

1 Stakeholder consensus on the use of compressed natural gas as automotive fuel in Nigeria

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17 Introduction

18 Since the late 1960s, the Government of Nigeria has sought both to exploit the country's natural gas resources and
19 to reduce the environmental impact and economic cost of the gas that is associated with oil production. Key
20 initiatives have included legislation prohibiting gas flaring and venting, the introduction of fiscal incentives for
21 gas utilisation projects, the development of international and regional gas export markets, the promotion of the re-
22 injection of gas in petroleum exploration and production processes, the use of natural gas in power generation and
23 as an industrial feedstock and, more recently in 1997, the proposal to adopt compressed natural gas (CNG) as an
24 automotive fuel. These efforts have yielded mixed results – ranging from the outright failure of legislation to abate
25 gas flaring, as reported in Ogunlowo et al. (2015), to success in becoming a leading exporter of liquefied natural
26 gas (LNG) (EIA, 2013) and as a supplier of piped natural gas to parts of West Africa (West African Gas Pipeline
27 Company, 2012). In addition, the Nigerian National Petroleum Corporation (NNPC, 2016) indicated that around
28 12% of the associated gas encountered during exploration and production processes in 2016 was re-injected,
29 compared to near zero in 1990. Onolemhemhen et al. (2017) observed that the domestic gas supply obligation
30 introduced in 2008, which mandates oil and gas companies to make a portion of the gas they produce available to
31 the local market, has further boosted national gas utilisation by over 40% between 2008 and 2017. The impact is
32 especially in the power and industrial sectors – evidenced by 23 gas-powered plants, with another two under
33 construction, improved utilisation of liquefied petroleum gas (LPG), and a resurgence in cement and fertiliser
34 production. Yet, the adoption of CNG as a transportation fuel has been slow, despite the fact that the country
35 continues to experience transportation energy shortages (Ezea, 2018). The country has a natural gas vehicle (NGV)

1 penetration of just 0.1% – that is, 6,000 NGVs out of a national fleet of more than six million vehicles (NGV
2 Global, 2017).

3 Natural gas is a realistic alternative to petrol and diesel (Carslaw and Fricker, 1995), presents a viable option across
4 all road transport segments (Marbek, 2010) and becomes competitive with gasoline at the same level of
5 infrastructural development (Nijboer, 2010). It also offers advantages for public health (Gurjar et al., 2010; Mena-
6 Carrasco et al., 2012) and is cleaner and safer as an automotive fuel (Clean Vehicle Education Foundation [CVEF],
7 1999; Marbek, 2010; NGV America, 2013; Goyal and Sidhartha, 2003). NGVs can offer similar performance to
8 conventional vehicles (Natural Gas Vehicle Institute [NGVi], 2013; US Department of Energy [DOE], 2013;
9 Southern California Gas Company, 2013) and provide long-term savings, particularly in the medium- and heavy-
10 duty segments (Marbek, 2010).

11 In terms of environmental impact, CNG may reduce greenhouse gas emissions by 15 to 25% depending on the
12 vehicle segment, eliminates the evaporative emissions that are responsible for at least 50% of hydrocarbon
13 emissions in conventional vehicles, produces little or no particulate matter and shows a reduction of up to 80% in
14 ozone-forming emissions compared to gasoline (NGV America, 2013; Marbek, 2010; Goyal and Sidhartha, 2003).
15 Furthermore, CNG offers a 30 to 45% advantage in price per equivalent unit of energy compared to gasoline (Pike
16 Research, 2012) and has operational advantages in situations where there are no distribution pipelines, as with
17 Nigeria (Buzcu-Guven et al., 2010). In Nigeria, the automotive use of CNG offers a significant opportunity for the
18 country to lower emissions of greenhouse gases, reduce gas flaring and increase domestic gas utilisation
19 (Ogunlowo et.al, 2015). This paper is the first attempt to seek to bring together views from the diverse stakeholders
20 to identify areas of consensus and thus a potential route forward.

21 The paper reports the findings of a Delphi study that explored the potential for consensus among key stakeholders
22 in the transportation and energy sectors in Nigeria on both the barriers to automotive use of CNG in the country
23 and policy interventions that might stimulate successful adoption, drawing out specific policy recommendations
24 that may enjoy acceptance among stakeholders. It builds on earlier stages of research which identified the critical
25 success factors in the adoption of CNG as an automotive fuel (Ogunlowo et al., 2015), used to benchmark here,
26 and work identifying both the barriers to adoption and potential policy solutions for Nigeria (Ogunlowo et al.,
27 2017). This paper focuses on the potential for building consensus on the issues and identifying ways forward.
28 While the study is specific to Nigeria, the findings and policy recommendations could be useful in countries with
29 similar energy and transportation market dynamics.

1 The paper is structured such that Section 2 outlines the methodological approach; Section 3 presents and discusses
2 the analysis and results, while Section 4 highlights the conclusions and policy implications.

3 **Methods**

4 The primary research question addressed here is: “What are the barriers to the use of compressed natural gas as an
5 automotive fuel in Nigeria and how can these be overcome?” The research question suits a hermeneutic or an
6 interpretative understanding, thus lending itself to the use of qualitative enquiry (Willis, 2007). Two major
7 methods for eliciting group opinion and judgment were evaluated in order to select an appropriate data collection
8 method to build group consensus on the pathways for successful implementation of the CNG programme, focus
9 group discussions and the Delphi method.

10 A focus group may be defined as an interactive discussion session in which a group of people are asked questions
11 on a specific subject, with the expectation that group interaction will stimulate participants to generate ideas that
12 might not have occurred to any one individual alone (see Henderson, 2009; Walker, 1985). Notable disadvantages
13 of the focus group include the danger that consensus could be unduly assumed (Harding, 2013), the possibility of
14 ‘groupthink’ or social desirability bias – in which the desire for harmony or conformity by any participant might
15 result in an incorrect or deviant decision-making outcome, and problems of external validity (Campbell and
16 Stanley, 1973). In this case, ideas on barriers and policy interventions have already been generated (Ogunlowo et
17 al., 2017) and thus a focus group approach was considered less appropriate.

18 The Delphi method, meanwhile, may be described as a survey conducted in multiple rounds anonymously among
19 a group of people considered as subject experts, in order to gain consensus where the views of the participants are
20 shared in between rounds, giving participants the opportunity to adapt their original assessment in subsequent
21 rounds (see Dalkey, 1969; Linstone and Turoff, 1975). The Delphi method has its disadvantages and these include
22 the extensive time that it takes to carry out, due to the iterative and sequential nature of the method (Jairath and
23 Weinstein, 1994; Williams and Webb, 1994), and the possibility of dilution of the best opinion, due to the
24 consensus approach (Sackman, 1975) and vulnerability to expert halo effect (Sackman, 1974). Nonetheless, the
25 Delphi approach was found to be appropriate here, as it: eliminates geographical limitations as the participants
26 need not be in close proximity; provides the opportunity for pre-defined criteria for group agreement; and enables
27 statistical group response, allowing both qualitative and quantitative evaluation with explorative, predictive and
28 normative elements. In addition, a Delphi survey has the potential to eliminate the possibility of “groupthink”,
29 social desirability bias and the possibility of there being any dominant participant due to its anonymous nature (see

1 Dalkey, 1969; Linstone and Turoff, 1975; Reynolds, 1994). Besides, the Delphi method has been applied
2 successfully as a research method in a wide range of disciplines to examine major issues, seek group consensus in
3 solving problems and to forecast the future. It has also been applied successfully in diverse transportation research
4 contexts – as, for example, in Rees et al. (2017), Wang et al. (2014) Liimatainen et al. (2014), Cafiso et al. (2013)
5 and Schuckmann et al. (2012), among others.

6 The Delphi method comprise of three distinct phases that Schmidt (1997) described as (i) the discovery of issues,
7 (ii) the determination of the importance of the issues and (iii) the ranking of the issues.

8 The first phase, i.e., the discovery of the issues, in the context of this study, is the identification of the barriers and
9 policy recommendations to be investigated and this was conducted through the application of semi-structured
10 interviews with senior staff from the energy supply, energy demand, regulatory agencies and advocacy groups
11 identified as being critical stakeholders in the successful implementation of CNG as automotive fuel in Nigeria
12 (Ogunlowo et al., 2017). The supply group included upstream (prospecting, drilling and production), midstream
13 (shipping and storing) and downstream (refining and distribution of products to consumers) stakeholders, while
14 the demand group included the largest fleet management and mass-transit companies, as well as retailers with the
15 highest market share in the new vehicle segment. The regulatory group contained government agencies with the
16 mandate to ensure compliance with the statutes and regulations governing both the demand and supply categories.
17 The advocacy group included formal entities outside of the other three groups that speak or write in favour of,
18 support or urge by argument or recommend publicly, transportation and/or energy policies in Nigeria. Analysis of
19 the interviews drew out common themes and perspectives evident across the stakeholder groups, resulting in the
20 identification of 31 barriers and 26 recommendations (Ogunlowo et al., 2017).

21 Rather than adopt generic classification such as those suggested by Browne et al. (2012), the study applied the
22 themes that emerged as expressly stated or inferred by the study participants to meaningfully interpret and
23 demonstrate the narratives. Tables 1 and 2 present the barriers, grouped under eight themes, and the
24 recommendations, categorised into four themes, respectively, where the ticks indicate that at least one participant
25 from the group expressed the view stated. With respect to barriers, there appears to be some degree of agreement
26 on issues relating to safety and understanding of CNG as an automotive fuel and the sparse distribution network.
27 With respect to policies, only two secured some degree of support across the groups: the removal of petrol
28 subsidies and the establishment of a coordinating agency. The next step is therefore to explore the possibilities for
29 consensus more fully within and between the groups.

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Table 1: Barriers identified

	Supply group	Demand group	Regulatory group	Advocacy group
A. Insufficient focus and misplaced priority of policy on natural gas				
1. Focus of government policy and legislation on gas flaring abatement initiatives	✓			
2. Absence of clear policy and regulation on automotive use of natural gas	✓		✓	
3. Focus on development of international and regional gas export markets	✓			
4. Absence of specific regulation and standards for natural gas vehicles	✓	✓	✓	✓
B. Unconducive energy market structure				
5. Inconsistent petroleum products pricing framework that favours gasoline	✓		✓	
6. Regulatory uncertainty caused by the non-passage of the Petroleum Industry Bill (PIB) ¹ into law	✓		✓	
7. Absence of market coordination on automotive use of natural gas	✓			
8. Poor and sparse gas transmission and distribution infrastructure	✓	✓	✓	✓
9. Obsolete standards and operational guidelines in the downstream sector of oil and gas industry	✓			
10. Arbitrariness in policy enforcement in oil and gas industry	✓			
11. Low technological and industrial base for energy consumption	✓			
12. Non-separation of regulatory and operating functions of Nigerian National Petroleum Company (NNPC) ²				✓
13. Poor credibility of the Power Holding Corporation of Nigeria ³ , the former major bulk buyer of natural gas	✓			
14. Lack of commitment to development of a domestic market for natural gas by international oil exploration and production companies	✓		✓	
C. Limited access to funding				
15. Poor access to long-term funding by indigenous oil companies	✓			
16. Slow response of NNPC to cash calls (requests for money) with respect to joint venture operations with international oil companies				✓
D. Safety concerns				
17. General inexperience of the population with gas handling	✓	✓	✓	✓
18. Safety of converted vehicles due to the old age and dilapidated state of existing national vehicle fleet	✓	✓	✓	✓
E. Insecurity of assets and personnel				
19. Militancy ⁴ in oil-producing areas	✓		✓	✓
20. Pipeline vandalism	✓		✓	✓
21. Outright stealing of petroleum products from the pipeline	✓		✓	✓
F. Technical and physical limitations				
22. Difficult physical terrain of the Niger Delta ⁵	✓		✓	
23. Incompatibility of loading and delivery facilities at seaports ⁶			✓	
24. Absence of any regulation or guidelines on retrofitting standards		✓		✓
25. Limited number of authorised and certified mechanics from original equipment manufacturers (OEM)		✓		✓
G. Weak transportation market structure				
26. Higher cost of natural gas vehicles compared to conventional vehicles		✓		
27. Lack of comprehensive transport policy		✓		
28. Absence of organised mass-transit companies and large-fleet owners and managers		✓		
29. Absence of vehicle emissions standards		✓		✓
30. Weak institutions for vehicle standards enforcement				✓
H. Low level of public education and awareness				
31. Absence of public awareness programmes to promote automotive use of natural gas	✓	✓	✓	✓

Source: Ogunlowo et al. (2017, p.67)

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1 The Petroleum Industry Bill (PIB) is a Bill for an Act to Provide for the Establishment of the Legal and Regulatory Framework, Institutions and Regulatory Authorities for the Nigerian Petroleum Industry; and to Establish Guidelines for the Operation of the Upstream and Downstream Sectors. The Bill was first introduced in the National Assembly (the legislative arm of government) in 2008 and was revised in 2012. It is yet to be passed into law.

2 Nigeria acquired controlling interests in the international oil companies (IOCs) operating in the country in 1971 and since then, petroleum operations have taken place with the country's participation as the majority shareholder. The NNPC, a state-owned company, holds the equity on behalf of the federal government under three types of contracts, comprising joint ventures (JVs), production sharing contracts

(PSCs) and service contracts (SCs). The Petroleum Inspectorate, a department within the NNPC, is responsible by law for the issuance of petroleum exploration and exploitation permits and licences.

- 3 The Power Holding Corporation of Nigeria (PHCN), before its privatisation in 2013, was one of the successor companies to the National Electric Power Authority, the government-owned company solely responsible for generation, transmission and distribution of electricity in Nigeria. Participants expressed the view that PHCN, despite buying natural gas at below market rate, consistently defaulted on its payment obligations and this resulted in cash-flow difficulties that hampered further investment in gas distribution.
- 4 Militancy results in business disruption, wilful business sabotage and hostage taking and kidnapping, with associated demands for huge ransoms from employers and relatives of the victims, and sometimes death of personnel, restiveness, stealing of oil, wilful destruction and outright terrorism. Participants observed that militancy has become an ineluctable attribute of oil-producing regions, and that it prevents investment in new ventures, especially those associated with major construction that transverses many communities, as would be required in the development of gas distribution pipelines.
- 5 The main oil-producing area in the country. It is the largest wetlands in Africa with about 36,000km² of marshland, creeks, tributaries and lagoons (Omotola, 2006).
- 6 The maximum capacity of vessels that can berth in the main port is 7,000 tons, whereas gas producers load vessels of 15–20,000 tons or more. Consequently, larger vessels are hired for storage, while the product is transferred to smaller vessels for shipment.

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Table 2: Policy recommendations investigated

Proposed policy interventions	Supply group	Demand group	Regulatory group	Advocacy group
Energy market reforms				
1. Remove pump price subsidy on petrol	✓	✓	✓	✓
2. Adopt market-based pricing for domestic supply of natural gas	✓		✓	
3. Extend existing fuel subsidy to natural gas until it is removed from gasoline			✓	
4. Pass the PIB into law “as is”	✓			
5. Pass less controversial provisions of PIB in the first instance	✓			
6. Establish a government gas infrastructure development intervention fund	✓			
7. Establish a coordinating agency to drive CNG use	✓	✓	✓	✓
8. Separate regulatory and operational functions of NNPC				✓
9. Expand alternative fuel options to include liquefied petroleum gas (LPG)			✓	
10. Remodel and upgrade delivery facilities at seaports			✓	
11. Extend gas transmission lines nationwide			✓	
Transportation sector reforms				
12. Develop a comprehensive transportation policy			✓	
13. Develop vehicle emissions standards		✓	✓	✓
14. Develop a NGV safety assurance plan		✓	✓	✓
15. Government and industry to establish retrofitting workshops				✓
16. Offer incentives for auto mechanics on retrofitting training				✓
17. Introduce retrofitting courses in federal technical colleges				✓
Fiscal and operational incentives				
18. Offer tax rebate on land used for CNG stations			✓	
19. Offer import duty concession for retrofitting kits, CNG equipment and components			✓	
20. Offer incentives to vehicle owners to convert to NGV			✓	
21. Offer 50-75% subsidy on LPG conversion kits			✓	
22. Offer incentive to mass-transit companies to use NGV		✓		✓
Public awareness				
23. Undertake public awareness campaign			✓	✓
24. Mandate government at all levels to include NGV in their fleets	✓		✓	
25. NNPC to site CNG stations in strategic locations	✓			
26. Involve senior government officials in the promotion of natural gas	✓			

Data Source: Ogunlowo et al. (2017, p.67)

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2.1. Delphi design

1 The Delphi survey was designed in three sequential stages, comprising conceptualisation, testing and
 2 revision. Conceptualisation was iterative, focused on clarity and consistency, completeness of lines of
 3 enquiry, and the matching of questions to analytical methods. Testing comprised two independent reviews
 4 of the questionnaires and pilot completion by three knowledgeable volunteers. The revision stage involved
 5 modification of both the form and content of questions based on feedback received from the pilot sample.
 6 The methodology adopted is presented retrospectively in Sections 2.2 to 2.5, below.

7 2.2. Delphi survey questions and response scales

8 The Delphi survey design involved a preliminary plan for the number of rounds, survey administration procedure
 9 and participant selection process. The number of rounds for a Delphi survey depends on how quickly the opinions
 10 of the respondents converge. However, as observed by Hsu and Sandford (2007), three iterations are often
 11 sufficient to establish consensus.. Hence, this study was designed with the anticipation that opinions would
 12 converge within three rounds as further discussed in Section 2.4. The Round 1 questionnaire used a combination
 13 of categorical, open-ended, ranking and rating questions to ask “What?” and “When?” questions that validated and
 14 established the relative importance of the issues. Round 2 explored the possibility of building consensus among
 15 participants on the issues where Round 1 did not achieve consensus. Round 3 focused on “Why?” to identify the
 16 reasons for any divergence on issues where Round 2 did not achieve consensus. Table 3 shows the composition,
 17 objective, type of question, measurement scale and the transition across the rounds.

18 **Table 3: Transition and characteristics of questions across the three rounds**

<i>Round 1</i>	<i>Round 2</i>	<i>Round 3</i>	<i>Objective</i>	<i>Type</i>	<i>Scale</i>
Q1. To which sector does your organisation belong?	Q1. To which sector does your organisation belong?	Q1. To which sector does your organisation belong?	Identification	Categorical	Rounds 1 to 3: Nominal list
Q2. Please rate each of the 31 barriers listed here based on your perception of how each has hindered automotive use of CNG in Nigeria	Q2. Please rate each of the 9 barriers listed here based on your perception of how each has hindered automotive use of CNG in Nigeria	Q2. Has militancy hindered the automotive use of CNG in Nigeria? Q3. Has pipeline vandalism hindered the automotive use of CNG in Nigeria? Please tick as appropriate and give reasons	Validation	Round 1: Rating Round 2: Rating Round 3: Categorical	Rounds 1 and 2: Ordinal unipolar – Not at all to Severely Round 3: Yes or No
Q3. Please list any barrier that is missing from the list provided	Terminated		Data gathering	Open-ended	None
Q4. Which 3 of the barriers (including your suggestions in Q3) have hindered the automotive use of CNG in Nigeria the most?	Q3. Nine barriers emerged from Round 1 as those that might have hindered the automotive use of CNG the most. Please rank these barriers exclusively in order of severity	Terminated	Prioritisation	Ranking	Ordinal ipsative Round 1: – 1 st to 3 rd Round 2: (1 = most severe and 9 = least severe)
Q5. Have any of the barriers influenced decision-making in	Terminated		Validation	Categorical	Nominal (Yes or No)

your organisation about CNG?					
Q6. If you answered Yes to Question 5, which ones?	Terminated		Validation	Categorical	Nominal (list)
Q7. Kindly indicate your level of support for the potential interventions identified by interview participants	Q4. Kindly indicate your level of support for the potential interventions listed	Q4. Do you support the proposal to pass into law the less controversial provisions of the PIB? Please tick as appropriate and give reasons	Validation	Rating	Round 1 and 2: Ordinal bipolar – Strongly disagree to Strongly agree Round 3: Yes or No
Q8. Is there anything missing from the list of interventions?	Terminated		Data gathering	Open-ended	None
Q9. Which 5 out of the interventions listed and your suggestions (if any) in Q8 do you consider most important?	Q5. Please rank all the policies listed below based on your perception of how they might stimulate the adoption of CNG as an automotive fuel in Nigeria	Terminated	Prioritisation	Ranking	Ordinal ipsative Round 1: (1 st to 5 th) Round 2: (1 = most important and 11 = least important)
Q10. Which 3 out of the interventions you listed in Question 9 do you consider most urgent?	Q6. Please rank all the policies listed below based on your perception of how urgently each is required fuel in Nigeria	Terminated	Prioritisation	Ranking	Ordinal ipsative Round 1: – 1 st to 3 rd Round 2: (1 = most urgent and 9 = least urgent)

1 Nominal scales were applied to categorical questions and ordinal scales were applied to ranking and rating
2 questions. As shown in Table 3, Question 1 in each round was a categorical question that enabled the identification
3 and classification of the respondents into pre-defined stakeholder groups. Open-ended questions provided
4 participants with the opportunity to contribute new insights and ideas that might not have been previously
5 identified, while the ranking questions asked participants to compare and order issues. The rating questions
6 allowed participants to compare the variables using a common ordinal scale. The scales for the rating questions
7 were unipolar and bipolar scales with five points each, such that the unipolar scale had an odd number of points
8 and the bipolar scale was balanced with an equal number of positive and negative categories and a neutral middle
9 point. These scales conform to the common practice of five or fewer points and seven or fewer points for unipolar
10 and bipolar scales, respectively, and both meet the general requirement for a balanced scale (see Salant and
11 Dillman, 1994). The ordinal scale for the ranking questions comprised ipsative measures that asked respondents
12 to rank choices in an exclusive order of 1-3, 1-5, 1-9 and 1-11. Unlike a unipolar or a bipolar ordinal scale, an
13 ipsative scale is used for exclusive ranking where no two or more variables can share the same rank and therefore
14 has as many points as the number of variables being ranked.

15 Word labels were used for all the scales for ease of interpretation. The unipolar ordinal measuring scale for the
16 questions that asked participants to rate each of the barriers based on their perception of how each has hindered
17 automotive use of CNG in Nigeria were “Not at all”, “Mildly”, “Moderately”, “Very” and “Severely”, while those

1 of the bipolar ordinal scale for the question that asked participants to indicate their level of support for the policy
2 interventions were “Strongly disagree”, “Disagree”, “Indifferent”, “Agree” and “Strongly agree”.

3 **2.3. Panellist selection**

4 Among the wide range of suggestions for the selection of panellists available in the literature, “employment status
5 as a top management decision-maker who might use the outcome of a study” (see Hsu and Sandford, 2007, p.3)
6 was considered most appropriate and was applied. Corporate rather than personal participation was used, due to
7 the inherent difficulty associated with the independent identification and solicitation of individuals who are subject
8 matter experts. Between 15 and 50 experts seemed appropriate, as the reference group has four stakeholder
9 categories and thus exhibits diversity (see Delbecq et al., 1975; Witkin and Altschuld, 1995; Ludwig, 1997). In
10 total, 56 key organisations involved in the transportation and energy sectors in Nigeria were invited to participate.
11 This provided a buffer to mitigate the risks of a low response rate and attrition in later rounds. Gaining access
12 involved the use of formal invitation letters to the identified organisations and requesting the nomination of senior
13 individuals who were knowledgeable about the automotive use of CNG in Nigeria to complete the questionnaire.
14 The resulting sample comprised participants such as principal officers of key government agencies, senior
15 engineers, heads of logistics departments, heads of petroleum marketing departments, executive directors and chief
16 executive officers from the transportation and energy sectors.

17 **2.4. Consensus criteria**

18 Consensus criteria provide a pre-defined condition for agreement. Dajani et al. (1979) argued that for a Delphi
19 study to be valuable, it must meet the requirements for both consensus and stability (i.e. consistency of responses
20 between successive rounds of a study) and proposed that hierarchical stopping criteria be defined to measure the
21 level of agreement only if a stable answer is reached (Dajani et al., 1979, p.85). The consensus criteria are used
22 strictly for gaining contextual understanding rather than to test any hypothesis.

23 The consensus measurement for this study fits the use of qualitative analysis and descriptive statistics only because
24 the study sample is a non-probability sample drawn in a purposive manner as discussed in Section 2.3. Besides,
25 the measurement scales and the variables do not support the use of inferential statistics. As seen in Riley et al.
26 (2000), parametric statistics are applicable to interval and ratio data that conform to a normal distribution and not
27 to nominal and ordinal variables.

28 As seen in Hill and Fowles, 1975; Hasson et al., 2000; von der Gracht, 2012, the most common qualitative analysis

1 and descriptive statistics applied in the analysis of Delphi surveys are: the stipulated number of rounds; a set
2 percentage; the average percentage of majority opinions (APMO) cut-off rate; measures of central tendency; the
3 interquartile range (IQR); and the coefficient of variation (CV).

4 If using a stipulated number of rounds, the exact round at which consensus would be declared is set prior to survey
5 administration and the views of the panellists at the end of that round constitute a consensus.

6 For a specific percentage of participants, the researcher sets the percentage for consensus before the analysis and
7 consensus is assumed when the percentage of participants agreeing on an issue is equal to or exceeds the set
8 percentage point. This method is the most frequently used and various studies have applied percentages ranging
9 from 51% to 95% (von der Gracht, 2012). However, Scheibe et al. (1975) argued that the use of percentage
10 measures alone is inadequate and suggested using the degree of stability of responses in successive iterations.

11 If using the APMO cut-off rate, consensus is defined as a percentage equal to or higher than the cut-off rate, where
12 the cut-off rate – as defined by Kappor (1987) – is the sum of the majority agreements and the majority
13 disagreements divided by the total number of opinions expressed as a percentage. Cottam et al. (2004, p.16) have
14 described explicitly the computation of the APMO cut-off rate.

15 If using the measure of central tendency, the mean, median or mode is prescribed as the consensus point by the
16 researcher before the analysis. Whereas the mode and median are applicable to all data forms, the mean is only
17 applicable to interval and ratio variables, which are rarely used for Delphi studies (see von der Gracht, 2012).
18 Studies that have applied measures of central tendency as consensus criteria include Hill and Fowles (1975) and
19 Hasson et al. (2000).

20 The use of IQR, a measure of variability, requires the researcher to rank the data set and divide it into four equal
21 parts, where the values that divide each part are called the first, second and third quartiles; denoted by Q1, Q2 and
22 Q3, respectively. The IQR is equal to Q3 minus Q1. In this instance, the researcher sets a certain figure as a
23 benchmark and consensus is reached when the IQR for the date set of the panellist opinions is lower than the set
24 benchmark. Studies that have used IQR include Spinelli (1983), Raskin (1994), Hahn and Rayens (1999) and
25 Rayens and Hahn (2000).

26 Finally, the CV, also known as the relative standard deviation, a standardised measure of dispersion of a probability
27 distribution or frequency distribution which is the absolute value of the ratio of the standard deviation to the mean,
28 is used to determine the stopping rule. The researcher sets a benchmark and if the magnitude of CV for the data
29 set of the panellist opinions is greater than the set figure, the survey will require additional round questionnaire

1 administration. Consensus is reached when the CV is lower than the benchmark. CV is only applicable to data
 2 measured on a ratio scale and thus may not have any meaning for interval, ordinal and nominal scales. A number
 3 of Delphi studies – such as Buck et al. (1993) and Zinn et al. (2001) – have applied this method. English and Keran
 4 (1976) proposed rules for the interpretation of the coefficient of variation for the measurement of consensus, while
 5 Dajani et al. (1979) proposed its use to measure stability and changes between two successive rounds. The
 6 application of these rules is, however, questionable considering that Delphi typically measures opinion, which
 7 limits the variables to nominal and ordinal scales that do not have a statistical mean.

8 With regard to significance tests, there are three prominent methods used, especially for ranking questions
 9 involving more than two dependent samples. These are the Friedman Test, Kendall’s coefficient of concordance
 10 (W) test and Cochran’s Q test. The Friedman test, also known as the Friedman two-way analysis of variance, is
 11 the significance test for more than two dependent samples that is used to test that no significant difference exists
 12 between the size of a dependent sample and the population from which it was drawn. Cochran’s Q Test is a non-
 13 parametric way to find differences in matched sets of three or more frequencies or proportions where responses
 14 are recorded for each subject with binary options, e.g. “success” or “failure”, while Kendall’s coefficient of
 15 concordance (W) is a measure of the agreement among several judges who are assessing a given set of objects.
 16 Among the three, Kendall’s W was found to be most suitable, as it is specific to the measurement of an agreement.

17 Kendall’s W is expressed as:

18 $W = \frac{12R}{m^2(k^3 - k)}$ where R is the sum of the squared deviation of the ranking for each variable expressed as:

19
$$R = \sum_{i=1}^k (R_i - \bar{R})^2$$

20 m is the number of panellists; and k is the number of variables ranked.

21 It is always the case that $0 \leq W \leq 1$. Table 4 presents the interpretation of W.

22 **Table 4: Interpretation of Kendall’s W**

W	Interpretation	Confidence in ranks
0.1	Very weak agreement	None
0.3	Weak agreement	Low
0.5	Moderate agreement	Fair
0.7	Strong agreement	High
0.9	Unusually strong agreement	Very high

23 Source: Schmidt (1997, p.757).

24 Other relevant statistics for the interpretation of the significance test include the degree of freedom (df), which is
 25 the number of variables that may vary independently. This is expressed as: $df = k - 1$, Chi-squared (X²), which is
 26 the product of the number of panellists, the degree of freedom and Kendall’s W, and the p-value, a function of the
 27 observed sample results that tests the level of marginal significance within a statistical hypothesis test and

1 represents the probability of the occurrence. It is defined as the probability of obtaining a result equal to or “more
 2 extreme” than what was actually observed, if the null hypothesis is true (Hubbard, 2004). Others include the
 3 significance level (α), which is the threshold value for a test. Hence, α for a given hypothesis test is a value for
 4 which a p-value less than or equal to α is considered statistically significant. If the p-value is less than or equal to
 5 the chosen α , the test suggests that the observed data are inconsistent with the null hypothesis, so the null
 6 hypothesis must be rejected. However, this does not prove that the tested hypothesis is true. Typical values for α
 7 are 5% (0.05), 1% (0.01) and 0.1% (0.001). These imply the following levels of confidence: 95% level = $p < 0.05$;
 8 99% level = $p < 0.01$; and 99.9% level = $p < 0.001$.

9 In light of the above, the stipulated number of rounds and the set of percentages are the most suitable consensus
 10 criteria for this study because the study applied nominal and ordinal measurement scales where the differences
 11 between adjacent values on the measurement scales do not necessarily represent equal intervals. Consequently,
 12 the study applied a combination of the two methods. Hence, the study was designed with the anticipation that
 13 opinions would converge and meet within three rounds based on pre-defined consensus criteria that comprised of
 14 the condition for convergence and the hierarchical stopping criteria shown in Table 5. The objectives of the three
 15 rounds were, in chronological order, to: (i) validate and prioritize the identified barriers and proposed policy
 16 interventions identified by the interview participants; (ii) explore the possibility of building consensus among the
 17 Delphi participants; and (iii) identify the reasons for any divergence where consensus was not achieved.

18 **Table 5: Consensus criteria for the study**

<i>Question</i>	<i>Condition for convergence</i>	<i>Hierarchical stopping criteria</i>
Rating	70% of the respondents' opinions fall within two adjacent points on the five-point scale	25% of the responses of a minimum of three out of the four stakeholder groups fall in these adjacent points
Ranking	51% of the respondents or more choose the same rank	25% of the responses of a minimum of three out of the four stakeholder groups fall on the same rank

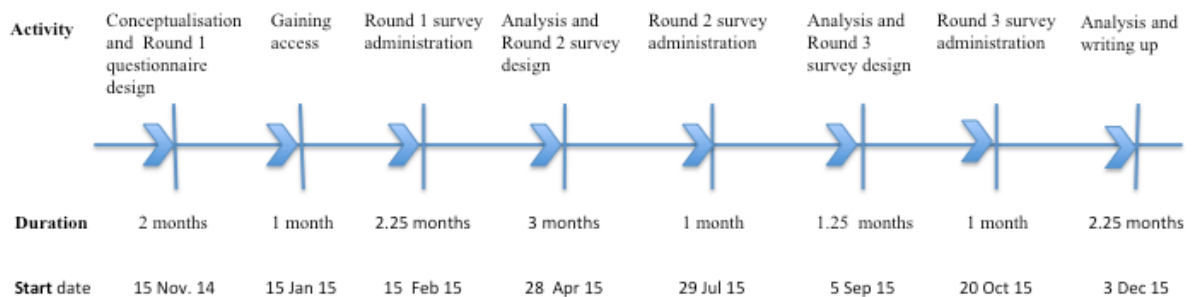
19 The percentage set as condition for convergence for the rating questions is the percentage point used by
 20 examination bodies in the country for the best grade in any examination to denote an “excellent “ score. A lower
 21 percentage point is set for ranking questions, because consensus is based on a single point as against two adjacent
 22 points used for the rating questions. This is because the questions required participants to rank in exclusive order.
 23 The consensus benchmarks are considered appropriate as they are within the range of 51% to 95% seen in the
 24 wider literature. Besides, the 70% mark for rating questions and the 50% mark for ranking questions were higher
 25 than and equal to the 50% threshold defined as majority by Dajani et al., respectively, while the 25% benchmark
 26 for secondary condition matches the plurality range.

1 Kendall's coefficient of concordance (W) was used to test for statistical significance of agreement for the ranking
 2 questions as applicable. The α value for the study was set at 0.001, in line with common practice for ranking
 3 questions in Delphi studies (see Schmidt, 1997).

4 The authors note that the use of post-group consensus examination, after the Delphi process has been completed,
 5 to measure the acceptability and convergence of the outcome to the final round responses of individual panellists
 6 has gained acceptance in Delphi studies (see Rowe and Wright, 1999). While this method might be useful for
 7 validation of study outcomes, it was not necessary for this study as there were high levels of convergence on the
 8 variables examined.

9 **2.5. Administration**

10 The Delphi method requires time between rounds, because the iterative and sequential nature makes the survey
 11 design, questionnaire administration, and data collection and analysis interdependent. Consequently, this study
 12 was undertaken over a period of about 14 months – as shown in Figure 1. Three rounds of surveys were
 13 conducted between 15 February and 25 April; 29 July and 31 August; and 20 October and 18 November 2015.
 14 The questionnaires were made available in three formats: electronic mail; surface mail with prepaid postage
 15 return envelope; and online. Participants had the option to choose whichever format was most convenient.



16
 17 **Figure 1: The Delphi survey process**

18
 19 **3. Analysis, results and discussion**

20 Consensus criteria, as discussed in Section 2.3, were applied to respondents' views in Rounds 1 and 2, while Round
 21 3 data analysis employed hermeneutics principles, i.e. the theory of achieving an understanding of texts and
 22 utterances (see Patterson and Williams, 2002); this is elaborated upon in detail in Section 3.3.

23 The three rounds of the survey had 64%, 59% and 34% response rates successively. The participants broadly
 24 represented the stakeholder groups. The distribution of respondents, shown in Table 6, satisfied the goal of the
 25 study. Although Round 3 did not record any respondents from the regulatory group, Delphi does not call for expert

1 panels to be made up of representative samples for statistical purposes (See Powell, 2003). The numbers of
 2 respondents required for both convergence and plurality in the first two rounds (rounded to the nearest whole
 3 numbers) are stated in Table 6. The participants' views on both the barriers that have hindered adoption of CNG
 4 as an automotive fuel in Nigeria and the proposed resolutions are presented in Sections 3.1 and 3.2, while issues
 5 that did not record consensus are discussed in Section 3.3.

6 **Table 6: Distribution of the respondents and consensus requirement**

	Invited for each round	Number of respondents			Condition for convergence				Condition for plurality	
		R1	R2	R3	R1 Rating questions	R1 Ranking questions	R2 Rating questions	R2 Ranking questions	R1	R2
Supply	18	17	15	7	25	18	23	16	4	4
Demand	16	8	8	5					2	2
Regulatory	5	3	2	0					1	1
Advocacy	17	8	8	7					2	2
Total	56	36	33	19						

7

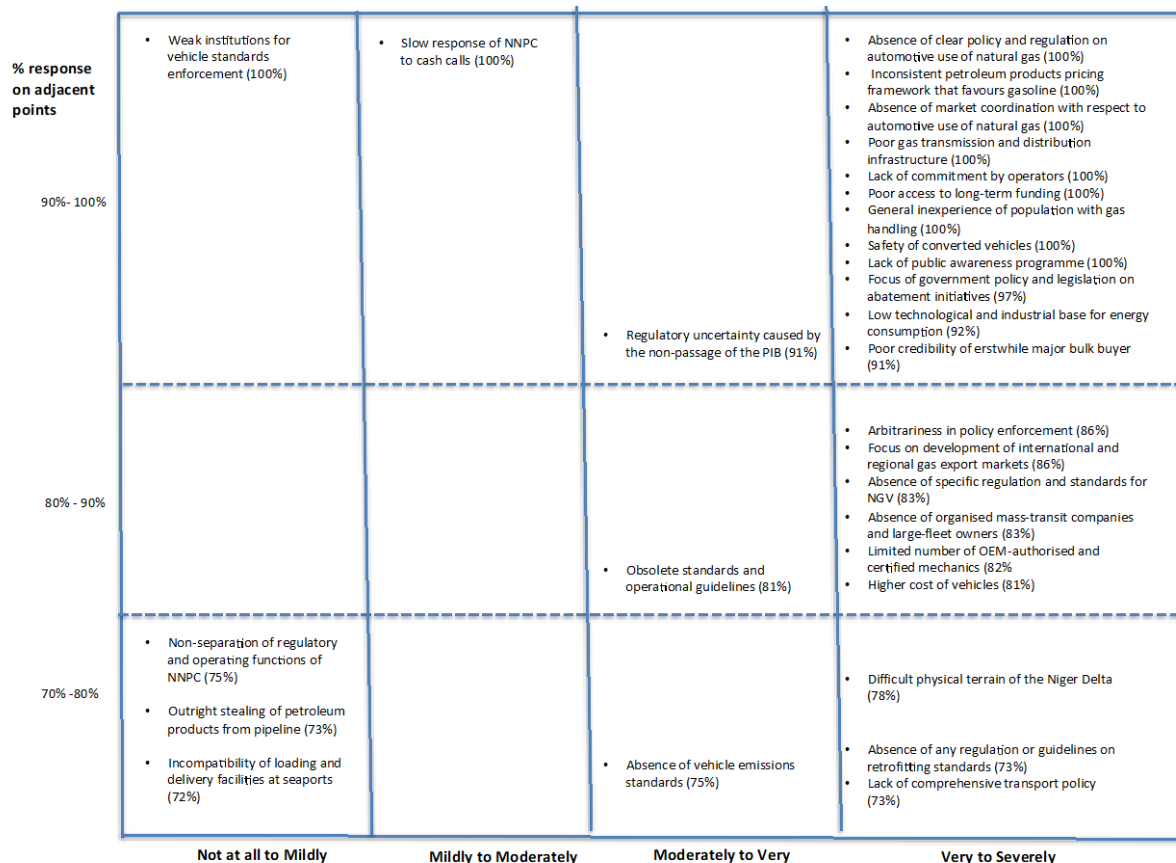
8 **3.1. Barriers to the use of CNG as an automotive fuel**

9 The participants did not identify any further barriers to add to the set derived from stakeholder interviews
 10 (Ogunlowo, 2017). It was concluded that the list of barriers provided was collectively exhaustive for the study
 11 participants. In response to the question that asked participants to rate the barriers listed in the questionnaire based
 12 on their perception of how each have hindered the automotive use of CNG in Nigeria, Round 1 achieved consensus
 13 on 22 of the 31 issues and this increased to 29 at the end of Round 2. Table 7 shows the respondents' views on
 14 how the 31 barriers investigated have hindered the automotive use of CNG in Nigeria while Figure 2 presents the
 15 consensus reached based on the consensus criteria. Table 7 further shows that the impact of Militancy and Pipeline
 16 vandalism as barriers towards the adoption of CNG as automotive fuel did not meet the consensus criteria set for
 17 rating questions as 70% of the respondents' opinions did not fall within any two adjacent points on the five-point
 18 scale. Consequently, Round 3 explored the reason for a lack of consensus on the impact of militancy and pipeline
 19 vandalism.

20 **Table 7: Perspectives on how the 31 barriers investigated have hindered automotive use of CNG in Nigeria**

Description	Not at all	Mildly	Moderately	Very	Severely
1. Focus of government policy and legislation on abatement initiatives			3%	19%	78%
2. Absence of clear policy and regulation on automotive use of natural gas				17%	83%
3. Focus on development of international and regional gas export markets		11%	3%	36%	50%
4. Absence of specific regulation and standards for NGV		3%	14%	22%	61%
5. Inconsistent petroleum products pricing framework that favours gasoline				36%	64%
6. Regulatory uncertainty caused by the non-passage of the PIB	3%	6%	39%	52%	
7. Absence of market coordination with respect to automotive use of natural gas				36%	64%
8. Poor gas transmission and distribution infrastructure				19%	81%

9. Obsolete standards and operational guidelines			31%	50%	19%
10. Arbitrariness in policy enforcement			14%	53%	33%
11. Low technological and industrial base for energy consumption			8%	28%	64%
12. Non-separation of regulatory and operating functions of NNPC	33%	42%	25%		
13. Poor credibility of erstwhile major bulk buyer (PHCN)			9%	48%	43%
14. Lack of commitment by operators				3%	97%
15. Poor access to long-term funding				31%	69%
16. Slow response of NNPC to cash calls	11%	42%	31%	16%	
17. General inexperience of population with gas handling				6%	94%
18. Safety of converted vehicles				6%	94%
19. Militancy	18%	12%	10%	27%	33%
20. Pipeline vandalism	15%	10%	15%	30%	30%
21. Outright stealing of petroleum products from pipeline	37%	36%	9%	9%	9%
22. Difficult physical terrain of the Niger Delta			22%	33%	45%
23. Incompatibility of loading and delivery facilities at seaports	69%	3%	14%		14%
24. Higher cost of vehicles			19%	14%	67%
25. Lack of comprehensive transport policy			27%	17%	56%
26. Absence of organised mass-transit companies and large-fleet owners			17%	22%	61%
27. Absence of vehicle emissions standards			53%	22%	25%
28. Absence of any regulation or guidelines on retrofitting standards	12%	9%	6%	24%	49%
29. Weak institutions for vehicle standards enforcement	37%	33%	9%	12%	9%
30. Limited number of OEM-authorised and certified mechanics	9%	6%	3%	12%	70%
31. Lack of public awareness programme					100%

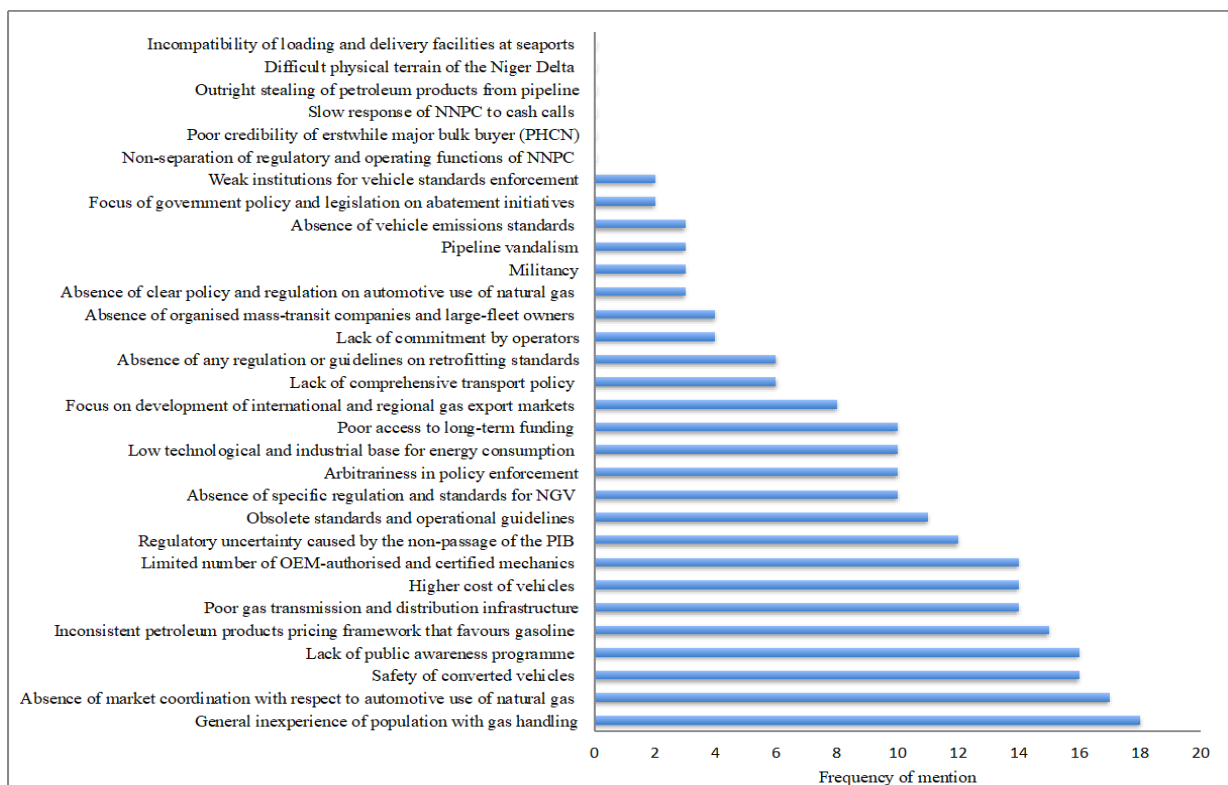


1
2 **Figure 2: Consensus on how 29 of the 31 barriers investigated have hindered automotive use of CNG in Nigeria**

3 In Round 1, participants were asked if any of the barriers listed had influenced decision-making in their
4 organisation concerning the automotive use of natural gas; 64% of respondents answered 'yes', mentioning 25
5 barriers (Figure 3). The most frequently mentioned barrier was the general inexperience of the population with gas

1 handling, with 18 responses. Other barriers mentioned by at least 70% of the respondents were the absence of
 2 market coordination with respect to automotive use of natural gas, safety of the converted vehicles, the lack of a
 3 public awareness programme, and the inconsistent petroleum products pricing framework that favours gasoline
 4 over other products. This result is consistent with the responses to Question 4 (Table 3), as the barriers rated as
 5 most severe are also those seen to have impact in the decision making in the participants' organisations with respect
 6 to the use of CNG as an automotive fuel. In addition, further analysis shows that the three most prominent barriers
 7 in Question 4 feature among the four barriers that were affirmed by at least 70% of the respondents. This result
 8 provides a useful insight into the impact of barriers in practice. The hindrances most frequently mentioned were
 9 mainly with respect to energy market structure and safety concerns.

10



11
12

Figure 3: Barriers that have influenced decision-making in participants' organisations

13 When asked to identify the three barriers that had hindered the use of CNG as an automotive fuel the most, only
 14 nine barriers were mentioned – as seen in Table 8. In Round 1, only the general inexperience of the population
 15 with gas handling, ranked second by 24 respondents in that round, met the requirement for consensus, i.e. 51% of
 16 the respondents or more choose the same rank, with 25% of the responses of a minimum of three out of the four
 17 stakeholder groups falling on the same rank. Neither of the barriers ranked first and third met the requirement for
 18 consensus, with lack of public awareness marginally missing the mark. The question was revised and repeated in

1 Round 2, where participants were asked to rank each of the nine barriers exclusively such that no two items could
 2 have the same ranking. As stated in Table 5, the consensus criteria applied for the ranking questions comprised of
 3 a primary condition for convergence and a hierarchical stopping criteria where 51% of the respondents or more
 4 choose the same rank with 25% of the responses of a minimum of three out of the four stakeholder groups falling
 5 on the same rank. At the end of Round 2, the ranking of barriers met the consensus criteria and i) the absence of
 6 market coordination, ii) the general inexperience of the population with gas handling, and iii) the lack of public
 7 awareness emerged as the three barriers that might have hindered the automotive use of CNG the most.

8 Table 8 shows the outcome of Round 2, which shows that Kendall's W for the ranking was 0.45, indicating a
 9 moderate level of agreement between the panellists. In addition, the p-value $< .001 = \alpha$, thereby allowing the
 10 rejection of the null hypothesis that there is no agreement among the respondents.

11 **Table 8: Ranking of barriers based on perception of severity**

Barriers	Frequency of ranking									Mean rank	Rank
	1 st	2 nd	3 rd	4 th	5 th	6 th	7 th	8 th	9 th		
Absence of market coordination	18	5	3	2	3	2	-	-	-	2.18	1 st
Inexperience of public with gas handling	3	20	1	6	3	-	-	-	-	2.58	2 nd
Lack of public awareness programme	2	-	17	2	2	3	3	3	1	4.33	3 rd
Inconsistent petroleum products pricing	3	4	5	12	4	2	3	-	-	3.85	4 th
Focus on abatement initiatives	-	-	2	6	10	4	7	4	-	5.61	5 th
Higher cost of NGV	3	-	-	3	1	8	-	11	7	6.64	6 th
Absence of vehicle emissions standards	-	2	-	-	-	4	13	12	2	7.06	7 th
Low industrial base for energy consumption	-	-	5	2	5	3	3	3	12	6.64	8 th
Poor gas distribution infrastructure	4	2	-	-	5	7	4	-	11	6.12	9 th
$m = 33 \quad k = 9 \quad df = 8 \quad W = 0.45 \quad R = 29202 \quad X^2 = 117.99 \quad p\text{-value} = 8.6E-22$											

12

13 **3.2. Proposed interventions to promote the use of CNG as automotive fuel**

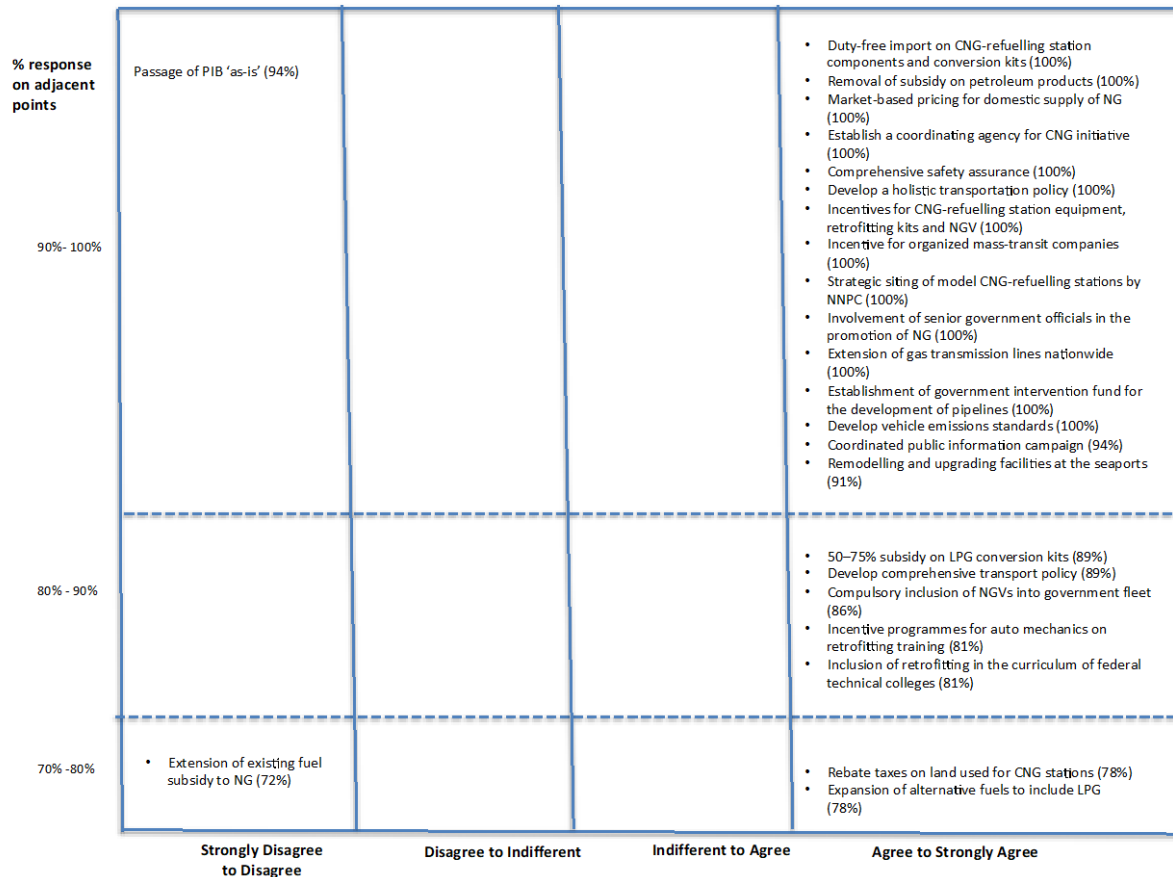
14 When asked to indicate their level of support for each of the 26 interventions listed, the views of the respondents
 15 converged on 24 proposed interventions. Of note was the total agreement among the respondents on the removal
 16 of the pump price subsidy on gasoline and the introduction of market-based pricing for the domestic supply of
 17 natural gas. Conversely, there was overwhelming rejection of the proposal to extend the subsidy to natural gas
 18 until it is removed from gasoline. The revised question in Round 2 focused on the two interventions where
 19 consensus was not achieved: proposals to pass into law the less controversial provisions of the Petroleum Industry
 20 Bill (PIB) and to separate the operational and regulatory roles of the NNPC. At the end of Round 2, there was
 21 support for the separation of the operational and regulatory roles of the NNPC, but there was still no consensus on
 22 the passage of PIB into law. Table 9 shows the respondents' views on the level of support for the policy
 23 recommendations investigated while Figure 4 presents the consensus reached based on the consensus criteria.

1 Table 9 further shows that the respondents' views on the proposal to pass the less controversial provisions of PIB
 2 to law did not meet the consensus criteria set for rating questions.

3 **Table 9: Perspectives on the level of support for the policy recommendations**

<i>Description</i>	<i>Strongly disagree</i>	<i>Disagree</i>	<i>Indifferent</i>	<i>Agree</i>	<i>Strongly agree</i>
Duty-free import on CNG-refuelling station components & conversion kits				22%	78%
50–75% subsidy on LPG conversion kits			11%	42%	47%
Rebate taxes on land used for CNG stations			22%	53%	25%
Expansion of alternative fuels to include LPG			22%	31%	47%
Develop comprehensive transport policy			11%	53%	36%
Removal of subsidy on petroleum products				17%	83%
Market-based pricing for domestic supply of NG				17%	83%
Extension of existing fuel subsidy to NG	44%	28%	14%	14%	
Pass less controversial provisions of PIB to law	12%	18%	9%	24%	36%
Passage of PIB 'as-is'	92%	3%	3%	3%	
Establish a coordinating agency for CNG initiative				11%	89%
Extension of gas transmission lines nationwide					100%
Separation of the operational and regulatory role of NNPC			9%	27%	64%
Establishment of government intervention fund for the development of pipelines					100%
Comprehensive safety assurance				17%	83%
Incentive programmes for auto mechanics on retrofitting training			19%	28%	53%
Inclusion of retrofitting in the curriculum of federal technical colleges			19%	33%	47%
Remodelling and upgrading facilities at the sea ports			6%	53%	42%
Develop a holistic transportation policy				36%	64%
Incentives for CNG-refuelling station equipment, retrofitting kits and NGV				6%	94%
Incentive for organized mass-transit companies				6%	94%
Develop vehicle emissions standards					100%
Coordinated public information campaign					100%
Compulsory inclusion of NGVs into government fleet			14%	36%	50%
Strategic siting of model CNG-refuelling stations by NNPC				36%	64%
Involvement of senior government officials in the promotion of NG				39%	61%

4



1
2 **Figure 4: Consensus on the policy recommendations investigated**

3 When asked if there is anything missing from the list of interventions provided, none of the respondents suggested
4 any additional policy recommendations. It was concluded that the list of policy interventions provided was
5 exhaustive for the study participants. Consequently, this question was terminated.

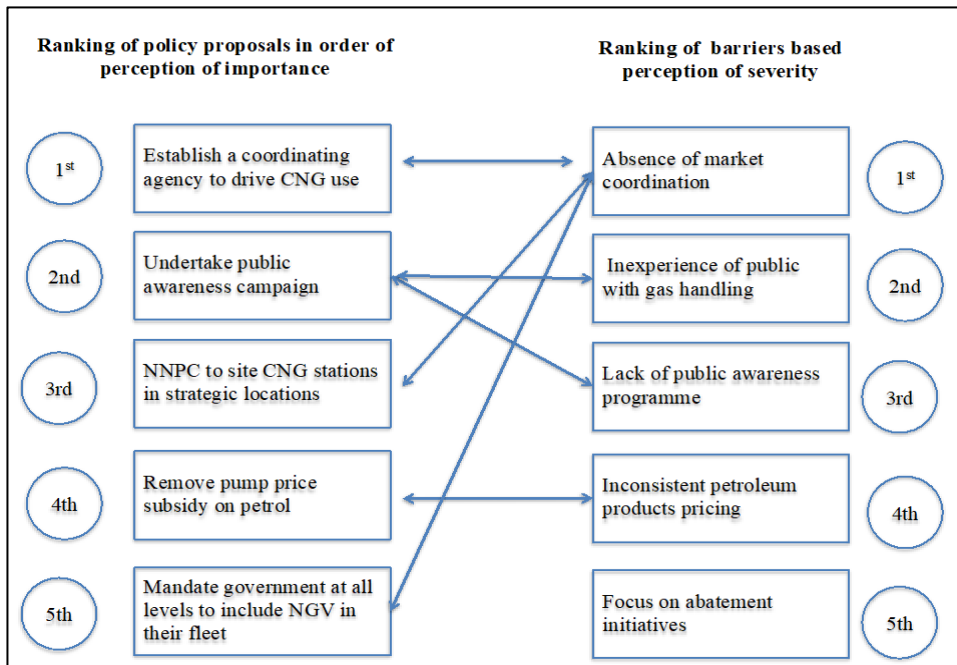
6 When asked to select five proposed interventions and rank them in order of importance, only 11 interventions
7 featured. Complete agreement was reached only on the establishment of an agency to coordinate CNG use. In
8 Round 2, respondents were asked to rank the 11 policy recommendations that emerged from Round 1. At the end
9 of Round 2 the ranking of the policy recommendations in order of the perception of importance met the consensus
10 criteria and i) the establishment of an agency to coordinate and promote the adoption of CNG as an automotive
11 fuel, ii) a coordinated public enlightenment campaign, iii) the strategic siting of model CNG refuelling stations by
12 the NNPC under the Mega Station initiative, iv) removal of the pump price subsidy on petrol and kerosene, and v)
13 compulsory inclusion of NGVs in government fleets emerged as the five most important policy interventions from
14 the perspective of the participants. Table 9 shows the outcome of the round, which indicates Kendall's W of 0.67
15 and suggests a high level of agreement between the panellists. Besides, the p-value $< .001 = \alpha$, thereby allowing
16 the rejection of the null hypothesis that there is no agreement among the respondents. It is important to note that

1 the top five in the ranking are essentially market-related and align with the ranking of the barriers, as illustrated in
 2 Figure 5.

3 **Table 9: Ranking of policy proposals in order of perception of importance**

Proposed policy	Frequency of ranking											Mean rank	Rank
	1 st	2 nd	3 rd	4 th	5 th	6 th	7 th	8 th	9 th	10 th	11 th		
Establish a coordinating agency to drive CNG use	19	6	6	2	-	-	-	-	-	-	-	1.73	1 st
Undertake a public awareness campaign	6	20	1	-	-	2	-	-	1	-	3	3.12	2 nd
NNPC to site CNG stations in strategic locations	4	1	16	2	6	2	-	2	-	-	-	3.64	3 rd
Remove pump price subsidy on petrol	3	3	3	23	1	-	-	-	-	-	-	3.48	4 th
Mandate government at all levels to include NGV in their fleets	1	1	2	5	13	6	1	2	1	-	1	5.24	5 th
Offer incentives to vehicle owners to convert to NGV	-	-	1	-	9	15	8	-	-	-	-	5.88	6 th
Offer incentives for auto mechanics on retrofitting training	-	-	1	1	-	-	9	8	6	4	4	8.24	7 th
Establish a government gas infrastructure development intervention fund	-	1	-	-	2	3	8	7	7	5	-	7.73	8 th
Remodel and upgrade delivery facilities at the seaports	-	1	-	-	-	3	2	6	11	8	2	8.58	9 th
Extend gas transmission lines nationwide	-	-	2	-	2	-	1	2	7	13	6	9.03	10 th
Separate regulatory and operational functions of the NNPC	-	-	1	-	-	2	4	6	-	3	17	9.33	11 th
m= 33 k= 11 df= 10 W= 0.67 R= 80570 X ² = 221.96 p-value = 4.2E-42													

4



5

6 **Figure 5: Matching of policy rankings on importance against ranking of barriers based on perception of severity**

1 Participants were also asked to identify and rank the three most urgent policy interventions. Nine policy
 2 interventions featured among the three most urgent. Although there was a high level of consistency in the ranking,
 3 only the establishment of a coordinating agency to drive CNG use met the criteria for consensus in Round 1. The
 4 question was revised in Round 2 and asked participants to rank the nine policy recommendations that emerged
 5 from the Round 1 exclusively in order of urgency. As shown in Table 10, Kendall's W for the ranking is 0.68,
 6 indicating a high level of agreement between the panellists and the p-value $< .001 = \alpha$, thereby allowing the
 7 rejection of the null hypothesis that there is no agreement among the respondents. The responses, therefore,
 8 satisfied the purpose of the question hence the question was terminated.

9 Also seen in Table 10, the ranking of the policy recommendations in order of the perception of urgency of
 10 implementation met the consensus criteria and i) a coordinated public enlightenment campaign, ii) the
 11 establishment of an agency to coordinate and promote the adoption of CNG as an automotive fuel, and iii) the
 12 strategic siting of model CNG refuelling stations by the NNPC under the Mega Station initiative emerged as the
 13 three most urgent policy interventions. Further analysis shows that these proposals also feature as the first three
 14 among the five considered most important. The proposal for coordinated public awareness raising is in line with
 15 the observation by Byrne and Polonsky (2001) that sales infrastructure is required to educate consumers, while the
 16 establishment of a coordinating agency is supported by the findings of Collantes and Melaina (2011) and Honoré
 17 (2004) and is prevalent in the countries with successful NGV experiences, including Argentina, Brazil, India, Iran
 18 and Pakistan. The mandate of the Agency as seen in these countries may include the development, introduction
 19 and management of structured operational and fiscal incentives for both the energy supply and demand sides to
 20 cover some of the specific policies such as the duty-free import of CNG refuelling station components; duty-free
 21 import of mass-transit vehicles; a subsidy on conversion kits; rebates on applicable taxes on land used for CNG
 22 stations; and incentive programmes for auto mechanics on retrofitting training, including the offer apprenticeships
 23 to a sizeable number of Nigerians to kick-start the programme.

24 A comparison of the policy recommendations that gained favourable consensus against the critical success factors
 25 for the use of CNG as an automotive fuel identified by Ogunlowo et al. (2015) in Table 11 indicates coverage in
 26 all key areas.

27 **Table 10: Ranking of policy proposals in order of perception of urgency of implementation**

<i>Proposed policy</i>	Frequency									Mean Rank	Rank
	<i>1st</i>	<i>2nd</i>	<i>3rd</i>	<i>4th</i>	<i>5th</i>	<i>6th</i>	<i>7th</i>	<i>8th</i>	<i>9th</i>		
Undertake public awareness campaign	18	6	3	3	3	-	-	-	-	2.00	<i>1st</i>
Establish a coordinating agency to drive CNG use	7	19	2	-	3	2	-	-	-	2.36	<i>2nd</i>
NNPC to site CNG stations in strategic locations	2	3	22	3	2	1	-	-	-	3.09	<i>3rd</i>
Remove pump price subsidy on petrol	4	1	3	22	2	1	-	-	-	3.61	<i>4th</i>

Establish a government gas infrastructure development intervention fund	-	-	-	3	11	7	8	2	2	6.03	5 th
Mandate government at all levels to include NGV in their fleet	1	3		2	6	10	8	3	-	5.61	6 th
Offer incentives to vehicle owners to convert to NGV	1	1	-	-	1	6	13	3	8	7.00	7 th
Separate regulatory and operational functions of the NNPC			1		2	4	2	14	10	7.67	8 th
Remodel and upgrade delivery facilities at the seaports	-	-	2	-	3	2	2	11	13	7.64	9 th
Total	33	33	33	33	33	33	33	33	33		
m=33 k=9 df=8 W=0.68 R=44680 X ² =180.5252525 p-value=1.8E-33											

1
2

Table 11: Policy recommendations align with critical success factors

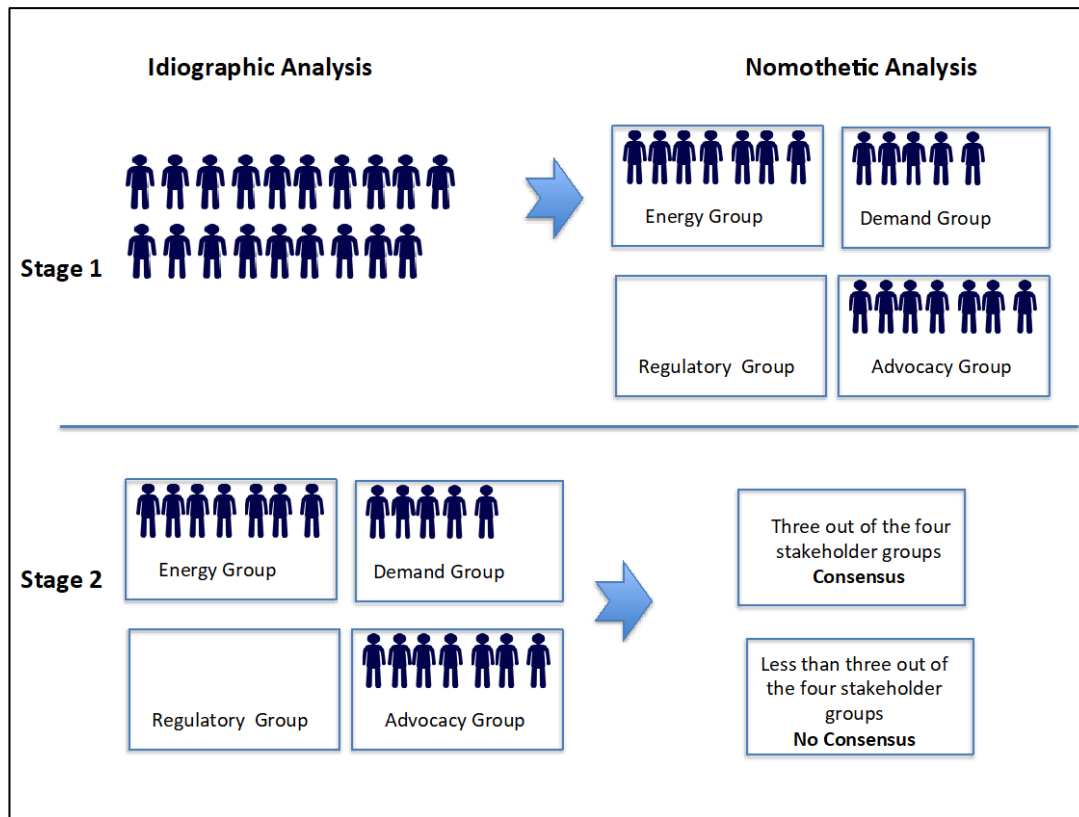
<i>Critical success factor (CSF)</i>	<i>Policy recommendation agreed to by Delphi participants</i>
1. Clarity of the strategic intent	<ul style="list-style-type: none"> Establishment of an agency to coordinate and promote the adoption of CNG as an automotive fuel
2. Legal backing in place to guide adoption process	<ul style="list-style-type: none"> Develop comprehensive transport policy Develop vehicle emissions standards and procedures for inspecting imported natural gas vehicles
3. Learning and adaptation	<ul style="list-style-type: none"> Inclusion of retrofitting in the curriculum of the Federal Technical Colleges Expansion of alternative fuels to include LPG
4. Assignment of responsibilities for market development	<ul style="list-style-type: none"> Establishment of an agency to coordinate and promote the adoption of CNG as an automotive fuel Separation of the operational and regulatory role of the NNPC
5. Financial incentives	<ul style="list-style-type: none"> Duty-free import on CNG refuelling station components and conversion kits 50-75% subsidy on LPG conversion kits Rebates on land use charge and tenement rate on land used for CNG stations Incentives programme for auto mechanics on retrofitting training Incentives for CNG refuelling station equipment, retrofitting kits and NGVs Incentives for organised mass-transit companies to deploy NGVs
6. Price gap between natural gas and conventional fuels	<ul style="list-style-type: none"> Removal of the pump price subsidy on petrol Market-based pricing for domestic supply of natural gas
7. Initiatives to boost consumer and market confidence	<ul style="list-style-type: none"> Coordinated public enlightenment campaign Strategic siting of model CNG refuelling stations by the NNPC under the Mega Station initiative Compulsory inclusion of NGVs in government fleets Involvement of senior government officials in the promotion of natural gas Comprehensive safety assurance plan, including vehicle safety standards
8. Focus, nature and sequence of natural gas infrastructure	<ul style="list-style-type: none"> Extension of gas transmission lines to nationwide Establishment of government intervention fund for the development of pipelines and refuelling infrastructure

3.3. Issues without consensus

Contrary to expectation, there was no consensus at the end of Round 2 on the impact of militancy and pipeline vandalism, which have both been widely reported to be inimical to the growth of the oil and gas industry (see Ejiofor, 2013; Onyebuchi, 2014). Similarly, there was no consensus on the policy proposal for the passage of the less controversial provisions of the PIB into law. Thus, Round 3 sought to gain understanding into the reasons for the divergence in opinion of the respondents on these issues.

The analysis employed hermeneutics principles and the steps suggested by Patterson and Williams (2002, pp.47-49). It was conducted at the individual level (idiographic) and across individuals (nomothetic) in two stages. During the first stage, the units of analysis were the participants (idiographic) and the stakeholder groups (nomothetic). During the second stage, each stakeholder group constituted the idiographic analysis, while the

1 nomothetic analysis was conducted across the four stakeholder groups with the application of the consensus
 2 criteria, as illustrated in Figure 6.



3
 4 **Figure 6: Stages of idiographic and nomothetic analysis for Round 3 responses**

5
 6 The analysis indicates a divergence in the opinions of the demand and supply groups on both issues investigated.
 7 Participants working in the energy sector overwhelmingly stated that militancy and pipeline vandalism have
 8 hindered the adoption of CNG as an automotive fuel in Nigeria and cited business disruption, hostage-taking and
 9 kidnapping, and sometimes death of personnel, as key reasons. They further argued that these factors are not
 10 conducive to business. In the words of some of the respondents:

11 “It is impossible to invest in new ventures when the safety of key assets is not guaranteed.” (*oil*
 12 *exploration and production, supply group*)

13 “Some companies are divesting their assets because of safety concerns. It is clear that the environment
 14 is not conducive for new investments.” (*oil exploration and production, supply group*)

15 Conversely, the demand group suggested that slow progress in the domestic utilisation of CNG as automotive fuel
 16 is due to lack of commitment on the part of the oil and gas companies, who they claim pursue economic gains to
 17 the detriment of the environment. They argued that militancy and pipeline vandalism were not limited to the natural
 18 gas market and therefore could not be blamed for the slow development of the sector. This view was shared by the

1 advocacy group, who blamed the slow progress on lack of commitment by the oil exploration companies. Below
2 are some of the views expressed:

3 “Militancy and vandalism cannot be blamed for lack of progress as long as the oil companies are still
4 pumping crude oil.” (*fleet manager, demand group*)

5 “Militancy and vandalism are not exclusive to natural gas. Hence, they cannot be accepted as reason for
6 lack of progress.” (*road transportation company, demand group*)

7 “Militancy did not start in the 1960s. It cannot be responsible for gross violation of the environment
8 through flaring.” (*non-governmental organisation, advocacy group*)

9 “Militancy and vandalism are outcomes of economic and social neglect. The proper harnessing of
10 natural gas might have prevented them in the first instance.” (*professional bodies, advocacy*)

11 Similarly, there was a noticeable division in the views of the respondents on the proposal that the National
12 Assembly should identify and pass into law the less controversial provisions of the PIB. Many of the respondents
13 from the advocacy and demand groups did not support the proposal and argued that the bill in its current state
14 should be passed into law, citing national interest over the commercial interests of the oil exploration and
15 production companies. While the proponents of the PIB argued that some of the extant laws were more than 50
16 years old and had become outdated and irrelevant amid changes in the oil and gas industry, opponents claimed
17 that the PIB, if passed into law in its current state, would give Nigeria the harshest fiscal regime in the world – due
18 to the proposed increases in royalties and taxes, decreases in allowances and incentives, and the establishment of
19 a new Petroleum Host Communities Fund (PHCF) which will require oil producing companies to contribute 10%
20 of their net monthly profits towards the long-term financing for the economic, social and infrastructural
21 development of communities within the petroleum-producing areas. Finding an amicable resolution is critical
22 to future developments in the oil and gas industry. However, the bill does not provide an explicit definition of a
23 “host community” and is silent on the administrative structure of the fund. Based on academic and industry reviews
24 of the implications of the PIB (see Oloyede, 2012; Sani and Abdel, 2014), the authors estimate that the new
25 provisions on taxation and royalties could increase the tax on joint venture operations (JVs) from 86% to 91%, on
26 production sharing contracts (PSCs) from 30% to 77%, and gas JVs from the current 0% to 60%, in addition to an
27 envisaged 5% tax increase for deep-water projects. In addition, advocacy groups and governments of the oil-
28 producing states have noted that the PIB confers excessive powers on the petroleum minister (see Okafor, 2013).
29 They have argued that the PIB in its current state would preserve and unduly strengthen the office, with the

1 potential to give the office holder an extraordinary plenitude of discretionary power, reducing checks and balances,
2 and limiting transparency, which may result in unintended adverse effects.

3 In the words of some of the respondents:

4 “What is the essence of passing what favours the oil companies to the detriment of the country?” (*trade*
5 *unions, advocacy group*)

6 “This proposal defeats the purpose of the PIB.” (*professional bodies, advocacy group*)

7 “The controversial provisions are the main elements of the PIB. Passage of other provisions without the
8 grit would be meaningless.” (*road transportation company, demand group*)

9 “The entire bill should be passed in the interest of the country.” (*fleet manager, demand group*)

10 Conversely, the respondents from the supply group argued that the bill was not in the interests of the country and
11 suggested its total review. The explanations offered by some of the respondents are presented below:

12 “The entire bill needs to be reviewed. There was no stakeholder involvement in the draft and this is the
13 result.” (*downstream petroleum marketing, supply group*)

14 “The bill is antithetical to progress and development. The entire bill should be discarded.” (*oil*
15 *exploration and production, supply group*)

16 Overall, industry experts and commentators have expressed the view that the stalemate caused by the non-passage
17 of the PIB is detrimental to the future development of the oil and gas industry in Nigeria, noting that the sector has
18 remained stagnant in terms of fresh inflows of substantial foreign investments, as international oil companies
19 (IOCs) are not willing to take up new ventures due to the uncertainties in the fiscal regime. Meanwhile there is
20 seemingly no end in sight to the delay in the passage of the bill. Bowman (2012) reported that as of 2012, IOCs
21 had withheld an estimated US\$40 billion of investment in Nigeria pending the passage of the PIB and Bala-Gbogbo
22 and Ibukun (2013) reported that Nigeria risks losing US\$185 billion within ten years if the PIB is passed in its
23 current state. Similarly, *The Economist* stated that:

24 “Regulatory uncertainty, among other things, has helped make Nigeria’s oil industry stagnant. The output
25 is about the same as it was a decade ago; the government has not held a licensing round for five years. A
26 Petroleum Industry Bill has been in the works for 15 years, intended to overhaul the industry, make it
27 more transparent, improve regulatory institutions and fiscal policies, and bring everything up to global
28 standards. However, the law has been stuck between government and parliament for five years, holding

1 back many billions of dollars in investment. Oil majors are loath to inject cash because they do not know
2 how much tax they will have to pay.” (*The Economist*, 20 October 2012)

3 **4. Conclusion and policy implications**

4 A Delphi survey conducted in three rounds, validated, prioritised and built consensus on 29 barriers and 25 policy
5 interventions among 31 barriers and 26 policy proposals identified through an earlier exploratory study. The
6 outcome showed moderate and high levels of agreement between the panellists on the barriers and policy
7 recommendations respectively. The three barriers ranked as the most severe and the policy recommendations
8 ranked as most urgent were all market-related factors. Contrary to expectation, there was no consensus on the
9 impact of insecurity of assets and personnel on the adoption of CNG as an automotive fuel in the country. Whereas
10 the Delphi survey provided the participants with a list of 31 barriers, only nine emerged as critical impediments.
11 Among these, i) absence of market coordination, ii) general inexperience of the population with gas handling and
12 iii) lack of public awareness were perceived to have hindered the adoption of CNG as an automotive fuel the most.
13 With respect to policy proposals, the study concludes that i) a coordinated public enlightenment campaign, ii)
14 establishment of an agency to coordinate and promote the adoption of CNG as an automotive fuel and iii) strategic
15 siting of model CNG refuelling stations by the NNPC under the Mega Station initiative are the three most urgent
16 interventions required to stimulate the adoption of CNG as an automotive fuel in Nigeria.

17 Based on the consistent submissions of the respondents, the alignment of the policy recommendations with
18 Nigeria’s National Oil and Gas Policy and the critical success factors for the use of CNG as an automotive fuel,
19 the study concludes that the areas of consensus may find acceptance with key stakeholders and stimulate natural
20 gas vehicle (NGV) and compressed natural gas (CNG) market development.

21 Considering the inter-relatedness of the policy recommendations for long-term market development, especially as
22 some are contingent on or have implications for others, the immediate creation of an independent agency to
23 coordinate the CNG implementation programme would be the first logical step. The scope of the agency should
24 include the creation of public awareness, recommendations for and implementation of appropriate incentives for
25 the supply and demand sides, facilitating and coordinating retrofitting workshops, collaborating with the regulatory
26 agencies on both the demand and supply sides to formulate appropriate standards for both vehicles and refuelling
27 infrastructure, including a comprehensive safety assurance plan, vehicle emissions standards, and procedures for
28 inspecting imported NGVs, among others.

1 Given the stalemate in the passage of the PIB and the clear disagreement on sectoral lines, a review and revision
2 where needed of the laws that would make up the PIB could be an effective alternative to single all-encompassing
3 legislation. This approach has the potential to remove the uncertainty associated with the deadlock on the PIB and
4 could make the legislative process less complicated. A holistic framework for retail pricing for petroleum products
5 is needed to create headroom for natural gas to thrive, especially as there is overwhelming support for the removal
6 of the subsidy on gasoline. The authors note the legislative developments after the study, particularly the passage
7 of the bill for an Act to provide for the Governance and Institutional framework for the Petroleum Industry and
8 for other related matters. The bill is a segment of the PIB and it seeks to unbundle the NNPC and provide for the
9 establishment of four separate entities as successor companies namely the Federal Ministry of Petroleum
10 Incorporated; the Nigerian Petroleum Regulatory Commission; the Nigerian Petroleum Assets Management
11 Company and the National Petroleum Company and Petroleum Equalisation Fund. While this bill has passed the
12 third reading in the National Assembly, it is yet to be signed into law.

13 In the short run, the NNPC could immediately establish CNG stations in strategic locations through its Mega
14 Station scheme to stimulate private sector involvement and market confidence, after which government could
15 mandate a percentage of its fleets at all levels to run on CNG to demonstrate the conviction and support of
16 government towards the policy.

17 In the medium term, retrofitting could form part of the curriculum of the Federal Technical Colleges, the only
18 available tertiary institutions for the training of technicians in the country, to address the lack of certification in
19 the auto mechanic trade. The offer of scholarships to a sizeable number of Nigerians might kick-start the
20 programme.

21 This study has shown a high level of consensus among the study participants, the alignment of policy proposals to
22 critical success factors and indicates a high possibility of success in the quest for the use of natural gas as
23 automotive fuel. Hence, a study to evaluate the political will is essential. In addition, as observed by Broto et al.
24 (2015), local people can engage meaningfully to co-produce technical knowledge, hence the authors recommend
25 further research to gain a broader understanding of the factors that have hindered the adoption of CNG from the
26 perspective of vehicle owners, with a view to providing insights that could be applied to deepen penetration.
27 Further research on the mode of implementation of the fiscal and operational incentives, the removal of the pump
28 price subsidy on gasoline and kerosene, a comprehensive safety assurance plan, and a transportation sector policy
29 are also both desirable and recommended. Although there was no consensus on the impact of insecurity of assets
30 and personnel on the adoption of CNG as an automotive fuel in the country, these acts have had an adverse impact

1 on the oil and gas industry generally and the Nigerian economy at large. Hence, addressing the root causes of these
2 acts will also be essential.

3

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