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CHAPTER 12: ENVIRONMENTAL SUSTAINABILITY AND CLIMATE CHANGE IN THE LOCAL GOVERNMENT SPHERE

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12.1 Introduction

The impact of climate change on world economies is increasingly taking centre stage in global socioeconomic and political debates and policies. The severity and frequency of associated natural disasters have made climate change one of the major threats to global economies in the 21st century. The hazards of climate change have manifested themselves in, among others, wide temperature variations, changes in rainfall patterns, rises in sea levels, unprecedented levels of air pollution, frequent floods and droughts, and increases in water- and vector-borne diseases (World Bank, 2010). Although every economy is vulnerable to the adverse impacts of climate change, this vulnerability is distributed disproportionately across continents and regions.

The developed world generates most of the negative externalities associated with climate change, while the poorest global populations bear the greatest risks. In the USA, per capita emissions of greenhouse gases (GHG) are 19 times greater than in Africa. Yet, although responsible for less than 7% of global GHG and 4% of CO2 emissions, Africa is the most vulnerable to the impact of climate change (Campbell-Lendrum and Corvalan, 2007). Inadequate adaptation and mitigation infrastructure, poorly functioning markets, weak institutions, and limited resources are some of the factors that make low-income countries more vulnerable to climate variability and change.

The government has recognised that climate change is a threat to the socioeconomic fabric of the country and to the environmental sustainability and vibrancy of cities. South Africa is party to many international agreements, including the following: Antarctic–Environmental Protocol, Antarctic Marine Living Resources, Convention for the Conservation of Antarctic Seals, Antarctic Treaty, Biodiversity, Climate Change–Kyoto Protocol, Desertification, Convention on International Trade in Endangered Species (CITES), International Treaty on Hazardous Wastes, Law of the Sea, Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter, Marine Life Conservation, and Ozone Layer Protection.

Furthermore, the government's 2009–2014 Medium-Term Strategic Framework includes the protection and enhancement of environmental assets and natural resources as one of the strategic priorities that were developed into 12 key outcomes. However, in spite of this recognition, lower tiers of government, especially local government, have not been proactively involved in efforts to adapt to and mitigate climate change. As principal drivers of economic growth, development and innovation, municipalities need to recognise the challenges posed by climate change. Yet, local authorities do not prioritise climate change because its impacts are not immediate; they consider themselves too small to have any influence and are reluctant to spend resources on what is a global problem. The result is inaction and a lack of appreciation that global climate change is a legitimate local (and global) concern (Betsill, 2001). Part of the problem is that municipalities have insufficient knowledge about the possible impacts of climate change at local level.

The Fiscal and Financial Commission (the Commission) is concerned about the effect of climate change because of its potential to strain public finances and so undermine any gains in intergovernmental fiscal relations, which the Commission is constitutionally mandated to promote. Another concern is the potential of climate change to undermine development and growth, imposing costs on society and government through expenditure related to ameliorating climatic

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effects. This chapter seeks to show how climate change is affecting the environmental sustainability and vibrancy of urban economies in South Africa. The primary objectives of this chapter are:

- To examine the impact of climate change on South Africa's municipalities, with a special focus on the water and energy sectors.
- To recommend possible and appropriate financial and fiscal policies and instruments for municipalities to deal proactively with the threats and opportunities that accompany climate variability and change.

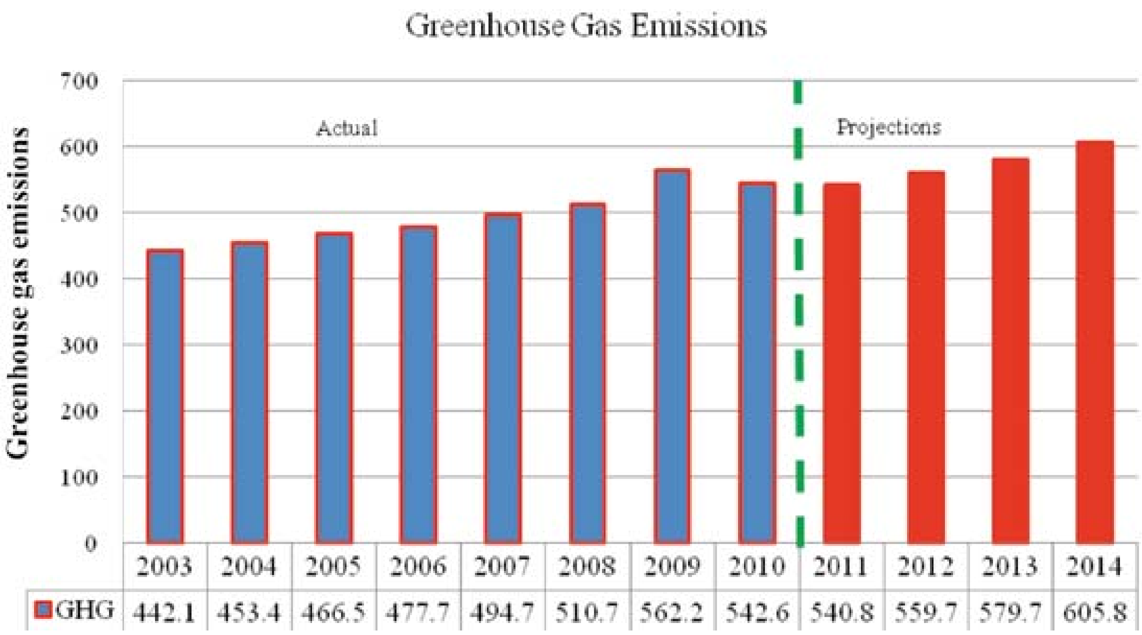
12.2 The State of the South African Environment

Since 1994, environmental sustainability has gradually been placed at the core of South Africa's socioeconomic and political agendas. South Africa has pursued policies that seek to promote the socioeconomic well-being of the population, while at the same time preserve the natural assets of the country. Through various policies, institutional developments and legislative frameworks, the country has integrated environmental sustainability within the broader development agenda.

South Africa's environment is characterised by deep-rooted degradation, which is due to many factors, including high levels of poverty, unemployment, inequality, rapid urbanisation, inefficient land-use patterns, and extensive use of fossil fuels. One of the main indicators of the deteriorating environment is the steady increase in GHG emissions, as shown in Figure 12.1.

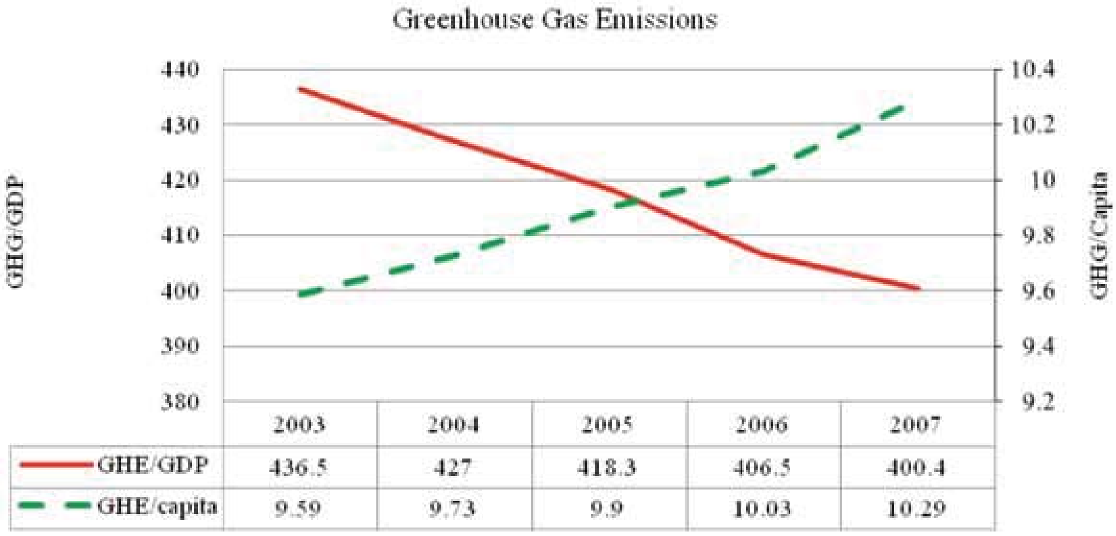
Between 2003 and 2007 GHG emissions increased steadily, from 9.6% to 10.3% per capita. However, as Figure 12.2 shows, the same period saw a steady decline in emissions as a proportion of gross domestic product (GDP), which may suggest the economy is moving to energy-efficient industries.

Figure 12.1 GHG emissions in South Africa



Source: Government of South Africa, 2009

Figure 12.2 GHG emissions as a percentage of GDP in South Africa



Source: Government of South Africa, 2009

As mentioned above, South Africa's commitment to a sustainable environment is reflected in the government's strategic priority areas. Key outcome 12 of these priorities is concerned with "Environmental Assets and Natural Resources that are well protected and continually enhanced", and includes the following outputs: (DEA, 2009)

- Enhanced quality and quantity of water resources;
- Reduced GHG, climate change impacts, and improved air and atmospheric quality;
- Sustainable environmental management; and
- Protected biodiversity.

South Africa has also linked its strategic priority areas to the Millennium Development Goals (MDGs), including MDG 7, which promotes sustainable environmental resource use and management. Progress towards achieving MDG 7 in South Africa is mixed (StatsSA, 2007):

- Targets already achieved: proportion of population using improved drinking water sources and proportion of population using solid fuels as the primary source of energy.
- Targets likely to be achieved by 2014: proportion of protected terrestrial and marine areas; proportion of population using improved sanitation facilities; reduced CO2 emissions and reduced consumption of ozone-depleting substances.
- Targets unlikely to be achieved by 2014: reduction in the number of species threatened with extinction and proportion of urban population living in slums.

12.3 Literature Review

Although the subject of climate change transcends many disciplines, such as ecology, (environmental) economics, geography, climatology and sociology, the focus of this review is on the economic and fiscal perspective. At a theoretical level, climate change is seen as a global externality, which makes solutions difficult to find, as the externality often transcends borders and generations and involves some interactions of the natural, climate and economic systems (Bulkeley, 2002; Cline, 1992; Brown and Jackson, 1986; Forrester, 1961; Forrester, 1968).

The impact of climate change varies by region and level of development and causes severe strain on global economies. Nordhaus (1991) and Tol (1995) estimate that climate change-related hazards will force the GDP of developed countries to contract in future. However, Stern (2007) found that the developing world is likely to lose out in terms of national GDP, which suggests that developing countries will carry a heavier burden of climate change than the developed world. The lack of adaptation and mitigation capacity and resources are perhaps the most important factors to explain why the economies of developing countries are likely to suffer most.

Many studies have looked specifically at the impact of climate change on water and energy resources. A common finding is that climate change will lead to an increase in the demand for energy (Tol, 2002; Pearce *et al*., 1996; Kurtze and Springer, 1999). Davidson *et al.* (2003) suggest that climate changes will compromise energy security, as supply and demand gaps are likely to widen. The water supply–demand gap will also widen because of climate change: water demand will increase while water supply will diminish (Muller, 2007). An increase in global mean temperature of 1°C will result in water resource losses in Africa worth $2.4 billion (Tol, 2002), while the quality and quantity of water will be compromised.

To ameliorate climate change-related hazards, many alternative policy instruments – fiscal, financial and other – are suggested (EarthLife Africa, 2009; African Development Bank, *et al*., 2003). They can be divided into two categories: regulatory instruments and economic/market-based instruments (Brown and Jackson, 1986). The regulatory instruments include setting up of rules, limits, restrictions, or sanctions that will discourage environmentally harmful behaviours. Economic instruments simply rely on the price mechanism, which will act when behaviours are environmentally harmful, encouraging environment-friendly alternatives. Market-based instruments include taxes, tariffs, subsidies and carbon trading. Another emerging set of policy instruments includes land-use policies, green procurement, green tendering, green budgeting, and other financial incentives (ibid.).

The literature is clear: climate change will have profound effects on water and energy supply and demand. These sectors form the backbone of urban and local government economies, and therefore the local sphere is vulnerable to climate change. Unless action is taken to tackle the consequences of climate variability and change (in particular mitigation and adaptation measures), efforts to build economically strong local economies will be compromised.

12.4 Methodology and Data Analysis

The link between climate change and municipal-level demand for water and electricity is examined using a conceptual framework that is premised on system dynamics modelling and empirical methodology based on econometric modelling.

12.4.1 The conceptual model: system dynamics framework

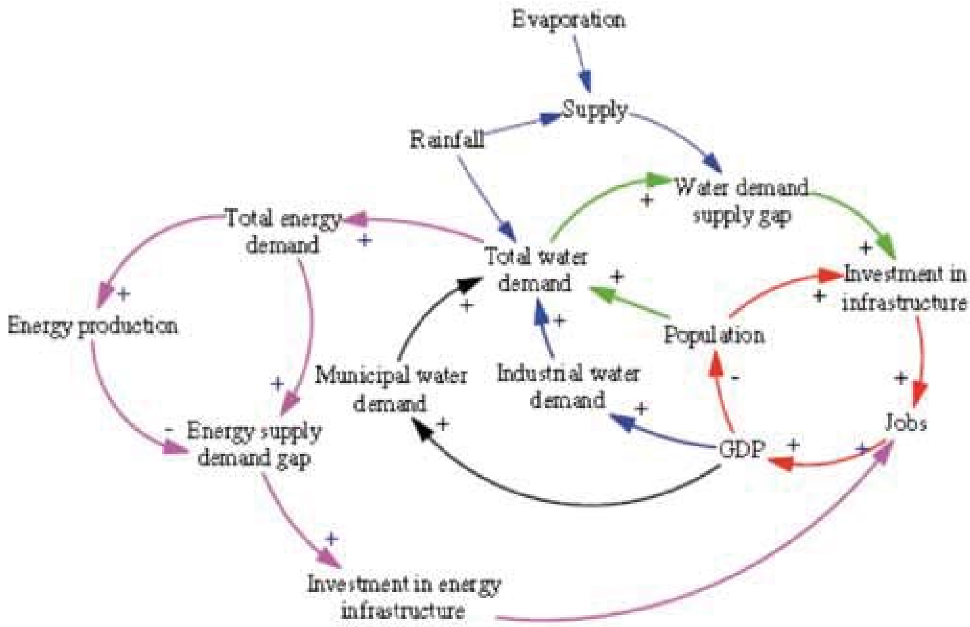
Climate change presents a number of challenges for sustainability around the globe. South Africa is no exception, as shown by several disasters such as floods, droughts and fires, which have resulted in huge and frequent economic and social damages. What is needed is to improve the representation of climatic and biophysical systems and, in particular, the anthropogenic (human) activities that influence or control the impacts of climate change at national, provincial and local levels.

System dynamics can help decision-makers to understand the structure and characteristics of a complex system. It integrates system-thinking theory, cybernetics and information theory, and is useful when dealing with problems of high-level, non-linear and multiple feedbacks.[172] It is a well-established approach for describing the behaviour of a system (Forrester, 1961, 1968) and uses causal loop diagrams or stock and flow diagrams. A system dynamics model provides a flexible way of understanding the dynamic relationships between the variables and their interactions/linkages. The principles used to develop such a model can be found in a number of studies, including Forrester (1961), Randers (1980), Richardson and Pugh (1981) and Mohapatra (1994).

A causal loop diagram (see Figure 12.3) was developed to illustrate the relationship between climate variability and change, municipal economic development and population, as well as factors associated with climate change and demand for electricity at municipal levels. South African municipalities need to put appropriate strategies in place to ensure sustainable provision of water services. Yet, population and industrial growth increase demand for water significantly, and climate conditions such as rainfall and temperature can affect its supply. The interactions shown in Figure 12.3 guided the selection of variables used to estimate the econometric models.

172 Feedback refers to the situation where X affects Y, and Y in turn affects X, perhaps through a chain of causes and effects (Sterman, 2000).

Figure 12.3 Causal-loop diagram



Note: A causal loop diagram explains the impact dynamics and feedback of the system being studied. The term 'causal' refers to a cause-and-effect relationship. '+' on an arrow connecting two variables indicates the variable at the tail of the arrow causes a change in the variable at the head of the arrow in the same direction; '–' indicates a change in the opposite direction.
Source: Authors

Figure 12.3 highlights a number of possible interactions between three systems: water (total water demand and supply); socioeconomic (municipal population, investment in water-related infrastructure and GDP); and climatic (rainfall and evaporation, which is a function of temperature and humidity). GDP growth is expected to lead to reduced population, but GDP and population growth will also raise water demand, which in turn will increase the water demand–supply gap; hence the need for more investment in infrastructure to meet the needs for water provision.The causal loop shown in Figure 12.3 reasonably represents the real-world relationships (water demand/supply, electricity demand/supply and climatic conditions) that empirical models need to consider. For instance, in the real world, water demand for industry, agriculture, and other municipal activities needs to indicate the feedback influences of rainfall, temperature and storage capacities.

12.4.2 The econometric models

The water and energy sectors are central to the welfare of citizens and functioning of municipalities in South Africa and beyond. Figure 12.3 shows how climate conditions (particularly changes in rainfall) affect water demand, which in turn affects the energy supply–demand gap. Using municipal expenditures on water and electricity as proxies for municipal water and electricity demand, the hypothesised link between these indicators and climate variability and/or change for municipality m at time t can be modelled as a system of equations as follows:

$$Water_{mt} = \beta_0 + \beta_1 C_{mt} + \boldsymbol{\beta_2 W_{mt}} + \varepsilon_{mt}$$
$$Electricity_{mt} = \alpha_0 + \alpha_1 C_{mt} + \boldsymbol{\alpha_2 X_{mt}} + \mu_{mt}$$

for $m = 1,.....N$ municipalities over $t = 1, ...T$ years. (1)

The dependent variable *Water* is the municipal expenditures (in rand) on water-related services and infrastructure, and *Electricity* is municipal expenditures (in rand) on electricity-related services and infrastructure. The climate change variables are represented by C, as the focus is on rainfall variability as a proxy for climate variability and change. In addition to these climate variables, characteristics of municipalities believed to affect municipal water and electricity expenditures are controlled for. They are captured by the vectors W and X for water and electricity expenditures, respectively. The parameters to be estimated are β_0, β_1, $\boldsymbol{\beta_2}$, α_0, α_1, and $\boldsymbol{\alpha_2}$. The error terms for each equation are denoted by ε and μ. These error terms are assumed to be such that $(C,\varepsilon), (\mathbf{W},\varepsilon), (C,\mu)$, and $(\mathbf{X},\mu) \sim i.i.d$ and (X, μ): $i.i.d$ and $N(0,\sigma^2)$.

Time-series data on water and electricity expenditures by municipalities, as well as rainfall variability and other control variables, is combined to form a panel dataset. In estimating the systems of equations in (1), this structure of pooled data can be taken into account in three ways, each introducing the intercept into the model in a different way. Specifically, the estimated model may have a common, fixed or random intercept term. In other words, the three model specifications are the common effects regression, fixed effects and random effects models.

The common effects regression model involves pooling all the data for the municipalities, assuming that the parameters do not vary across sample observations, as done in (1). In this model, the level of demand for water and electricity – proxied by municipal expenditures on water- and electricity-related infrastructure and/or services, respectively – is assumed to be homogeneous across municipalities. These assumptions imply that the equations in (1) can be estimated using panel data ordinary least squares (OLS).

Alternatively, the intercept term could be allowed to vary across municipalities. This is done by introducing dummy variables to take into account the differences in the levels of water and electricity expenditure across the municipalities. Referred to as the fixed effects model, it can be represented as:

$$\begin{aligned} Water_{mt} &= \sum_{i=1}^{N} \beta_i M_{it} + \beta_1 C_{mt} + \boldsymbol{\beta_2 W_{mt}} + \varepsilon_{mt} \\ Electricity_{mt} &= \sum_{i=1}^{N} \alpha_i M_{it} + \alpha_1 C_{mt} + \boldsymbol{\alpha_2 X_{mt}} + \mu_{mt} \end{aligned} \quad (2)$$

where β_i and α_i represent the intercept coefficient for the ith cross-sectional municipality in each respective equation, M_{ii} are dummy variables that take a value of one for observations belonging to the ith municipality and zero otherwise.

This is appropriate when specifying a different intercept coefficient for each cross-sectional unit that adequately captures differences in municipalities.

A random effects model can be used as an alternative to the fixed effects model. It assumes that the coefficients are random variables drawn from a larger population such that:

$$\begin{aligned} Water_{mt} &= \beta_0 + \beta_1 C_{mt} + \boldsymbol{\beta_2 W_{mt}} + u_i + \varepsilon_{mt} \\ Electricity_{mt} &= \alpha_0 + \alpha_1 C_{mt} + \boldsymbol{\alpha_2 X_{mt}} + \eta_i + \mu_{mt} \end{aligned} \quad (3)$$

where it is assumed that: $E[u_i] = 0, E[u_i^2] = \sigma_u^2, E[u_i u_j] = 0 \text{ for } i \neq j, E[u_i \varepsilon_{it}] = 0$; and

$$E[\eta_i] = 0, E[\eta_i^2] = \sigma_\eta^2, E[\eta_i \eta_j] = 0 \text{ for } i \neq j, E[\eta_i \mu_{it}] = 0$$

The structure of the model means that, for a given municipality, the correlation between any two disturbances in different time periods is the same. In other words, the correlation is constant over time and identical for all municipalities. Using the random effects estimator means that, in addition to controlling for unobserved effects, the intra-municipality correlation can also be controlled due to unobserved cluster effects (Wooldridge, 2002). The principle is that the results from a random effects model can be generalised to the whole population from which the sample is taken. Thus, while the fixed effects specification assumes municipality-specific effects are fixed parameters, the random effects specification assumes municipalities are made up of a random sample and the municipality-specific effects are assumed to be independently distributed with a mean of zero and a constant variance.

In principle, both the fixed and random effects specifications provide some estimation efficiency gains over the simple common effects regression model when using panel data. However, in deciding which model specification to base the inferences on, several post-estimation statistical tests are performed. An F-test is used to test for the common coefficients specification against the fixed and random effects specifications. In case the specification is rejected, which implies that the common effects estimators are biased and spurious, a Hausman test is used for the fixed versus the random effects specification.

12.4.3 Simulating the impacts of rainfall variability scenarios

Following the estimations of models (1)–(3) and choosing the most appropriate model based on the statistical tests described above, the estimates are used in a simulation exercise. This is meant to project the impact of climate variability and/or change (focusing on rainfall variability) on municipal water and electricity expenditures.

Data

The municipality is the unit of analysis. A municipal-level panel data set is used, containing comprehensive information on the characteristics of the municipalities, as well as the average socioeconomic characteristics of the households or individuals residing in those municipalities. The empirical panel data covers 283 municipalities across South Africa for the period 2005–2009.

The dependent variable, Water, is expenditure (in millions of rand) on water-related services and infrastructure, and Electricity is expenditure (in millions of rand) on electricity-related services and infrastructure. The level of expenditures is used as a proxy for municipal water and electricity demand. The assumption is that, in response to changes in water and electricity demand from their residents, municipalities change the level and composition of water and electricity-related infrastructure and/or service provision, which in turn changes the level of water and electricity-related expenditures.

Rainfall Variability is of primary interest to this study. The coefficient of variation is the indicator used to measure variability or dispersion of rainfall levels at municipal level. This is a normalised measure of dispersion of a variable – rainfall levels – computed as the ratio of standard deviation and average rainfall such that:

$$\text{Coefficient of variation} = \frac{Std.Deviation_m}{\overline{\text{Rainfall}}}$$

$Std.Deviation_m$ is the standard deviation of rainfall for municipality m.

This is computed as the square root of variance, where the sample variance is computed as:

$$Variance_m = \frac{1}{n}\sum_{t=1}^{n}(\text{Rainfall}_{mt} - \overline{\text{Rainfall}})^2$$

where n is the number of years for which rainfall data was recorded within each municipality (five in cases where rainfall data was found for each of the five years covered in the panel). Rainfall is the average level of rainfall within a particular municipality for the five years covered in the panel data.

The main advantage of using the coefficient is that, unlike the variance and standard deviation which need to be understood in the context of the mean of the variable, the coefficient of variation is a dimensionless number. The coefficient of rainfall variation thus illustrates how wide the spread of annual rainfall values is, recorded by municipalities. The larger the coefficient of variation, the more scattered the observed rainfall levels are on average. Specifically, they tend to be further from the average rainfall levels observed in the five years covered in the study. Rainfall variability indicators are computed at municipality level, implying that the values will be the same within municipalities but vary across municipalities.

The other control variables used in the empirical analysis include the value of unconditional grants allocated to municipalities by the national government (in thousands of rand); gross value added (GVA), in thousands of rand, which is an equivalent of GDP at municipal level; the municipality's population; the land area covered by each municipality; population density; the share of population that is less than 19 years old; the share of population that is over 65 years old; and the number of councillors in a municipality, which indicates the size of the local government. The definition and descriptive statistics of these variables are presented in Table 12.1.

Table 12.1: Definition and descriptive statistics of the variables used in the econometric model

Variable name	Variable definition	Mean	Std. Deviation	Obs.
Water	Municipal expenditures on water-related infrastructure and provision (in million rand)	39.92	118.80	678
Electricity	Municipal expenditures on electricity-related infrastructure and provision (in million rand)	24.21	98.72	646
Rainfall	Annual rainfall in millimetres	417.83	1348.86	443
Variance of rainfall	Variance of annual rainfall in millimetres	1.30E+06	1.23E+07	470
Standard deviation of Rainfall	Standard deviation of annual rainfall in millimetres	228.95	1118.26	470
Rainfall variability	Coefficient of variation of annual rainfall	0.44	0.30	470
Population	Number of persons in municipality	167356.50	380108.50	1285
Municipal area	Area covered by the municipality, in square kilometres	4626.27	4423.01	1350
Population density	Population/municipal area, persons per square kilometre	80.12	208.36	1260
Grants	Unconditional grants allocated to the municipality by the national government (in thousand rand)	4.87E+07	9.61E+07	1410
Gross value added	Gross value added (in thousand rand)	5592.33	23047.13	1310
Population under 19	Proportion of population under the age of 19	0.44	0.04	1285
Population over 65	Proportion of population over the age of 65	0.05	0.01	1275
Councillors	Number of councillors	31.41	28.99	1406

Source: Own calculations

Table 12.1 shows that an average municipality spends close to R40 million per year on water-related infrastructure and/or services and about R24 million per year on electricity-related services and infrastructure. The average annual precipitation, for municipalities where rainfall data was recorded, is 418 mm. Indicators reveal huge variability of rainfall across the years within municipalities, with an average coefficient variation of close to 44%. An average municipality covers around 4,626 square kilometres and is home to about 167,357 residents, an average population density of close to 80 persons per square kilometre. The GDP equivalent for each municipality, on average, is around R6 million, while the average unconditional grant received by municipalities from the national government is approximately R49 billion. In an average municipality, 44% of the population is below the age of 19 years old, while 0.5% is over 65 years old.

The variables discussed above are used to estimate equation (1). However, due to missing data for these variables, especially data on annual rainfall in most municipalities (as revealed in Table 12.1 column 5), the effective sample used in the estimations covers 74 municipalities for which comprehensive rainfall data was available.

12.5 Results and Discussion

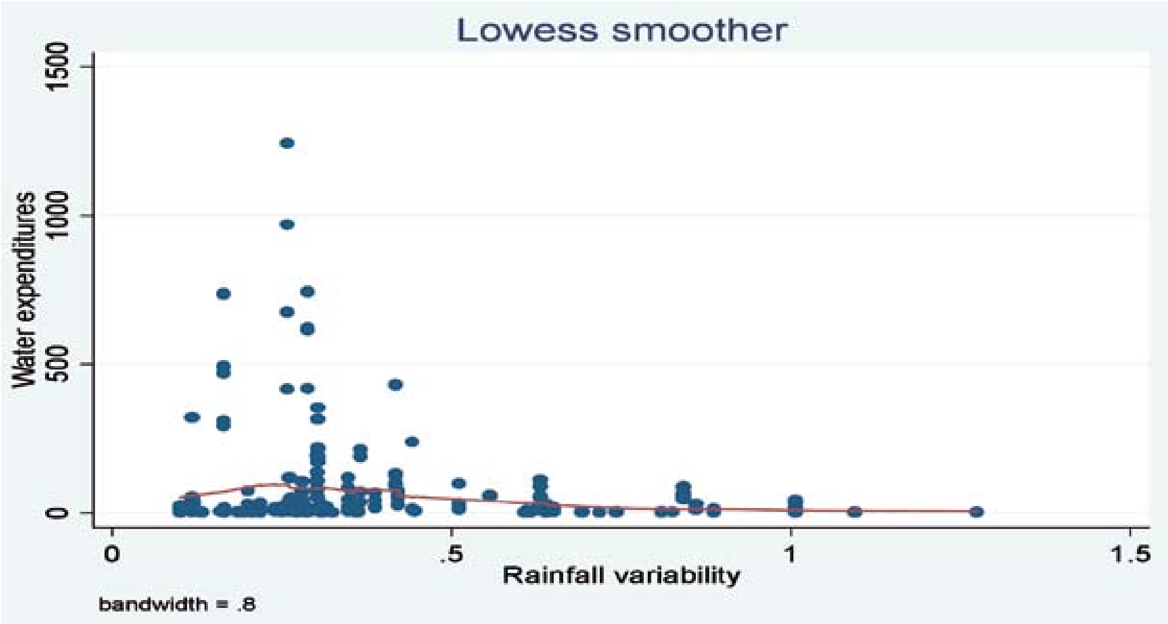
This section presents and discusses the results from econometric estimation of equations (1) to (3). A smoothing procedure provides an indication of how linear (or non-linear) the relationship is between municipal spend on water and electricity and climate variability as proxied by rainfall variability.

12.5.1 Rainfall variability and municipal expenditures: Lowess estimation

A non-parametric smoothing method, the locally weighted scatterplot smoothing (Lowess) estimation is conducted to examine whether the econometric relationship between municipal expenditures and rainfall variability to be estimated is specified correctly. This is a local linear regression estimator, which calculates a local estimate of the regression curve at each point by using only a neighbourhood of points, then weighting them according to how close they are to the point in question (Cleveland, 1979). Essentially it uses a rolling local average of the dependent variable over a wide window around each value of an independent variable to produce a smoother estimate. The bandwidth – the proportion of the full sample used in each regression – determines the range of the independent variable. Consistent with standard practice, this study uses 80% of the sample to run each regression (i.e. a bandwidth of 0.8).

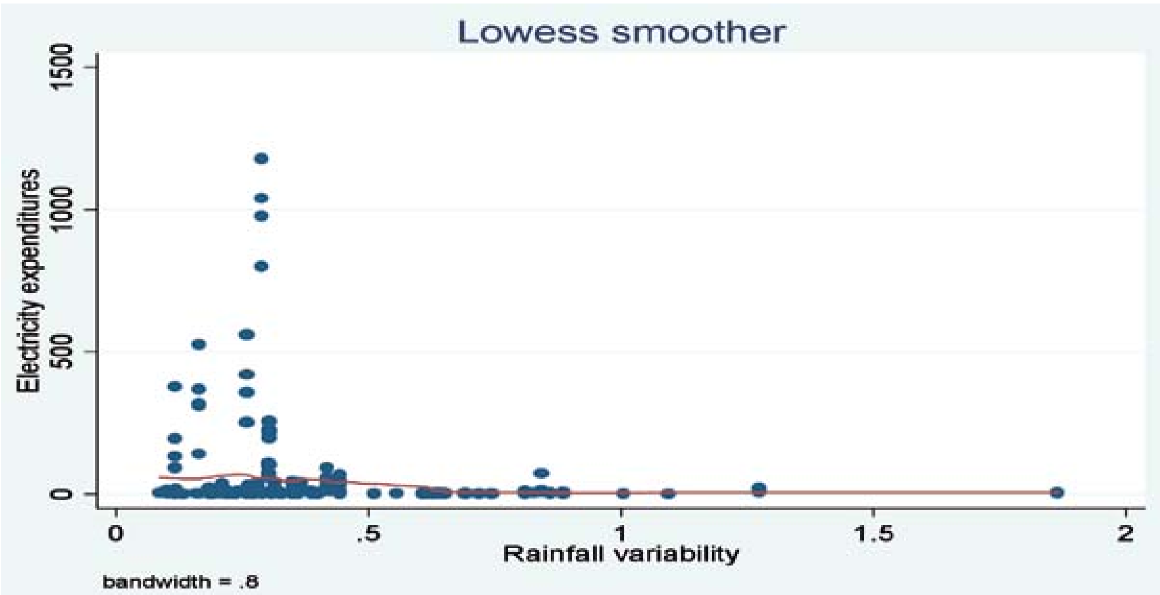
The advantages of using Lowess include: it imposes minimal structure on the data; it is locally robust, since far away observations in the sample have no influence on the estimated local relationship; it has a variable bandwidth range; and it uses a local polynomial estimator to minimise boundary problems (Cameron and Trivedi, 2005). Its major limitation is that it does not allow controlling for other possible determinants of municipal expenditures. Specific to this study, the Lowess estimator is used to give a smoother estimate based on a rolling local average of Water and Electricity over a wide window around each value of Rainfall Variability. The results of the Lowess smoothing procedure are presented in Figures 12.4 and 12.5 with Water and Electricity as dependent variables, respectively.

Figure 12.4 Lowess estimation of Water and Rainfall variability



Source: Own calculations

Figure 12.5 Lowess estimation of Electricity and Rainfall variability



Source: Own calculations

Figures 12.4 and 12.5 suggest a non-linear relationship between municipal expenditures on water and electricity and rainfall variability as proxied by the coefficient of variation of rainfall. An inverted U-shape or quadratic relationship is suggested. Accordingly, the square of Rainfall variability is introduced as an additional explanatory variable in the econometric models used to estimate the system of equations specified in (1). Arguably, the relationship between municipal expenditures and rainfall variability might not be as simple as Figures 12.4 and 12.5 suggest and might include non-climatic factors. Additional factors or variables that might affect municipal expenditures need to be controlled in order to isolate, as far as possible, the impact of rainfall variability on municipal expenditures. Given this, a multivariate econometric framework is used to further explore the relationship between expenditures and rainfall variability.

12.5.2 Rainfall variability and municipal expenditures: econometric evidence

As the discussion of the econometric model indicated, the econometric strategy employed to estimate the impact of rainfall variability on municipal water and electricity expenditures uses three model specifications: (i) common effects (essentially pooled OLS), (ii) fixed effects, and (iii) random effects models. However, as rainfall variability variables are indexed to municipalities, the fixed effects model cannot be estimated. That is, the fact that rainfall variability variables do not vary within municipalities indicates that a fixed effect model would naturally drop them from the estimation. Common and random effects estimations are carried out, using Water and Electricity as dependent variables and controlling for the explanatory variables specified in Table 12.1. The regression results for the common and random effects are provided in Table 12.2. Models (a) and (b) are from pooled OLS estimation of Water and Electricity, respectively, while models (c) and (d) are from random effects estimation of Water and Electricity, respectively. All these models use the coefficient of variation as an indicator of rainfall variability.

Table 12.2 Pooled and random effects regression results for water and electricity models

	Pooled OLS estimations		Random Effects estimations	
Variable	Water (a)	Electricity (b)	Water (c)	Electricity (d)
Rainfall variability variables				
Rainfall variability	237.226***	49.066***	244.541***	85.205**
	(69.064)	(17.508)	(92.446)	(38.415)
Rainfall variability squared	-200.216***	-27.458**	-205.123***	-51.157**
	(57.233)	(10.847)	(77.888)	(22.227)
Other control variables				
Population density	0.209***	0.333***	0.164**	0.213**
	(0.048)	(0.052)	(0.073)	(0.092)
Grants	0.000***	-0.000	0.000**	0.000***
	(0.000)	(0.000)	(0.000)	(0.000)
Gross value added	0.001	0.001***	0.002**	0.003***
	(0.000)	(0.000)	(0.001)	(0.001)
Population under 19	387.881**	127.980	438.444*	463.566**
	(194.104)	(100.720)	(226.915)	(206.776)
Population over 65	1,426.013**	37.068	1,121.671	70.388
	(684.580)	(354.962)	(1,253.787)	(658.798)
Councillors	-0.202	-0.771***	-0.960	-2.291***
	(0.324)	(0.280)	(0.613)	(0.671)
Dummy for 2006	15.620	11.950	17.120*	9.459**
	(13.473)	(10.317)	(9.685)	(4.611)
Dummy for 2007	24.437*	15.803*	22.845**	10.133**
	(14.121)	(9.439)	(10.206)	(4.325)
Dummy for 2008	31.652**	28.998***	25.381**	16.648***
	(13.747)	(10.751)	(10.671)	(6.237)
Dummy for 2009	10.080	44.673***	-3.058	7.846
	(15.712)	(14.826)	(16.000)	(9.636)
Constant	-303.255***	-72.562	-297.851**	-198.806*
	(114.025)	(55.133)	(140.264)	(103.742)
R-squared	0.737	0.864		
Wald X^2 (12)			64.07	210.61
ρ			0.5217	0.864
Breusch and Pagan Lagrangian multiplier test for random effects: $X^2(1)$			104.59	154.66
Observations	246	272	246	272
Number of municipalities			74	85

*Notes: Dependent variable for models (a) and (c): municipalities' expenditures on water. Dependent variable for models (b) and (d): municipalities' expenditures on electricity. Robust standard errors in parentheses; *** p<0.01, ** p<0.05, * p<0.1.*
Source: Own calculations

Breusch and Pagan Lagrangian multiplier tests for random effects are performed for both random effects specifications. These tests provide the statistical significance of the coefficient ρ which represents the proportion of the observed total variance of the error term due to random effects. The results of these tests support the hypothesised existence of random effects: the X^2 (1) is equal to 104.59 and 154.66 in the case of models *(c)* and *(d)*, respectively. This justifies the use of a random effects estimator.

The estimated coefficients for both the rainfall variability variables (rainfall variability and rainfall variability squared) for *Water* and *Electricity* models are statistically significant. These results indicate that increased variability of rainfall (a proxy for climate variability) is significantly associated with increases in municipal water and electricity expenditures, which implies that rainfall variability increases water and energy demand by municipalities. Specifically, a concave relationship between rainfall variability and municipal water and electricity expenditures is found. This suggests that after a threshold level of rainfall variability, the marginal impact of rainfall variability on municipal water expenditures and electricity expenditures starts to decline. The result is robust for Water and Electricity random effects model estimates, which show this threshold is around 0.6 for water expenditures and 0.8 for electricity expenditures.

Two interlinked explanations can be used to contextualise this result, particularly the increase in municipal expenditures that is associated with increased rainfall variability. The first explanation, and consistent with Mukheibir (2007), is that variability of rainfall complicates local government planning processes, particularly in relation to water and electricity supply and demand management. Increased rainfall variability introduces an element of uncertainty to municipal water and electricity demand/supply, and it becomes challenging for municipalities to plan for times of severe rainfall variability (e.g. drought and/or floods).

Altered water balance affects water resources, which means that municipal water-related infrastructure and water provision services must adapt to the changes in water demand and supply. In some cases this could involve changing municipal water management strategies.

Rainfall abundance determines the management, distribution and use of electricity by municipalities, suggesting that rainfall variability may require municipalities to adapt to electricity-related services and infrastructure; most particularly when changes in energy resources affect the electricity demand–supply gap.

Adaptive behaviour will result in changes to municipality expenditure on water and energy sectors, suggesting that increased rainfall variability should be treated as an increased risk to residents. Municipalities should respond to this increased risk by investing in water- and electricity-related infrastructure and/or water and electricity provision channels to protect residents. Furthermore, results suggest that local government's response to increased climate variability is non linear, as municipalities will only increase water expenditures up to a certain threshold, after which such investments will decline.

The second explanation relates to the use of water and electricity expenditures as proxies for water and electricity demand by municipalities (water and electricity that is distributed to consumers). As indicated above, increased variability of rainfall reflects increased risks associated with rainfall/water scarcity. This translates into increased risks (fluctuations) in the provision of services that are dependent on rainfall; in this particular case municipal provision of water- and energy-related services and/or infrastructure. Water and electricity demand will rise as municipalities attempt to smooth water and electricity supply or distribution to their residents. The increased water and electricity demand is shown to be non linear: municipalities will only increase water expenditures up to a certain threshold, after which demand declines.

12.5.3 Rainfall variability and municipal expenditures: simulation results

The empirical estimates reported in Table 12.2 were used as inputs to simulate the average level of municipal expenditures on water and electricity for given rainfall variability levels. The rainfall variability values range between zero and two for simulation of municipal expenditures, as the rainfall variability indicator – the coefficient of variation of rainfall – in the data ranges from 0.087 to 1.861. The results obtained from the simulation are reported in Figure 12.6.

Figure 12.6 supports the quadratic relationship between municipal expenditures and rainfall variability revealed in Table 12.2. This result is robust to simulations based on both pooled OLS and random effects estimates. Both Figure 12.6a and Figure 12.6b suggest that low levels of rainfall variability are associated with increased average municipal expenditures on water and electricity. However, for water expenditures, this changes when the coefficient of variation value reaches somewhere between 0.6 and 0.75, when increased variability starts to be associated with reduced average water expenditures. The turning point for electricity expenditures is reached when the coefficient of variation is somewhere between 0.85 and 1.

Figure 12.6 Predicted average expenditures for different levels of rainfall variability

Figure 12.6a Predictions based on pooled OLS estimates

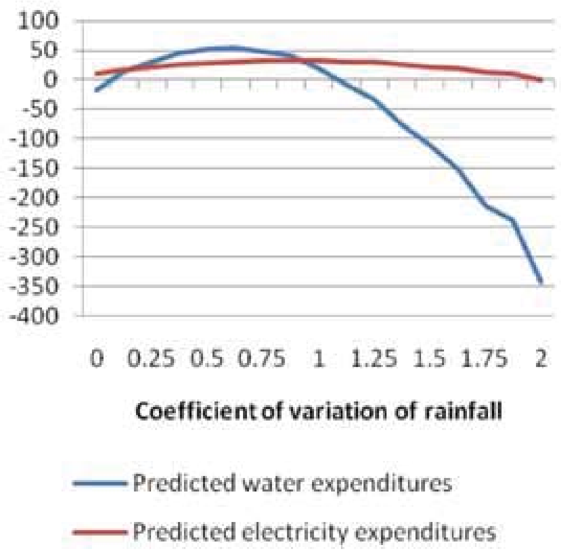
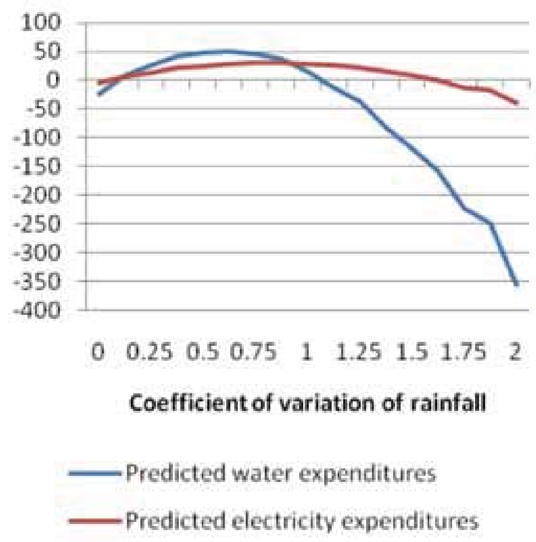


Figure 12.6b Predictions based on random effects estimates



Source: Own calculations

Figure 12.7 complements Figure 12.6 by showing how the predicted municipal expenditures reported in Figure 12.6 change from one level of rainfall variability to another. The results indicate that rainfall variability is expected to influence future municipality expenditure levels strongly. The change in predicted expenditures declines with the level of rainfall variability, for the averages of both water and electricity expenditures. Interestingly, Figure 12.7 suggests that water expenditures change faster than electricity expenditures, which is consistent with the turning point revealed in Figure 12.6: the rainfall variability value where the level of waters expenditures begins to decline is reached faster than that of electricity expenditures. As variability goes beyond a certain threshold, both Figure 12.6 and Figure 12.7 could easily be interpreted as suggesting some form of disinvestment in water and electricity by municipalities. However, in real life, disinvestment might not be seen as a viable strategy, which implies that the high levels of uncertainty associated with high levels of rainfall variability pose a challenge and difficulty for municipal planning processes. Low levels of investment or expenditure in water and electricity may result, but will not necessarily be from a deliberate policy to disinvest in these sectors. Nevertheless, the high decrease in predicted water expenditure attributed to increasing rainfall variability implies that municipalities lack the appropriate adaptation strategies, which makes them vulnerable to the climatic change.

Figure 12.7 Changes in predicted average expenditures for different levels of rainfall variability

Figure 12.7a Changes in predicted expenditures based on pooled OLS estimates

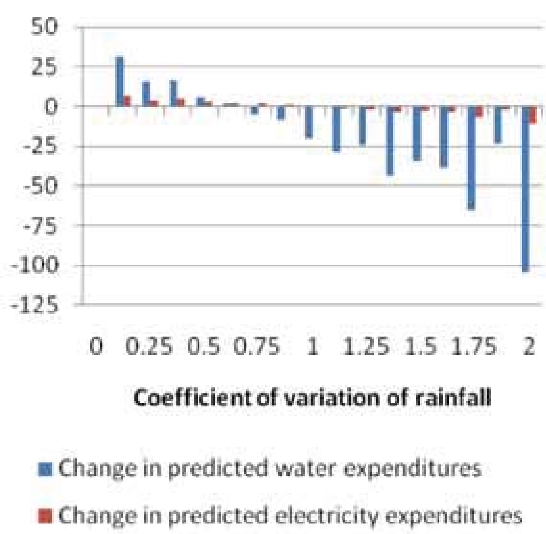
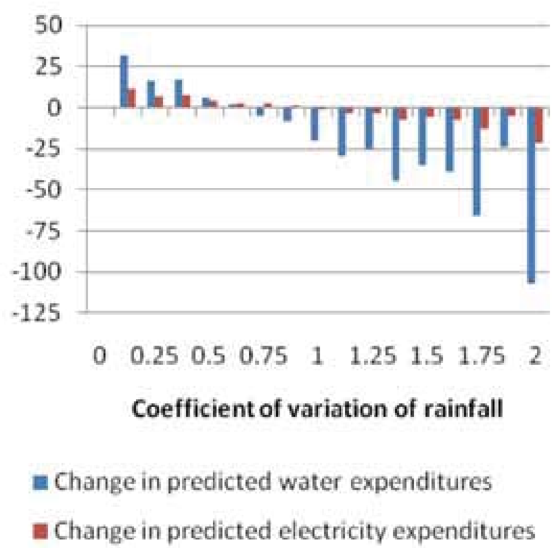


Figure 12.7b Changes in predicted expenditures based on random effects estimates



Source: Own calculations

Overall, these results from the Lowess smoothing, econometric estimation and post-estimation simulation suggest that climate variability and change affect South African municipalities. In particular, South African municipalities must change water resource and electricity management strategies to satisfy changes in water and electricity demand and supply associated with climate change and variability. Climate variability and change will pose challenges for municipalities to reconcile water and electricity supply and demand, in the short and long term. In the short term (for periodic drought or short-term water shortages) municipalities will have to develop coping strategies. Long-term responses will have to involve adaptation strategies to build resilience to the impacts of climate variability and change in municipalities. Either way, climate variability and change has real financial implications on (South African) municipalities. Therefore, municipalities, along with other relevant stakeholders, need to be involved in efforts to mitigate and adapt to climate variability and change. However, it is important to remember that municipalities differ and that they have different development objectives and trajectories, which should be taken into account to promote relatively sustainable and feasible ways to 'green' municipalities.

12.5.4 Other correlates of municipal expenditures

Municipal expenditure on water- and electricity-related infrastructure and services is affected by factors other than the climate (rainfall variability). The results suggest that population densities have a positive and significant impact on water and electricity expenditures. While increased population density can be expected to reduce the per unit cost of water and electricity service delivery, it might increase some costs, especially in very large cities (Kushner *et al*., 1996).

The results also show the importance of GDP on municipality water and electricity-related expenditure. As expected, the higher the income at the municipality's disposal, the higher the expenditure on water and electricity-related infrastructure and/or services. This is because the two variables that are used as proxies for available municipal income – the level of unconditional grants municipalities get from the central government and the GVA or municipal GDP – influence water and electricity expenditures positively and significantly.

The composition of population also affects municipal water and electricity expenditures. Consistent in both models (c) and (d) is the finding that water and electricity-related expenditures increase with the share of population under the age of 19, but are not affected significantly by the share of population over 65. This could suggest that municipalities respond to the differences in the needs of different population groups through changes in expenditure, and the response is primarily driven by the needs of the younger population.

Increasing the number of councillors (model (d)) has a significantly negative impact on electricity expenditures. This result could be pointing at competing use of financial resources: the more money spent on maintaining a local government consisting of many councillors means less is available for other uses, particularly for electricity-related services and/or infrastructure.

The dummy variables for the different years suggest that time-variant factors are not explicitly controlled in the estimations, but they significantly determine the level of monetary resources spent on the water sector. Specifically, models (c) and (d) indicate that, on average, municipalities spent more on the water and energy sector in the years 2006, 2007 and 2008 than in 2005.

12.6 Dealing with Climate Change in the Local Government Sector

South African municipalities already face a number of pervasive problems with water and electricity provision: water and electricity losses as the result of aging infrastructure, illegal connections, inappropriate pricing, and poor water quality. Water and energy resources are central drivers of local government growth and development and must be used efficiently, in order to help minimise costs that municipalities incur as a result of climate variability and change-related impacts on water and energy demand and supply.

Water loss must be minimised, as water loss in South Africa is significant (Table 12.3). Unaccounted-for water represents about 30% of the total water demand in South Africa. Water losses of this magnitude may be a result of aging infrastructure,[173] and so it is vital that mechanisms (and adequate budgets) are put in place to minimise incidences of poor maintenance.

173 A study conducted in parallel with this report indicates that the repair and maintenance of infrastructure by many municipalities is at a low level. In addition, the budget allocated for the repair and maintenance is remarkably low.

Table 12.3 Distribution of water

	Municipality Category				Total
	A	B1	LW	DW	
Water sold	1,299,702	498,567	342,738	499,999	2,641,004
Residential customers	907,989	386,523	299,392	440,156	2,034,060
Non-residential customers	391,713	112,044	43,346	59,842	606,945
Unaccounted-for water	557,015	213,671	146,888	214,285	1,131,859
Bulk water requirement	1,856,716	712,238	489,625	714,284	3,772,863

Notes: A = metropolitan municipalities; B = local municipalities with the highest operating budgets and a large urban spatial pattern; LW = local municipalities with water service powers; DW = district municipalities with water and sanitation service powers and functions.
Source: PDG, 2010

Local authorities need to become champions of energy efficient[174] initiatives, to promote the adoption of renewable energy in their municipalities and to encourage energy efficiency in building and construction, agriculture and forestry, alternative energy efficient transportation, recycling and proper waste management (the 13th Finance Commission, 2009). Municipalities need to deal proactively with the consequences of climate change. The econometric results suggest that rainfall variability increases municipal water and energy-related expenditures. Therefore, to tackle the consequences of climate change on the water and energy sectors, a number of instruments, including the budget, can be applied. For instance, clean environmental objectives could be mainstreamed into the budget ('greening' budgets). In this case, the intergovernmental fiscal relations framework is used to encourage innovative approaches to environmental management, and to reward good environmental performance (ibid.). For example, local authorities can use their budgets (e.g. taxes and subsidies) to influence sustainable energy production and consumption.

12.6.1 Environment-friendly instruments

Subsidies

Subsidies are an important mechanism for achieving environmental goals. Subsidies can be used to encourage the production of eco-friendly goods and services or discourage the production of goods that harm the environment. In South Africa, green initiatives could be encouraged through subsidising, researching and developing eco-friendly technologies. The cost of such subsidies can be recouped by taxing competing, non-environment-friendly technologies.

Transfers

Grants are also a potent mechanism for driving the eco-friendly agenda. Lessons from the 13th Finance Commission (2009) are useful for the South African local government sector. In India, grants have been used to reward good environmental performance and environmentally-sound programmes. In South Africa, the government should consider establishing a separate, special-purpose conditional environmental grant that would seek to achieve the following:

- Reward and encourage environment-friendly actions and performances in the local government sphere.
- Provide for repair and maintenance and rehabilitation of water and energy infrastructure.
- Build capacity to address climate change management in local government.
- Provide minimum environmental protection services.
- Fund research into best adaptation and mitigation practices and new environment-friendly technologies (especially water- and energy-efficient technologies), waste management, green building, etc.

When establishing a separate special purpose environmental grant, attention should be given to its design: the grant should be sensitive to factors such as the municipality's size, topography, vulnerability and risk to climate-related hazards.

174 Energy efficiency means minimising energy wastage, using less energy to perform the same activities and shifting to cleaner energy sources.

Green public procurement

As municipalities are the main buyers of goods and services in their areas, mainstreaming environmental concerns in their procurement policies can promote a clean environment. In green procurement (also known as sustainable procurement or green tendering), public authorities deliberately and strategically procure eco-friendly goods and services from a selection of environmentally conscious suppliers or contractors. Public officials can also set environmental requirements in procurement contracts. Cities can be turned into 'green' zones through easing the development of, and sustaining, environmentally sensitive markets.

Adaptation and mitigation

The burden imposed by climate change means that municipalities need to minimise its impact by putting in place appropriate adaptation and mitigation plans and mechanisms. Some municipalities already have functional climate change adaptation and mitigation strategies in place, for example Cape Town and eThekwini (McKenzie, 2011). In developing adaptation and mitigation mechanisms, municipalities need to take the following into account.

Sound analysis of climate change at municipality level

Rigorous analysis of climate change impacts is required. Municipalities should endeavour to develop their own municipal-level risk analysis, which includes identifying primary and secondary hazards, assessing relative exposure and vulnerability of the population, and analysing institutional capacities. This analysis will then support their adaptation and mitigation plans and strategies. An understanding of the individual impacts is important for crafting municipal-level adaptation and mitigation strategies.

Adequate financing of adaptation and mitigation

Successful and sustainable adaptation and mitigation depend on sustainable financing. Elsewhere in the world, 'climate change' grants have been used to fund adaptation and mitigation strategies and programmes. Climate or environmental grants can also be considered in the case of the South African local government sector. In addition, municipalities themselves need to consider budgeting for adaptation and mitigation programmes, as climate change disasters are becoming more frequent and intense. Collective financing could be considered in cases of budgetary or capacity constraint.[175]

Timely and adequate information, communication and awareness

Both short- and long-term impacts of climate change must be understood and communicated to individuals and organisations that are likely to be affected by climate change. Timely and adequate information will minimise uncertainties that often surround climate change issues.

Community involvement

Local communities should be involved in mitigation and adaptation programmes and projects, so that the sustenance of the projects and programmes will be guaranteed.

12.7 Conclusions and Recommendations

Climate change poses a real threat to municipalities in South Africa, especially to water and energy security at the local government level. Therefore, local governments need to be proactively involved in local, national and global efforts to adapt to and mitigate climate change impacts. Individual municipalities need to understand and establish their climate change impact assessments, taking into account their specific conditions and circumstances. This will give rise to the crafting and implementation of effective, efficient and well-targeted policy measures and programmes.

175 This means pooling resources to finance a common activity.

This chapter makes the following recommendations:

- The government should ensure that municipalities develop their own climate change mitigation and adaptation strategies and plans as part of the Integrated Development Planning process. Government should provide support to municipalities over the next three years, distinguishing between different types of municipality by both location and capacity in terms of the mandatory requirements placed on them.
- The government should consider providing performance-based conditional grants to municipalities. Such grants should reward and encourage environmentally efficient action and response to the adaptation and mitigation challenges of climate change. The design of the proposed grant should pay attention to municipality-specific factors such as area, topography, coastal/or otherwise, and vulnerability to climate change. Specific focus areas for this grant should include:

  i. Efficient water management practices, including the minimisation of water losses (unaccounted-for water), effective asset management or rehabilitation programmes, and demand management;

  ii. Efficient energy management practices, including the minimisation of electricity losses (unaccounted-for electricity), the elimination of illegal connections and energy savings by households and industry; and

  iii. The implementation of green procurement principles.

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