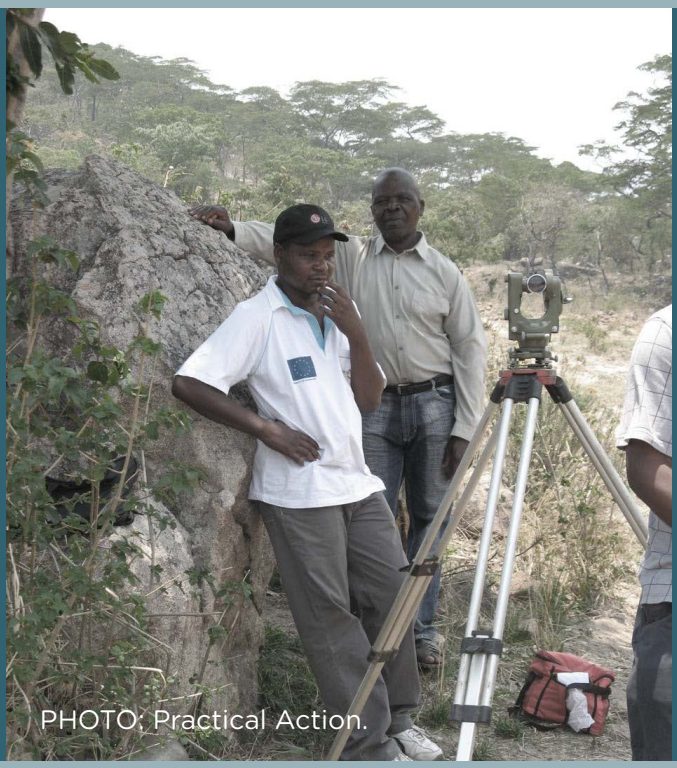
CASE STUDIES

Energy roadmap in Ghana and Botswana

Emmanuel Essah



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GDEE GLOBAL DIMENSION IN ENGINEERING EDUCATION

CASE STUDIES **Energy roadmap in Ghana and Botswana**

EDITED BY
Global Dimension in Engineering Education

COORDINATED BY
Agustí Pérez-Foguet, Enric Velo, Pol Arranz, Ricard Giné and **Boris Lazzarini (***Universitat Politècnica de Catalunya)*
Manuel Sierra *(Universidad Politécnica de Madrid)*
Alejandra Boni and **Jordi Peris** *(Universitat Politècnica de València)*
Guido Zolezzi and **Gabriella Trombino** *(Università degli Studi di Trento)*
Rhoda Trimingham *(Loughborough University)*
Valentín Villarroel *(ONGAWA)*
Neil Nobles and Meadhbh Bolger *(Practical Action)*
Francesco Mongera *(Training Center for International Cooperation)*
Katie Cresswell-Maynard *(Engineering Without Border UK)*

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ENERGY ROADMAP IN GHANA AND BOTSWANA

Dr. Emmanuel Essah, University of Reading, Reading, UK.

INDEX

1. INTRODUCTION

The relationship between energy and economic development has been the centre of debate over the past 30 years with many researchers arguing that there are conflicting views as to the exact relationship between the two (e.g. Kraft and Kraft, 1978; Yu and Choi, 1985; Ang, 2008; Apergis and Payne, 2009). Nonetheless the underlying argument is that, access to affordable and reliable energy services especially electricity is a significant aid to human, social and economic development in every country. Intermittency of supply, increasing demand and lack of access to energy have been acknowledged to undermine energy security hence are major challenges for policymakers and organizations all over the world. These challenges became more prominent in the 1970's when energy became a major concern due to the aftermath of the oil crisis (Bhattacharyya and Timilsina, 2010). It goes without saying that underdeveloped and developing countries suffer the most when it comes to energy shortage and the lack of energy security. Notably, 95% of the 1.3 billion people in the world who do not have access to electricity and 2.6 billion people who are without clean cooking facilities reside in either sub-Saharan Africa (made up of 47 Countries most of which are either developing or underdeveloped) or developing Asia (IEA, 2014). This is a substantial percentage which will eventually impact on the economic development and growth of these countries. With these challenges, energy conservation and efficient use does not only make good economic sense but is also a matter of economic survival.

Pertaining to energy management, attention has to be paid to all sectors of the economy. Nevertheless, the domestic (residential) sector has proven to be a substantial consumer of energy in almost all countries (developed and developing). Values quoted in different countries are within a range of 16-50% of the total energy demand and averages to 30% worldwide (Saidur et al., 2007).Considering the fact that energy forms are diverse (e.g. electricity, gas etc), for the purpose of this case study, the main focus will be on electricity use. Here after electricity and energy may be used interchangeably.

Ghana and Botswana (both sub-Saharan countries) are currently faced with a widespread dearth of electricity supply. Current generation and imports are able to

meet only 30-40% of the population's needs. This has resulted in prolonged power cuts that last for many hours and/or days. It is in the light of this that the aim of this case study is to develop a critical understanding of electricity consumption in Ghana and Botswana's domestic sector, through the identification of household profiling and appliance usage and its impact on national electricity use.

1.1. Disciplines covered

The main discipline covered by this case study is the issue surrounding energy efficiency through the profiling of domestic appliances and energy use and how that fits into the national profile. A background of basic mathematics would be required as well as basic Ohm's law equations in Physics. The aim is that students would be able to understand the demand loads from domestic energy usages' considering profiling of appliance. This would then be used to extrapolate to the national level assuming all parameters stay the same in that year.

To do this it is important that research is carried out to determine how much energy households use and which of their appliances use more energy. In this case householders can make informed decisions towards energy management which will contribute to reducing energy shortage.

1.2. Learning outcomes

The main learning outcomes expected draws on the student(s):

- Understanding through literature review, the predicament of the lack of access to electricity in sub-Sahara countries and its consequences on human development.
- Developed learning through the development of a critical understanding of energy use in Ghana and Botswana's domestic sector using quantitative methods.
- Ability to analyse the impact of household energy use and to establish the level of understanding required for any variables (age, gender, etc) to be integrated in the exploration of the total energy use.

1.3. ACTIVITIES

Phase 1

Students must be set up in groups of two persons. Between them, one should opt for Ghana (Accra) and the other Botswana (Gaborone). As a team, investigate (your individual assigned countries) through literature review the following;

a) Location, yearly energy consumption, source of energy to meet the country's demand.
b) Type of energy sources and percentage configuration,
c) Population size, population percentage with or without electricity
d) Reasons for lack of electricity supply in places
e) Possible alternative energy sources to findings in ***"a"*** above
f) Any additional relevant information

Write this up as the background section of the literature review report.

Phase 2

This phase would involve the design of a grid system of appliances in 3 domestic properties ideally for varying household types (say 1 person household to a 5 person household) should be considered (see section 2.1 of the Project design approach). In particular, the details of home appliances must be considered in relation to the categorization of individual components as illustrated in the figure 1. By no means is this an exhaustive list. Preferably there should be the same groups of 2 persons; one investigating the appliance usage for Botswana and the other for Ghana (following on with choices from Phase 1).

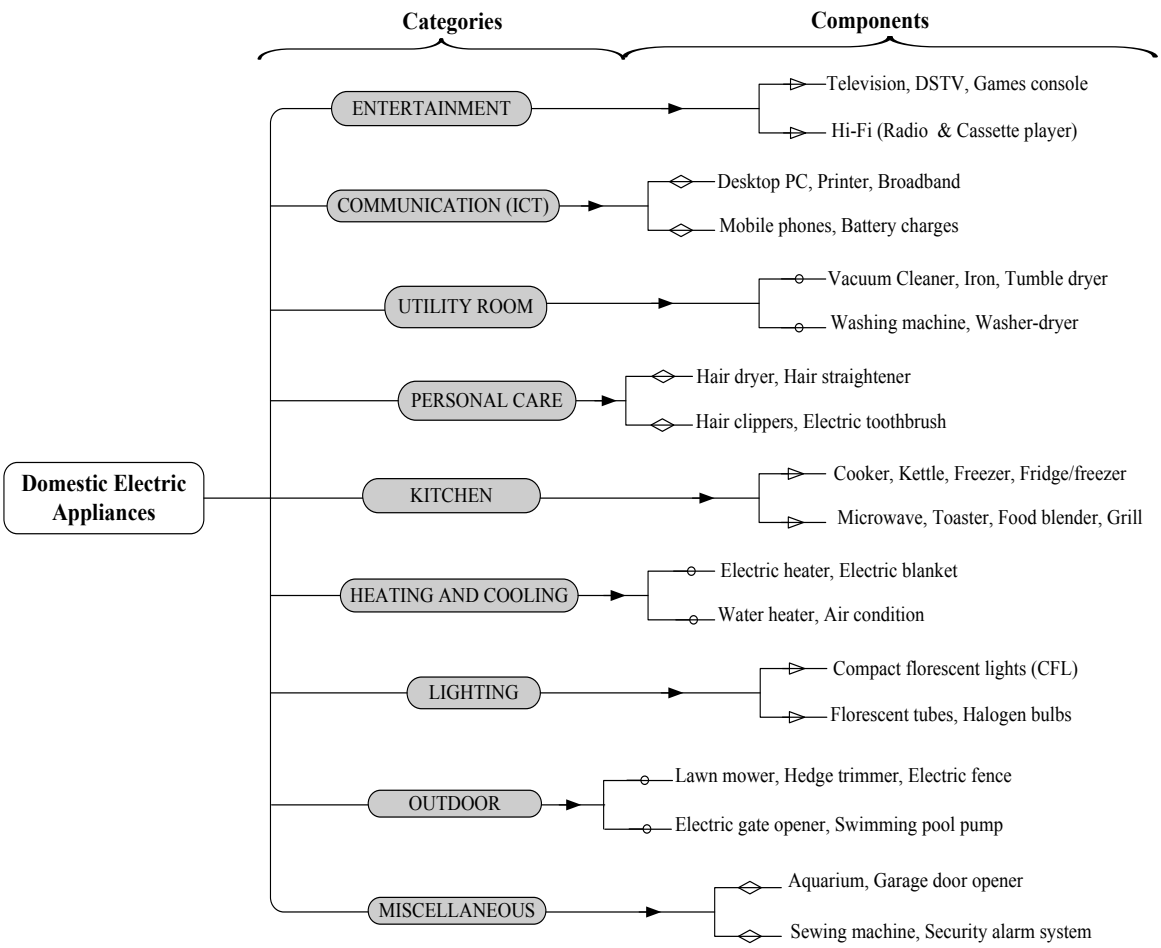

Figure 1: *Energy consumption appliance categories and some of their specific components (Adapted from Essah and Ofetotse, 2014)*

At the end of this phase of the activity a discussion and comparison between the student groups should be made. The discussions should be written as a report and presented for discussion in the class which would be led by the lecturer. This would foster detailed understanding of electricity use/the lack of, depending on household numbers, household type (terrace, flats etc) or number of appliances amongst others.

Phase 3

Develop an innovative approach to manage the electricity use in these houses ensuring all appliances are still available to the household.

Phase 4

Assuming a linearity of percentage energy use, extrapolate the electricity use for other sectors and hence the country as a whole. *Depending on the source of electricity generation, estimate the total carbon emission by sector in tones of CO_2 equivalent.* Using graphical illustrations and discussion notes, present the results as part of the report.

2. DESCRIPTION OF THE CONTEXT

Ghana and Botswana (both sub-Saharan countries) are currently faced with a widespread dearth of electricity supply. Current generation and imports are able to meet only 30-40% of the population's needs. This has resulted in prolonged power cuts that last for many hours and/or days. It is in the light of this that the aim of this case study is to develop a critical understanding of electricity consumption in Ghana and Botswana's domestic sector, through the identification of household profiling and appliance usage and its impact on national electricity use.

3. CLASS ACTIVITY

Project Approach

In this aspect the class will be split into two main groups made up of students who worked on Ghana in group A and those who worked on Botswana in Group B. Within each main group are sub groups of 5 person's maximum (depending on class size).

Phase 1

First, students are divided in their respective groups at the proposed phases in Chapter one considered. During the first hour;

- Students would average all their domestic energy results to further reduce any errors (that is average of the averages).
- Calculate the overall energy consumption of the domestic sector, considering the percentage usage provided in Tables 3 & 4.

- Assuming all sector percentages provided stays the same and are grid connected, calculate the percentage energy consumption of the other sectors. This is assuming the consumption percentages stay constant and it is a linear representation of the country's energy consumption.

This aspect would consist of a 2 hour class session each being supervised by the lecturers. This session requirements will be explained by the lecturer(s) for clarity to help solve the problem if required.

Phase 2

For the first hour, all sub-group members must work together as a united team (A or B) to discuss their results and summarise the key outcomes. For instance

- What has caused the variation in energy consumptions
- Would the results change if a different city, number of household was considered
- Etc.

Summary reports must not be more than 2-sides of an A4 sheet. ***Group B*** must engage with the above steps as ***Group A*** Simultaneously.

The second hour must be organized as a class debate/discussion with team Group A against team Group B. Each group must select 3 representatives and a secretary (4 members in total). Topics to be considered in the debate are;

- The relevance of location
- Domestic demand-challenges, limitations etc. Students must at this stage make reference to the literature survey in Section 1
- How does the energy consumption compare with developed counties? What are the main differences
- Is energy security really an issue in Ghana Vrs Botswana? If yes why, if no why not?
- Discuss strategies that can be put in place to improve the infrastructure in the country's under research

3.1. SOLUTION AND EVALUATION CRITERIA

The lecturer remains the coordinator and assessor of this session. A group summary of key points would be submitted after the debate within a stipulated period (to be confirmed by lecturer (s)). This does not involve any further work than such is written by the secretary.

At the end of each session, the lecturer gathers the summary reports from each group for their evaluation and feedback. At the end of the final group session, the final reports are submitted within reason (as per the lectures advice) for assessment.

Most activities overlap with the Homework calculations. The only outstanding activities in this section are;

- The report writing
- Debate/discussion

Debate/Discussions

This aspect should be assessed for coordination, coherency in storyline and responses to arguments and counter arguments.

This session must be coordinated by the teachers and bust be aligned with points raised in Phase 2 of Section 3.

4. HOMEWORK ACTIVITY

This activity is prepared for a dedication time of around 10 hours for each member in the group. Its designed and prepared for both individual work (homework) and class activities. Altogether it is estimated that there would be a total of 5 -10 hours spent on individual home work. This would include the literature review in phase 1, completing the home appliance grid (Table 1) analysis (Phase 1 & 2) and the writing-up of reports (Phase 3).

Phase 1: Literature Review

Considering the points raised in section 1.3 above, review the literatures provided in Section 4 (not by any means exhaustive) and produce a report no more than 3 pages that draws on the most important points in literature. The expected time for this task is around 4 hours.

Table 1: *Appliances grid for domestic electricity use*

APPLIANCES		Quantity	Hours per day	Number of days per week	Energy Use per week (kWh/week)	Total Power used /year(kWh/year)
Entertainment						
TV						
Satellite/ Freeview/ cable box						
Digital/ analogue radio						
Video/DVD player/recorder						
Games console						
Home theatre system						
.						
.						

Phase 2: Analysis and Results

Complete the appliance grid for 3 houses each with a different household size (say 1 person, 2 persons etc). Note that the household numbers may have an impact on the appliance usage hence the overall energy consumption.

A simplified relation between appliance, its rating and duration of use was developed (Essah and Ofetotse, 2014) to investigate the energy consumption per appliance per week. This relation is as illustrated in Equations 1.

$$E_e = N_a \times A_r \times H_u \quad (1)$$

Where:

E_e = energy use per appliance per week

N_a = the number of appliances (of same kind)

A_r = the power rating of appliances in watts

H_u = the duration of an appliance usage in hours per week

Equation 1 is applicable to all categories of domestic appliances but for cold appliances where this is not applicable because even though the appliances are in continuous use (i.e. switched on all the hours of the day) their compressors do not run continuously hence they do not draw a constant amount of power. ***Conduct a research into cold appliance usage for this exercise and each household.*** The expected time for this task is around 4 hours. Once each group member has completed their grid, compute the individual totals and discuss your findings with your group member.

Phase 3: Calculations and Report

Compute the average domestic electricity consumption assuming insignificant deviation across the entire population. Using this average, estimate the total energy consumption using the percentages cited in Tables 3 & 4 Write a report of the outcome of your results focusing only on the domestic sector of your chosen country, stating all necessary assumptions. This exercise is estimated to last for a maximum of 2 hours.

4.1. Solution and Evaluation Criteria

Literature Review

This should entail a critical review of the following aspects

- The location statistics: population, demography etc
- Methods used
- General information about energy use
- Available generation power
- Percentage of coverage

By no means exhaustive, use literatures provided as basis and refer to Section 1.3, phase 1 for more aspects for consideration. The literature should feed into the method and analysis.

Domestic Appliance Estimation

Typical appliance estimation for a domestic property in Ghana is given in Table 2. This has to be repeated for two other houses in Ghana (3 in total) and 3 (total) in Botswana. Assuming this is the case then a summary result is presented in Table 3.

Table 2: Estimated energy consumption for a residential house in Ghana. Note: Power per year is obtained using Equation 1.

Appliances	**Rating (W)**	**Quantity**	**Hours (per day)**	**Power (kWh/year)**
Hi-Fi radio	20	1	2	14.6
Mobile Phone(Charging 3 times/ week)*	-	1	3	0.7
Television (14 inch)	60	1	3	65.7
Computer with LCD screen	150	1	2	109.5
Ceiling Fan (max speed)	45	1	0.5	8.2
Telephone **	3.6	1	24	6.3
Refrig./freezer(22 cf***)	1200	1	-	292.0
Electric Stove	5500	1	-	876.0
Kettle	1200	1	0.2	73.1
Microwave	1000	1	0.2	73.0
Blender	700	1	0.1	25.6
Lights:				
11W compact fluorescent	11	3	2	24.1
Incandescent	40	4	3	175.2
Iron	1000	1	0.14	51.1
Total				**1795.1**
Total Demand (assume 4 person household of population) **GWh**				**10,770.5**

** Mobile Phone Charger (http://www.willsmith.org/climatechange/domestic.html)*
*** Charges a DC researchable battery (6v 600mA)*
*** cf - cubic foot (*www.PVSyst.com*)

Source: Essah, 2011

Table 3: Estimated Residential Electricity Consumption Values

House	Number of Household	Ghana (GWh)	Botswana (GWh)	
1	2	15,500	20,220	
2	4	10,770	22,000	
3	5	20,770	25,900	
		15,680	**22,707**	Average

Assuming linear relationship in percentage values presented in tables 6 and 7, then the total estimated energy consumption is calculated assuming the domestic energy consumption percentage is equal to the consumption values in table 3. Hence the summary result is calculated and presented in Table 4.

Table 4: Estimated country wide energy consumption

BOTSWANA

Sector	%	Appliances (A) (GWh)	Estimated (E) (GWh)	Total (A+E) (GWh)	CO_2 Emissions ($KgCO_2/kWh$)*
Mining	42		**39,737**		20,623,330,000
Residential	24	**22,707**			11,784,760,000
Commercial	25		**23,653**		12,275,791,667
Government	9		**8,515**		4,419,285,000
Total	**100**			**94,611**	**49,103,166,667**

GHANA

Sector	%	Appliances (A) (GWh)	Estimated (E) (GWh)	Total (A+E) (GWh)	CO_2 Emissions ($KgCO_2/kWh$)*
Residential	34.5	**15,680**			8,137,920,000
Non-residential	16.3		**7,408**		3,844,872,348
Industrial	45.1		**20,498**		10,638,266,435
Street Lighting	4		**1,818**		943,526,957
Total	**100**			**45,404**	**23,564,585,739**

**For these calculations, CO_2 emissions are assumed to be from grid supply electricity, table 9*

Compare these values (Table 4) with the current values in tables 5 and 8. Discuss the results in line with meeting the demand.

For an extra attempt, estimate the values for the populations of each country.

Relevant Data

GHANA

Table 5: Electricity consumption by customer class (GWh)

Year	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
Residential	1,479	1,612	1,670	1,727	1,840	1,956	2,130	2,095	2,269	2,418	2,738	2,761	2,803	3,228
Non-Residential	551	580	544	621	591	676	701	702	927	884	966	1,041	1,153	1,525
Industrial[3]	4,306	4,336	3,904	2,206	2,029	2,542	3,593	2,687	2,963	2,921	3,156	3,900	4,153	4,224
Street Lighting	31	36	42	50	63	85	144	137	171	184	264	274	315	377
Total	6,367	6,564	6,160	4,604	4,523	5,259	6,568	5,621	6,330	6,407	7,124	7,976	8,552	9,355

[3]Special load tariff customers of ECG and NEDCo as well as bulk customers of VRA including VALCO
Data do not include transmission and distribution *(commercial and technical)* losses
Source: ECG, NEDCo, VRA and GRIDCo

Source: http://energycom.gov.gh/files/ENERGY%20STATISTICS.pdf

Table 6: Percentage by sector-Ghana

Sector	**GWh**	**%**
Residential	3228	34.5
Non-residential	1528	16.3
Industrial	4224	45.1
Street Lighting	377	4.0
Total	**9357**	**100.0**

Using 2013 figures to calculate percentages (-Table 5)

BOTSWANA

Table 7: Percentage by sector-Botswana

Sector	**GWh**	**%**
Mining	1086	42
Residential	879	24
Commercial	910	25
Government	323	9
Total	**3198**	**100**

Table 8: Electricity consumption and percentage of total consumption by sector

Electricity consumption and percentage of total consumption by sector.

Year	Electricity consumption by sector (GWh)					Shares of electricity consumption by sector (%)			
	Mining	Commercial	Domestic	Government	Total	Mining	Commercial	Domestic	Government
2000	760	492	280	139	1671	45.5	29.4	16.8	8.3
2001	899	462	334	147	1843	48.8	25.1	18.1	8.0
2002	920	478	371	187	1955	47.0	24.5	19.0	9.5
2003	1001	533	420	196	2150	46.6	24.8	19.5	9.1
2004	1077	573	489	227	2366	45.5	24.2	20.7	9.6
2005	1047	613	539	217	2416	43.3	25.4	22.3	9.0
2006	1184	631	584	227	2626	45.1	24.0	22.3	8.6
2007	1199	634	682	262	2777	43.2	22.8	24.6	9.4
2008	1186	684	745	274	2889	41.0	23.7	25.8	9.5
2009	1123	735	769	290	2917	38.5	25.2	26.4	10.0
2010	1141	831	829	308	3109	36.7	26.7	26.7	9.9
2011	1117	820	873	308	3118	35.8	26.3	28.0	9.9
2012	1086	910	879	323	3198	34.0	28.5	27.5	10.0

Source: BPC (2010, 2011, 2012).

Essah and Ofetotse 2014

Table 9: CO2 emission factors

Fuel	**Carbon Emission Factor** ($kgCO_2/kWh$)
Natural Gas	0.2160
LPG	0.2410
Biogas	0.0980
Oil	0.3190
Coal	0.3450
Dual Fuel (Mineral + wood)	0.2260
Biomass	0.0310
Grid Supplied Electricity	0.5190
Grid Displaced Electricity	0.5190

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Yu, E. S. H., Choi, J.-Y. 1985. The causal relationship between energy and GNP: an international comparison. *Journal of Energy and Development,* **10** (2), pp. 249-272.

FURTHER/SUGGESTED MATERIAL

The literature to be reviewed has been attached in a folder labelled as Papers. Other sources of reference are the internet links below;

Internet Links

Ghana

- http://energycom.gov.gh/
- http://energycom.gov.gh/files/ENERGY%20STATISTICS.pdf
- http://energycom.gov.gh/Energy-Statistics/2012-energy-outlook-for-ghana.html
- http://energycom.gov.gh/files/Energy%20Commission%20%202014Energy%20Outlook%20for%20Ghana_final_2014.pdf

Bostwana

- http://sustainabledevelopment.un.org/content/documents/1009National%20Report%20(Energy)%20-%20Botswana.pdf
- http://www.laurea.fi/en/connect/results/Documents/Botswana%20Country%20Report.pdf
- BPC, 2014a. Saving electricity at home. http://www.bpc.bw/Pages/saving_electricity.aspx.
- BPC, 2014b. Network map. http://www.bpc.bw/Pages/network_map.aspx
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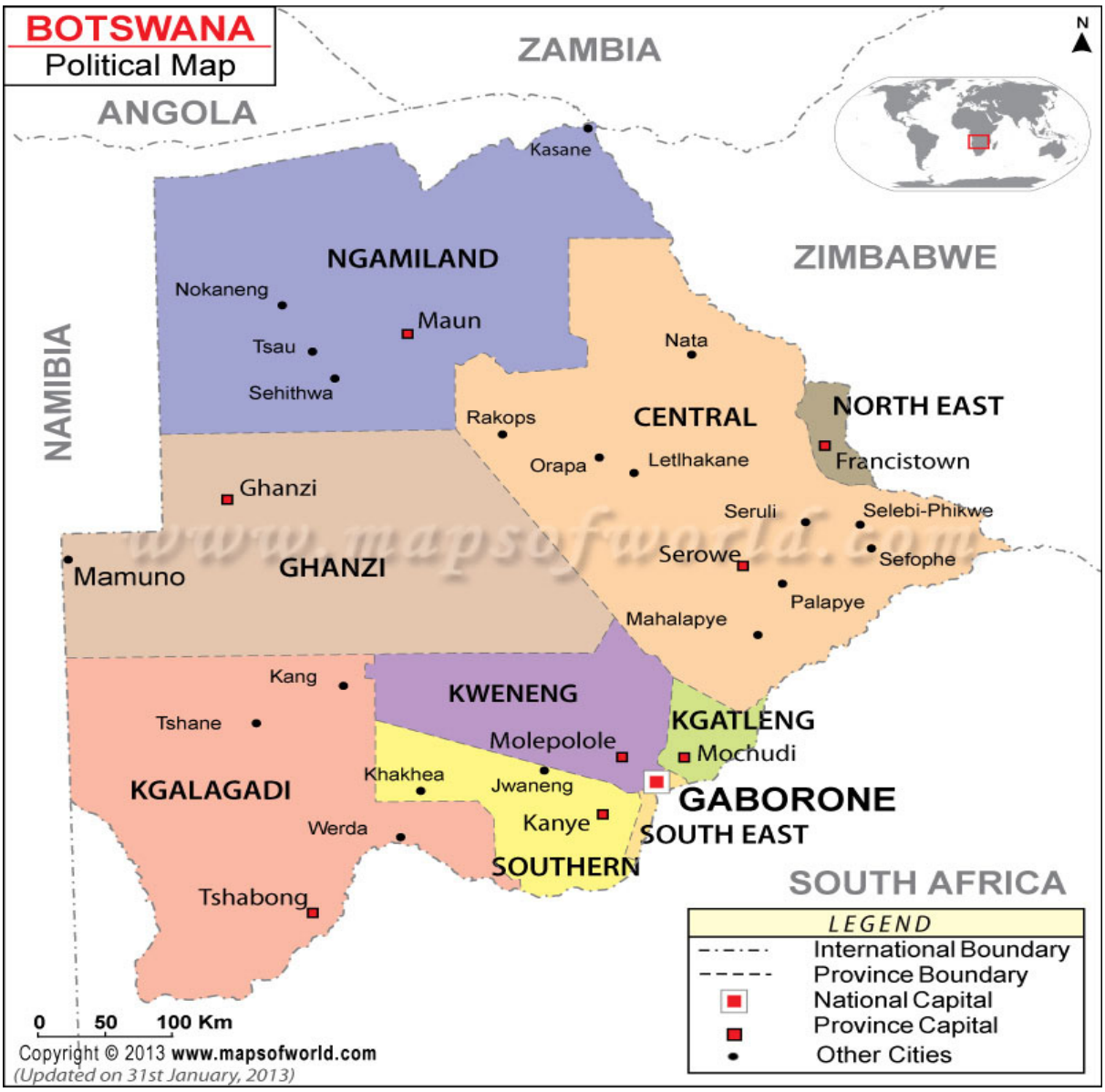
Appendix - Maps

Africa – Ghana, Botswana location

Map of Ghana


GHANA
BURKINA FASO
UPPER EAST
Bolgatanga
UPPER WEST
BENIN
Wa
Tamale
NORTHERN
TOGO
COTE D'IVOIRE
BRONG-AHAFO
Sunyani
VOLTA
ASHANTI
Ho
Kumasi
EASTERN
Koforidua
GREATER ACCRA
WESTERN
CENTRAL
Accra
Cape Coast
Gulf of Guinea
Sekondi

Map of Botswana



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PRACTICAL ACTION Technology challenging poverty

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