technical not feasible in the context of the country or carbon pricing instrument? – How can an obligated entity demonstrate unreasonable costs or technical infeasibility? – Determining stocks at the end of the reporting period may not necessarily be possible. For example, at midnight on December 31 in the calendar year reporting. For this reason, legislation should allow obligated entities to choose the next appropriate date and then reconcile that data to the end of the reporting period, for example, by pro-rating according to the number of days before/after the period end.

Appendix H – Direct Measurement-Based Methodologies

Part A of this appendix provides information on the differences between a Continuous Emissions Monitoring System (CEMS) and the emerging alternative approach of Predictive Emissions Monitoring (PEMS). Part B indicates how direct measurement is applied in a number of different reporting mechanisms.

When determining if direct measurement-based methodologies are the most appropriate, the technical capability of obligated entities needs to be considered. For example, if facilities are not fitted with CEMS or PEMS (either when constructed or retrofitted) and industry is not technically prepared to do direct measurement, it is not recommended to require obligated entities to apply these methodologies unless there is no other choice or only allowing it only under specific conditions (such as demonstration that the data are more accurate than from a calculation).

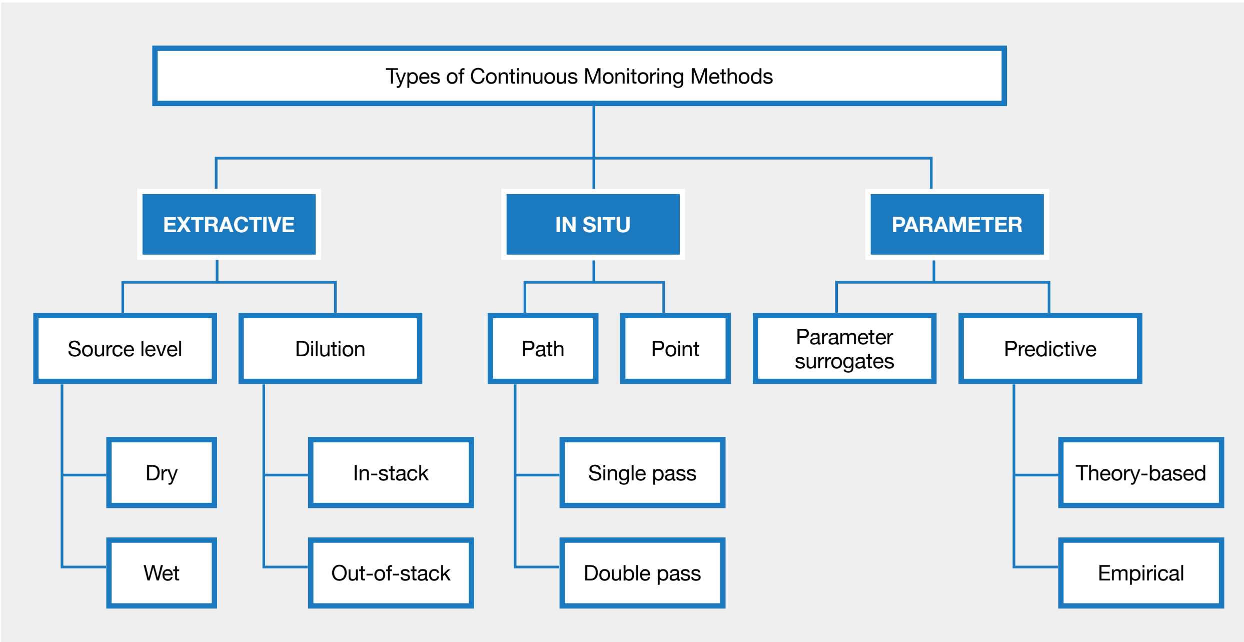
A. CEMS versus PEMS

Primarily carbon pricing instruments that allow direct measurement of emissions use a Continuous Emissions Monitoring System (CEMS). However, an alternative approach – Predictive Emissions Monitoring (PEMS) - may also be used. Typically, PEMS is used as a backup for traditional analyzers.

173 For example, correlating data using a reasonable proxy that has a direct relationship to the fuel consumption such as deriving a factor based on prior year consumption and product output to create an estimate of current reporting year emissions based on current production output. For further information, please see section 6.1.2 of the *EU ETS MRR Guidance Document I: The Monitoring and Reporting Regulation – General Guidance for Installations* at https://ec.europa.eu/clima/sites/clima/files/ets/monitoring/docs/gd1_guidance_installations_en.pdf.

Figure H.1below outlines the types of direct measurement methods available, and table H.1 gives examples of the differences between CEMS and PEMS.

FIGURE H.1: Types of Direct Continuous Measurement.



Source: US EPA[174]

TABLE H.1: Examples of Differences between CEMS and PEMS

	CEMS	PEMS
Emissions values	– Measured using instruments	– Predicted using a software model based on operational parameters
Type	– Hardware and software; environmentally controlled housing	– Software model and one computer (server, PC, or laptop) linked to existing process control system or plant information system which supplies the input data to the model
Capital costs	– Significant	– Much lower
Ongoing costs	– Significant	– Much lower
Time to install	– A number of months for install using skilled technicians (electrical, mechanical, computer) plus start up and testing.	– Typically, a month plus start up – Initial set-up will require a full relevant data set of process parameters to establish the model design and testing.
Training requirements for operators	– Five to eight days of specialist training	– One to two days of training
Input data	– Gas flow to, and concentration of the target gas(es) in the flue.	– Operational parameters such as temperature, pressure, flow of the main units feeding into the flue
Analyzer requirement	– Dual/multi range analyzer to cover entire range of operational conditions may be required.	– Standard process analyzer(s) and other sensors

174 *Handbook: Continuous Emissions Monitoring Systems for Non-Criteria Pollutants,* (US Environmental Protection Agency, Washington, DC, 2011), https://cfpub.epa.gov/si/si_public_record_Report.cfm?Lab=NRMRL&dirEntryID=96227.

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	CEMS	PEMS
Calibration gases, auto calibration, and the like	– Generally, require piping, wiring, gas regulators or software that meets regulatory requirements.	– Generally, has software-based auto-calibration of analyzers. – Periodic mathematical optimization of the model based on real world time series parameter values
Drift	– Instruments may be subject to drift unless appropriately checked and calibrated. – Contamination of sample transport and train may result in drift.	– Inherently no drift unless the underlying operational instruments do so
Data loss	– Failure of an instrument or critical component may require data substitution.	– Software model can accommodate some instrument failure as there are usually redundant input data points that it can use.
Preventive maintenance	– Daily, monthly, quarterly, annual maintenance in line with regulatory requirements – May require independent testing, calibration and or validation depending on regulatory requirements – Spares may need to be held in stock.	– Not required (although underlying process instruments would require normal operational maintenance and calibration) – Software upgrades may be required. – Model may require update and optimization if real world operational conditions change. – No spares required.

B. Examples of Direct Measurement-Based Methodologies

Table H.2 below provides examples of how CEMS is applied in some carbon pricing instruments and mandatory reporting programs. It also indicates when PEMS is allowed. The CEMS requirements in EU ETS and US EPA reporting rules are sophisticated, building on a number of years of experience. The CEMS rules for Chile's green tax have been based on US EPA rules with some elements adapted to local circumstances. The CEMS rules in the Mexican RENE[175] are less developed: only a very limited number of the companies reporting under RENE have applied CEMS.

TABLE H.2: Examples of Direct Measurement-Based Methodologies

Direct measurement	Chile green tax	EU ETS	Mexico RENE	US EPA
Application	Obligated entities can choose between methodologies. In general, most obligated entities apply CEMS to CO_2, NO_x and SO_2. If it is not possible or too costly to install CEMS, alternative methodologies[176] are generally applied.	Obligated entities are free to choose between calculation and direct measurement for CO_2.[177] For N_2O the application of CEMS is required unless it concerns unabated emissions of N_2O from adipic acid, glyoxal and glyoxylic acid production and it is not technically feasible. CEMS is also required for transferred CO_2.	For facilities where it is not technically feasible to apply calculation-based methodologies, CEMS can be used.[178] Only a very limited number of companies have used CEMS.	Rules specify when to use CEMS.[179] When alternative methodologies are allowed in addition to CEMS, obligated entities must demonstrate that these methodologies have the same precision, reliability, accessibility, and timeliness as a certified CEMS.

175 Registro Nacional de Emisiones in Mexico.
176 Measurement based on samples that are analyzed by accredited laboratories, calculation.
177 In the previous trading periods (the first and second trading period), CEMS could be applied only if the obligated entity demonstrated that CEMS was more accurate.
178 This is the case when it is technically not feasible to apply the standard emission factor approach, when the carbon content of the materials or substances cannot be determined, or when the standard variation of the carbon content of the fossil fuel is greater than 10 percent.
179 If a unit is coal-fired or combusts any type of solid fuel, CEMS is in general applied to all parameters. If a unit is oil or gas fired or if it combusts very low sulphur fuels, alternative methodologies may be applied.

Direct measurement	Chile green tax	EU ETS	Mexico RENE	US EPA
Is PEMS allowed?	Yes, but conditions apply	No	No	Yes, but conditions apply
Methodology and data aggregation	Measurement of hourly average concentration and hourly average flow rate. Obligated entity is responsible for aggregating hourly averages to emissions per emission point and eventually to total emissions. Specific requirements apply to determining humidity.[180]	Determination based on hourly average concentration and the hourly average flow rate.[181] The obligated entity is responsible for collecting and aggregating to total emissions.[182] The tier approach is applicable to CEMS. An uncertainty assessment must be carried out to demonstrate compliance with tier requirements. Specific requirements apply to application of CEMS in the determination of N_2O emissions and transfer of CO_2 emissions.	Hourly average concentration and flow gas rate is determined through CEMS. The obligated entity is responsible for aggregating the data to total emissions. Concentration is multiplied by flow rate and a conversion factor, taking into account moisture correction.	Determination is based on hourly average concentration and hourly average flow rate. Data is reported automatically to regulator for monitoring purposes. Specific requirements apply to determination of emissions and heat input based measured values. Requirements differ depending on the type of emissions measured. Requirements also specify when to take into account the moisture content of the stack.
Is corroboration used?	In some cases	For determination of CO_2 emissions, measured values are corroborated by a separate calculation.	No	In some cases
Specific requirements in case of multiple stacks	Specific requirements are included in legislation. These reflect different approaches ranging from installing CEMS in each of the chimneys; measuring in the main chimney and other approaches.[183]	Not applicable, as CEMS is applied at each stack that comprises an emission point, where relevant	Not applicable. If an emission source shares a chimney with other emissions sources, procedures must be implemented to ensure representative samples. In some cases, monitoring systems must be placed in more chimneys.	Specific requirements are included in legislation to ensure completeness of data, these must be implemented by obligated entities. In some cases, monitoring systems must be installed at more than one stack or duct location.

180 Several approaches can be applied, ranging from measurement of humidity to using default values, measuring with an O2 CEMs that is capable of measuring on a dry and wet basis or based on a humidity sensor calibrated according to technical specifications from the manufacturer.

181 Guidance Document 7: "The Monitoring and Reporting Regulation Continuous Emission Measurement System," (European Commission, General Climate Action Directorate, 2017), https://ec.europa.eu/clima/sites/clima/files/ets/monitoring/docs/gd7_cems_en.pdf.

182 Gas concentration must be measured with CEMS instruments. The flue gas can be determined by either a mass balance or CEMS instruments.

183 Using calculation reference methods, default values, average values based on several measurements, or specific sampling methods for the by-pass chimney.

Direct measurement	Chile green tax	EU ETS	Mexico RENE	US EPA
Missing data	Substitute data must be applied, but no clear requirements are included in legislation.	Substitute data. The method to determine substitute values depends on whether data is missing for the concentration[184] or for other parameters.[185] Where the CEMS is out of operation for more than five days, the obligated entity must notify the regulator and take corrective action. It must have a procedure in place to deal with these situations.	No specific requirements have been included in legislation.	If one of the required monitoring systems is not working or is out-of-control,[186] data from an approved backup monitor or from an EPA reference method may be reported. If quality-assured data from a back-up monitor or reference method are not available, the obligated entity must use missing data substitution procedures[187] described in federal legislation.
Quality assurance	CEMS must, in principle, be validated before operation and installed properly according to specifications. Validation is carried out according to specific guidelines. Only under certain conditions can CEMS be operated without validation, provided quality assurance and control measures are adopted.	Quality assurance must be carried out according to EN 14181. This standard includes: – Testing whether the CEMS meets requirements (QAL 1) – Calibration and validation of the CEMS (QAL 2) – Ongoing quality assurance during operation (QAL3) – Annual surveillance test Laboratories carrying out measurements, calibrations, and relevant equipment assessments for CEMS must be accredited to ISO/IEC 17025 for the relevant analytical methods or calibration activities. Non-accredited laboratories can be used only under specific conditions.	Calibration must be carried out by laboratories or persons that are approved according to federal law on metrology and standardization. Calibration is carried out according to manufacturer's specifications or either Mexican standards or international standards. Calibration frequency is prescribed by the manufacturer. An accuracy level of ±5 percent applies. QA/QC procedures must be set up, implemented, and documented. If calibration cannot be performed, the obligated entity should demonstrate that the required accuracy level is met.	Quality assurance procedures are specified in legislation, including: – Initial certification tests – Re-certification tests – Quality assurance tests – Data verification tests Tests include accuracy test audits, bias tests, quarterly linearity checks, and daily calibration error tests to detect drift.[188] Quality-assurance tests for CEMS include daily assessments (such as calibration error tests), quarterly assessments (such as linearity checks), and semi-annual (or annual in most cases) relative accuracy test audits (RATAs).
Recording data	Data related to CEMS needs to be recorded. Specific rules are included in legislation.	Data related to CEMS need to be stored at least 10 years from the date of submission of the emissions report. Rules include what data to retain.	Data needs to be recorded and retained for 5 years. No specific rules are included on what data to retain.	Data has to be kept at least three years electronically using a data acquisition and handing system (DAHS).

184 Substitution values have to be calculated as the sum of an average concentration and twice the standard deviation.

185 Substitute values should be obtained through a suitable mass balance model or an energy balance of the process. Validation of the results is needed by using the remaining measured parameters and data at regular working conditions, considering a time period of the same duration as the data gap (See section 5 GD7 on Continuous Emission Measurement https://ec.europa.eu/clima/sites/clima/files/ets/monitoring/docs/gd7_cems_en.pdf.)

186 For example, if it fails one of its required quality assurance tests.

187 The substitution values and data described in these procedures are, in general, historical data; values used depend on historical availability, length of missing data, and for NOx and flow rate, the hourly unit loads during the missing data period.

188 Relative accuracy test audits are tests against reference methods. Bias tests are carried out to check if the CEMS reading is consistently low

Direct measurement	Chile green tax	EU ETS	Mexico RENE	US EPA
Data submission to regulator	Facilities have to report data quarterly using the PRTR uniform public service system.	The operator of the installation submits an annual emissions report to the regulator by March 31 of each year.[189] This annual report includes emissions data and underlying data on parameters.	Annual reporting by obligated entities to the regulator. This annual report includes emissions data and underlying data on parameters.	For units under the Acid Rain Program and/or the CAIR annual SO_2 and NO_x programs, an emissions report must be submitted once for each calendar quarter to the regulator.

Appendix I – Examples of Data Gap Approaches

Table J.1 below outlines the different approaches taken by various carbon pricing instruments that have chosen to allow obligated entities to fill data gaps.

TABLE J.1: Examples of Methods to Fill Data Gaps

Carbon pricing instrument	Approach to filling data gap
California ETS	A range of approaches are specified, depending which tier reporting method is used, the data capture rate, and the nature of the fuel consumption, for example: – Missing fuel characteristic or consumption data may be substituted with the average of pre- and post-failure results, the highest value of the reporting year and 2 prior years, the greater value of the last 10 years, a default value, or an estimate based on equipment load.[190] Full details are given in MRR §95129.[191] – CEMS: in the first 720 hours after initial certification of the CEMS where prior quality assured data are available, the average hourly CO_2 concentration of the hour either side of the gap will be used. Where no prior quality assured data are available, the maximum potential hourly CO_2 concentration is used. After the first 720 hour period, if <5 percent of data are missing and the gap is ≤1 day, the average hourly CO_2 concentration of the hour either side of the gap will be used; if the gap is >1 day, a value is selected that is the higher of the hourly average CO_2 concentration or the 90th percentile hourly concentration from the previous 720 operating hours. Further specifications are made for other ranges of available data and gap sizes. Full details are given in 40 CFR §75.31 and §75.33.
Canada Alberta ETS	Methodology rules outline how data gaps should be addressed. Typical approaches for filling data gaps are calculation methodologies with proxy values. These methodologies are specified in section 17.4.2. of QM CCIR/SGRR[192]).
Chile green tax	In principle, CEMs must be carried out. However, alternative methodologies can also be applied. Where none of the proposed alternative methodologies can be applied by an obligated entity because of technical infeasibility, it may propose its own alternative quantification methodology, provided the proposed alternative is recognized internationally for the purposes of quantification of taxed or other related regulations. Technical infeasibility must be justified. An obligated entity must submit evidence and the technical background necessary for evaluation of its claims (Chapter 6.7, p.11, Titulo 1).

189 In some Member States, earlier deadlines are included in legislation.
190 The component or portion of a circuit or piece of equipment that actively consumes energy. The amount of input energy required to operate equipment can be estimated from its energy consuming load required to produce the expected output.
191 *Unofficial Electronic Version of the Regulation for the Mandatory Reporting of Greenhouse Gas Emissions,* (California Air Resources Board, April 2019), https://www.arb.ca.gov/cc/reporting/ghg-rep/regulation/mrr-2018-unofficial-2019-4-3.pdf?_ga=2.104446528.1775044070.1557508454-1111296313.1557434350.
192 *Quantification Methodologies for Carbon Competitiveness Incentive Regulation and the Specified Gas Reporting Regulation,* (Alberta Climate Change Office, Nov 2018), https://open.alberta.ca/dataset/61542074-8233-4f6c-a351-1454d57c0a32/resource/28cd6f46-ff55-4304-a863-dd8b193dfff1/download/cci-quantification-methodologies.pdf.

Carbon pricing instrument	Approach to filling data gap
EU ETS	The MRR specifies that an installation must describe approaches for filling data gaps in its monitoring plan that has been approved by the responsible regulator. If such a plan does not contain an approach for filling data gaps, installations must notify the regulator when a gap occurs and propose an approach for the regulator's approval. Guidance has been developed on when a data gap can occur and what possible approaches exist to fill data gaps.[193] This guidance includes applying safety factors to ensure conservativeness. For CEMS, specific rules have been included in case the CEMS breaks down and hourly data are missing.
Singapore	Whenever the primary quantification approach for activity data or conversion factor involves a measurement instrument, the taxable facility has to specify in its monitoring plan an alternative approach to cover data gaps (such as measurement instrument failure). This alternative approach may be used for up to a maximum of 90 days within one reporting period/calendar year. For failure periods >90 days, the taxable facility is required to seek approval from the regulator on the extension of the alternative approach and to provide justification.

Appendix J – Quantitative Uncertainty and Measurement Instrumentation

This appendix provides further information underpinning the concept of quantitative uncertainty and how it impacts quantification methodologies.

A) Quantitative Uncertainty[194]

When determining the quality of measurements, metrology and international standards refer to the quantity of uncertainty. When using this term in plain language it is often used interchangeably with the terms error, precision and accuracy. Although these terms have a bearing on uncertainty, they are not the same as uncertainty:

- **Accuracy** means the closeness of agreement between a measured value and the true value of a quantity. If a measurement is accurate, the average of repeated measurement results is close to the true value.[195] If a measurement is not accurate, inaccuracy can sometimes be due to a systematic error, which can often be overcome by calibration and adjustment of instruments.

- **Precision** describes the closeness of results of repeated measurements of the same measured quantity under the same conditions. It is often quantified as the standard deviation of the values around the average. It reflects the fact that all measurements include some random error; this error can be reduced, but not completely eliminated.

- **Error** means the difference between a measurement and the true value of the quantity being measured.

- **Uncertainty** characterizes the range within which the true value is expected to lie with a specified level of confidence. It is the overarching concept that combines precision and assumed accuracy. Measurements can be accurate but imprecise, or vice versa. The ideal measurement is both precise and accurate.

193 *EC Guidance on conservative estimation approaches for annual emissions reporting* at https://ec.europa.eu/clima/sites/clima/files/ets/monitoring/docs/guidance_conservative_estimates_ca_en.pdf.
194 Further information can be found in EU ETS MRR Guidance document 4 (27 November 2017).
195 Which may, for example, be the nominal value of a certified standard material.

Errors in relation to meters and measurement devices are made up of two elements:

- The known **inherent uncertainty** of the instrument that results from its design specification. This attribute cannot be changed, provided that the instrument is installed correctly.[196]
- The unknown **associated uncertainty** related to the way that the instrument has been used, maintained, and calibrated. This attribute can be changed and, therefore, requires evaluation and action to reduce it as far as possible.

Quantitative uncertainty associated with a measurement, commonly expressed as a ± percentage, gives a range within which the actual quantity being measured is expected to lie. Dependent upon the rules of a CT or ETS, the acceptable quantitative uncertainty[197] of measurement devices may be specifically defined.

Appendix K – Resources

Table K.1 below provides information on the type and amount of resources needed for development and implementation of a quantification protocol. Activities mentioned in the table are primarily those for regulators and obligated entities. Factors that can influence the type of resources and measures that can be taken to reduce costs are outlined. For some of these activities support can be gained from international projects initiated by national governments, Europe Aid, World Bank programs and other international organizations.

TABLE K.1: Examples of the Type and Amount of Resources Needed for the Development and Implementation of a Quantification Protocol

Phase	Activity	Type of resources needed	Factors that influence amount of resources	Measures to reduce resource requirements
Design & set up of frameworks	Legislative framework	Staff and advisors to develop legislation; initially as a one-off activity before the carbon pricing instrument starts operation but also a potentially reoccurring requirement for future updates of legislation.	– Complexity of legislation and whether it is primary or secondary – The number of institutions involved in drafting legislation – Whether MRV legislation is developed in parallel with other carbon pricing legislation – Whether (elements of) existing legislation and institutions can be used as a basis	– Combining design of the quantification legislative framework with drafting of details for the overall carbon pricing instrument. This alignment improves efficiency and has a positive effect on output quality and consistency. – Developing quantification legislation in parallel with that for verification and accreditation of verifiers (if relevant) ensures consistency and auditability.

196 However, the design accuracy of a meter cannot actually be specifically measured, only the range within which it should lie with a known probability. So, there is also an element of known design uncertainty.
197 Inherent and associated.

Phase	Activity	Type of resources needed	Factors that influence amount of resources	Measures to reduce resource requirements
	Institutional framework	As a one-off activity before the carbon pricing instrument becomes operational, both staff and financial resources are required for setting up new (or adapting existing) institutions along with relevant systems and procedures and/or institutions.	– The number of regulators involved, and whether they include local or regional regulators – The carbon pricing instrument's complexity and number of obligated entities involved – Whether there are existing structures and institutions to build on – Whether or not there is (or can be) co-ordination between regional authorities	– Making use of existing institutions that have the competence and capacity to carry out the required work
	Stakeholder engagement	Typically, an ongoing activity over time that can help strengthen quantification, identify problems, and build capacity. Staffing and costs are needed for setting up consultations, workshops and other engagement on an ad hoc or regular basis.	– Stand-alone events vs engagement through existing organizations – The number of stakeholders involved – The complexity of the carbon pricing instrument and associated legislation and guidance and the like	Using existing channels for communication and engagement, including representative groups such as industry associations and professional institutes
Design implementation processes and tools	Staff instructions/ processes for implementing carbon pricing.	Consistent implementation and enforcement require formalized work processes and instructions to be developed for activities to be carried, such as assessing monitoring plans, evaluating entity compliance, and review of emissions (and verification) reports.	– Resources of a country – Whether the carbon pricing instrument requires obligated entities to submit a monitoring plan for approval by the regulator – Approach chosen to assess compliance of obligated entities – Type of institutions carrying out activities (for example number of regulators and number of facilities or companies involved)	Utilizing existing procedures / structures
	Guidance, tools and templates	– Costs for advisory support in drafting and consulting on documents – Staff involved in developing guidance, templates and tools	– Quantity and complexity of guidance, templates, and tools	Utilizing engagement processes to get contributions to and feedback on documents. This engagement could also increase costs, if engagement processes generate extensive feedback. Structuring the engagement process is therefore important.

Phase	Activity	Type of resources needed	Factors that influence amount of resources	Measures to reduce resource requirements
	Designing helpdesks (if applicable)	– Costs for advisory support by experts – Costs for setting up the helpdesk; this could range from setting up an email address to which questions can be directed, to setting up procedures for answering questions, and creating a helpdesk tool/ system. – Staff involved in designing helpdesk (for operating and maintaining the helpdesk, see implementation and ongoing management)	– Area in which the helpdesk provides support (only MRVA topics or also other questions) – Sophistication and type of helpdesk (only email or also phone, online platform), response times	– Utilizing existing sources – Utilizing simple functionalities such as general e-mail to which questions can be sent – Begin simple and make it more advanced when system is up and running.
	Designing IT systems (if applicable)	– Costs for specialist IT advisory support – Costs of IT system and hosting	– Whether IT covers the carbon pricing instrument's whole workflow or only parts – Whether all stakeholders are expected to have access to the IT system and whether all are required to use the IT systems (or whether parallel non-IT-based systems also need to be established and maintained) – The sophistication and type of IT system (such as whether it uses web-forms, xml) – Whether it needs to communicate with other electronic environmental reporting systems and registries	– Alignment with existing systems – One system for all, no parallel systems – While IT systems in first instance increase costs, these could be paid back by increases in efficiency and quality in the long run in other phases of the process.
	Training (if applicable)	– Establishment of a training syllabus and associated materials (such as slides, briefings and exams) – Specialist qualified trainers (such as experienced auditors[198] /technical experts who can also train)	– The complexity of the carbon pricing instrument and how many types of training are required and for whom.[199] – Whether the training is paid for by the regulator; and whether it is open market or regulator provided	– Specifying a training syllabus and letting the open market develop materials and deliver classes in response to demand (either with or without a process of approval of training providers) – Requiring the obligated entity to pay for training so that it goes to those most likely to deliver work.[200]

APPENDICES

198 Emissions auditors know the rules, requirements, and potential issues well from their work reviewing entity's emissions quantification and accounting and reporting systems, which makes them well-placed to deliver training

199 For example, the training done for the Californian and the Republic of Korea's ETSs and associated crediting mechanisms included sector specialist training for the majority of sectors involved in the ETS and Lead Auditors.

200 Where training has been provided and paid for by the regulator, it has been found that many of the successful training participants did not necessarily go on to provide technical support or verification work. Participation cost them nothing and required no ongoing commitment

Phase	Activity	Type of resources needed	Factors that influence amount of resources	Measures to reduce resource requirements
				– Gaining support from international projects initiated by national governments, Europe Aid, World Bank programs or other international organizations
Implementation and ongoing management	Helpdesk operation.	– Staff support. – Maintaining functionalities of helpdesk system/ procedures	– Complexity of the carbon pricing instrument and areas for which helpdesk provides support	– Set-up processes for staff to structure and record responses so that reoccurring questions can be easily answered – Draft frequently asked questions and publish these on a website.
	Activities of regulator during M&R cycle.	– Staff involved in approval of monitoring plans or methodologies (if relevant). – Staff involved in the communication with obligated entities/ inspectors/ verifier (if applicable). – Staff involved in dealing with notification of changes to the monitoring methodologies or monitoring plans.	– Complexity of the carbon pricing instrument and number of obligated entities involved. – Resources involved. – Type of communication structure.	– Develop simple communication lines. – Use existing structures.
	Activities of obligated entities.	– Staff involved at the obligated entity in quantification, monitoring and reporting (re-occurring). – Costs for placement of measurement instruments/ systems (one-off). – Costs for setting up or adapting procedures and QA/QC costs for capacity-building of staff. – Calibration/ maintaining measurement instruments and system (re-occurring). – Financial resources for outsourced activities (such as an external accredited laboratory for sampling and analysis for emission factors) (re-occurring). – Costs for hiring internal/ external verifiers, (if applicable; reoccurring) – Maintenance and documentation of procedures and control activities (reoccurring)	– Complexity of carbon pricing instrument and sector scopes covered by the carbon pricing instrument, and whether approval is done on sector-specific scopes or not. – Complexity of quantification methodologies applied	– Tools to facilitate implementation of activities including standardized planning schedules, checklists and template process and reporting forms. – Robust QA/QC procedures targeted at the entity's M&R risks. – Consider designing simplified quantification methodologies for obligated entities that are small or simple.

Phase	Activity	Type of resources needed	Factors that influence amount of resources	Measures to reduce resource requirements
	Monitoring the quality of M&R by regulator (reoccurring)	– Staff of regulator involved in carrying out activities (dealing with changes to a quantification methodology, carrying out inspections, review of emissions reports, and so on) – Financial resources to pay experts or other parties to carry out inspection (if applicable) – Costs for carrying out relevant activities (such as traveling costs in the case of on-site inspections, use of inspection tools)	– Which option is chosen to monitor compliance of the obligated entity. The regulator doing basic checks on emissions reports would cost less than doing full-blown inspection with site visits. – Complexity of carbon pricing instrument and number of obligated entities involved	– Developing tools to facilitate such monitoring (such as checklists, use of IT systems) – Developing risk criteria to determine the type of checks to be done
	Regulator payment of external verifiers (if relevant)	– Financial budget – Administrative staff to manage accounts and check invoices or other documentation	– Budget cycles and whether it is identified as long-term funding[201] – Source of the funding (such as government general revenue or capitation of tax, trade, or crediting values)	– Require obligated entities to pay for external verifiers and implement rigorous rules on impartiality
	Ongoing capacity building	– Costs for training and briefing workshops for obligated entities and verifiers (such as involving trainers, maintaining training material, organizing training). – Staff involved with updating guidance, FAQ, help desk responses – Advisory costs for updating guidance/other materials	– The complexity of the carbon pricing instrument and how many types of training required – Whether the training is paid for by the regulator or obligated entity/ verifier; and whether it is open market or regulator provided – Other ongoing capacity building (such as workshops)	– Approving/recognizing publicly available training courses (with or without a standardized curriculum) – Encouraging active engagement of all stakeholders in knowledge sharing/capacity building (formal or informal)
	Ongoing stakeholder engagement	– Costs for setting up consultations, workshops, or other events – Staff involved in stakeholder engagement	– Stand-alone events versus engagement through existing organizations (such as professional institutes) – The number of stakeholders involved – The complexity of the carbon pricing instrument and legislation	– Utilizing existing channels for communication and engagement

201 This primarily impacts the availability and timing of resources, which, in turn, may impact the practicalities of when external verification can occur. For example, if the regulator is paying the verifier from a current year budget, it may not be possible to commission the verifier until the budget is finalized. If the new financial year is close to the deadlines for emissions reporting or if budgets are delayed/agreed late, this could squeeze the available time for delivery of verification work with knock-on consequences on quality and potential for error.

Phase	Activity	Type of resources needed	Factors that influence amount of resources	Measures to reduce resource requirements
	Information exchange between main regulator and other regulators or parties	– Man-days staff to exchange information – Costs involved in creating information databases – Costs involved in developing tools/ templates for information exchange (if applicable)	– Type(s) of information to be exchanged – Type of communication method (informal, by email, through IT systems, and the like) – Frequency of information exchange – Whether templates or data bases are used	– Creating templates, choosing simple communication methods
Review and evaluation of a quantification protocol	Assessment of system and update of system or legislation, (if applicable)	– Costs involved in developing questionnaires to get stakeholder input on system functioning – Stakeholder consultation costs – Costs for carrying out impact assessments or studies evaluating the carbon pricing instrument (workdays, advisory costs in carrying out studies) – Staff involved in amending legislation (if needed)	– Complexity of the carbon pricing instrument – The number of years a carbon pricing instrument is in operation – The type of evaluation method chosen – The scope of system changes foreseen/ feasible – The type of stakeholder consultation	– Using existing structures for evaluation and tailored questionnaires/ studies – Defining evaluation methodologies and required parameters to be monitored ex ante; monitoring of those parameters during system operation
	Monitoring the quality of the quantification protocol	– Costs for organizing this activity – Staff involved in carrying out this activity	– Type of method chosen and the extent to which this approach is applied	– Start simple but evolve over time. In any case it is important to continue to evaluate the quality of the protocol.

Appendix L – Using Information Technology (IT) to Support Quantification Protocols

In today's digital world, IT systems are essential for the delivery and management of a quantification protocol. At its core, the role of IT systems is to enable obligated entities to transmit data to the government and to facilitate the maintenance of a reliable emissions database for use by the government.

IT is often considered secondary to the regulatory framework that is set in law on paper. This approach is a valid during the policy development phase, but during implementation, IT tends to take a more central role. IT has the following uses:

- IT can improve the quality of data submitted by obligated entities both through automated checks during data submission and ad-hoc queries and after data submission.
- IT is the main tool of central oversight. Without an up-to-date and easily accessible database of entity data, the regulator or policy makers have no clear idea about how its carbon pricing instrument is working,

how emissions are evolving, and whether entities have complied with their obligations. Such information is particularly relevant for emissions trading systems and more complex (such as downstream) tax systems.

- In addition to data reporting, a smart IT system can also be used for workflow management; enabling a two-way exchange between regulator and obligated entity in relation to, for example, application and approval of monitoring plans; and submission of notifications.

- IT is the prime tool for enforcement in the case of trading systems, for example. In an ETS where there are registry trading accounts, blocking such an account for non-compliance is often more effective than other regulatory or court action.

- IT also presents the public face of the carbon pricing instrument. This view is the case for obligated entities who will use its interface to submit data and potentially carry out transactions. It is also true of market intermediaries and the general public interested in emissions. When setting up an IT system with public interfaces, policy makers need to be aware that any IT systems containing valuable information will be subject to cyber-attacks. This is a particular risk in the case of carbon pricing systems where accounts hold allowances or credits, which are very much like money. These systems also contain confidential and market-sensitive information on transactions and verified emissions that need protection. In such cases, the levels of IT security need to equal that used by online banks.

Although IT is a secondary matter in the initial establishment of the carbon pricing instrument, as the regulatory framework evolves and measures move into their second or third iteration, the speed and cost of IT development involved in a regulatory change will become an important consideration. The system needs to be sufficiently flexible to implement changes in the case of regulatory amendments.

IT development of any kind tends to be costlier and more time-consuming than initially predicted. A key reason for this is that laws and implementing regulations, however specific, are usually still too general to be converted into an IT specification without additional work. An example is the UNFCCC's Kyoto accounting IT system, which is regulated in COP-decisions that are only a few pages long, but the system could only be built after drafting a 506-page Data Exchange Specification.[202] IT specification is painstaking work because the software can handle only binary choices and nothing can remain vague. IT systems cannot be expected to make reasonable assumptions as to the intent of the policy maker. The European Union found this fact out the hard way in April 2006 when the verified emissions from the first year of the EU ETS were submitted by operators by March 31, but were not supposed to be publicly visible until May 15. The public website of the EU's transaction log for the EU ETS had been incorrectly specified and, while the verified emissions were not directly visible on the public website, it was possible to download them with a separate data export function.[203] As verified emissions are market sensitive data, this accidental release of data gave an unfair market advantage to those market participants who noticed it. This minor specification error was a significant cause for embarrassment for the EU.

A good way to save on IT development time and costs is to find an existing emissions quantification system and adapt that to local circumstances.

Examples of IT systems being used for carbon pricing instruments include:

- Canada's SWIM system

- The EU's Declare System

- Germany's Form Management System

202 Additional information about registry systems for the Kyoto protocol is available at https://unfccc.int/files/kyoto_protocol/registry_systems/application/pdf/des_full_v1.1.10.pdf.
203 For additional information, see „State and Trends of the Carbon Market 2007" (World Bank, Washington, DC, 2007), https://openknowledge.worldbank.org/bitstream/handle/10986/13407/399230Carbon1Trends.pdf?sequence=1&isAllowed=y.

- Québec's Air Emissions Inventory system (IQEA)
- The UK's ETS Workflow Automation Project (ETSWAP) used by a number of EU MS

Some of these systems collect not only GHG data, but also data on air and other pollutants. This approach makes sense because obligated entities for GHG are largely the same as those responsible for other pollutants. A unified reporting system simplifies the compliance process, and it also allows for easier cross-checking of submitted data by the regulators.

BOX L.1: CYBER SECURITY

During 2007-2012, the EU ETS IT systems were subject to several cyber-attacks (from phishing to hacking) that resulted in the theft of a large number of emissions allowances. A related problem was pervasive VAT-fraud, which had been enabled by the weak controls on account opening requirements. To fight cyber-crime and VAT fraud, the EU introduced a range of IT security measures. These protections were similar to the ones used in banking systems, such as two-way secure socket layer authentication for communication between component systems, two-factor authentication for users, and a strict password policy. Another important safety element was the introduction of what is known in banking as know-your-customer checks; these checks are to make sure that the account holders are real and traceable persons using valid IDs.

Appendix M – Gathering Information to Understand Compliance by Obligated Entities and Identify Weaknesses

Policy makers and regulators use a number of ways to obtain information to enable them to maintain oversight of how quantification protocols are being implemented and where there may be weaknesses or challenges that should be reviewed when updating legislation and quantification protocols. Table M.1 below outlines measures that can be taken by regulators to both ensure compliance by obligated entities and gather information. The options outlined below can be applied together, and they can be built into quantification protocols as part of QA/QC requirements or be in separate legislation. Some carbon pricing instruments apply options 1, 2, and 4,[204] whereas for other carbon pricing instruments,[205] policy makers apply options 1 and 3. Application of multiple options together can evolve over time as the carbon pricing instrument develops.

TABLE M.1: Examples of How Regulators Can Obtain Information to Ensure Compliance

Option	Considerations for policy makers
1 Regulator does checks on (verified) emissions reports	Procedures are needed to ensure consistency on what checks are done and how to do them; procedures can be as simple as a guided checklist. Standard reporting templates and checklists also help. IT systems can support the process, for example, with automated completeness and sense/plausibility checks. Clear criteria are needed on how regulators follow up any identified issues – both in terms of who and how follow-up will be done and approaches to enforcing corrective actions and compliance. Identifying common problem areas can indicate where the quantification rules requires strengthening or more guidance needs to be provided. **Examples of application:** In most carbon pricing instruments basic checks on (verified) emissions reports are carried out by regulators (such as completeness checks) to obtain information allowing them to follow up failure to comply.

204 Some countries in EU ETS and California ETS.
205 US RGGI.

Option	Considerations for policy makers	
	Advantages – Insight on whether all reports have been submitted and contain all required information – Low level of resources needed, depending on the type of checks carried out – Low implementation costs	**Disadvantages** – Limited checks may not give sufficient overview of reported data quality and/or quality of the process that resulted in the verification report (if required). More detailed checks on all or a sample of reports would improve the process.
2 Regulator does on-site inspection of obligated entity to examine application of the quantification protocol	Some countries that use this option have independent inspection carried out by other regulatory agencies, departments, or functions within the regulator, often using inspectors that conduct checks for other pollution control regulation. Different approaches can be applied to selecting obligated entities for inspection, including risk-based approaches to determining who to visit, what to inspect, or how frequently to inspect. Physical inspection on the ground can help identify where rules may not be sufficiently clear in terms of which sources/source streams need to be (or can be) included; it can help with understanding of what is practically possible in terms of measurement instrumentation and application of direct measurement methodologies. **Examples of application:** Multiple countries in the **EU ETS** and **European** carbon tax systems have implemented additional inspection and enforcement of the obligated entity, as has the **US RGGI** system.	
	Advantages – Allows on-site checks on procedures, processes, and evaluation of the specific situation on site – Gives a good overview of the entity including emission sources, application of its quantification methodology, and metering equipment – High control by regulator over the quality of compliance (and reported data if detailed data checks are also done) – Can be built into existing programs of inspection conducted for other environmental permitting reasons	**Disadvantages** – Potentially higher administrative burden (although applying risk-based approaches to choosing entities can mitigate this burden) – When using standard regulatory inspectors,[206] capacity building and training is required to develop competence specific to the carbon pricing instrument rather than competence related to the normal inspection activities
3 Requiring self-certification by obligated entities	This approach can work well where regulators have confidence in the obligated entities' compliance rates. Self-certification needs to be underpinned by a strong inspection, enforcement, and sanctions policy such that obligated entities are aware of the penalties for failing to certify appropriately to their situation. **Examples of application: US RGGI**	
	Advantages – Limited costs for regulators	**Disadvantages** – Some administrative costs for obligated entities – Limited assurance that obligated entities actually comply with the protocol without high penalties for incorrect certification
4 Verification of emissions reports	More information on this option is provided in the 'PMR A&V Guide'. In most carbon pricing instruments verification is required for some or all obligated entities. However, for upstream and midstream carbon tax systems, verification is generally not carried out because quantification and reporting processes are straightforward and tax authorities generally do checks on reports. Third party verifiers look at the entity's emissions accounting process in detail and include physical inspection of sources and measurement instrumentation; evaluation of internal controls to manage data quality and compliance; and checking of data gathering systems and spreadsheets. Feedback from verifiers on application of quantification protocols in practice provides robust input to reviews and evaluation of protocols and carbon pricing instruments; it also highlights areas where FAQs and further guidance would facilitate consistent implementation. **Examples of application: Australian Emissions Reduction Fund, California ETS, Chile green tax, Chinese national ETS, EU ETS, New Zealand ETS, Republic of Korea ETS, Singapore carbon tax, Turkey ETS.**	

206 Such as those that inspect for environmental pollution permits, or other regulation.

Option	Considerations for policy makers	
	Advantages – Positive effect on environmental integrity – Increased confidence in accuracy of data from third party checks – Improvement of quantification and reporting process via verifier identification of weaknesses and improvement opportunities	**Disadvantages** – Increase in costs for obligated entities if they pay for the verifier. Some carbon pricing instruments have the regulator pay verifiers, in which case costs for regulators are increased.

Appendix N – Examples of Approaches to Address Permanent Changes to Quantification Methodologies

Table N.1 below shows how countries have implemented requirements on how to address changes to quantification methodologies.

TABLE N.1: Examples of How to Address Changes to Quantification Methodologies

Carbon pricing instrument	Approach for addressing changes to the quantification methodology
Chile green tax	**Approach taken to ensure obligated entities cannot make arbitrary changes:** Chile applies the key principle that quantification methodologies should be changed only if the new methodology ensures improved completeness or accuracy; this approach ensures that data are comparable over time by ensuring consistency except in these two situations. Conditions apply to when an obligated entity can change between methodologies: If CEMS is prescribed, a change between methodologies is not allowed. If a voluntary CEMS is implemented, request to change to another methodology can be made after the CEMS has been used for at least three years. If reference methods, estimation methods, or other alternative methods described in the rules have been applied, a request to change to another methodology can be made after one year if this results in an improvement; if there is no improvement, a request to change may be made only after three years. If there are changes within the methodology itself, requests for change may be made to the regulator. All changes to methodologies are subject to regulator approval. **Procedure for implementing changes:** Deadline for making notifications and requests to change between methodologies is July 31 of the year prior to the annual cycle in which the change will be implemented. If approved, the change would be implemented from January 1 following the year in which the request was made. Changes within methodologies have to be made 90 days before the change is implemented.

Carbon pricing instrument	Approach for addressing changes to the quantification methodology
EU ETS	**Approach taken to ensure that obligated entities cannot make arbitrary changes:** Emissions quantification methodology, installation boundaries, and QA/QC are recorded in an approved monitoring plan. Operators are required to submit a notification of change to the responsible regulator. The regulator has to approve significant changes to the monitoring plan; significant changes include changes: – To the category of installation if such as change leads to change in the prescribed quantification methodology – To emission sources and tiers – From one type of quantification methodology to another type – In categorization of source streams (de minimis, minor, major) – In default values or introduction of new methods for sampling, analysis, and calibration **Non-significant changes must only be notified. All changes need to be recorded in the emissions report and the monitoring plan needs to be updated.** – Verifiers assess implementation of the monitoring plan and changes to the plan during verification of the annual emissions report. – Installations regularly assess if they can improve their quantification methodology. In certain cases, they are required to submit an improvement report (for example, when source streams do not meet the highest tier or in response to non-conformities[207] and recommendations for improvement reported by the verifier). Changing quantification methodologies to less accurate ones is not allowed unless an installation operator can justify it because of unreasonable costs or technical infeasibility. These terms are defined in legislation. There are specific tools and approaches to determine unreasonable costs and technical infeasibility. **Procedure for implementing changes:** Significant changes to monitoring plans have to be reported without undue delay. For non-significant changes, installation operators can choose to report them once a year (by December 31). The MRR protocol contains specific requirements on when changes to monitoring plans should be implemented.
Singapore carbon tax	**Approach taken to ensure obligated entities cannot make arbitrary changes:** Emissions quantification methodology and QA/QC are documented in a monitoring plan that is approved by the regulator. If there are changes to the monitoring plan, the taxable facility is required to obtain updated approval from the regulator. Significant changes to the monitoring plan include: – Addition of an emission source or source stream – Change to an emissions quantification method and alternative approach – Change in the conversion factor tier **Procedure for implementing changes:** For significant changes, the updated monitoring plan must be endorsed by the facility's chief executive and resubmitted within 30 days of the change being implemented. For minor changes, the updated monitoring plan must be submitted by 31 January of the year following the reporting period.

207 Non-compliance with the approved monitoring plan.

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