

IMPROVED METROLOGY INFRASTRUCTURES FOR THE DEVELOPMENT OF ENERGY INDUSTRY IN TANZANIA: PERSPECTIVES FROM THE DISCOVERIES OF NATURAL GAS

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ABSTRACT

The growing importance of the natural gas market domestically and internationally creates an urgent need to build a metrology infrastructure to provide industry and society with accurate and reliable measurements. This study has contributed to that goal. The paper examined the core significance of metrology infrastructure in the development of energy sector and its roles in the economy development in Tanzania. The areas examined are the national metrology policy in comparison with international framework, integration of metrology legislation in energy sector and traceability framework. The investigation was performed through a thorough survey which was conducted to the Tanzanian metrology institutes which is the Tanzania Bureau of Standard (TBS) and the Weights and Measures Agency (WMA), the Tanzania Petroleum Development Cooperation (TPDC), testing and calibration laboratories, through interview and questioner. The paper established that a less than 30% metrological control in the energy sector has been implemented like the verification of electrical meter, natural gas meters and petroleum meters. This might deny the fair trade, restrain transparency in energy transaction and hinder the removal of barriers to trade especially in the natural gas. Some improvements should be made in the national metrology infrastructure to foster the growth of natural gas sector.

Keywords: *Metrology Infrastructure, National Quality Infrastructure, Natural gas, Energy and Economy.*

1.0 INTRODUCTION

Each developing country chooses the level of metrology infrastructure according to its needs, technological advancement, level of economy, and trade. This helps her to achieve fair trade, consumer protection and competitiveness in domestic and international markets. Some other countries have poured huge investments into the metrological development of their own national metrology infrastructure in support of trade and economic benefits. In Tanzania, the development of the energy sector escalates the need of improvement of metrology infrastructure to support the measurement of energy utilities like natural gas, oil, electricity and water. This strategy would remove barriers to trade, improve energy market, and facilitate the development of energy industry as a whole. OIML D1 (2012) suggests that, "no quantity can be correctly and consistently measured without metrology and without a metrological infrastructure" [1].

The importance of metrology is ever increasing due to the rapid technological developments, innovations and the emergence of information technology [2]. Consumers and the industry make decisions every day based on measurement results which affect their economic and personal wellbeing. This is because manufacturers, importers and sellers of most products are responsible for the associated measurement processes. However, buyers (individuals as well as companies), who are generally not appropriately informed about these processes are at a potential disadvantage regarding the measurement results and their interpretation. Fair and accurate measurements help to ensure fair competition [3]. Therefore to ensure maximum economic benefits, countries adopt proper national metrological infrastructure especially to significant economic resources such as natural gas.

In the natural gas sector, Tanzania has started exploiting and distributing natural gas to domestic consumers like households, industries, factories and commercial users. The discovery of huge reserve of natural gas of about 55.08 TCF in Tanzania [5], might rocket future enormous supply of natural gas and LNG to domestic and international markets. The world energy outlook 2019 by international energy agency, has marked Tanzania as an emerging producer of natural gas from its huge discoveries of resources but face challenges of getting domestic value from gas [6]. This calls for integration of metrology infrastructure in the value chain to guarantee market competition, removal of barrier to trade, trade transparency and consumer protection.

Metrology as a key component of quality infrastructure (QI), has a lot to do with precise measurements. Metrology facilitates fair trade, drives innovation, promotes efficient production, support regulation in consumer protection, advances the protection of citizen in health and helps in meeting social goals like energy efficiency and reduced consumption [1]. The improvement of quality infrastructure includes metrology, standardization, conformity assessment and accreditation. To

become an industrialized country the improving conformity assessment is indispensable; this comprises of essential bodies like metrology laboratories, inspection bodies, training, research and development, testing, certification and calibration laboratories. However, the development of accreditation body is also essential; this would speed-up the accreditation process to local quality bodies and at a very low cost. Bodies required to be accredited includes but not limited to calibration laboratories, inspection bodies, verification agencies, medical laboratories, chemical, mechanical and micro-bio laboratories, pharmaceutical laboratories, forensic laboratories and veterinary laboratories. Currently accreditation to Tanzanian conformity assessment bodies is done by SADCAS and only 23 Tanzania quality bodies have been accredited[4]. The increase of accredited conformity assessment bodies would definitely speed-up industrial development, remove barrier to trade and provide assurance of quality to imported and locally produced goods. Therefore to ensure maximum safeguard of public interest and economic benefits, the country should adopt and implement proper national metrological infrastructure (NMI).

1.1 Research Objectives

The current paper aimed at assessing the roles of metrology infrastructures in energy measurements with a focus to natural gas and petroleum products. Specifically, the study intended; to examine the existence of national quality infrastructure (NQI) and the Tanzanian national metrology policy; to ascertain functions of metrology to energy sector; to develop national metrology infrastructure framework for natural gas measurement; and to propose strategies to be used in improving metrology infrastructure

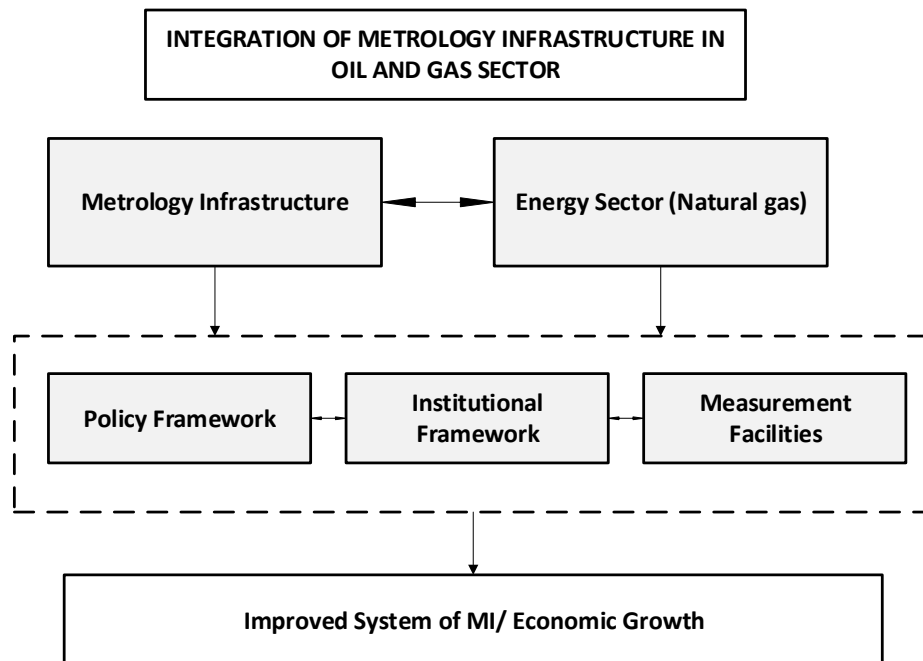


Figure 1: Conceptual framework

2.0 METROLOGY AS THE COMPONENT OF QUALITY INFRASTRUCTURE

The improvement of national quality infrastructure (NQI) has to do with the improvement of the National Metrology Infrastructure (NMI) or the National Metrology Institute. Quality infrastructure in any country refers to all aspects of standardization, metrology, testing, conformity assessment and quality management including accreditation and certification [1]. This includes both public and private institutions and the regulatory framework within which they operate. In Tanzania, a national legal metrology institute (NMI) represented by TBS and a national metrology institute (NLMI) represented by weights and measures agency (WMA) are two public institutions that take responsibility to underpin the major functions of quality ranging from metrology and standardization. However, to complete the whole QI system the national accreditation body and conformity assessment bodies need to be combined.

The QI of countries rely on many standards and technical regulations for their trade-related activities, consumer protection, etc. In order to sustain the improved quality in production, manufacturing and services, most countries have established their national quality infrastructure following the framework recommended by the World Bank. Figure 2 below represents the proposed NQI to be adopted by Tanzania for best performance in metrology.

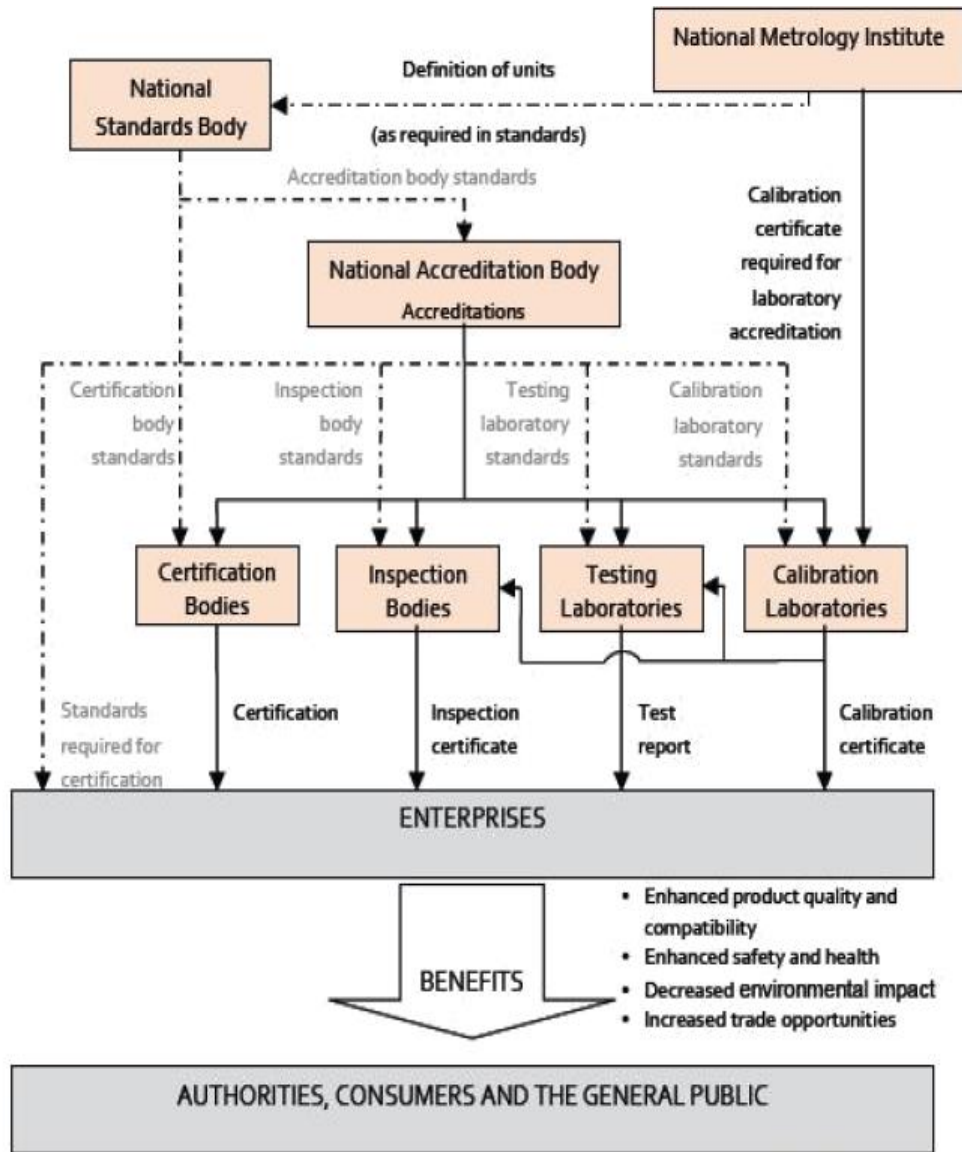


Figure 2: The National Quality Infrastructure (Source: World Bank 2007)

In line with figure 2 above, accreditation is an apex entity in the QI system, and it plays a vital role in the infrastructure like accrediting certifications bodies for different standards and accrediting the testing and calibration laboratories. Accreditation also ensures regulators use reliable testing, certification and inspection services. The international lab accreditation cooperation (ILAC) and international accreditation forum (IAF) remain to be the world and MRA of national metrology institution with international bureau of weights and measures (BIPM & CIPM).

3.0 TANZANIA METROLOGY POLICY

Every country adopts a metrology policy depending on its economic and development strategies. However, to ensure industrial sector growth, the Government must aim at providing the country with a metrology infrastructure that is able to ensure fair trade, foster economic development and efficiency, technological and scientific progress of the country, and foster protection of health and environment and the protection of citizens and consumers [7],[8]. With regards to metrology policy requirements, Tanzania has strived to establish metrology coordination institutions and metrology laboratories which work as separate bodies. She has become an associate member state of The BIPM through her national bureau of standard TBS (national metrology institute) since 1st January 2008 [9] and has also become a member state of the OIML through her Weights and Measures Agency WMA (a national legal metrology institute). Tanzania has also become a member state of regional metrology and regional legal metrology organization like SADC MET and SADC MEL represented by TBS and WMA respectively. Moreover, as part of implementation of the proposed metrology framework,

Tanzania through WMA has recently amended her Weights and Measures Acts with regards to subcontracting tasks in legal metrology to private inspectors with bodies outside the administration, (out of role of the state authorities)[10].

Some shortcomings on the metrology policy in Tanzania include the delayed decision to create a single institute by merging the metrology institutes; hence creating an interdepartmental metrology coordination units. Another drawback is the limited number and lack of support to the development of calibration laboratories, requirement of integration of metrology infrastructure in energy sector, and development of the effort for R&D of metrology. This present study proposes some improvement strategies on addressing these gaps.

4.0 PRESENT SITUATION OF METROLOGY INFRASTRUCTURE IN TANZANIA

Metrology infrastructures include all systems and bodies to support the consistency of measurement used as the basis for decision making in the industry, trade, technology, market economy, governmental regulation and the community at large[8],[1]. Due to their public good qualities metrology infrastructures are regulated and provided by government just like other economic and social infrastructure.

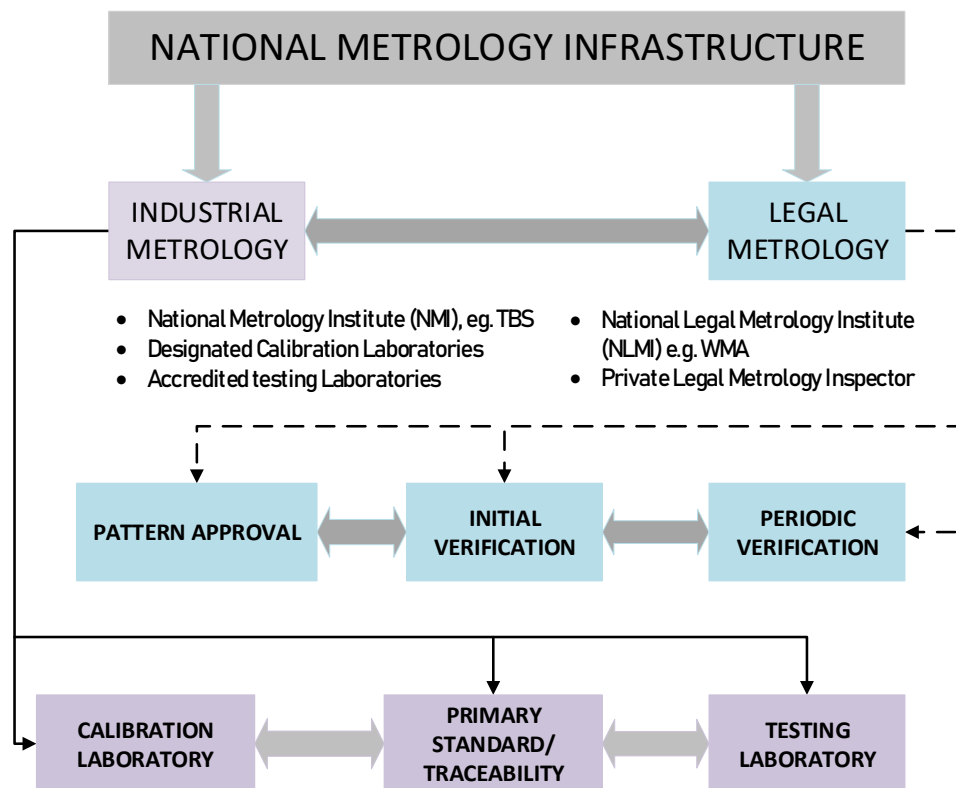


Figure 3: The national metrology infrastructure framework

Generally, measurement infrastructure include the international system of units of physical quantities (SI), the national metrology institutes (NMIs) that maintains and develops the national standards of measurement, the calibration laboratories that maintain the traceability path, and the accreditation laboratory organizations. It further includes the pattern approval testing laboratories, the measurement legislation and the enforcement of these measurement regulations, as well as metrology training institutions of metrologists and measurement engineers and technicians[1]. The figure 3 above details the structure of metrology infrastructure.

4.1 National Metrology Institute (NMI)

The national metrology institutes consist of one or more standards laboratories which can also be part of academic or professional institutions like a university or any other scientific institute. This is designated by the national decision to develop and maintain national measurement standards for one or more quantities [2]. Generally, many countries traditionally distribute responsibilities of different quantities or units among different institutes coordinated either by a principal institute or by an agency due to the expanding scope of metrology[1].

NMI in Tanzania represented by TBS also works with a number of accredited laboratories, such as medical laboratories, chemists, water, food, fish quality and microbiology testing laboratories and calibration laboratories. However, there are limited number of calibration or metrology laboratories apart from the TBS metrology laboratory. The noticeable constrains to improvement of national metrology institute is the absence of designated laboratories, lack of relationship between NMI and the designated institutes, and relationship between NMI and the accredited laboratories. Further constrains include the absence of state accreditation body, lack of accredited private metrology laboratories, lack of authority by NMI to nominate designated national laboratories, relationship between NMI and the industry and the framework of NQI. The study suggests best practice of NMI.

Table 1 Current capacity of National Metrology Institute (NMI) in Tanzania

S/n	Accredited Laboratory /Body type	Belonging to TBS	Belonging to other organizations	Accreditation Organization
1	Medical Laboratories	-	10	SADCAS
2	Testing Laboratories	6	8	SADCAS
3	Calibration/ Metrology Laboratories	3	-	SADCAS

4.2 National Legal Metrology Institute (NLMI)

The OIML D1 (2012) define national legal metrology institute as a public organization in charge of studying technical specifications for legal metrology, issuing type approvals and providing technical coordination and support to other legal metrology bodies [1]. The legal metrology obligations like metrological control, measurement inspection, verification and pattern approval may also be distributed among several institutes specializing in different fields under an appropriate coordination. The authority of NLMI in Tanzania lay on the Weights and Measures Agency (WMA); this organization operate as an independent metrology body with its own testing laboratories to ensure confidence to measurement in trade, industry, environment, consumer protection and safety. The testing and inspection of NLMI are harmonized by regional and international organization from which Tanzania is a member state like SADCMEI and OIML respectively. WMA operates in 23 regions of Tanzania mainland to underpin the verification and pattern approval and its verification capacity is presented in Table 2 below.

Table 2: Current capacity of the weights and measures agency in legal metrology

s/n	Metrology control	Number of station/regions	Capacity level (%)
MI-001	Water meter	23	10%
MI-002	Gas meter	-	-
MI-003	Electricity energy meter and measurement transformer	-	-
MI-004	Pre-packaged goods	23	95%
MI-005	Measure system other than water (Fuel pumps, flow meters et.)	23	95%
MI-006	Automatic weighing instruments	-	-
MI-007	taximeter	-	-
MI-008	Material measures (tanks and capacity measures)	23	95%
MI-009	Dimensional measurement	23	95%
MI-010	Exhaust gas analysers	-	-
MI-011	Static weighing scales/ bridge	23	95%
MI-012	Automatic volumetric filler	23	60%

4.3 Mutual Recognition Arrangements

Both metrology institutes are encouraged to enter into regional and international agreements establishing the equivalence of national measurement standards of participating countries. To be able to harmonise the national measurement with other countries, the country through its metrology institutes should consider the possibilities of legal recognition of traceability to other signatories of the Mutual Recognition Arrangement (MRA) issued under the International Committee of Weights and Measures (CIPM MRA). Figure 4 below presents the metrology framework with international affiliation.

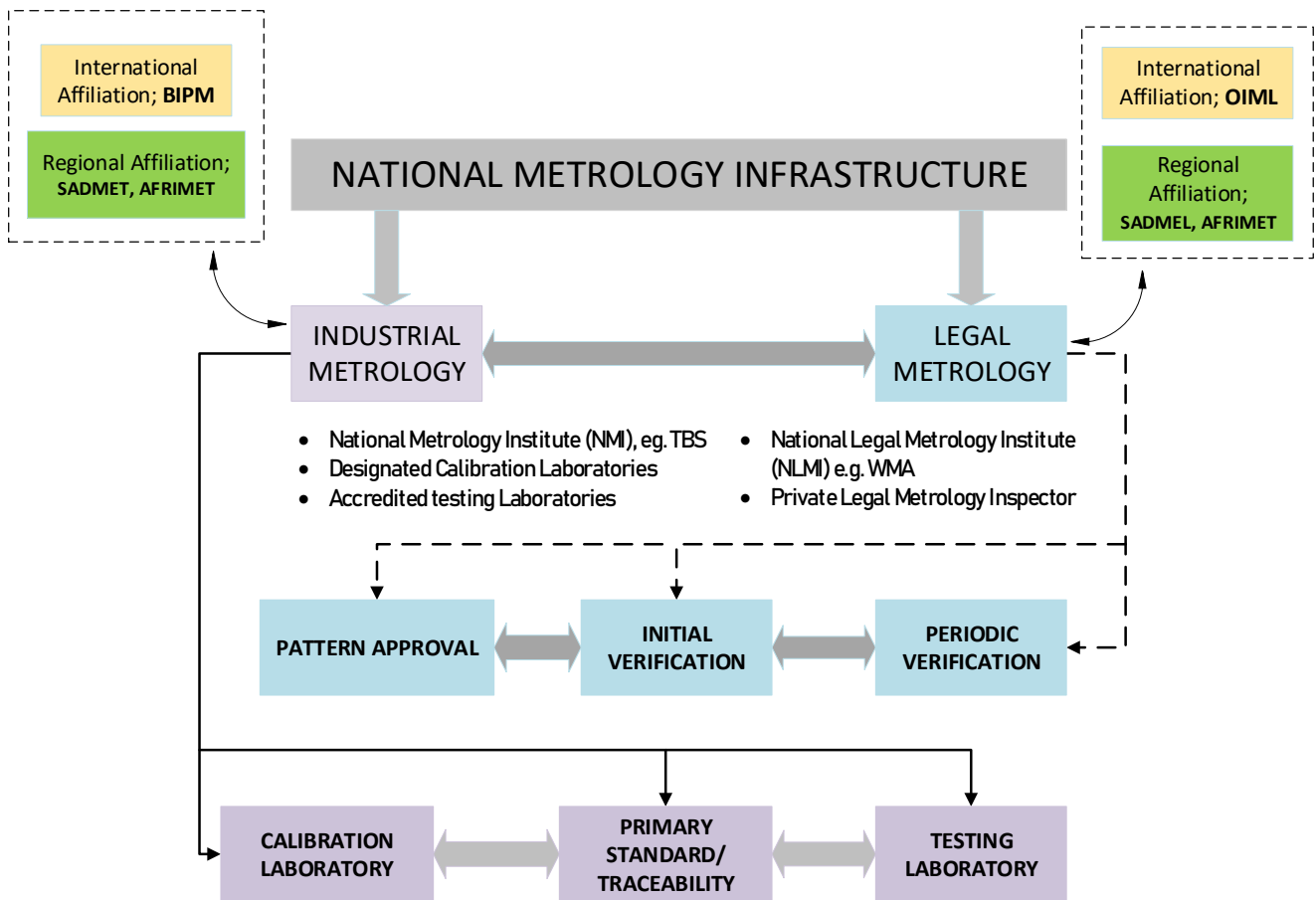


Figure 4: Metrology Infrastructure, regional international affiliation

5.0 METROLOGY INFRASTRUCTURE FOR ENERGY MEASUREMENT

Energy measurement has its importance throughout its value chain, ranging from its production to eventual consumption. Classification of measurement of energy like liquefied natural gas depends on its function in the supply chain, whereas upstream measurement performed for the purpose of stock allocation, the downstream energy measurement performed for the purpose of custody, fiscal measurement, trading and for household and industrial consumption. The level of accuracy in measurement at downstream measurement requires to be high.

This study examines the integration of metrology infrastructure (role of legal and industrial metrology) in energy measurement whilst natural gas being cited as principal objective. For example, legal-metrology in the gas sector generally encompasses the practices and process of applying regulatory structure and legislation to control units of measurement, measuring instrument or systems and methods of measurement. These activities are performed on behalf of government authorities[11],[12]. In addition, industrial metrology helps to enable companies to determine accurately the values of gas transferred between different custody transfer points and thus leads to a fair competition in a sector. In industrial metrology the measurements are done for what is called ‘self-interest’ of the interested companies to establish the quality and accuracy of measurement but are not bound to a regulatory requirement[8].

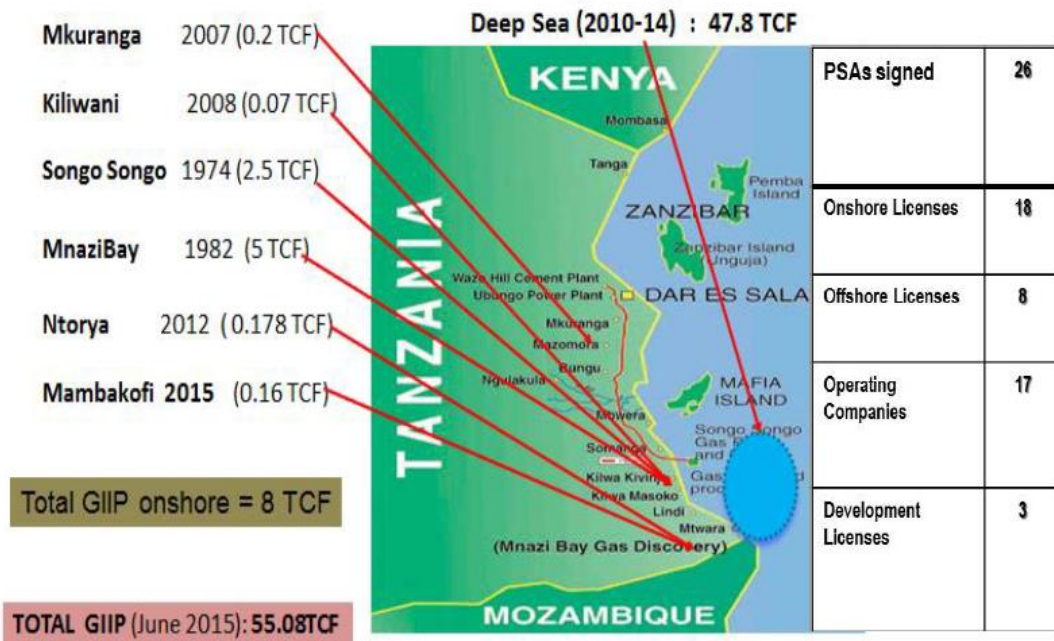


Figure 5 Discoveries of natural gas reserve in Tanzania (Source: TPDC, 2015 <http://www.tpdc.tz.com>)

6.0 METROLOGY IN NATURAL GAS SECTOR

Natural gas measurements are typically in four different purposes throughout its value chain. These are fiscal measurement to calculate government taxes, inventory allocation measurement, operational measurement and the measurement for custody transfer [13],[14]. Natural gas measurements involves significant financial risk due to a lack of accurate information and measurement uncertainties in the transferred energy. This uncertainty translates to financial risk for both the buyer and seller. The uncertainty in natural gas is estimated to lack accuracy to uncertainty of 0.5 - 1.0% and even higher [15]. However, correct measurement of natural gas volume in both midstream and downstream operations is very significant for the economy and the energy industry development. Correct measurement of natural gas enhances accurate estimation of royalty and other taxes which are paid by concessionaires to the government, a fair trade and consumer protection. This calls for efforts to develop effective national metrology infrastructures motivated by the need to ensure a more diversified and secure energy supply and fair and transparent trade in natural gas [16]. Presently, the ISO 15970 (2008) and GIIGNL hand book [14] provides the guideline and standard for natural gas measurements. The quantity of natural gas or LNG transferred has to be invoiced by considering three measurement parameters which are natural gas volume, gross calorific value and the density for LNG.

The need of metrology infrastructure for gas measurement comes into a special account especially when gas is transferred between ownership and between the buyer and the seller. The measurement of energy of natural gas which is transported and or consumed involves both quantity estimation and energetic quantity [16]. Quantity should be estimated in volume (cubic feet) using flow meter of typical minimum uncertainty. However, considering that volume of gas can be influenced by both temperature and pressure, therefore getting actual volume of gas transferred is vital. Moreover, the energetic potential (gas quality) can be estimated from determining the gross calorific content of natural gas by using chromatography [14]. The uncertainty of transferred natural gas can be quantified after measurement of gas quantity, gas temperature, pressure and calorific content. The combined uncertainty from the four parameters will be calculated to establish the actual transferred amount of gas for billing, taxation, consumption and transportation [15].

There are basically two natures of measurement practices in natural gas, one is done at high pressure (upstream); here the transfer of gas is done when there is ownership changes, or when transporting gas from production to pipeline or from pipeline to distribution point (downstream). High pressure measurement also takes place during custody transfer. Where gas ownership changes, the measurement has to be done at bulk and involves royalty and tax calculation.

In high pressure natural gas measurements, flow meters like coriolis or mass flow meters as specified by API-14.9 [17], turbine flow meter as recommended in by AGA 7 [18], ultrasonic flow meter [19] and orifice plate [20],[21] can be used. In custody transfer, accurate measurements in determining the transferred gas quantity and quality is essential because the transferred natural gas is subjected to royalty and government tax. The uncertainty not exceeding 1% is recommended for

fiscal metering system in custody transfer [22]. Measurement of natural gas at low pressure is performed by using orifice plate (typical different pressure) flow meter, turbine flow meter and rotary positive displacement meters.

To avoid incorrect measurement of natural gas distributed or transferred in household, residential, commercial use and factories, and industries consumption, accurate measurements with minimum uncertainty should be ensured. Gas measurement at consumption point can be done at low pressure which is below five bars and at a very low flow rate of about 400m³/h [16]. On one hand, the role of metrology institute at this stage comes into effect by ensuring the traceability of measurement, standard and measurement calibration like temperature measurement, pressure measurement instruments, flow meter and chromatography. On the other hand legal metrology institute is responsible for metrological control of gas flow meter following Mutual Recognition Arrangement (MRA), OIML recommendation and country metrology regulation in approving the metering pattern and performing gas meter verification (both initial and subsequent). The role of legal metrology at this stage is to ensure consumer protection and fair trade [1].

The calibration of metering system has to be done periodically using primary standard to ensure measurements reliability and consistence of accuracy. The volumetric measurement of gas flow goes simultaneous with the calculation of Gross Calorific Value (GCV) and hence to determine the energy measured. GCV is calculated by determining the quantitative analysis of the natural gas composition using chromatography analyser. The gas component like methane, ethane, propane, isobutene, other heavier carbohydrates, nitrogen and carbon dioxide can be analysed to determine the quality of natural gas.

The current status of natural gas metrology in Tanzania illustrated in the **Table.3** below implies that a more effort should be put to the establishment of calibration laboratories for gas meters and chromatography. However, effort should also be put to capacitate the legal metrology in natural gas where the verification of gas meters, pattern approval and market surveillance has to be done by the weights and measures agency (WMA). The data collected indicates that the capacity of natural gas measurement control in Tanzania is less than 30%.

Table 3 Current status of metrology infrastructure for natural gas in Tanzania

Industrial Metrology (NMI/DMI)	Gas Flow Meter (<i>cf/m³</i>)	Pressure Measurement (<i>PT, etc.</i>)	Temperature Measurement (<i>RTD, etc</i>)	Chromatography (<i>GCV</i>)
Primary Standard	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Calibration Laboratories	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Designated laboratories	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Reference standards (traceability)	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
In-situ calibration facility	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Uncertainty analysis	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Testing laboratories	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Private Calibration Laboratories	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Legal Metrology (NLMI)	Gas meters	Temperature measurement	Pressure measurement	Chromatography
Approved Regulation	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Initial verification	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Subsequent/periodic verification	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Pattern/type approval	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Exceptional verification	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Private legal metrology institution	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

6.1 Role and Impact of Metrology Infrastructure in Natural Gas Sector

The growing exploitation and distribution of natural gas in Tanzania escalates the growing importance of natural gas market and which creates an urgent need to integrate metrology infrastructure so as to provide the industry and the society

with accurate and reliable measurements. Currently natural gas produced at Mnazi bay in Lindi and Madimba in Mtwara has been transported to Kinyerezi through pipelines and then distributed to some industries, commercial and pilot households for consumption. Tanzania will in future export LPG to other countries; this should ultimately call for improvement of metrology infrastructure, by considering that the transfer of natural gas from sellers to buyer involves significant financial risk due to a lack of accurate estimation of transferred energy [15]. Like other countries the improved metrology infrastructure in natural gas hinges on developing metrology policy, integrating legal metrology and industrial metrology in the gas sector.

The lack of accurate and controlled measurement of quantity and quality impend the transportation and trading of energy. Knowing that before exporting natural gas, the market value of natural gas has to be determined in tan of oil equivalent (toe), by considering its ‘heating capacity’[6]. As the matter of fact, the price of transported or distributed natural gas is determined by the measured volume and the energy value. Metrology for natural gas accounts into many impacts such as fair distribution of resources, setting fair and competitive market price, trade transparency to both private and public institutions, guarantee consumer protection, and encourages good resources management.

6.2 Requirements for Metrology Infrastructure in Natural Gas

The Tanzania Natural Gas policy of 2013 provides the regulatory, production, storage, transportation and distribution framework[5], more less, the integration of metrology infrastructure remain very essential in the value chain. Tanzania is the member state for OIML and BIPM hence, it has moral obligation to implement OIML recommendations and follow key comparisons or standards in natural gas measurement. The implementation of recommendation, comparisons and standards are made through its national legal metrology institute (NLMI) and the national metrology institute (NMI). Legal metrology in natural gas chain measurement is one of the legislative metrology infrastructures. Legal metrology includes the metrological control of measurements and measuring instrument used in natural gas through provision of pattern approval, initial and subsequent verification for custody transfer metering systems, gas dispensers, and commercial and household gas flow meter. Legal metrology aspect is taken care by the national legal metrology institute (NLMI), whereas in Tanzania, the WMA has legal obligation.

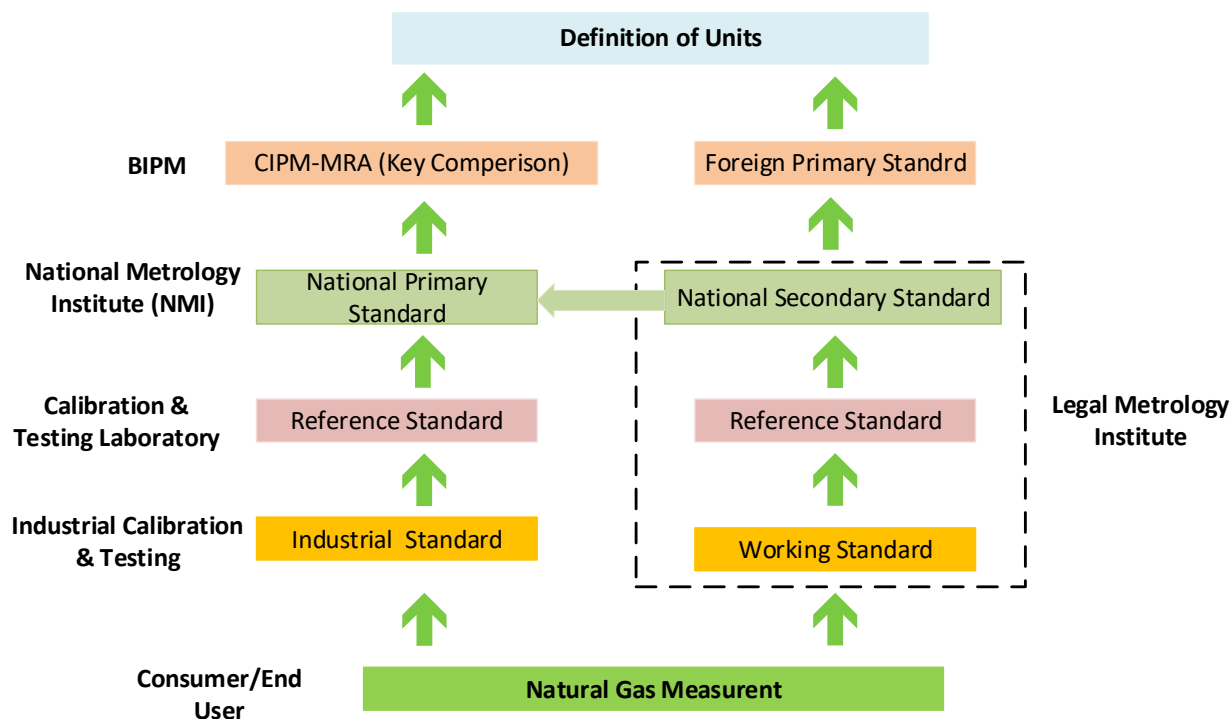


Figure 6: Traceability in natural gas metrology

Industrial metrology is another framework of metrology infrastructure whose major function is to ensure quality measurement and testing of natural gas and associated measurement parameters like pressure, temperature and gross calorific content. This is mainly important in the upstream although is not enforced by legislation but still important to companies which operate in the sector like the natural gas producers, pipeline operating companies local distributors and large consumer like gas fired power generation plant [16]. Generally, industrial metrology is the measurement at self-

interest of companies but helps in estimating the energy transported between different locations and thus increases fair completion in the sector. National metrology institute, designated metrology laboratories and the conformity assessment bodies (testing laboratories, calibration laboratories) are obligated to take industrial metrology for natural gas. Some of the role of NMI in gas sector involves; provision of primary standard for gas flow meter, chromatography and other measurements like pressure and temperature, developing traceability framework and calibration of measurement instrument (pressure, temperature, flow meter).

7.0 RECOMMENDATION AND SUGGESTED IMPROVEMENTS

The improvement and adoption of metrology infrastructures in the natural gas sector is the entity of great importance to the development of industry and economy. The production, transportation, distribution and exporting of natural gas goes hand to hand with improvement of metrology infrastructure to optimize the resource and enhance transparency of gas trade to domestic and international market. In order for Tanzania to exploit the natural gas for better economic return, the metrology infrastructure should be restructured as in the framework illustrated in **figure 3**.

Despite of the presence of NMI and NLMI there also should be an accreditation body, number of designated laboratories, number of private legal metrology inspectors, improved primary standard and traceability as well as presence of a number of improved calibration and testing laboratories. Henceforth, the impact of metrology in the natural gas sector to society and economy would include the consumer protection, effective stock control, full collection of government taxes based on measurement, and full national benefit for LNG export and support transparency and fare trade.

In the process of improving the quality infrastructure (QI) as a whole, Tanzania should adapt the QI framework illustrated in **figure 1** as suggested by the World Bank. While the integration the metrology infrastructure in the natural gas sector will foster the sector socio-economic efficiency, institutionalization of a national accreditation body would accelerate the accreditation process of conformity assessment laboratories in the country.

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