Abu Dhabi Technical Report - Greenhouse Gas Emissions Factors

A preliminary assessment and gap analysis report for greenhouse gas emissions factors specific to the Emirate of Abu Dhabi

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1   Executive Summary

Sustainability is a cornerstone of Abu Dhabi's vision to be a globally competitive, knowledge-based economy. The Emirate has made great strides towards implementing quality and conformity standards in this arena through the launch of the Abu Dhabi Quality and Conformity Council (QCC), which aims to lead, facilitate and develop an efficient, effective, and globally integrated quality infrastructure in Abu Dhabi.

In order to support this vision, in 2014 the Environment Agency of Abu Dhabi prepared the Climate Change Strategy for the Emirate of Abu Dhabi aimed at '*accelerating progress towards protecting the climate through the mitigation of anthropogenic pressures, as well as adapting to the environmental, social and economic impacts of climate change*'. This strategy in turn has been supported by the Abu Dhabi GHG emissions inventory (published in 2013), which is based on 2010 data of key several government and private sector stakeholders operations.

One recommendation from this inventory to develop local emission factors to enable more accurate estimation of Abu Dhabi's GHG emissions, and, in turn, support the UAE's agenda in this regard. As a result, this study reports the key findings of a preliminary assessment and gap analysis related to understanding the current status of GHG emissions accounting approaches in Abu Dhabi and the level of effort required to determine country-specific GHG emission factors in accordance with Intergovernmental Panel on Climate Change (IPCC) Tier 2 or 3 methodologies.

That is why this report focuses on developing a preliminary assessment and identifying the current status and data gaps of GHG emissions factors for main activity sources (electricity, water, fuel and waste) in key sectors of Abu Dhabi. The intent of this study is to support the goals of the GHG Emissions Factors Working Group.

Key economic sectors in the Emirate like oil and gas, power and water, as well as major industries (e.g. aluminum smelting) have implemented data collection policies that have yielded substantive GHG emissions measurements. Additional programs undertaken by entities such as Abu Dhabi National Oil Company (ADNOC) and Emirates Steel to continuously monitor smoke stacks have resulted in greater efficiency in the data collection of actual GHG emissions. In addition, entities such as Khalifa Industrial Zone – Abu Dhabi (KIZAD) offer instructive models for how to measure emission outputs based on local data. However, all these efforts in providing GHG Emission Inventories/measurements for different sectors in Abu Dhabi will not be accurate until GHG Emission Factors are available and can be used specifically for the Emirate of Abu Dhabi.

Research to develop GHG Emission Factors is still to be done in order for Abu Dhabi to meet best practices at international level. Incomplete and missing data such as calorific values or/and carbon content of different sources in key sectors must be obtained, and the life cycle of products and their local, regional and global impact in sectors such as waste should be more thoroughly understood.

In addition to Emission-Factors-Specific Analysis, this report recommends that the Emirate of Abu Dhabi develops a central data acquisition plan that employs bottom-up methodology to increase accuracy of data collection and reporting. Such a method would provide quality checks and transparency, and also any issues on setting emission boundaries. Establishing local-specific standards, guidelines, or other regulatory frameworks for inventory data acquisition can also improve the reliability, scope, and quality of acquired data consistent with IPCC Guidelines, and shift much of the responsibility for data access, availability, and quality to the actual entities associated with these emissions. Such standards and guidelines would identify priorities for

measurement and verification of GHG emissions in consideration with the Abu Dhabi Emirate and UAE context and the relative contribution to global emissions.

Strategically, country-specific emissions factors for key activity sources in Abu Dhabi could aid the Emirate in its quest towards sustainability by having more robust data for future GHG inventories and to formulate policies that improve its carbon footprint performance.

2 Introduction

It is a fact well known that most of the global warming in the past half-century has been caused by emissions of greenhouse gases (GHG) from anthropogenic activities. Certain gases such as carbon dioxide (CO_2) are not only harmful to humans, but are a major contributor to global climate change. For the United Arab Emirates, key vulnerabilities associated with climate change include sea-level rise, coastal flooding, increased salinity and temperature of the ocean and coastal aquifers, impacts on the marine environment, heat wave/heat stress and built-environment impacts, more extreme weather events (floods, droughts, etc.), and the increased risk of dust storms.[i]

In order to mitigate these climate change impacts, in 2014 the Environment Agency of Abu Dhabi prepared the Climate Change Strategy for the Emirate of Abu Dhabi aimed at '*accelerating progress towards protecting the climate through the mitigation of anthropogenic pressures, as well as adapting to the environmental, social and economic impacts of climate change*'. This strategy supports the Abu Dhabi GHG emissions inventory (from April 2013), which is based on 2010 data of key several government and private sector stakeholders operations.

A key recommendation of this inventory is the need to develop local emission factors to enable more accurate estimation of Abu Dhabi's GHG emissions, and, in turn, support the UAE's Climate Change Agenda. As a result, this study reports the key findings of a preliminary assessment and gap analysis related to understanding the current status of GHG emissions accounting approaches in Abu Dhabi and the level of effort required to determine country-specific GHG emission factors in accordance with Intergovernmental Panel on Climate Change (IPCC) Tier 2 or 3 methodologies.

3 Scope of Work

The aim of this report is to conduct a preliminary assessment and identify the current status and data gaps of GHG emissions factors for the main activity sources (electricity, water, fuel and waste) in key sectors of the Abu Dhabi economy. Based on this aim, the intent of this study is to support the following goals of the GHG Emissions Factors Working Group:

- Propose a methodology to determine country-specific GHG emission factors for Abu Dhabi based on the IPCC guidelines;
- Understand the resources and level of effort required by the various government entities to close the data gaps; and
- Determine priority actions focusing on the major contributing sectors of GHG emissions within Abu Dhabi and considering the UAE context

4   Background Research

The 2010 GHG emissions inventory for Abu Dhabi was developed in accordance with the 2006 IPCC Guidelines in collaboration with key stakeholders that represent the main contributing sectors, namely oil and gas, electricity production and water desalination, manufacturing industry, transport, agriculture, land use change and forestry, and waste.

The IPCC provides a 3-tiered estimation approach for determining GHG emissions based on sources of activity data, from where emission factors are derived:

- TIER 1: Estimated on the basis of the quantities of fuel combusted (usually from national energy statistics) and average emission factors.[ii]
- TIER 2: Emissions from combustion are estimated from similar fuel statistics, as used in the Tier 1 method, but country-specific emission factors are used in place of the Tier 1 defaults.
- TIER 3: Detailed emission models or measurements and data at individual plant level are used where appropriate.[iii]

The approach followed in developing this study is predicated upon undertaking a consultation process with the same key stakeholders from the 2010 GHG Inventory, and reviewing examples of international practices in other countries that have undertaken a similar exercise. The following case studies have been analyzed:

- Case Study I: United Arab Emirates   (Tier 1 Analysis)
- Case Study II: Japan   (Tier 1 & 2 Analysis)
- Case Study III: EU Member States   (Tier 2 & 3 Analysis)
  - Overview – Eurostat NIR
  - Country Example – Finland

4.1   Stakeholder Engagement

Meetings were carried out with a number of stakeholders across a variety of economic sectors that contribute to the Abu Dhabi GHG emissions. These stakeholders were split between public and private sectors, and include:

- Abu Dhabi Department of Transport (DoT);
- Abu Dhabi Ports Company & Khalifa Industrial Zone Abu Dhabi (KIZAD);
- Abu Dhabi Regulation and Supervision Bureau (the Bureau);
- Abu Dhabi Water and Electricity Company (ADWEC);
- Abu Dhabi Oil Company (ADNOC);
- Center for Waste Management - Tadweer (CWM);
- Environment Agency Abu Dhabi (EAD); and
- Emirates Steel.

During these meetings, stakeholders had the opportunity to present activities related to their GHG emissions inventory programs, if any. The meetings also focused on evaluating how these programs have evolved since the initial GHG emissions inventory study, and assessed what further steps could be taken to refine and expand current initiatives.

4.2   Country-Specific Case Studies

4.2.1   Case Study I: United Arab Emirates (Control Group)

Summary: The Greenhouse Gas Inventory for Abu Dhabi Emirate started in April 2011 and took two years to produce the final report. It is a comprehensive inventory for energy, industrial processes, agriculture, land use change and forestry, and waste.

Scope: Focus on fuel combustion emissions, industrial processes in metal and minerals, CO2 removal in land use change and forestry. Direct and indirect emissions were estimated from all activity sectors including agriculture and waste, which were considered minimal GHG contributors).[iv] Priority was given to direct greenhouse gases CO_2, CH_4, N_2O and PFCs, and to a lesser degree to indirect gases CO, NO_X, SO_2 and NMVOC.

General Methodology: The inventory, with 2010 as the base year 2010[v], is based on international guidelines[vi] and experience gained from previous UAE national inventories. The emission factors of previous national inventories were only used where local data was not available. The Abu Dhabi GHG inventory includes key category analysis based on its estimates of emissions. Data on emissions-generating or sequestering activities were collected from local and national sources through sector-specific questionnaires.[vii]

Tier 1 level analysis was conducted for all sectors due to lack of data in previous local inventories and lack of country-specific and technology-specific emission factors.[viii] However, collected country-specific data with assumptions was used for oil and gas, electricity and water desalination, estimation was applied for data gaps especially in the areas of solid waste, and land use change and forestry.[ix]

Country specific emissions factors were used in the Energy Sector, where calculations were based on the submitted values by local entities or on values used in the UAE's previous national inventories, and were adjusted to reflect local conditions. These emission factors differ from the IPCC default values that correspond to uncontrolled emissions, while typically in the UAE combustion of fuels includes controls. Country-specific emission factors were also used in previous UAE inventories except for CH_4 for gasoline for on-road transport, for which local factor was calculated. This is because the used CH_4 emission factor in UAE previous inventories 0.68 kg/TJ was very far from the IPCC default (4-9 kg/ TJ).[x]

The other sectors break down as follows: in Electricity & Water Desalination, there were very few data gaps and inconsistencies. For the incomplete data, values were taken from UAE's previous national inventory or default IPCC factors. In Transport, emissions were calculated based on a set of assumptions due to the lack of detailed data on fuel consumption by transport mode, incomplete fuel sales quantities for the year 2010, and a lack of information to calculate the local emission factors.[xi] For Waste, the local average DOC (degradable organic carbon) value for Abu Dhabi was calculated based on the provided data on the waste composition in the Emirate and the IPCC default DOC content in wet waste.[xii] The IPCC defaults were also used for LPG, fuel oil, international fuel bunkers, industrial processes sector, agriculture, land use change & forestry, and wastewater.[xiii] The 2010 Abu Dhabi GHG Inventory is summarized in the figure below.

Sectors	IPCC Tier	Total GHG emissions	
		Gg CO2-e	%
Energy	1	71,924	73%
Industrial processes	1	17,907	18%
Agriculture	1	2,413	2%
Waste	2	6,857	7%
TOTAL		99,101	
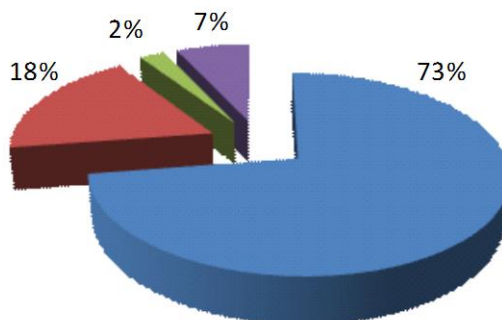
Conclusion: There is little data available on the local emission factors. For missing data, assumptions were made to undertake calculations of emissions; the factors used in the previous UAE national inventories and/ or the commonly accepted emissions factors from IPCC and other standard guidelines were used.[xiv]

4.2.2   Case Study II – Japan

Summary: The National Greenhouse Gas Inventory Report of Japan 2014 contains the information on emissions and removals of GHGs, including indirect GHGs and SO_2 in Japan from FY1990 to FY2012.[xv]

General Methodology: The inventory is based on international guidelines.[xvi] Tier 1 and Tier 2 level assessment and trend assessment were carried out for key category analysis.[xvii] The Tier 1 Sectoral Approach was also used to calculate emissions.[xviii]

Country-specific methodologies were used for some categories (e.g., "4.C. methane emissions from rice cultivation") in order to reflect the actual emission status in Japan.[xix] Country-specific EFs were used for all types of fuel, with emission factors developed based on three different concepts; (a) energy sources other than blast furnace gas (BFG) and town gas, (b) BFG, and (c) town gas as follows:[xx]

$$E = \sum_{ij} \left[(A_{ij} - N_{ij}) \times GCV_i \times 10^{-3} \times EF_i \times OF_i \right] \times 44/12$$

E	: CO_2 emissions from fossil fuel combustion [t-CO_2]
A	: Energy consumption [original unit (t, kl, $10^3 \times m^3$)]
N	: Non-energy product use of fossil fuels [original unit]
GCV	: Gross calorific value [MJ/original unit]
EF	: Carbon content of the fuel [t-C/TJ]
OF	: Oxidation factor
i	: Type of fuel
j	: Sector

Additional country specific emissions factors included CH_4 emissions in conjunction with transportation[xxi] and town gas supply networks,[xxii] and CH_4 and N_2O emissions from the energy industry. Emissions from fuel combustion were calculated using Tier 2 country-specific emission factors via fuel-specific, sector-specific and furnace-specific activity data.[xxiii] Lastly, the oxidation factor for each type of town gas energy (COG, kerosene, refinery gas, LPG, LNG, indigenous NG) was calculated using a country-specific EF. [xxiv]

Various non-energy sectors also used country-specific emissions factors, including Cement Production,[xxv] THC (Total Hydro Carbon) emissions of CH_4 and N_2O from motorcycle emissions,[xxvi] Jet Kerosene,[xxvii] Dolomite,[xxviii] Soda Ash,[xxix] and Rice Cultivation.[xxx]

Additional sectors for country-specific emissions factors include[xxxi]: Industrial Processes, such as the production of lime[xxxii], ammonia, adipic acidic, calcium carbide, ethylene, 1-2-dichloroethane, styrene, and coke. HFCs as a by-product of HCFC-22 production, HFCs and PFCs in domestic refrigerator production, HFCs, PFCs and SF_6 in semi-conductor production and HFCs, PFCs, SF_6 from liquid crystals, and SF_6 from electrical equipment, as well as F-gases from automatic vending machine production and air-conditioning production.

In Agriculture, country-specific EF factors are calculated for the management of cattle, swine and poultry (manure, piling, grazing, etc.). In addition, EFs are estimated locally for the emissions/removal of GHGs in synthetic fertilizers; nitrogen-fixing crops; N_2O emissions for paddy of organic soil; nitrogen content for rice, wheat, barley, and oats; carbon stock changes in living biomass in forest land and remaining forest land; carbon stock changes in organic soils; and CH_4 emissions from biodegradable waste.

In Water Management, CH_4 and N_2O emissions are estimated for the industries that release organic-rich wastewater; H_4 and N_2O emissions from treatment of wastewater at sewage treatment plants; emissions from incineration of MSW without energy recovery; industrial waste incineration; sewage sludge; incineration of waste oil and infectious plastic waste; emissions from municipal waste (plastics) used as alternative fuel; emissions from waste tires used as raw materials and alternative fuels; and emissions from incineration of waste processed as fuel. [xxxiii]

4.2.3   Case Study III – EU Member States

Overview – Eurostat NIR

Summary: The European Union (EU) reports annually on greenhouse gas (GHG) inventories for the years 1990 to X-2 (i.e. two years before the current year). Total GHG emissions reported include all anthropogenic emissions by sources and removals by sinks of all GHGs not controlled by the Montreal Protocol.[xxxiv]

Twenty-two Member States used EU Emission Trading Systems (ETS) data to improve country-specific emission factors and 22 Member States reported that they used activity data (e.g. fuel use) provided under the ETS in the national inventory.[xxxv] However, Member States are responsible for the methodological choice regarding their own estimates.[xxxvi]

Country Example – Finland

Summary: Finland was one of the first Member States to use country-specific emissions factors in compiling its GHG inventory. The annual GHG inventory provides information on the trends in national GHG emissions and removals since 1990.[xxxvii]

General Methodology: The inventory identified national key categories for the base year and the latest reported inventory year, as described in GPG 2000, using tier 2 level and trend assessment.[xxxviii] Tier 2 QC analysis was applied for emission factors: country-specific emission factors were crosschecked and compared with IPCC default values.[xxxix] Tier 3 analysis was used for sectors such as energy industries, manufacturing industries and construction, transport, and other sectors.[xl]

Country-specific emissions factors are calculated for the Energy Industries and Manufacturing Industries and Construction, for which calculations of CO_2 emissions is based on a country-specific method.[xli] CO_2 Emissions for Road Transportation are based on national figures,[xlii] while Fuel Consumption by Transport Mode are partly derived from the ILMI calculation system (run by Finavia). In addition, emissions factors for CH_4 and N_2O are a sum of hot driving, idle and cold start-ups. [xliii]

In Steel Production, the calculation method of CO_2 emissions from the iron and steel industry is a country-specific bottom-up methodology. Both fuel-based emissions and process emissions are calculated in connection with the ILMARI calculation system using plant/process level data. The methodology is slightly plant-specific, because all plants differ from each other.[xliv]

Additional sectors include N_2O Emissions for Medical Use,[xlv] Mineral Soils,[xlvi] Wooden Materials in Finnish Construction – the procedure for estimating the carbon stock for the year 2005 is country-specific and based on national statistics,[xlvii] Solid Waste Disposal on Land,[xlviii] and Municipal (Domestic) Wastewaters, which are country-specific, based on expert knowledge, for the methane conversion factor.[xlix]

5 Preliminary Assessment for Determining Country-Specific GHG Emission Factors

According to the IPCC, if an activity source is a major contributor of emissions for a country ('key source'), it is good practice to develop a country-specific emission factors for that activity. Estimating the GHG emission factors depends on the precise technology applied when fuel is combusted, products are manufactured, transportation is used, etc. In this regard, it is important to consider to what extent in Abu Dhabi country-specific emission factors need to be estimated for both direct GHGs (CO_2, CH_4, N_2O and PFCs) and indirect GHGs (CO, NOx, SO_2 and NMVOC).

A preliminary assessment of the main sectors of the Abu Dhabi economy has revealed that the main activity sources from where these GHGs are emitted are:

- Fuel (mainly natural gas) combusted to generate electricity and produce desalinated water;
- Transportation fuels derived from the oil and gas sector processing activities;
- Chemical reactions from industrial processes;
- Waste degradation.

The above high level analysis is illustrated in the graphic below.
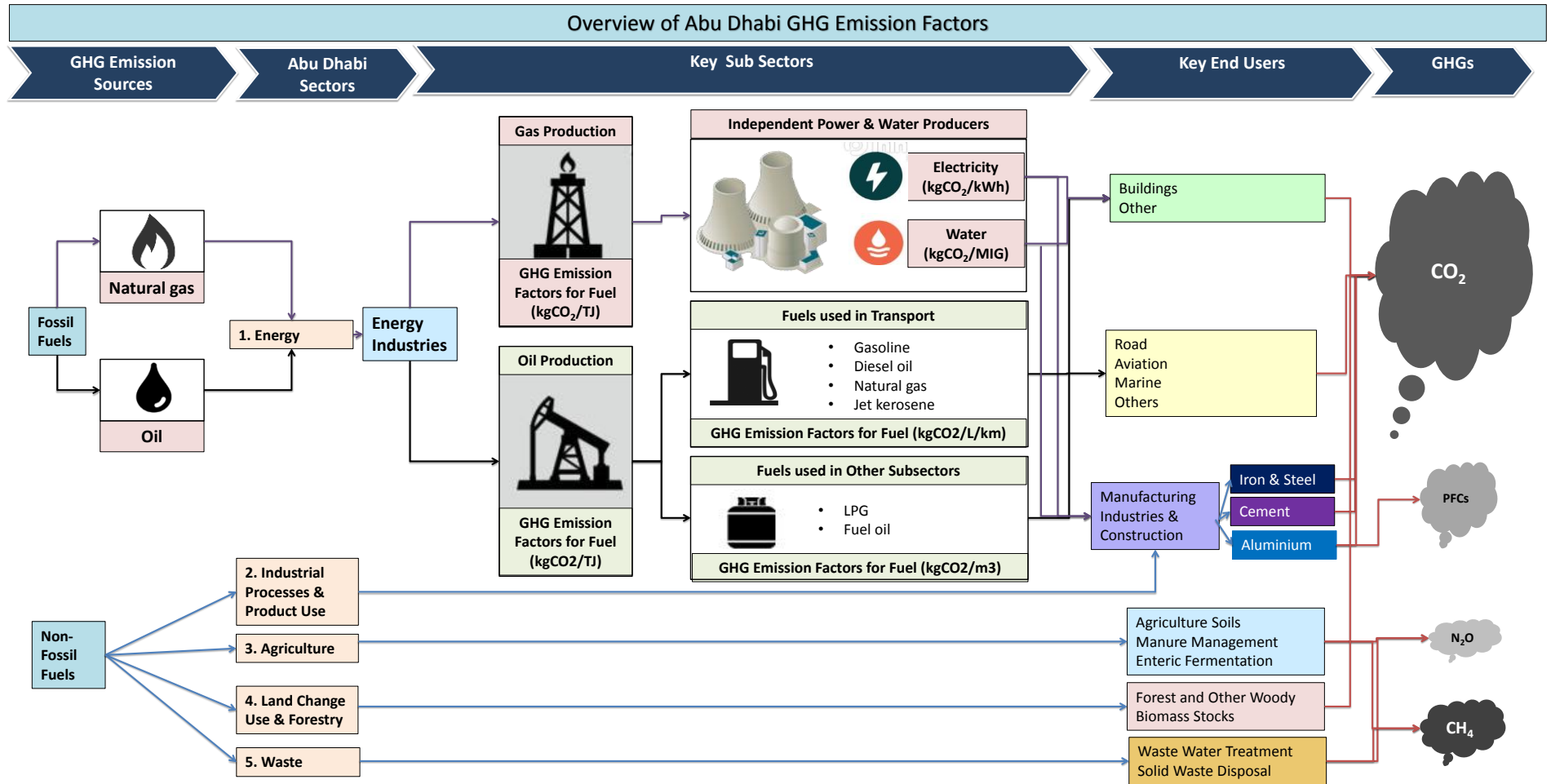
The 2010 Abu Dhabi GHG Inventory reported that CO_2 comprises around 79% of total GHG emissions. The majority of these CO_2 emissions result from burning natural gas during the electricity generation (and water desalination) processes and oil processing operations and other major manufacturing processes (e.g. steel and aluminum industries).

5.1 GHG Emissions from Fossil Fuels (Natural Gas and Oil)

According to the Revised 1996 IPCC Guidelines, the GHG emissions from energy sector include emissions from fuel combustion activities (energy industries, manufacturing industries and construction, transport and others) and fugitive emissions from fuel extraction, transformation, transportation and storage. Examples are leakage of natural gas and flaring during oil/gas extraction and refining.

During combustion the carbon and hydrogen of the fossil fuels are converted mainly into carbon dioxide (CO_2) and water (H_2O), releasing the chemical energy in the fuel as heat. This heat is generally either used directly or used (with some conversion losses) to produce mechanical energy, often to generate electricity (and desalinate water) or for transportation. In Abu Dhabi Emirate, CO_2 accounts for 94% of energy sector emissions with methane and nitrous oxide responsible for the balance.

CO_2 emissions from the combustion of fuel can be estimated with a high degree of certainty regardless of how the fuel is used as these emissions depend almost exclusively on the carbon content of the fuel, which is generally known with a high degree of precision. The same is true for sulfur dioxide (SO_2), since sulfur contents of fuels are also generally well known. Both carbon and sulfur are almost completely oxidized during combustion and all carbon and sulfur atoms in the fuel will be present in the flue gases as CO_2 and SO_2 respectively.

مجـلـس أبـوظبـي لـلـجـودة والـمـطابـقـة
ABU DHABI QUALITY AND CONFORMITY COUNCIL

Overview of Abu Dhabi GHG Emission Factors

GHG Emission Sources → **Abu Dhabi Sectors** → **Key Sub Sectors** → **Key End Users** → **GHGs**

Fossil Fuels
- Natural gas
- Oil

1. Energy → **Energy Industries**

Gas Production
GHG Emission Factors for Fuel (kgCO$_2$/TJ)

Oil Production
GHG Emission Factors for Fuel (kgCO2/TJ)

Independent Power & Water Producers
- Electricity (kgCO$_2$/kWh)
- Water (kgCO$_2$/MIG)

Fuels used in Transport
- Gasoline
- Diesel oil
- Natural gas
- Jet kerosene

GHG Emission Factors for Fuel (kgCO2/L/km)

Fuels used in Other Subsectors
- LPG
- Fuel oil

GHG Emission Factors for Fuel (kgCO2/m3)

Non-Fossil Fuels
- 2. Industrial Processes & Product Use
- 3. Agriculture
- 4. Land Change Use & Forestry
- 5. Waste

Buildings / Other

Road / Aviation / Marine / Others

Manufacturing Industries & Construction
- Iron & Steel
- Cement
- Aluminium

Agriculture Soils / Manure Management / Enteric Fermentation

Forest and Other Woody Biomass Stocks

Waste Water Treatment / Solid Waste Disposal

CO$_2$

PFCs

N$_2$O

CH$_4$

In contrast, the levels of other air pollutants and non-CO_2 greenhouse gas emissions from combustion depend on the precise technology applied when fuel is combusted. These emissions are basically caused by either incomplete combustion of a small fraction of the fuel (CO, CH_4, NMVOCs) or by complicated chemical and physical processes during the combustion and in the smoke stack or tailpipe.

The oil and gas sub-sector of energy comprises exploration and production of oil and natural gas, and refining of oil. Emissions arise from these activities by combustion and as fugitive emissions. The 2010 Abu Dhabi GHG Inventory reported that there were three types of fuels consumed for oil and gas activities namely, natural gas, gas/ diesel oil, and refinery gas. However, due to data limitations and assumptions made, estimation of GHG emissions was conducted for the oil and gas activities using Tier 1 level of analysis.

It is noted that ADNOC recently reported that it has implemented Tier 2 and 3 bottom-up approaches based on international best practice in the oil and gas industry to estimate GHG emissions factors associated with their operations (including fugitive emissions).

The electricity and water sub-sector of energy refers to public electric generation and water desalination that is usually combined in cogeneration plants known as Independent Water and Power Producers (IWPPs). GHG emissions arise from this sub-sector by combustion of fossil fuels (mainly natural gas). The Abu Dhabi Water and Electricity Authority (ADWEA) collects data from all the IWPPs related to fuel consumption, electricity generation and water production and estimates the CO_2 NO, SO_x and CO intensity of their operations. Since natural gas is the main fuel input, the GHG emissions factors related to this sub-sector rely on the downstream GHG emissions factors of the oil and gas sub-sector. In terms of the accounting allocation of emissions for the water and electricity outputs, there are several variables that need to be considered to enable an estimation of the specific emission factors. Each IWPP has a unique equipment configuration and respond to electricity and water demands differently, thereby driving the need to allocate emissions based on a variable "power to water ratio". As a result, it might be prudent to estimate GHG emission factors for each IWPP in order to more accurately complete GHG emissions inventories of major end users.

Research from the Masdar Institute (2012)[i] suggests that the most precise technique to determine the GHG emission factors from these processes is the *exergy method*, which utilizes a detailed physical model of the cogeneration plants to calculate the energy required for both the electricity generation and water production. Once these emission factors are determined (e.g. kg CO_2/kWh and kg CO_2/gallon), they can be used by the end users of these resources (i.e. industry, buildings, etc.) to estimate the GHG emissions associated with their operations.

In the transport sub-sector, the local emissions factor for methane (CH_4) for gasoline for on-road transport has already been approximated. In this sense, the estimation of emission factors related to fuel combustion in mobile vehicles/engines, could be initially obtained through a fairly generic life cycle assessment approach, because these emissions depend highly on the content of the fuel and the vehicle/engine type or size.[li] However, this approach might not sufficiently address typical local conditions such as baseline emission factors for local-specific typical petrol composition/content, local climate, user habits, above average vehicle/engine size, inefficiency of fuel use, poor vehicle maintenance, lack of exhaust gas filtration through catalytic converters and monitoring of emissions. While the total fuel sales for transport are expected to be well defined in

Abu Dhabi, the main challenge that would need to be addressed relate to old and varying vehicle standards in use that makes the estimation of GHG emissions difficult.

5.2 Non-Fossil Fuel GHG Emissions

Non-Fossil Fuel GHG emissions refer to emissions that result from , manufacturing industries physical and chemical reactions, waste degradation in landfills and wastewater treatment processes, agricultural soils, livestock and manure, and deforestation.

The main industrial process where non-fossil fuels GHG emissions are released is the alumina electrolytic reduction process where perfluorocarbons (PFCs) are released. It is understood that Emirates Aluminium has robust data accounting processes that would enable a Tier 2 or 3 approach for estimating PFCs emissions.

In the Abu Dhabi's 2010 GHG Inventory for the waste sector, solid waste data was collected from CWM by disposal facility through a waste data questionnaire, as well as relevant statistical data provided by SCAD.[lii] It was estimated that 92% of waste emissions were due to solid waste disposal in the landfills, and about 8% were due to wastewater handling and treatment. The dominant direct emission was CH_4.

5.3 Pros and Cons of Determining Country-Specific GHG Emission Factors for Abu Dhabi

Studies show that emission factors from other countries are not easily transferrable to Abu Dhabi Emirate due to several reasons, such as but not limited to: climatic conditions, different product ingredients or manufacturing technologies, different environmental standards/requirements, lack of availability of local sourcing and associated impacts from transport mode and travel distances of raw materials and ingredients, and waste management processes/end of life scenarios.

Given that CO_2 comprises around 79% of total GHG emissions in the Emirate of Abu Dhabi[liii] it would be sensible to focus on activity sources causing high CO_2 emissions as a first priority. This is the contribution of energy industries including both electricity/water, and oil/gas. This would also include CO_2 sources like stationary combustion, and mobile combustion like road vehicles, which were responsible for around 44% and 12% of total GHG emissions in 2010, respectively.[liv]

If Abu Dhabi were to derive its own country-specific GHG emission factors for the energy sector and other key sectors, then detailed life cycle assessments (LCAs) that include full fuel cycles and energy balances for these are recommended to obtain accurate figures. These LCAs can determine sector or industry specific local GHG emissions up to the level of identifying the specific manufacturing process or product ingredient which is causing the majority of the environmental impact and thus support the development of effective GHG emissions reduction strategies. Obtaining data about the GHG emissions of fuel and sources would be fairly easy, assuming a level of standardization across fuel types and sectors and following a standardized methodology.

5.3.1 Pros

The pros for determining country-specific GHG emission factors for Abu Dhabi are:

- Abu Dhabi will be able to estimate a large portion of its GHG emissions with country-specific emission factors through an accurate GHG assessment based on the IPCC Tier 2 and Tier 3 bottom-up approach when updating the Abu Dhabi GHG inventory in the future.

- With accurate GHG emissions factors, key sectors in Abu Dhabi will be able to establish their carbon footprint baselines and formulate strategies and action plans to reduce emissions.
- Local and regional impacts associated with GHG emissions from different sectors will be more thoroughly quantified. This will help government agencies in Abu Dhabi and UAE in developing effective policies and strategies to mitigate climate change impacts.
- Abu Dhabi will meet best practices at international level and could become a benchmark for the region with regard to sustainability policies.

5.3.2   Cons

Obtaining actual data for determining country-specific GHG emission factors for various sectors (such as oil and gas, manufacturing, transport, etc.) would require time and effort that might otherwise be replaced by an uncertainty analysis as per IPCC standards. However, once the GHG emission factors are determined, a standard or guideline could be developed to help streamline future calculations.

5.4   Preliminary Assessment Conclusion

Strategically, country-specific emissions factors for key activity sources (electricity, water, fuel and waste) in Abu Dhabi could aid the Emirate in its quest towards sustainability by having more robust data for future GHG inventories and to formulate policies that improve its carbon footprint performance.

The use of IPCC default emission factors would not be appropriate for Abu Dhabi given the unique nature of the fuel extraction and combustion processes applied in the energy sector.

Formulating country-specific emission factors would address the country's largest activity sources and enable energy industries and other industry sectors to benchmark its progress in its quest to reduce emissions.

However, it should be considered that the improvement in local emission factors alone will not lead to an improvement in the overall accuracy of the inventory, if the GHG emissions data of the contributing industry sectors is not collected in an appropriate manner. In this regard, a set of guidelines should accompany the set of GHG emission factors on the proper application of these factors in the different sectors of the economy.

Yet in order to do so, Abu Dhabi will have to invest significant effort in obtaining sector-specific and facility-level data using a bottom-up approach that will take time, effort and strategic coordination among local and federal entities. If found useful at improving the accuracy of the GHG emissions inventory, a standard or guideline could be derived to help streamline future calculations after being carried out the first time. This is typically done in countries where GHG emissions inventories are reported annually, and therefore Abu Dhabi would benefit from these experiences to develop tailor-made local guidelines.

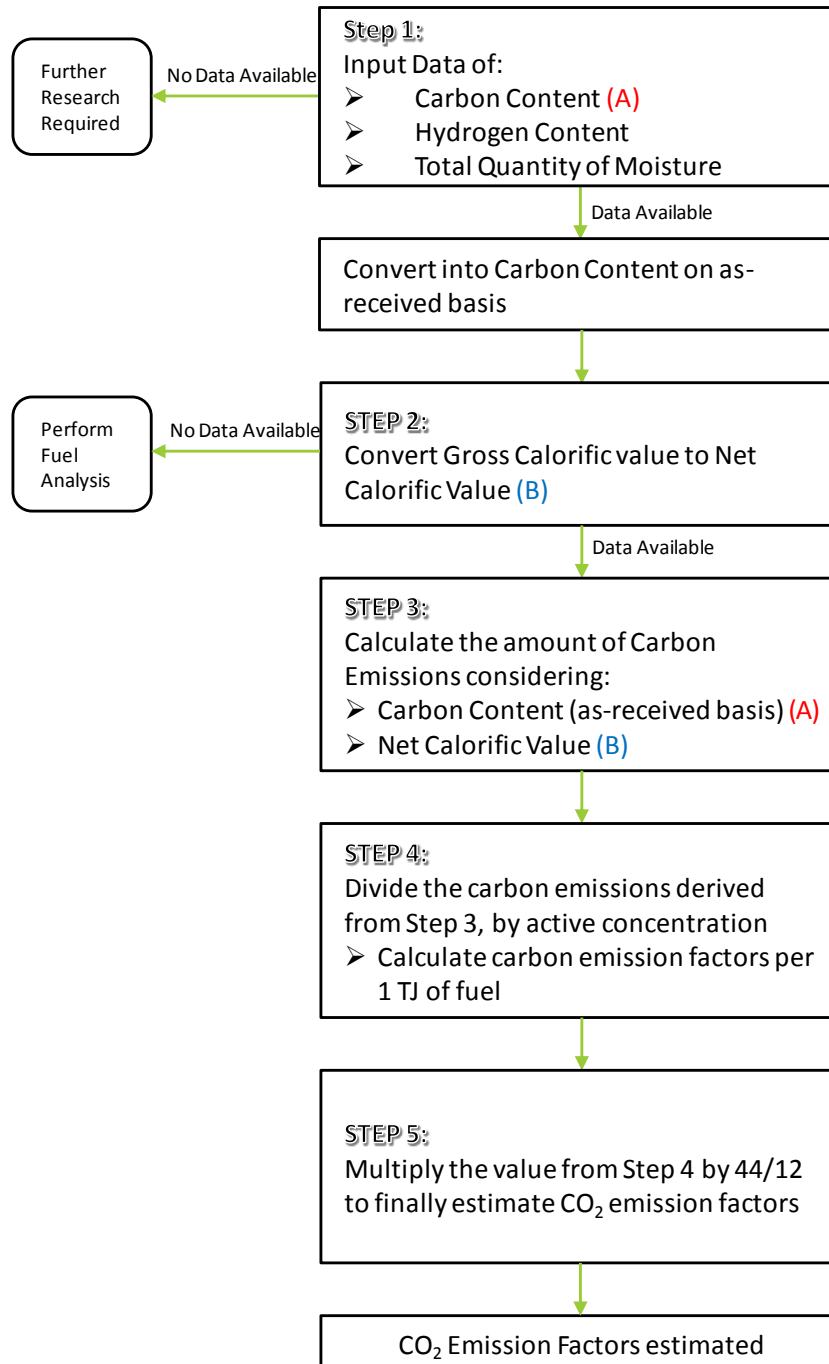# 6   Gap Analysis for Determining Local GHG Emissions Factors

This section of the report presents the gap analysis related to the main activity sources (electricity, water, fuel and waste) that contribute to the Abu Dhabi current carbon footprint performance. This analysis is based on the preliminary assessment outlined above and the data and reports provided by key government stakeholders that contributed to the Abu Dhabi 2010 GHG Inventory.

The gap analysis is focused on the fossil fuels produced in Abu Dhabi (natural gas, oil and derivatives) in order to understand the data requirements for determining country-specific GHG emissions factors associated with their extraction, processing and use. The IPCC approach to estimate GHG emission factors is recommended to be followed. It includes five (5) steps as illustrated below.

Approach to Estimate GHG Emissions Factors for Fuel
In Abu Dhabi*

	Step 1: Input Data of: ➢ Carbon Content (A) ➢ Hydrogen Content ➢ Total Quantity of Moisture

Further Research Required ← No Data Available

↓ Data Available

Convert into Carbon Content on as-received basis

↓

Perform Fuel Analysis ← No Data Available	STEP 2: Convert Gross Calorific value to Net Calorific Value (B)

↓ Data Available

STEP 3:
Calculate the amount of Carbon Emissions considering:
➢ Carbon Content (as-received basis) (A)
➢ Net Calorific Value (B)

↓

STEP 4:
Divide the carbon emissions derived from Step 3, by active concentration
➢ Calculate carbon emission factors per 1 TJ of fuel

↓

STEP 5:
Multiply the value from Step 4 by 44/12 to finally estimate CO_2 emission factors

↓

CO_2 Emission Factors estimated

* Based on IPCC Fuel Analysis Method

This approach will enable the estimation of GHG emission factors associated with the energy sector, from where other sub-sector specific emission factors can be derived. In this regard and based on the stakeholders consultation process and data provided for the 2010 Abu Dhabi GHG Inventory, Table outlines the current data availability and gaps and the level of effort related to obtaining data required to carry out a calculation of GHG emissions for sectors accounted for in Abu Dhabi's GHG Emissions Inventory.

Table 1: Summary of Gap Analysis and Level of Effort for Main Activity Sources				
Activity Source	**Sector**	**Data Available**	**Data Gaps**	**Level of Effort required to address data gaps**
Natural gas	Energy (Oil & Gas)	• Fuel quantity • Fuel energy content • Fuel composition	Net calorific value (NCV) and abatement efficiency	• Undertake studies and measurements to determine the NCV of gas and apply the IPCC Fuel Analysis Method
Oil and derivatives	Energy (Oil & Gas)	• Crude oil throughput in refineries. • Sulfur content in NG fuel and sulfur abatement efficiency.	• Facility-level and category-level data of types of fuel consumption (natural gas, kerosene, LPG, petroleum coke, refinery gas). • Full fugitive emissions data from oil and gas activities (extraction, refining, storage, and handling). • Facility-level sulfur content.	• Measure facility-level and category-level data of types of fuel consumption (natural gas, kerosene, LPG, petroleum coke, refinery gas) • Obtain full fugitive emissions data from oil and gas activities (extraction, refining, storage, handling) • Facility-level sampling of sulfur content to determine actual levels.
Oil and derivatives	Energy (Transport)	• Partial data collection occurred via SCAD, ADNOC, and DOT • Emission factor of CH_4 for gasoline for on-road transport	• Actual fuel consumption or domestic fuel sales by transport mode (e.g. air travel)[lv] • Fuel consumption for activities such as air compressors used in the transmission of natural gas in pipelines, harbors, coast guard/ touristic boats and ground activities in airports.[lvi] • Consumption statistics of increase of use of Compressed Natural Gas (CNG) among vehicle fleets. • In-country air travel fuel consumption. • Fuel used for fishing.	• Coordinate with relevant fleet companies/entities, i.e. taxi companies, commercial trucking, CWM's transport, port & airport authorities, etc to obtain consumption statistics of increased use of Compressed Natural Gas (CNG) among vehicle fleets • Review the vehicle registration database / in-service vehicle test database held by the Police to obtain vehicle motive power, vehicle class by licence plate, & number of km travelled between re-registration tests. • Coordinate with relevant bodies (General Civil Aviation Authority, Abu Dhabi Airports) to obtain determine In-country air travel fuel consumption • Calculate if GHG emissions from fishing are substantive enough to warrant local emissions factor

Table 1: Summary of Gap Analysis and Level of Effort for Main Activity Sources				
Activity Source	Sector	Data Available	Data Gaps	Level of Effort required to address data gaps
Direct emissions (PFCs, HFCs & SF_6)	Manufacturing processes	Limited manufacturing production data	• Detailed inventory of PFCs and HFCs. • Production data from major industries: cement[lvii], lime, chemicals, etc. • SF_6 emissions associated with electric switchgear. • Specific data on the import, use, and leakage of HFCs and SF6 in the applications of refrigeration, fire extinguishers, foam products and solvents. • Quantities and nature of electrical electronic and waste (EEW).	• Conduct a more thorough inventory of PFCs, HFCs and SF_6 (esp. associated with electric power transmission). This should include specific data on the import, use, and leakage of halocarbons and sulfur hexafluoride in the applications of refrigeration, fire extinguishers, foam products and solvents. • Collect missing data in production of major industries identified through consultation with the Chamber of Commerce/ Municipalities or other institutions. • Collect EEW data to assess actual contribution of this waste stream
Direct Emissions (CO_2 & CH_4)	Waste	• Actual waste quantity per waste stream has been provided to EAD's Waste Policy Team. • Clinical waste incineration process data	• Degradable organic carbon (DOC) present in the waste, the estimate CH_4 and CO_2. • Sampling MSW organic waste (e.g. food content) to confirm actual emissions. • Wastewater treatment plants waste streams • Industrial wastewater outputs beyond sewage treatment plants (e.g. septic tanks)	• Measure the amount of anticipated DOC and food waste in order to determine DOC and oxidation processes for all landfill sites. • Sample MSW organic waste emissions from Al Ain, Abu Dhabi and other major waste collection or processing facilities within the Emirate of Abu Dhabi. • Site visits to septic facilities with a field team and experts in water management / septic systems. • Conduct LCAs for all waste streams and processes to determine specific local Emission Factors.

7 Conclusions and Recommendations

7.1 Concluding Remarks

Abu Dhabi has made significant progress in recording GHG emissions from key economic sectors. However, the lack of reliable GHG Emission Factors for Abu Dhabi, precludes it from conducting a Tier-3, bottom-up analysis of emissions, which is the most rigorous analysis recommended by the IPCC.

Incomplete and missing data, such as calorific values and/or carbon content of different sources in key sectors of Abu Dhabi, must be calculated to be able to obtain GHG Emission Factors. The life cycle of products and their local, regional, and global impact in sectors such as waste should be more thoroughly understood.

Given that CO_2 comprises around 79% of total GHG emissions in the Emirate of Abu Dhabi[lviii] it would be sensible to focus on activity sources causing high CO_2 emissions as a first priority. This is the contribution of energy industries including both electricity/ water, and oil/ gas. This would also include CO_2 sources like stationary combustion, and mobile combustion like road vehicles, which were responsible for around 44% and 12% of total GHG emissions in 2010, respectively.[lix]

Strategically, country-specific emissions factors for key activity sources in Abu Dhabi could aid the Emirate in its quest towards sustainability by having more robust data for future GHG inventories and to formulate policies that improve its carbon footprint performance. Such emission factors could be determined by detailed life cycle assessments (LCA) that include full fuel cycles and energy balances.

Abu Dhabi government can assist the different sectors by creating a data acquisition plan and standard or guideline that uses a facility-level or company-level approach. This can increase category-specific quality checks, enhance transparency, and help to identify relevant emission boundaries. This approach would also link data to specific operations, sites and geographic locations, allowing GHG mitigation strategies to be implemented at multiple levels.

7.2 General Processes Recommendations

1) Establish a systematic approach for data acquisition and emission registration through which the data is accessed and managed by a central GHG database system.
2) Develop a data acquisition plan that emphasizes greater disaggregation using a more bottom-up approach that considers facility-level or company-level data. This can offer advantages regarding category-specific quality checks, increased transparency, and identification of relevant emission boundary issues. Implementing a standardized systematic data reporting requirement at the establishment level (i.e., factory, power plant, facility, project, etc.) can aid in linking the data to specific operations, sites, geographic locations, business processes and owners so that GHG mitigation strategies can be developed at multiple levels.
3) Develop research partnership programs in coordination with local and regional organizations (e.g. education and research institutions) for integrated monitoring models of atmospheric emissions.
4) Establish a standard, guideline, or other tool for inventory data acquisition to improve the reliability, scope, and quality of acquired data consistent with IPCC Guidelines. This standard could shift much of the responsibility for data access, availability, and quality to the actual entities associated with the emissions and facilitate data collection procedures that allow the same data to be efficiently collected on an ongoing basis, following 2-year cycles.

5) Ensure that data acquisition and GHG inventory design within each sector's facilities is guided by ISO Standards. Specifically, the 14067, 14064, 14044, and 14025 series on formulating, designing and implementing GHG inventories at the organizational level are particularly instructive.

6) Entities need to track their emissions in order to resolve the data gaps, bearing in mind that inventory compilation is a continuous and consequent process that goes through cycles to iteratively improve the quality of inventory.

7) Verify the inventory results by using multiple approaches such as the sectoral bottom-up approach and reference top-down approach. Involve local and international experts and utilize best practices for quality assurance of the inventory.

8) For waste related emissions, consider the use of Waste Reduction Model (WARM) calculator from the United States or tools like WRAP from the United Kingdom to help organizations track and voluntarily report greenhouse gas emissions reductions from several different waste management practices.[lx]

9) Prepare a series of future scenarios of GHG emissions (e.g. for the reference years 2030 and/or 2050) along with the relevant energy scenarios and development plans.

7.3   How Local Efforts Can Integrate with UAE National GHG Agenda

The 2013 Abu Dhabi GHG Inventory supports a larger vision of creating a national GHG inventory for the UAE. Sector-specific efforts in Abu Dhabi can contribute to this vision by offering best practice guidelines and exploratory models of how to efficiently and effectively collect, catalogue, analyze and model data for an accurate assessment of overall GHG emissions. Briefly listed here are current initiatives that have been undertaken by key sectors.

Waste Management
The Center for Waste Management does not currently collect GHG emissions data, but is putting practices in place to better understand the waste management cycle and establish more accurate emissions factors related to waste.

Industrial Sector / Manufacturing / Construction
KIZAD developed a robust modeling for GHG emissions through close work with EMAL and adjacent power plants that resulted in estimation of localized GHG emissions factors. Such models, when extended to other adjacent facilities and similar industrial zones, can help to more accurately calculate overall GHG emissions associated with this sector.

Emirates Steel – one of many entities involved in the manufacturing sector – collects and reports GHG emissions data in partnership with UK Cares. Together, they implement a sustainability management system, monitor data, and constantly try to improve processes, such as continuously monitoring emissions of some stacks.

Such efforts can help to demonstrate best practices in the manufacturing sector and reduce associated GHG emissions as per the national agenda.

Oil and Gas Subsector
The oil and gas sector is particularly active in a number of initiatives to reduce GHG emissions. ADNOC has actively worked to reduce the presence of air emissions while striving to ultimately eliminate of hydrocarbon flaring, improve energy efficiency, promoting renewable energy, eliminate continuous venting of hydrocarbons and achieve zero losses of halons and chlorofluorocarbons (CFCs), whilst gradually phasing them out.

ADNOC measures GHG emissions based on calculations from the American Petroleum Institute, with additional support from the standards and methods used by the US Environmental Protection Agency. ADNOC's monitoring covers more than 20 entities, including onshore, offshore and petrochemical installations.

The company has also voluntarily launched a program to collect stack emissions through predictive emissions monitoring systems (P.E.M.S.), and expects full implementation and reporting in approximately 5 years. As part of this program, ADNOC recently reported that it has implemented Tier 2 and 3 bottom-up approaches based on international best practice in the oil and gas industry to estimate GHG emissions factors associated with their operations. It is recommended that these data is reviewed in order to close the data gaps currently identified for the oil and gas sector.

Electricity Production and Water Desalination Subsector

Power and water are co-produced in Abu Dhabi with exhaust heat from power generation being utilized in thermal desalination processes currently used to produce the majority of water in the Emirate. ADWEC makes information publicly available on the total fuel consumed and net electricity generated by the IWPPs and other power plants, which demonstrate a level of transparency and efficiency that may be adopted at the national level by all electricity and water authorities.

Moreover, ADWEC calculates CO_2 intensity through the application of fuel specific emission factors relative to specific plants; specifically, based upon actual fuel consumed on a month by month basis at each plant. Various methodologies are available to allocate fuel consumption to power and water production, and thereby the associated CO_2 intensity.

At the same time, Masdar Institute has carried out an assessment on the "CO2 Allocation for Power and Water Production in Abu Dhabi (2012)[i] ". It is recommended that the data available from this sector is validated with the methodology proposed in this study.

Synopsis for local efforts integrated with UAE National GHG Agenda

Sector-specific efforts to capture, collect, and analyze data related to GHG emissions is a critical part for assembling a larger national GHG inventory. Partnering with private firms, engaging in cross-sectoral collaboration, standardizing methods, as well as setting internal entity-specific targets are several ways in which Abu Dhabi has engaged in the measurement and reduction of GHG emissions. Together, such initiatives can solidify local GHG inventories and contribute to reducing emissions for Abu Dhabi. Local successes within the Emirate can then be shared among stakeholders in government, industry, and other relevant sectors throughout the UAE to help contribute to refining the data for future national GHG inventories. This alignment between local and national efforts would help to gain a better understanding of GHG emissions, and demonstrate how the UAE is contributing to worldwide efforts to understand, adapt to and mitigate climate change impacts.

Appendix 1   Glossary of Terms

ADNOC	Abu Dhabi National Oil Company
ADWEC	Abu Dhabi Water and Electricity Company
BFG	Blast furnace gas
Bureau	Abu Dhabi Regulation and Supervision Bureau
CFCs	Chlorofluorocarbons
CH4	Methane
CO	carbon monoxide
CO_2	Carbon dioxide
CWM	Center for Waste Management - Tadweer
DOC	Degradable Organic Carbon
DoT	Abu Dhabi Department of Transport
EAD	Environment Agency – Abu Dhabi
EF	Emissions factor
EMAL	Emirates Aluminum
ETS	Emission Trading Systems
EU	European Union
GH	Greenhouse
GHG	Greenhouse gas
HFCs	Hydrofluorocarbons
IPCC	International Panel on Climate Change
kg	Kilograms
KIZAD	Khalifa Industrial Zone – Abu Dhabi
LCA	Lifecycle Assessment
LFG	Landfill gas
LNG	Liquefied natural gas
LOE	Level of Effort
LPG	Liquefied petroleum gas
MSW	Municipal Solid Waste
N_2O	Nitrous oxide
NG	Natural Gas
NMVOC	Non-methane volatile organic compounds
NO_X	Generic term for the mono-nitrogen oxides NO and NO2 (nitric oxide and nitrogen dioxide)
OGVs	Ocean-going vessels
PEMS	Predictive Emissions Monitoring Systems
PFCs	Perfluorinated Chemicals
QCC	Abu Dhabi Quality and Conformity Council
SCAD	Statistics Center Abu Dhabi
SO_2	Sulfur Dioxide
TJ	Terajoule
UAE	United Arab Emirates

Appendix 2   References

[i] Hamed, Hussein and Prathap John. *Greenhouse Gas Inventory for Abu Dhabi Emirate: Technical Basis and Results of First Inventory*. Environment Agency – Abu Dhabi and Norwegian Institute for Air Research. Apr 2013. 16.

[ii] Note: CO_2 emissions can be estimated fairly accurately based on the total amount of fuels combusted and the averaged carbon content of the fuels; however, emission factors for methane and nitrous oxide depend on the combustion technology and operating conditions and vary significantly, which can introduce relatively large uncertainties.

[iii] IPCC. "Introduction." 2006 IPCC Guidelines for National Greenhouse Gas Inventories. V2: 1: Ch1. April 2007. 7-8. Available at: http://www.ipcc-nggip.iges.or.jp/public/2006gl/

[iv] Abu Dhabi GHG Inventory, 10.

[v] Three GHG inventories were executed at the UAE national level (1994, 2000, 2005) by the Ministry of Energy. They provided indicators for the key category sectors on energy and industrial processes and recommended future improvements (data access, emission factors, capacity of resources). Ibid, 20.

[vi] See: *Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories*, *IPCC Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories (GPG2000)*, *Good Practice Guidance for Land Use, Land-Use Change, and Forestry (GPG2003)*. Ibid, 22.

[vii] Ibid, vii.

[viii] Ibid, 28.

[ix] Ibid, 26.

[x] Ibid, 49.

[xi] Ibid, 49.

[xii] Ibid, 82.

[xiii] Ibid 26.

[xiv] Ibid, 11.

[xv] Ministry of the Environment, Japan Greenhouse Gas Inventory Office of Japan (GIO), Center for Global Environment Research – National Institute for Environmental Studies, Japan. *National Greenhouse Gas Inventory of Japan*. Apr 2014. 26. Available at: NIR-JPN-2014-v3.0.pdf

[xvi] Japan's estimations use the *Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories*, the *Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories (2000)*, and the *Good Practice Guidance for Land Use, Land-Use Change and Forestry*. Annual inventory is reported in accordance with the UNFCCC Reporting Guidelines on Annual Inventories. Supplementary information is reported in accordance with Annotated outline of the National Inventory Report including reporting elements under the Kyoto Protocol.

[xvii] Ibid, 29.

[xviii] Ibid, 58.

[xix] Ibid, 29.

[xx] Ibid, 58.

[xxi] The uncertainty of activity data was 10%; this was determined as a standard value by the Committee for the Greenhouse Gas Emission Estimation Methods. As a result, the uncertainties for the emissions were determined to be 27% for CH_4. The uncertainty assessment methods are summarized in Annex 7. 126-127.

[xxii] As the uncertainty for emission factors of the town gas supply network, the default value presented in the GPG (2000) (25% for CH_4) was applied because the default value of expert opinion or the GPG (2000) was to be adopted in accordance with the decision tree of uncertainty assessment of emission factors. 129.

[xxiii] Ibid, 69.

[xxiv] Country-specific oxidation factors were established considering the actual conditions of fuel combustion in Japan based on survey on related industrial associations, manufacturing corporations and experts. 63.

[xxv] Multiplying the CaO content of clinker by the molecular weight ratio of CaO and CO_2 (0.785) yields the country-specific emission factor (equation in report). Ibid, 139.

[xxvi] Emissions are calculated from two sources: "hot start" and "increment at cold start" (equation in report). Ibid, 92.

[xxvii] EF is obtained from actual measurement and is lower than IPCC Guidelines Ibid, 101.

[xxviii] EF is calculated by adding the value obtained when multiplying the molecular weight ratio of CO_2 and $CaCO_3$ by the percentage of CaO that can be extracted from (equation in report). Ibid, 145.

[xxix] CO_2 emissions from soda ash use are calculated by multiplying soda ash consumption by the country-specific emission factor (equation in report).Ibid, 148.

[xxx] CH_4 emissions have been calculated by using country-specific emission factors for different soil types and for different organic amendments Ibid, 236.

[xxxi] Ibid, 150, 153, 158, 160, 161, 162, 165, 175, 179, 181, 183, 186, 187, 199, 201, 202, 227-229, 238, 244, 251, 261, 279, 295, 351, 365, 372, 391-392, 399, 404, 407, 416, 422, 424.

[xxxii] Ibid, 142.

[xxxiii] Ibid, 150, 153, 158, 160, 161, 162, 165, 175, 179, 181, 183, 186, 187, 199, 201, 202, 227-229, 238, 244, 251, 261, 279, 295, 351, 365, 372, 391-392, 399, 404, 407, 416, 422, 424.

[xxxiv] European Environment Agency. "Note on Different Emissions Estimates by EU Institutions – Consolidated." Jun 2014. Sources of inventory: Member States, the European Commission's Directorates-General Climate Action (DG CLIMA), Eurostat, the Joint Research Centre and the European Environment Agency (EEA) and its European Topic Centre on Air Pollution and Climate Change Mitigation (ETC/ACM).

[xxxv] European Environment Agency. *Annual European Union Greenhouse Gas Inventory 1990–2012* And *Inventory Report 2014 Submission To The UNFCCC Secretariat*. Sept 2014. 21. Available at: http://www.eea.europa.eu/publications/european-union-greenhouse-gas-inventory-2014 and http://unfccc.int/national_reports/annex_i_ghg_inventories/national_inventories_submissions/items/8108.php

[xxxvi] For gap-filling, the EEA uses the latest activity data available at country level to estimate the emissions. For emission sources for which no appropriate datasets exist, emissions are extrapolated from past trends, or emissions from the previous year are kept constant if historic data do not show a clear trend. Note on Different Emissions Estimates by EU Institutions – Consolidated, 2.

[xxxvii] Statistics Finland. *Greenhouse Gas Emissions in Finland, 1990-2012.* April 2014. 7. Key category table available on p. 25. Available at: http://www.stat.fi/tup/khkinv/fin_nir_2012_2014_04_15.pdf

[xxxviii] Ibid, 24. The goal is to screen the long list of category-gas combinations (about 160 categories), and find those that are the most important in terms of the emissions level and the trend.

[xxxix] Ibid, 387.

[xl] Ibid, 58.

[xli] Method is consistent with Tier 3, Revised (1996) Guidelines using detailed activity (fuel consumption) data and fuel-specific emission factors. Ibid, 69.

[xlii] They differ slightly from those expressed in the IPCC guidelines. The emission factors are based on product analysis in Neste Oil laboratories. Neste Oil is the leading company in oil product manufacturing in Finland (market share over 90%). Reformulated gasoline and diesel oil have different CO_2 emission factors. The same emission factor is used for both gasoline types E95 and E98. Ibid, 103.

[xliii] Country-specific calculation method is consistent with a Tier 2 method. Data is obtained from the energy statistics and it includes fuel sales to ships and aircrafts going abroad. Ibid, 130.

[xliv] Ibid, 174.

[xlv] In the estimation of the N_2O emissions sales data are obtained from the companies delivering N_2O for medical use and other applications in Finland. Ibid, 212.

[xlvi] The methodology for estimating carbon stock changes in soil, litter and dead wood on mineral soils builds on the research by Liski et al. (2006). This method combines forest inventory data, biomass models, litter turnover rates and the dynamic soil carbon model. Ibid, 282.

[xlvii] Ibid, 366.

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[xlviii] Country-specific (CS) expert estimations and/or IPCC default values are used. Ibid, 379.

[xlix] Ibid, 391.

[l] Ibid, 58. "CO2 Allocation for Power and Water Production in Abu Dhabi (2012), Masdar Institute.

[li] US Energy Information Administration. "How Much Carbon Dioxide is Produced When Different Fuels Are Burned?" Available at: http://www.eia.gov/tools/faqs/faq.cfm?id=73&t=11

[lii] Technical Basis - Results of the First GHG Inventory, 80.

[liii] Technical Basis: Results of the First GHG Inventory, 12.

[liv] Ibid, 92.

[lv] Ibid, 48.

[lvi] Ibid, 48.

[lvii] Ibid, 63.

[lviii] Technical Basis: Results of the First GHG Inventory, 12.

[lix] Ibid, 92.

[lx] EPA. "Waste Reduction Model (WARM)." Available at: http://epa.gov/epawaste/conserve/tools/warm/index.html