Towards sustainability: reducing energy consumption and carbon emission footprints – examples and lessons learned from Potchefstroom, a medium sized African city

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Abstract

Less than 200 years since human beings began emitting greenhouse gas (GHG) emissions, global concentrations of these gases are increasing at an alarming rate. As a result of the acceleration in the rate of GHG emissions, the total concentration of GHG’s in the atmosphere has increased by 30% since pre-industrial times. Especially since the late eighties the international community became increasingly concerned with the future impacts of anthropogenic GHG emissions. Scientists are predicting that increases in GHG levels may result in elevated average global temperatures, changes in regional precipitation rates, increased incidence and intensity of extreme weather events, and a rise in sea levels. It is also predicted that anticipated changes in climate patterns will detrimentally affect cities and urban areas. Changes in precipitation will adversely affect urban water supplies, while an increase in extreme weather events may damage urban infrastructure, and higher sea levels will eventually inundate infrastructure and settlements in many coastal cities. Local governments, therefore, are challenged to acknowledge and address their contributions to the long-term risks posed by climate change, as well as to realise the multiple benefits of cleaner and more efficient energy consumption practices. Through their leadership roles and decision-making powers, local governments directly influence and control many activities that generate GHG emissions. If the issue of climate change is to be addressed successfully, then the reduction of GHG emissions must also be addressed at the local level. One of the most efficient scenarios to reduce the GHG footprint of cities in the developing world
is to adopt and implement strategies and practices that are more efficient. This article explains advances made by the city of Potchefstroom, South Africa, to reduce its GHG emission footprint, while financial resources are also saved that may be utilised for social development programmes.

1 Introduction

In December 1997, the Third Conference of the Parties (COP3) to the United Nations Framework Convention on Climate Change was held in Kyoto, Japan. At the Kyoto Protocol, 160 countries reached an agreement, whereby the world’s developed countries pledged to collectively reduce their GHG emissions to an average of at least 5.2% below 1990 levels, in the commitment period 2008 to 2012 (Worthington & Sherman [1]). Developing countries were granted some extension before the global targets apply to them. South Africa acceded to the Kyoto Protocol in the beginning of 2002.

The current resource needs of cities, as well as their pollution levels, their contribution to GHG emissions and waste generation capacity, including rapid population growth rates in developing countries, are inherently unsustainable when compared to declining yields of their resource bases. Cities in the developing world are also characterised by poor air quality profiles that negatively impact on both quality of life and investor confidence.

Administrators of cities in developing countries increasingly acknowledge that they need to become as innovative as their colleagues in the private sector to pro-actively reduce the ecological footprints of their activities, services and facilities, and to improve the quality of life of their citizens while they grow their local economic base.

The biggest challenge is to get mayors and councillors excited about sustainability issues in view of other pressing socio-political and socio-economic issues and priorities (Bilodeau & Nel [2]).

One possible strategy to excite decision-makers at the local level in the developing world to support sustainability programmes, is to combine programmes that aim to achieve improvements in environmental management performance, with opportunities to save costs, create jobs, transfer skills and reduce poverty (Nel [3]).

2 Cities and global warming

The twenty-first century is the first true urban century. More than fifty per cent of the world’s population will be living in cities and up to seventy five per cent of all production will occur in urban areas. The ecological footprint and resource needs of modern, industrial cities are orders of magnitude larger than the areas covered by cities. Cities are therefore heavily subsidised by surrounding rural areas as far as resource needs are concerned.

Energy demands in the rapidly growing cities of the developing world, are set to soar (Sullivan [4]). Increases in energy needs will have devastating
environmental impacts as is illustrated by the ecological footprint of generating one kWh of electricity in South Africa (Eskom [5]). (See Table 1.)

One of the more elegant strategies to reduce GHG emissions generated by cities is to improve the energy efficiency of facilities and activities that are either controlled or influenced by local authorities. (Sullivan [4]).

Table 1: Environmental footprint of generating one kilowatt-hour of electricity in South Africa.

<table>
<thead>
<tr>
<th>Element</th>
<th>Unit</th>
<th>Conversion rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water usage</td>
<td>Litres</td>
<td>1.21</td>
</tr>
<tr>
<td>Coal usage</td>
<td>Kilograms</td>
<td>0.49</td>
</tr>
<tr>
<td>Ash produced</td>
<td>Grams</td>
<td>130</td>
</tr>
<tr>
<td>Ash emitted</td>
<td>Grams</td>
<td>0.35</td>
</tr>
<tr>
<td>SO₂ emissions</td>
<td>Grams</td>
<td>7.95</td>
</tr>
<tr>
<td>NOₓ emissions</td>
<td>Grams</td>
<td>3.56</td>
</tr>
<tr>
<td>CO₂ emissions</td>
<td>Kilograms</td>
<td>0.85</td>
</tr>
</tbody>
</table>

3 ICLEI’s Cities for Climate Protection (CCP) Programme

The city of Potchefstroom, South Africa, joined the Cities for Climate Protection (CCP) Programme of the International Council for Local Environmental Initiatives (ICLEI) in 2001 (ICLEI [6]). This program is a performance-oriented campaign that offers local governments a framework for developing a strategic agenda to reduce their GHG and air pollution emissions, with the added benefit of improving living conditions of local communities.

The CCP Programme provides local governments with a milestone framework, helping them to identify their GHG emissions, set reduction targets and develop and implement action plans to reach their targets.

The CCP milestones are:
- Conduct a GHG emissions inventory of current council and community activities and forecast growth in GHG emissions in the future;
- Establish a GHG emissions reduction goal;
- Develop a local action plan;
- Implement the local action plan;
- Monitor and report on the implementation of the local action plan.

One of the corner stones of any city’s CCP programme is improvement in energy efficiency rates.
4 The city of Potchefstroom's base case energy demand and GHG footprint

The annual contribution to CO₂ emissions by the different energy users in the city of Potchefstroom from 1995 to 2002, is listed in Table 2.

Table 2: The annual contribution to CO₂ emissions by the different energy users from 1995 to 2002.

<table>
<thead>
<tr>
<th>Year</th>
<th>Total electricity CO₂ emissions (Ton)</th>
<th>Total petrol CO₂ emissions (Ton)</th>
<th>Total diesel CO₂ emissions (Ton)</th>
<th>Total CO₂ emissions (Ton)</th>
<th>Methane recovery (Ton)</th>
<th>Total Methane recovery diesel emissions (Ton)</th>
<th>Total CO₂ emissions (Ton)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1995</td>
<td>16 938</td>
<td>594</td>
<td>801</td>
<td>13 095</td>
<td>287</td>
<td>31 715</td>
<td></td>
</tr>
<tr>
<td>1996</td>
<td>18 626</td>
<td>556</td>
<td>815</td>
<td>13 753</td>
<td>302</td>
<td>34 052</td>
<td></td>
</tr>
<tr>
<td>1997</td>
<td>19 261</td>
<td>667</td>
<td>854</td>
<td>14 390</td>
<td>316</td>
<td>35 488</td>
<td></td>
</tr>
<tr>
<td>1998</td>
<td>17 899</td>
<td>687</td>
<td>872</td>
<td>15 048</td>
<td>331</td>
<td>34 837</td>
<td></td>
</tr>
<tr>
<td>1999</td>
<td>16 856</td>
<td>670</td>
<td>852</td>
<td>15 706</td>
<td>345</td>
<td>34 429</td>
<td></td>
</tr>
<tr>
<td>2000</td>
<td>16 811</td>
<td>679</td>
<td>866</td>
<td>16 364</td>
<td>359</td>
<td>35 079</td>
<td></td>
</tr>
<tr>
<td>2001</td>
<td>16 453</td>
<td>685</td>
<td>876</td>
<td>17 021</td>
<td>374</td>
<td>35 409</td>
<td></td>
</tr>
<tr>
<td>2002</td>
<td>16 822</td>
<td>683</td>
<td>879</td>
<td>717</td>
<td>0</td>
<td>19 101</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>139 666</td>
<td>5 221</td>
<td>6 815</td>
<td>106 094</td>
<td>2 314</td>
<td>260 110</td>
<td></td>
</tr>
</tbody>
</table>

The calculations were made by Guillaume Nel, the Potchefstroom CCP Programme Intern.

5 Projects implemented to achieve Potchefstroom's GHG reduction targets

The city of Potchefstroom identified a number of projects to reduce its contribution to GHG emissions. Improvements in energy efficiency and hence reductions in the city’s contribution to GHG emissions are based on the 1995 base case. (See Table 2.)

Some of the projects ensure improvements in the energy efficiency of various facilities, while others ensure reductions in GHG emissions through CO₂ sequestration, as well as reduction in emissions of CO₂ equivalents by means of methane recovery. At the time of writing some of these GHG reduction projects
have been concluded, while others are ongoing and new projects are investigated and planned.

The energy efficiency projects include: improvements in energy efficiency at the airport, street lighting as well as new council buildings.

5.1 Improvement of energy efficiencies by upgrading streetlights

Two projects have been identified to improve the energy efficiency of street lighting in the city. It is common knowledge that HPS light emitters are the most efficient light source available for use in area lighting. This is calculated as the amount of light generated compared to the power consumption of a specific light emitter. Another benefit of HPS emitters is that they have a very good life span with good lumen maintenance.

The first street light project in Potchefstroom entailed replacement of outdated light emitter technologies with more energy efficient emitters in the city’s main thoroughfares. The second project, however, focused on making street lighting in residential areas more efficient. The latter is a pilot project to verify social acceptance of the new more efficient technologies (Nel, Snyman & Nel [7]).

5.1.1 Thoroughfares

A total of 7 334 (seven thousand three hundred and four) 200 Watt incandescent streetlights have been upgraded with 125 Watt Mercury Vapour (MV) and 70 Watt High Pressure Sodium (HPS) light emitters in the thoroughfares in Potchefstroom. With Mercury Vapour light emitters an average energy saving of 23% was achieved, while High Pressure Sodium light emitters yield an average energy saving of 50.5%. In monetary terms savings in energy bills amount to an average annual saving of ZAR84 762.65. (US$8 500.00) while a saving of 334 300 kg of CO₂ is achieved. Currently 99% of all streetlights in thoroughfares have been replaced with more efficient light emitters. Only 640 incandescent streetlights still exist in the city of Potchefstroom.

5.1.2 Pilot study: Residential area

The city engineers were reluctant to replace existing 200 Watt incandescent or 125 Watt MV light emitters with 70 Watt HPS light emitters, as they argued that HPS emitters have an unacceptable colour rendering index (Cri), as the true colour of objects are not rendered. It is generally argued that people prefer white lights in residential areas that enhance recognition of colour. It is also argued that the monochromatic nature of HPS lamps inhibits perception of the three-dimensional properties of objects, making it difficult to recognise for instance facial features. Therefore it was argued by the city engineers that retrofitting of inefficient light emitters in residential areas need to be done with circumspection, as public opposition against such retrofits may result. It was decided to identify a pilot project to test social acceptance of the more efficient HPS light emitter technologies.
A residential area was identified for a pilot project to replace 200 Watt incandescent streetlights with 70 Watt HPS light emitters. A total number of 110 streetlights were replaced at a cost of R65 700.00 (US$6570.00), excluding labour. A saving of 1 765 kWh per month is achieved. The projected annual savings in CO₂ amounts to 18 000 kg. (See the Eskom conversion rates in Table 1). This project will be evaluated after completion to compare actual savings in kWh to performance factors, resident complaints and other specifications.

If the outcome of the evaluation is positive, further upgrading of residential streetlights will be done. A further 1 330 incandescent streetlights will be upgraded with 70 Watt HPS light emitters at a cost of R650.00 per streetlight. The estimated additional energy saving will be 16.5 kWh per streetlight per month.

The total amount of CO₂ saved annually as a result of upgrading of inefficient street light emitters, amounts to 362 103 kg. In monetary terms the savings amount to R91 759.00 (US$9 176.00) per year.

5.1.3 Retrofitting of the airport runway and taxiway with energy saving light emitters

In 2001 and 2002 the airport runway was retrofitted with energy saving light emitters. This installation heralded the end of the airport being labelled as "no lights available". The retrofitting is complete and operational. Actual energy saving in the first year was 58 251 kWh or ZAR11 921.00 (US$1 192.00) with a saving of 48 614 kg of CO₂ per year.

Deployment of a wind turbine at the airport is under investigation to reduce reliance on fossil based energy even further.

5.2 Incorporating energy efficiency specifications into the design plans of new municipal buildings

The design specifications of the new Municipal Council Building were audited against the new South African Energy and Demand Efficiency Standard (SAEDS) (Grobler & Van der Merwe [8]). SAEDS is an energy efficiency guideline for new and existing commercial buildings. The purpose of the SAEDS is to reduce energy consumption and/or demand of buildings. Following the SAEDS audit, modifications to design specifications were made to ensure that the new building is a hundred per cent in conformance with SAEDS requirements. These modifications achieved an annual saving of 14 000 kg of CO₂ or ZAR2 670.00 per year. In future all new council buildings will conform to the SAEDS requirements.

5.3 Alternative energy sources: Recovering methane from the sewage treatment plant

Recovery of methane from the sewage treatment plant is the biggest contributor to the GHG reduction program in Potchefstroom. Methane is recovered from the
sewage works before being emitted to atmosphere. The recovered energy source is used to incinerate solid screenings of the inlet to the sewage treatment works. The incinerator used previously was fired by diesel. Generation of methane is controlled to ensure that just enough methane is generated to meet the needs of the incinerator. As incineration demand increases, more methane will be generated under controlled conditions. As a result of improved control over methane generation, significantly less methane is generated when compared to previous arrangements. (See Table 3.)

Table 3: Old and new wastewater treatment plants: biogas generation.

<table>
<thead>
<tr>
<th>Type of biogas emissions</th>
<th>Old plant configurations</th>
<th>New plant configurations</th>
</tr>
</thead>
<tbody>
<tr>
<td>CH₄</td>
<td>2 289.60 kg/day</td>
<td>471.43 kg/day</td>
</tr>
<tr>
<td>SO₂</td>
<td>70.35 kg/day</td>
<td>41.64 kg/day</td>
</tr>
<tr>
<td>CO₂</td>
<td>2 140.80 kg/day</td>
<td>667.90 kg/day</td>
</tr>
<tr>
<td>Total biogas emissions</td>
<td>4 500.75 kg/day</td>
<td>1 180.97 kg/day</td>
</tr>
</tbody>
</table>

The calculations were made by Guillaume Nel, the Potchefstroom CCP Programme Intern.

According to Lennon [9], the CO₂ equivalent of methane (CH₄) is a CH₄ to CO₂ ratio of 1:21. The total improvement in GHG efficiencies that are attributed to upgrades made at the sewage treatment works amount to a saving of 16 304 000 kg of CO₂ equivalents/year.

The following parameters were also considered when the total contribution of methane recovery to improved performance in GHG emissions was calculated:
- Contribution of CO₂ generated by the sewage treatment process;
- CO₂ generated as a result of methane combustion;
- Improved efficiencies due to incineration of sewage screens using methane in stead of diesel as fuel;
- Increased energy demand by the aerators to control methane production.

This project elegantly combines financial savings with improvements in environmental performance as well as replacing a fossil fuel with a sustainable energy source that would otherwise have had a very detrimental impact on the environment.

6 Non-energy based CO₂ sequestration

The city of Potchefstroom embarked on a tree planting campaign in the poorer suburbs of the city to enhance the leafy character of the city. At the time of writing a total number of 4 405 trees have been planted since 1996 and a total of 14 208 kg of CO₂ is sequestrated annually.
7 Total improvements in energy efficiencies and performance in GHG reduction

The total improvement in GHG reduction achieved by the city of Potchefstroom is listed in Table 4. The total reduction of CO₂ emitted by the city amounts to 16 733 196 kg/year or a reduction of 39.8% as measured against the base case footprint of 1995. (See Figure 1.)

Table 4: The total amount of CO₂ saved by the Potchefstroom CCP projects.

<table>
<thead>
<tr>
<th>Facility</th>
<th>Project cost (ZAR)</th>
<th>Project cost per kg CO₂ saved in the first year (ZAR)</th>
<th>CO₂ saved per year in kg</th>
<th>% Savings</th>
<th>ZAR savings per year</th>
</tr>
</thead>
<tbody>
<tr>
<td>Replacement of streetlights</td>
<td>608 350</td>
<td>1.82</td>
<td>334 331</td>
<td>2</td>
<td>84 762</td>
</tr>
<tr>
<td>Retrofitting of airport</td>
<td>735 700</td>
<td>15.12</td>
<td>48 657</td>
<td>0.35</td>
<td>12 021</td>
</tr>
<tr>
<td>Retrofitting of Mieder Park streelights</td>
<td>175 650</td>
<td>9.75</td>
<td>18 000</td>
<td>0.15</td>
<td>6 997</td>
</tr>
<tr>
<td>Tree planting (accumulating each year)</td>
<td>162 800</td>
<td>13.02</td>
<td>14 208</td>
<td>0.04</td>
<td>No monetary saving</td>
</tr>
<tr>
<td>Recovery of methane from sewage works</td>
<td>2 206 000</td>
<td>0.13</td>
<td>16 304 000</td>
<td>97.43</td>
<td>453 600</td>
</tr>
<tr>
<td>New mayoral wing</td>
<td>No extra cost</td>
<td>No extra cost</td>
<td>14 000</td>
<td>0.03</td>
<td>2 670</td>
</tr>
<tr>
<td>Total</td>
<td>3 888 500</td>
<td></td>
<td>16 733 196</td>
<td>100</td>
<td>560 050</td>
</tr>
</tbody>
</table>

The calculations were made by Guillaume Nel, the Potchefstroom CCP Programme Intern.

8 Future energy management projects

The city of Potchefstroom has identified two new projects that will reduce the city’s contribution to GHG emission even further, while energy efficiencies are significantly improved. The first project entails investigation of and improvements in current energy inefficiencies of existing council buildings and facilities such as the water treatment works, pumping stations as well as sewage treatment works. This project is planned and to be implemented in association with a Canadian service provider.

The other project entails introduction of greener fleet management principles whereby energy efficiency of the city’s fleet will be improved as well.
Improvements in energy efficiency – lessons learned from a medium sized African city

Adoption and implementation of the Cities for Climate Programme by the city of Potchefstroom resulted in a reduction of its CO$_2$ footprint by 39.8% when compared to the 1995 base case scenario at the time of writing. Improvements in energy efficiencies by the city that include street lights, the new council chambers, the airport and methane recovery amount to 99.96% of the total amount of CO$_2$ that has been reduced.

Should the CO$_2$ be traded internationally at the conservative price of US$5.00/ton the city can generate an additional income of US$47 221.50/year. In addition to that, improved energy efficiencies in the city amounts to a saving of US$56 000/year that can be utilised for socio-economic development projects.

10 Conclusions

The combined impact of improvements in environmental performance by the city with financial savings, have excited political decision-makers and city officials to the extent that environmental performance is a fixed agenda point on council meetings. City decision-makers have also launched other sustainability and environmental performance projects as a direct outcome of the successes achieved by the CCP programme.

Improvements in energy efficiencies have been the catalyst for transforming the city of Potchefstroom to become a green city. Experience in the city of Potchefstroom has shown that improvements in energy efficiencies
may be achieved very cost effectively, while return on investment is excellent.

Improvements in energy efficiencies may also be used in other cities in developing countries to be the appetiser of low hanging, sweet fruit that may be offered to decision-makers to convince them to embark on the journey of improved environmental performance that would otherwise have had a very low priority when compared to other challenges.

References


