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RESEARCH TO DEVELOP A MONITORING, REPORTING AND VERIFICATION (MRV) FRAMEWORK FOR GHG EMISSIONS IN THE METALLURGICAL SECTOR

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Abstract: *Monitoring, Reporting and Verification (MRV) of greenhouse gas emissions in the metallurgical sector will support the development and implementation of greenhouse gas (GHG) emission reduction activities and mitigation targets in this sector. MRV implementation will consist of three processes: (i) Monitoring GHG emissions (M); (ii) Reporting the results of GHG emissions (R); and (iii) Verifying the results of GHG emissions (V). In particular, the development of the Monitoring process will include the development of monitoring indicators for GHG emissions from metallurgical activities. Developing a reporting process consists of developing tables and forms and identifying stakeholders involved in data collection and reporting of results. The establishment of the Verification process includes the identification of third parties and the procedure and method of re-examining reported GHG emissions from the metallurgical sector. The study has applied Delphi and MCDA methods to develop GHG emission monitoring indicators; and expert consultation methods for producing the table, report form, and Verification process. The research has created 16 GHG emission monitoring indicators with a bottom-up approach and detail by each metallurgical facility. Nine tables, reports on GHG emissions results, and diagrams describing the roles and responsibilities of stakeholders are recommended in the MRV framework of the metallurgical sector.*

Keywords: MRV, Delphi method, metallurgical sector.

1. INTRODUCTION

Climate change is one of the significant challenges in the 21st century. According to the Intergovernmental Panel on Climate Change (IPCC), the key driver of global

climate change is the excessive GHG emissions from human socio-economic development activities (IPCC, 2007). Countries need to commit and reduce GHG emissions to stabilize the concentration of greenhouse gases (GHGs) in the atmosphere

for human intervention in the climate system. Controlling GHGs has always been the main topic of negotiations at the United Nations Framework Convention on Climate Change (COP) Conference.

There are some requirements for nations to implement GHG emission reduction activities successfully. Countries need to have a detailed GHG emission inventory system and build a baseline GHG emission and develop a national strategy on Measurement, Reporting and Verification for mitigation activities (MONRE, 2015).

The metallurgical industry in Vietnam recently has been rapidly developing in both technology and production. The average energy consumption for steelmaking and metallurgical production in Vietnam is about 3 GJ/t, while the excellent practice is between 2.1 and 2.4 GJ/t worldwide. Therefore, the energy consumption of steel and metallurgical production in Vietnam is about one third higher than the scope of good practice in the world. However, about 50 % of factories in Vietnam are reaching that international good practice standards (Trinh Van Hoan, 2014). Recently, The Agence Française de Développement (AFD) report estimated the potential of improving energy efficiency in the metallurgical sector in Vietnam by 5 to 30%, bringing a significant emissions reduction potential of this sector.

This paper develops an MRV process, including the development of monitoring indicators for GHG emissions from metallurgy; the development of tables and forms and identifying stakeholders in data collection and reporting of results; and the identification of a third party, its procedures and methods for verifying GHG emissions from the metallurgical sector. The study has applied the Delphi method to develop GHG emission monitoring indicators, expert consultation methods for composing tables, report forms and verification process.

2. METHODOLOGY

2.1. Delphi methodology

The Delphi method is a consultation process to reach the consensus of experts on specific issues. The Delphi method is an iterative stakeholder consultation process. Besides, we also use qualitative research methods (which do not contain statistical parameters) to describe the level of consensus on some reports.

There are two ways to use Delphi: the traditional Delphi method and four-stage Delphi (Harold, 2002). The Delphi method is applied in many fields: economy, environment, sustainable development, land use, agriculture, transportation, tourism, climate change, etc. Bunting used the Delphi method to facilitate interactive engagement and reached a consensus in sustainable aquaculture development (Bunting, 2008). In the transport sector, a combination of the Delphi method and the Bayesian Network Model predicts highway accidents in developing countries (Anthony et al., 2016). Seyyed Ali Delbari uses the 2-stage Delphi method and the Analytic Hierarchy Process (AHP) to prioritize critical competitive indicators for aviation services (Seyyed et al., 2016). The future of 3D printing is also consulted with experts using the Delphi method. Eighteen forecasts have been developed to provide future scenarios for the 3D printing industry (Ruth J. et al., 2017). According to Thomas F. (2017), the Delphi method has been used in 1085 articles on nursing research, and 799 papers have been published in nursing journals.

In 2015, Nguyen An Thinh used the Delphi method combined with the DPSIR framework (Drivers- Pressures-States-Impacts-Responses) to evaluate climate change adaptation measures of coastal communities. Questions were used to assess the level of consensus among members of the consultative group. The Kendall value

calculated after the second round reached 0.681, showing the high level of agreement among the members. The study indicates that sustainable ecosystem development and new rural planning are considered as appropriate local adaptation measures in the study area (Nguyen An Thinh, 2017). Le Trinh Hai and the research team used the Delphi method to develop sustainable development indicators focusing on environmental and health fields, applied for Quang Tri province.

The paper applies the Delphi method with the analysis process divided into three stages: before, during, and after consultation. The consultation process is carried out in several rounds. In the first round, a series of open-ended questions appropriate to the problem is developed and sent to experts for answers to find criteria that can be used to prioritize measures. However, as this priority evaluation is widespread globally, the research will inherit these studies and synthesize general evaluation criteria. Moreover, assessment criteria that are specific and appropriate to national conditions will be consulted by experts on climate change mitigation. After evaluating the criteria, the questionnaire of their importance and suitability will be delivered to experts to assess further and achieve the consent index (Kendall index ≥ 0.5). The Delphi implementation process to identify specific evaluation criteria is as follows:

a) Before consultation:

Step 1. Selection of expert groups involving into Delphi process:

Ten experts working in climate change mitigation from the Department of Climate Change - Ministry of Natural Resources and Environment, Institute of Science Meteorology, Hydrology and Climate Change, Energy Institute, Energy and Environment Consulting Joint Stock Company, Institute of Agricultural Environment, Ministry of Transport, Ministry

of Construction, Ministry of Industry and Trade, etc. were selected in the consultation process.

Step 2. Summary of GHG emission assessment criteria for metallurgical activities and consultation with national experts on some specific criteria of Vietnam. Indicators are divided into six groups:

Group of Emissions from burning fuels in metallurgical activities;

Group of Emissions from steel production processes (non-energy);

Group of GHG emissions from the production of ferroalloys;

Group of GHG emissions from aluminum production;

Group of GHG emissions from lead production; and

Group of GHG emissions from zinc production.

Step 3. Develop criteria table and evaluation criteria matrix according to the Delphi method.

b) During consultation:

Step 4. Application of the Delphi method for the first round:

Meetings and interviews with experts are organized to rank criteria from low to high with increasing importance. Table 1 shows an example of a matrix that evaluates the significance and appropriateness of criteria.

Table 1. Matrix of criteria evaluation according to the Delphi method

	Criteria 1	Criteria 2	Criteria 3	Criteria 4	Criteria 5	Criteria 6	...
Expert 1	1	3	4	5	2	6	
Expert 2	3	5	4	1	6	2	
Expert 3	5	4	6	3	1	2	

Step 5. Data analysis for the first round:

After collecting data using Delphi Method, the Kendall coefficient was used to assess the suitability of the indicator. The level of consensus is scored according to the thresholds of 0.0-0.1; 0.1-0.3; 0.3-0.5; 0.5-0.7; 0.7-1.0 (representing very weak; weak; medium; strong; very strong level of consensus). The Kendall coefficient is calculated as follows:

When there are two signs x and y whose values correspond to a set of values of the other sign in the form of statistical distribution, the Kendall coefficient can be used to assess correlation and consensus. Here, experts are independent variables, and criteria are variables classified according to increasing importance.

The Kendall coefficient (W) is calculated by the following formula:

$$W = \frac{S^2}{1/12K^2(n^2 - n)} \quad (1)$$

n is the number of elements x (the number of experts); k is the number of y elements (number of criteria). W has a value in the range (0, 1).

$$S^2 = \sum_{j=1}^K (R_j - R)^2 \quad (2)$$

$$R = \sum_{j=1}^n \frac{R_j}{n} \quad (3)$$

R is the sum of the terms for each element of y ; R_j is the average of the sum of these terms.

Step 6. Application of the Delphi method for the second round:

In case the Kendall coefficient (W) is more than 0.5 in the first round, the evaluation process ends in step 5: The experts agreed with the proposed index group. In case the Kendall coefficient (W) is less than 0.5 in the first round, the evaluation results will be sent to experts together with more specific questions about the reason and basis of the evaluation in the first round to find out the disagreements between experts. The evaluation process will be repeated until the Kendall coefficient (W) is more than 0.5.

c) After consultation:

After finishing the data collection, the results are analyzed. The weighted value of the criteria will be determined based on the results of rankings evaluated by experts.

2.2. Data

After analyzing and consulting national experts on the six groups of criteria related to climate change mitigation mentioned above, the study synthesized 58 critical criteria divided into six groups and made a questionnaire to conduct a consultation with ten experts.

In the first round consultation, experts evaluated the importance of criteria according to the collected data, ranked from 0 to 5.

Table 2. The evaluation scale of the importance of the indicators

Level of importance	Very important/ Can be collected	Very important/ Hard to be collected	Important/ Can be collected	Important/ Hard to be collected	Less important/ Can be collected	Less important/ Hard to be collected
Scale	5	4	3	2	1	0

Table 3. List of criteria for consultation

Group of criteria on Emissions from burning fuels in metallurgical activities	Unit	Description
M1. Fuel consumption	ton	This criterion monitors and assesses fuel consumption for each type of metallurgy. Fuel consumption is a basic indicator to monitor GHG emissions from fuel combustion of metallurgical activities by Tier 1

Group of criteria on Emissions from burning fuels in metallurgical activities	Unit	Description
calculation.		
Group of criteria on Emissions from steel production processes (non-energy)	Unit	Description
M2. Amount of coke smelted for steel production	ton	This criterion is a primary indicator to monitor GHG emissions from coking for steel production by Tier 1 calculation.
M3. Amount of materials and fuels of different types, such as natural gas and fuel oil, are consumed and burned for coking at steel production facilities	ton	This criterion is a basic indicator to monitor GHG emissions from coking for steel production by the Tier 2 calculation method.
M4. The amount of blast furnace gas consumed in coke ovens	m ³ or ton, GJ	This criterion is an essential indicator to monitor GHG emissions from coking for steel production by the Tier 2 calculation method.
M5. Amount of Coke is produced at steel production facilities	ton	This criterion is a basic indicator to monitor GHG emissions from coking for steel production by the Tier 2 calculation method.
M6. The transferred amount of coke oven gas	m ³ or ton, GJ	This criterion is a basic indicator to monitor GHG emissions from coking for steel production by the Tier 2 calculation method.
M7. The volume of by-products from the coking process in steel manufacture is transferred to another facility or factory	ton	This criterion is a basic indicator to monitor GHG emissions from coking for steel production by the Tier 2 calculation method.
M8. The carbon content of input or output material	ton C/unit of material	This criterion is a basic indicator to monitor GHG emissions from coking for steel production by the Tier 2 calculation method.
M9. Crude steel manufactured by Basic Oxygen Furnace (BOF) technology	Ton	This criterion is a basic indicator to monitor GHG emissions from steel (non-energy) production by Tier 1 calculation method.
M10. Crude steel manufactured by Electric Arc Furnace (EAF) technology	Ton	This criterion is a basic indicator to monitor GHG emissions from steel (non-energy) production by Tier 1 calculation method.
M11. Crude steel manufactured by Open Hearth Furnace (OHF) technology	Ton	This criterion is a basic indicator to monitor GHG emissions from steel (non-energy) production by Tier 1 calculation method.
M12. Pig iron production (not used for steel production)	Ton	This criterion is a basic indicator to monitor GHG emissions from steel (non-energy) production by Tier 1 calculation method.
M13. Direct Reduced Iron production	Ton	This criterion is a basic indicator to monitor GHG emissions from steel (non-energy) production by Tier 1 calculation method.
M14. Sinter production	Ton	This criterion is a basic indicator to monitor GHG emissions from steel (non-energy) production by Tier 1

Group of criteria on Emissions from burning fuels in metallurgical activities	Unit	Description
		calculation method.
M15. Pellet production	Ton	This criterion is a basic indicator to monitor GHG emissions from steel (non-energy) production by Tier 1 calculation method.
M16. Quantity of coke consumed in iron and steel production (not including sinter production)	Ton	This criterion is a basic indicator to monitor GHG emissions from steel (non-energy) production by Tier 2 calculation method.
M17. Quantity of onsite coke oven by-products consumed in the blast furnace	Ton	This criterion is a basic indicator to monitor GHG emissions from steel (non-energy) production by Tier 2 calculation method.
M18. Quantity of coal directly injected into a blast furnace	Ton	This criterion is a basic indicator to monitor GHG emissions from steel (non-energy) production by Tier 2 calculation method.
M19. Quantity of limestone consumed in iron and steel production	Ton	This criterion is a basic indicator to monitor GHG emissions from steel (non-energy) production by Tier 2 calculation method.
M20. Quantity of dolomite consumed in iron and steel production	ton	This criterion is a basic indicator to monitor GHG emissions from steel (non-energy) production by Tier 2 calculation method.
M21. Quantity of carbon electrodes consumed in EAFs	ton	This criterion is a basic indicator to monitor GHG emissions from steel (non-energy) production by Tier 2 calculation method.
M22. Quantity of other carbonaceous and process materials consumed in iron and steel production, such as sinter or waste plastic	ton	This criterion is a basic indicator to monitor GHG emissions from steel (non-energy) production by Tier 2 calculation method.
M23. Quantity of coke oven gas consumed in a blast furnace in iron and steel production	m ³ or ton, G	This criterion is a basic indicator to monitor GHG emissions from steel (non-energy) production by Tier 2 calculation method.
M24. Quantity of iron production not converted to steel	ton	This criterion is a basic indicator to monitor GHG emissions from steel (non-energy) production by Tier 2 calculation method.
M25. Quantity of blast furnace gas transferred offsite	m ³ or ton, GJ	This criterion is a basic indicator to monitor GHG emissions from steel (non-energy) production by Tier 2 calculation method.
M26. The carbon content of material input or output	ton	This criterion is a basic indicator to monitor GHG emissions from steel (non-energy) production by Tier 2 calculation method.
M27. Quantity of coke oven gas consumed in a blast furnace in sinter production	m ³ or ton, GJ	This criterion is a basic indicator to monitor GHG emissions from steel (non-energy) production by Tier 2 calculation method.
M28. Quantity of blast furnace gas consumed in sinter production	m ³ or ton, GJ	This criterion is a basic indicator to monitor GHG emissions from steel (non-energy) production by Tier 2 calculation method.

Group of criteria on Emissions from burning fuels in metallurgical activities	Unit	Description
M29. Quantity of other process material a, other than those listed as separate terms, such as natural gas, and fuel oil, consumed for coke and sinter production in integrated coke production and iron and steel production facilities	ton	This criterion is a basic indicator to monitor GHG emissions from steel (non-energy) production by Tier 2 calculation method.
M30. Quantity of sinter off-gas transferred offsite either to iron and steel production facilities or other facilities	m ³ or ton, GJ	This criterion is a basic indicator to monitor GHG emissions from steel (non-energy) production by Tier 2 calculation method.
M31. The carbon content of material input or output x	ton C/ton of material	This criterion is a basic indicator to monitor GHG emissions from steel (non-energy) production by Tier 2 calculation method.
M32. Amount of natural gas used in direct reduced iron production	GJ	This criterion is a basic indicator to monitor GHG emissions from steel (non-energy) production by Tier 2 calculation method.
M33. Amount of coke breeze used in direct reduced iron production	GJ	This criterion is a basic indicator to monitor GHG emissions from steel (non-energy) production by Tier 2 calculation method.
M34. Amount of metallurgical coke used in direct reduced iron production	GJ	This criterion is a basic indicator to monitor GHG emissions from steel (non-energy) production by Tier 2 calculation method.
Group of criteria on GHG emissions from the production of ferroalloys	Unit	Description
M35. Production of ferroalloy	ton	This criterion is a basic indicator to monitor GHG emissions of ferroalloy output by Tier 1 calculation method.
M36. Mass of reducing agent	ton	This criterion is a basic indicator to monitor GHG emissions from ferroalloy production by Tier 2 calculation method.
M37. Mass of ore	ton	This criterion is a basic indicator to monitor GHG emissions from ferroalloy production by Tier 2 calculation method.
M38. Carbon content in the ore	ton of C/ tons of ore	This criterion is a basic indicator to monitor GHG emissions from ferroalloy production by Tier 2 calculation method.
M39. Mass of product	ton	This criterion is a basic indicator to monitor GHG emissions from ferroalloy production by Tier 2 calculation method.
M40. Mass of non-product outgoing stream l	ton	This criterion is a basic indicator to monitor GHG emissions from ferroalloy production by Tier 2 calculation method.

Group of criteria on Emissions from burning fuels in metallurgical activities	Unit	Description
Group of criteria on GHG emissions from aluminum production	Unit	Description
M41. Metal production from the Prebake process	ton	This criterion is a basic indicator to monitor GHG emissions from aluminum production by Tier 1 calculation method.
M42. Metal production from the Söderberg process	ton	This criterion is a basic indicator to monitor GHG emissions from aluminum production by Tier 1 calculation method.
M43. Net prebaked anode consumption per ton of aluminum	ton C / ton of aluminum	This criterion is a basic indicator to monitor GHG emissions from aluminum production by Tier 2 calculation method.
M44. Sulfur content in baked anodes	%	This criterion is a basic indicator to monitor GHG emissions from aluminum production by Tier 2 calculation method.
M45. Ash content in baked anodes	%	This criterion is a basic indicator to monitor GHG emissions from aluminum production by Tier 2 calculation method.
M46. Paste consumption	ton/ ton of aluminum	This criterion is a basic indicator to monitor GHG emissions from aluminum production by Tier 2 calculation method.
M47. Emissions of cyclohexane soluble matter	kg/ton of aluminum	This criterion is a basic indicator to monitor GHG emissions from aluminum production by Tier 2 calculation method.
M48. Binder content in the paste	%	This criterion is a basic indicator to monitor GHG emissions from aluminum production by Tier 2 calculation method.
M49. Sulfur content in pitch	%	This criterion is a basic indicator to monitor GHG emissions from aluminum production by Tier 2 calculation method.
M50. Ash content in pitch	%	This criterion is a basic indicator to monitor GHG emissions from aluminum production by Tier 2 calculation method.
M51. Hydrogen content in pitch	%	This criterion is a basic indicator to monitor GHG emissions from aluminum production by Tier 2 calculation method.
M52. Sulfur content in calcined coke	%	This criterion is a basic indicator to monitor GHG emissions from aluminum production by Tier 2 calculation method.
M53. Ash content in calcined coke	%	This criterion is a basic indicator to monitor GHG emissions from aluminum production by Tier 2 calculation method.
M54. Carbon in skimmed dust from Söderberg cells	ton C / ton of	This criterion is a basic indicator to monitor GHG emissions from aluminum production by Tier 2

Group of criteria on Emissions from burning fuels in metallurgical activities	Unit	Description
	aluminum	calculation method.
Group of criteria on GHG emissions from lead production	Unit	Description
M55. Quantity of lead produced by Direct Smelting	ton	This criterion is a basic indicator to monitor GHG emissions from lead production by Tier 1 calculation method.
M56. Quantity of lead produced from the Imperial Smelting Furnace	ton	This criterion is a basic indicator to monitor GHG emissions from lead production by Tier 1 calculation method.
M57. Quantity of lead produced from secondary materials	ton	This criterion is a basic indicator to monitor GHG emissions from lead production by Tier 1 calculation method.
Group of criteria on GHG emissions from zinc production	Unit	Description
M58. Quantity of zinc produced	ton	This criterion is a basic indicator to monitor GHG emissions from zinc production by Tier 1 calculation method.

Source: IPCC Guideline for National GHG inventory, 2016, and 1996 revised versions.

3. RESULTS AND DISCUSSIONS

3.1. List of simplified MRV criteria

The Kendall coefficient is 0.57 from the above-collected data. With the value of more

than 0.5, the expert group has a high consensus with the proposed set of indicators, so there is no need to conduct Delphi second round. The shortened set of criteria includes 16 indicators, as shown in Table 4.

Table 4. List of simplified MRV criteria

Criteria on Emissions from burning fuels in metallurgical activities	Unit
M1. Fuel consumption	ton
Criteria on Emissions from steel production processes (non-energy)	Unit
M2. Amount of coke smelted for steel production	ton
M9. Crude steel manufactured by BOF technology	ton
M10. Crude steel manufactured by EAF technology	ton
M11. Crude steel manufactured by OHF technology	ton
M12. Pig iron production (not used for steel production)	ton
M13. Direct Reduced Iron production	ton
M14. Sinter production	ton
M15. Pellet production	ton
Criteria on GHG emissions from the production of ferroalloys	Unit
M35. Production of ferroalloy	ton
Criteria on GHG emissions from aluminum production	Unit
M41. Metal production from the Prebake process	ton
M42. Metal production from the Söderberg process	ton
Criteria on GHG emissions from lead production	Unit
M55. Quantity of lead produced by Direct Smelting	ton

M56. Quantity of lead produced from the Imperial Smelting Furnace	ton
M57. Quantity of lead produced from secondary materials	ton
Criteria on GHG emissions from zinc production	Unit
M58. Quantity of zinc produced	ton

3.2. Forms of data and reports on GHG emissions for the metallurgical sector

Information on group inventory and measurement of GHG emissions

Establishing a GHG measurement and inventory group is essential when implementing emission reduction programs and projects and implementing MRV. The members of the group may be officials of the enterprise, may have additional support from external experts, or maybe a third party. The size of the group depends on the size of the business. For large enterprises, the GHG measurement and inventory group should include representatives of the management board and other managerial departments. For smaller organizations, the team may consist only of the management representative and the manager of the production. Team members must hold regular meetings, have open and creative discussions, review and re-evaluate the current technology and management process, and be capable of applying mitigation ideas.

In steel and metallurgical plants, the members of the GHG emission measurement and inventory group should be considered, including managers, accountants, and engineers, etc. Inviting additional financial staff and non-business consultants is also an appropriate way to collect better objective ideas. The GHG emission measurement and inventory groups collect necessary production information of the enterprise for joint analysis with group members. The data collected may use the Reporting Form No.1.

The measurement and inventory of GHG emissions require background information

Source: Synthesizing from interview results based on several existing documents, records, and reports of the enterprise. The checklist in Reporting Form No.2 helps the team consider the availability of data.

Table 5. Reporting form No.1: Basic information

Name and address of enterprise				Number of working day per year:	
Information of greenhouse gas emissions measurement and inventory group					
Name		Role - Department		Role in group	
1					
2					
3					
Basic production information of the business					
Main products		Designed capacity (ton/year)		Actual capacity (ton/year)	
Raw materials used					
Main materials	Scrap steel	ton/year	Auxiliary materials	Electrode	Quantity
	Pig iron			Slag substance	kg/year
	FeMn			Furnace material	kg/year
	FeSi			Golden sand	kg/year
	Other (specify)			Grease	kg/year
			Other (specify)	kg/year	
Water and energy	Country	Quantity	Equipment	Furnace	Capacity
	Charcoal	m ³ /year		Refining furnace	tons/hour
	electricity	m ³ /year		Casting machine	tons/hour
	Gas	tons/year			
	Qx	Kwh/year			
	Other (specify)	kg/year			

Source: Developing from Guidelines for cleaner production for steel and metal casting sectors.

Table 6. Reporting form No.2: Availability of data

Data	Yes/No	Source and accessibility	Note
Floor plan			
Output records			
Profile consumption materials			

Data	Yes/No	Source and accessibility	Note
Profile consumption of water and energy			
Technological scheme			
Energy balance			
Equipment maintenance records			
Environmental status profile			
Technology information:			
- Process of operating electric arc furnace			
- Operating process of casting machine			

Source: Developing from Guidelines for cleaner production for steel and metal casting sectors.

Note that many enterprises do not have enough initial information, and the team members will discuss how to collect additional data. Only documents that reflect the current production status are of high value in assessing economic, technical, and environmental efficiency.

Analysis of stages and assessment of emissions

Once all essential information about enterprises, the GHG emission measurement and inventory group collected, it is recommended to describe the current production process in the common language by listing all steps in the process. The team needs to survey to identify the technology

information and find obvious improvement opportunities, which are easy to do as a starting point for the evaluation. This is an opportunity to review the production process, identifying the flow of raw materials, determining emissions, and re-evaluating losses.

It is necessary to survey each factory in turn, according to the technological process and operation regulations, from the stage of data entry, material preparation, metallurgy, casting, warehouse to boilers review and electrical systems, etc.

During the survey, the team should record the following essential information:

- Inputs and outputs of each stage (see Reporting Form No.3). For the production, it is required to specify the type of emissions as Solid (S), Liquid (L), or Gas (G)

- Observations on the waste of materials at each stage (Reporting form No.4). These are initial observations, and the team will continue to explore opportunities for improvement. For steel production enterprises, the limitations of the management process and compliance with operation regulations are one of the leading causes of raw material losses

- Expenses for primary raw materials and materials (Report form No. 5), recording the prices of raw materials and the fuel used as the basis for calculations

Table 7. Reporting form No.3

Stage	Input		Output		
	Main material		Name and type of emissions		
	Material	Fuel	Solid (R)	Liquid (L)	Gas (K)
Stage 1					
...					
...					

Auxiliary equipment
Processing system

Source: Developing from Guidelines for cleaner production for steel and metal casting sectors.

Once the group identifies the necessary input and output flow of the production process, it is recommended to name the technology step according to the nature of technology (such as "processing" or by equipment such as "electric arc furnaces"). At the next step, details of stages such as the transition process between stages, technology stages, and emissions, should be listed in detail.

Table 8. Reporting form No.4: Current situation of internal management

Area	Data
Resources	Arranging ground to receive materials Sorting and transporting materials The spilled material
Electric furnace	Layout plan Equipment maintenance Feed, control tempering temperature, remove liquid steel Heat loss / emissions
Refining furnace	Adjust chemical composition Temperature homogenization Eliminate impurities
Foundry	Loading materials, operating procedures, products Handling and storage of products Amount and nature of cooling water
Auxiliary	Overflowing water Water temperature after cooling Furnace

Source: Developing from Guidelines for cleaner production for steel and metal casting sectors.

The observations given are not critical (e.g., the cooling water has not been fully recovered) but needs to be observable (water overflow in the cooling tower). This will support mitigation measures.

After the observations, it is possible to come up with mitigation measures. These are exact display solutions that have not been previously considered for the operation. The participation of external experts in this step is incredibly effective.

Experienced operation control and site management in steel mills is often overlooked and is the most specific, most attractive part of starting the approach to reducing emissions. Moreover, many mitigation options have been identified as those that can be implemented for short periods of time, at low cost, requiring only minor device changes or improvements in maintenance. The application of these measures has been proven to be a good start for efforts to reduce plant GHG emissions, encouraging managers and officials to conduct mitigation assessment.

Table 9. Reporting form No.5: Cost of input materials

Names of raw materials and fuels used	Unit	Cost VND/unit	Used quantity tons/year	Used quantity unit/ton of product	Cost VND/ton of product
---------------------------------------	------	---------------	-------------------------	-----------------------------------	-------------------------

Scrap metal

Pig iron

FeMn

FeSi

Al

....

Electricity

Water

Gas

....

Electrode
Fluxes
Coal dust
Refractory
materials

Source: Developing from Guidelines for cleaner production for steel and metal casting sectors.

The above table only covers costs for the main fuel. This is the basis for measuring program effectiveness, and partly shows the correlation rate between materials. The overall picture of overall production costs is complemented by the cost of human resources, energy, and the operation of an environmental treatment system.

Prepare production line diagram

The preparation of production line diagrams and technological process diagrams is an essential step in measuring and inventorying GHG emissions. The block diagram of a production line consists of production steps (not by device name) with input, output, waste, and emissions streams. Every used material should be included in this diagram because it will remain in the product or lose in the waste stream. Seldom used raw materials should also be named. Although the GHG measurement and inventory team is familiar with the technology line, it may be necessary to conduct a site visit a few times before reaching an agreement on the production line diagram used for measuring and inventorying GHG emissions.

With large scale production or pilot MRV implementation, a detailed production line will be built for the selected area for deployment. This must be the largest polluting area. Enterprises producing steel by electric arc furnaces have simple production lines. The application of MRV is usually carried out on the whole line, or with steel refining at electric arc furnaces.

The best technology scheme should achieve the following points:

- The production steps are described
- A list of input and output materials: The input materials are on the right, the output materials are on the left of the production description.
- Include material recovery and reuse
- Material balance

Material balance is a tool to record the materials used at each step of production quantitatively. Good material balance plays a vital role in measuring and inventorying GHG emissions because it can quantify unknown losses or emissions. A good fuel balance also supports the benefit-cost assessment of mitigation measures. The basic principle of material balance is that the material that goes into the production process will have to exit the products at some point, in some form. Materials can be balanced in one of the following two ways:

- Overall balance: used for all types of raw materials and materials into the production line. The balance is carried out through each stage with the change of all components involved in the production line.
- Component balance: only used for a valuable material or component. Track changes in this component on every stage.

Reporting Form No.6 can be used to record the material balance. There are two ways of recording the material and material balance: by table or by technological process diagram. When using technical process diagrams to record the proportion of raw materials and materials, the composition and concentration of each input and output material type must be clearly stated. Material balance can be based on daily, monthly, or annual measurements.

No balance is perfect. When combined data of each stage and the overall data of the whole step will appear errors due to the inaccuracy of the data because the sum of much small waste streams is not included, such as evaporation, spillage etc. The purpose of material balance is to find the most massive waste streams to focus on minimizing.

Table 10. Reporting form No.6: Material balance

Stage	Input		Output		Emissions		
	Type	Quantity	Type	Quantity	Liquid	Solid	Gas
Stage 1	Materials...		Product 1		Liquid	Solid	Gas
	Materials...		1		1.1	2.1	3.1
	Fuel...					Solid	
	Fuel...					2.2	
Stage 2	Product 1		Product 2	
	Materials...		2				
	Fuel...						

Source: *Developing from Guidelines for cleaner production for steel and metal casting sectors*

Data used in material balancing can be collected from a bookkeeping or direct measurements. The used data should be converted to the same production unit. Particularly for the powder must be converted in absolute dry form to avoid moisture from different raw materials.

Ideally, the discharge data in the material balance should be accompanied by additional material parameters or a new modified form of materials lost according to the waste stream, to facilitate the determination of waste stream costs in the next step.

Each waste stream should be numbered (e.g. L1, L2, L3 for liquid waste, G for gas, and S for solid) to facilitate cost identification and subsequent cause analysis.

3.4. Verifying process

Verification is a process that verifies the authenticity of the data and description for a GHG inventory report and is closely related to the methods and content of inventory. The verification process can be done once or in different stages.

The verification process mainly includes reviewing documents and inventorying GHG emissions at the facility. The MRV system needs to specify or require a sampling plan for sampling businesses by region.

The verification process can be divided into three basic steps: preparation of verification, verification at the facility, preparation, evaluation, and submission verification reports.

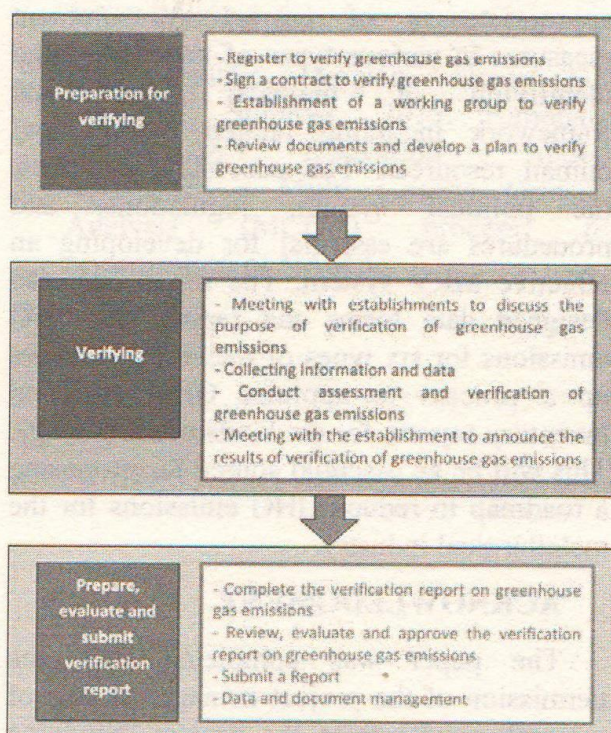


Fig 1. Verifying process for GHG emissions from the metallurgical industry

4. CONCLUSION

MRV is widely used in many cases for a variety of purposes. MRV is also a fundamental element of the governance system of actions developed throughout

history, particularly in systems that tax production processes, such as agriculture, industry, and trade. The proposed national MRV framework is based on top-down or bottom-up approaches. In which the integrated MRV system includes multiple reporting categories for different levels (central and local). The central government is responsible for reporting and verifying activities, focusing on one or a specific group of policies, actions, or areas. Therefore, the development of an appropriate MRV system requires a detailed analysis of the approach in designing the institutional structure and guidelines for MRV.

The report has developed an MRV process for reducing GHG emissions in the metallurgical sector by analyzing the appropriateness of current measurement measures in various types of metallurgy and identifying a practical institutional framework including related entities and human resources. The necessary resources, the political system, regulations, and procedures are essential for developing an effective MRV system. The report has also designed data forms and reports on GHG emissions for six types of metallurgy and set up a process to appraise GHG emission inventory reports for six kinds of metallurgy. This will be an essential source for proposing a roadmap to reduce GHG emissions for the metallurgical industry.

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