Analysis of the Clean Development Mechanism

As a Vehicle for Achieving

Sanitation Objectives of the UN Millennium Goals

By

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Abstract

The UN Millennium Development Goals identified sanitation objectives as being fundamental to stopping the downward spiral of impoverished nations. This basic improvement is so important to quality of life that it is the foundation for protecting public health, the environment, and building economic stability. Climate change and its disproportionate impact on the poor make achieving the goals more elusive as poor nations struggle to adapt while limiting greenhouse gas (GHG) emissions. The Clean Development Mechanism (CDM) provides market incentives for reducing GHG emissions while investing in sustainable development. This master's project looks at the feasibility of applying the CDM to provide a financial incentive for improving wastewater treatment facilities in Durban, South Africa. Specifically, it looks at algae based wastewater treatment systems to create biofuel, fertilizers and other useful byproducts.

Algae wastewater treatment enhances water quality through nutrient removal and can create certified emission reduction (CER) credits by replacing the secondary treatment process to eliminate N_2O emissions and reduce energy and chemical operations costs. Algae research investment and venture capital have grown exponentially to create numerous partnership opportunities for financing. South Africa and eThekwini Municipality are competent in the CDM process, have experience with algae technology, and stand poised to leverage opportunities.

A recent carbon market downturn and escalating administrative costs in the CDM make a weak cost-benefit ratio for smaller scale projects. A "Sectoral" approach to include the entire Water and Sanitation unit of eThekwini Municipality is recommended. CDM proposals should consider multiple algae wastewater treatment plant retrofits with production of algae biofuels. The biofuels should be used by the municipality to increase offsets and credits to be more cost effective. This would increase the volume of CERs that can be generated and therefore the economic incentive available to improve sanitation.

Acknowledgements

This master's project was initially inspired by Dr. Diego Rosso and his vision of carbon sequestration credit through the Clean Development Mechanism for wastewater treatment. It was assisted by Dr. Glen Diagger's kindness to introduce me to Dr. Chris Buckley of the Pollution Research Group of KwaZulu-Natal University. Professor Buckley was welcoming, supportive, and made every resource and connection available to me. Most important to informing this project and drawing conclusions was Dr. Stephen Lyons, a lifelong scientist in the study of algae for wastewater technology. Last, but not least, I would be remiss not to acknowledge the nurturing support of Dr. Norman Christenson who pushed me forward and made me believe I could meet the project's challenges.

I dedicate this work to "mio nipote" Lorenzo Mason Bailey, born May 18, 2008. His birth has invested me even more in the future. It is my hope that in some small way the vision of this project and the questions it provokes will contribute to a better world for his generation.

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INTRODUCTION

> "In a real sense all life is inter-related. All men are caught in an inescapable network of mutuality, tied in a single garment of destiny. Whatever affects one directly affects all indirectly. I can never be what I ought to be until you are what you ought to be, and you can never be what you ought to be until I am what I ought to be. This is the inter-related structure of reality."
>
> Rev. Martin Luther King, Jr.

At the turn of the 21st century and in an unprecedented showing of human solidarity, the world's nations recognized and agreed on a plan to eradicate poverty. The United Nations (UN) Millennium Development Goals were signed in 2000 as a framework to stop the spiraling cycle of poverty in the world's poorest nations. These goals acknowledged the moral obligation to reduce suffering. They also recognize the "inter-related structure of reality" referred to in the quote above that infers a self-serving reason for the developed world to care about the poor. Our ultimate destinies are tied to each other.

No more is this true than in climate change. As threats grow, efforts to adapt to and mitigate its effects will be undermined by impoverished nations frantically scratching out an existence. Destitute people are forced to exploit whatever resources available, no matter the negative effect on the environment. Haiti is just one example where forests have been stripped away for their energy source. Ecosystems have been devastated and the protective functions of biological diversity virtually eliminated.[1] The effects of climate change will only magnify the poor's desperation because they have fewer resources for adaptation. Wealthier nations will find their quality of life from the earth's life-sustaining ecosystems dependent on elevating the

world's poorest from their plight. The fight against poverty and the effects of climate change are interrelated. Solutions must address both poverty and climate change mitigation.

Today, one out of three or 2.6 billion people live without adequate sanitation.[2] This statistic is sadly juxtaposed against the health professional's survey that regards proper sanitation as the number one most important medical advance in the last 140 years.[3] As industrialization in developing countries escalates and urban populations concentrate into megacities[4], wastewater treatment becomes all the more paramount to sustainability for humans and ecosystems.

Climate change threats will make the sanitation crisis all the more difficult to overcome. As temperatures increase and the hydrologic cycle intensifies, extreme weather patterns of drought and flooding will become more common. Water supplies will be threatened by reductions in snowmelt, river flows, and groundwater levels. Water quality will be compromised by runoff under intense rain events and pollutant concentration in drought conditions. Saltwater intrusion threats will increase as sea levels rise.

Human water needs will likely drive mass migrations which could result in further stress of water resources. The security and stability of nations will be at risk. Water knows no boundaries; water pollution problems created in one country can quickly be passed to another. Disputes over water resources are now, and will be in the future, the source of numerous border disputes and war.

Despite some progress by the UN, climate change may well block achievement of the Millennium Development Goals. Ironically, poor countries that have contributed the least to the problem will feel the worst of its consequences.

The Kyoto Protocol through its Clean Development Mechanism (CDM) provision allows for market based solutions that reward industrialized countries when they assist developing countries. Technology transfer and investment in clean infrastructure is made in exchange for Certified Emissions Reductions (CERs). Realized to its fullest, the CDM has the potential to more evenly distribute wealth of countries and contribute to a foundation for prosperity in developing nations.

Is there potential through the CDM to make investments in sanitation that enhance water quality and mitigate GHG emissions? Doing so would create an incentive and supply additional resources for overcoming the world sanitation crisis and meeting the objectives of the UN Millennium Development Goals.

Objective

In my master's project I will determine if the CDM provision of the Kyoto Protocol can be leveraged to enhance water quality in developing countries. Specifically it will look at the feasibility of applying advanced wastewater treatment through a new technology using algae generated through wastewater to produce biofuel and fertilizer.

I selected Durban, South Africa, for this feasibility study because it is eligible to generate CERS through the CDM. It is a good candidate for these particular technologies because it has developed, although deteriorating, infrastructure and may see benefits. In addition, the sunny and warm climate of Durban is well-suited for algae technology.

Methods

The analysis for evaluating the CDM's ability to achieve sanitation objectives will be based on five criteria:

1. Is the algae wastewater treatment process a viable technology and is it appropriate for Durban, South Africa?

2. To what extent does South Africa have the organizational capacity and political will to engage in the CDM process?

3. Are there financial institutions and/or business capital to invest in the new technology?

4. Is water quality enhanced for public health, the environment, and the business environment?

5. What is the value of CERs from GHG emissions savings and is it adequate to provide some incentive for instituting the technology.

In addition to evaluating these criteria, I will need to answer the following questions to determine feasibility for implementing algae wastewater technology in Durban, South Africa.

- What is the current status of algal to fuel technology and near future potential?
- At what points in the wastewater treatment process are GHG emissions released?
- What is the water situation – resources, facilities, level of treatment, management of solids, etc. in Durban, South Africa?
- What is the CER application process under the South African DNA?

UN MILLENNIUM GOALS

A global partnership is embodied in the Millennium Goals Declaration. It reflects our evolved understanding that individual fates are tied to humanity's success as a whole. Toward the end of the 20th century in light of the developed world's abundance and the 90's soaring economy, nation's decided to take action and set concrete goals. This action was different from past attempts to aid the poor. For the first time, there was a recognition based on the '90 Human Development Report that the wealth of a nation cannot be based solely on GNP.

The approach rejects a top-down externally driven strategy focused on GNP in favor of one based on human capabilities. Human development should focus on people and not simply wealth generation as they are not necessarily one in the same. There could be no clearer demonstration than climate that economic wealth development is not the same as human progress. Civilization's industrialization has been dependent on GHG intense energy sources with no price paid for the external negative impacts to the poor, future generations and the earth. This "Capability Approach" is the basis for the Human Development Index which defines a countries development status i.e. developed, middle income, etc.[5] it is based on the work of '98 Nobel Prize Winner for Economics Amartya Sen.

To eliminate the pain and suffering that comes with rampant disease and starvation the UN identified eight goals with specific targets as the "foundation for stable societies."[6] One of the goals is to "ensure environmental sustainability." It specifically articulates three targets:

- Integrate the principles of sustainable development into country policies and programmes and reverse the loss of environmental resources.
- Halve, by 2015, the proportion of the population without sustainable access to safe drinking water and basic sanitation.

- To improve the lives of at least 100 million slum dwellers by 2020 - defined as lacking at least one of the basic conditions of decent housing: adequate sanitation, improved water supply, durable housing or adequate living space.

Wastewater treatment practices are particularly critical to meeting each of these targets. Appropriately treated wastewater can be returned to the environment as a water resource ensuring sustainability of water supply. Improved wastewater treatment can improve public health and longevity by eliminating the spread of waterborne disease. In order to adapt to climate change, we must adopt a much more nurturing and sophisticated relationship to water resources.

Urban collection systems and water treatment infrastructure to insure recycling and reuse for human populations and the environment will be essential. However, in the face of a changing environment, we will need to think differently about infrastructure investment that meets drinking water and sanitation goals.

Water and wastewater treatment has historically been driven by water quality standards and available financial resources. Greenhouse gas (GHG) emissions and energy use must now be included. Water treatment and delivery systems are energy intensive, in many cases, electricity usage represents as much as 30% of operating costs.

Within developed countries the water and wastewater sectors have already begun to consider adaptations and technologies as they pertain to sustainability. Specifically, in wastewater treatment a number of U.S. cities have begun to implement biogas energy recovery in wastewater treatment. This captures emissions and reduces energy use or even generates energy that can be fed back into an electricity grid. Opportunities exist to increase efficiencies, capture emissions, and reduce energy overall within the U.S. water and wastewater treatment

sector.

These efficiencies and new technologies can easily be transferred to developing countries where substantial gains in sanitation and public health will result. Political momentum and support has grown in recent years for meeting the sanitation problem. The opportunity could potentially be inspired from financial incentives gleamed by the CDM. A synergy may develop to target the sanitation objectives of the UN Millennium Development Goals.

The Sanitation Crisis

The public health benefits provided by sanitation are a fundamental prerequisite to other development progress. There are 2.6 billion people[7] without access to adequate sanitation in the world today. More than 1.5 million children under five years die from waterborne (diarrheal) diseases each year[8]. As former UN Secretary-General Kofi Annan has stated on several occasions, "We shall not finally defeat AIDS, tuberculosis, malaria, or any of the other infectious diseases that plague the developing world until we have also won the battle for safe drinking water, sanitation, and basic health care."

Adding to the problem is the immigration trend to urban areas. Rural areas currently have the largest numbers of people without sanitation. However, that is changing as immigration to cities increases. Within a generation the greatest sanitation challenges are anticipated in the cities and megacities of developing countries.[9] Already an estimated one billion people live in slums and shanty-towns.[10] The UN Population Fund reports: (UNFPA 2007)

> "While the world's urban population grew very rapidly (from 220 million to 2.8 billion) over the 20th century, the next few decades will see an unprecedented scale of urban growth in the developing world. This will be particularly notable in Africa and Asia where the urban population will double between 2000 and 2030: That is, the accumulated

urban growth of these two regions during the whole span of history will be duplicated in a single generation. By 2030, the towns and cities of the developing world will make up 81 per cent of urban humanity."

Densely populated urban areas without water and sanitation infrastructure are crisis waiting to become catastrophe. Epidemics of disease threaten public health while environmental degradation eliminates aquatic resources and potable water supplies.

Political momentum for fixing the world's sanitation crisis is building. To create opportunities for awareness building and education the UN declared 2005-2015 the International Decade for Action under the slogan "Water for Life." They also dedicated 2008 as the "Year of Sanitation." Its purpose was to draw attention in order to meet the Millennium Development Goal (7c) to halve the number of people in the world without sanitation.[11] The public education campaign had five key messages:

1. Sanitation is vital for health
2. Sanitation contributes to social development
3. Sanitation is a good economic investment
4. Sanitation helps the environment
5. Sanitation is achievable – there are tried and tested models that can be applied at an affordable price of US$9.5 billion a year[12].

The last message is quite poignant. Although many countries allocate funding to water and sanitation, in fact, less than 5% goes to the later (UN-Water 2008). The dollar amount needed is only a fraction of what the United States currently spends on the war in Iraq. The problems

are solvable – we know the solutions. What appears to be lacking is the political will.

Part of the problem has been the taboos surrounding sanitation. The subject doesn't make for polite social conversation. It suffers the same negligence of discussion and attention that the HIV virus did. That avoidance in itself creates obstacles to meeting relatively simple challenges. Even occupations surrounding sanitation are stigmatized and/or held in low esteem. Politicians, civil society and the general public don't want to talk about it. As a result, it is an invisible crisis. We must transform our thinking.

Resource Recovery

In addition to protecting public health and preventing environmental pollution, wastewater treatment also offers opportunities for resource recovery. In the developing world, approximately 90% of sewage[13] is released untreated into rivers and streams. The water is polluted impacting plant, aquatic life and human health. It also represents a major loss in nutrients which the world will be forced to value more in future decades. Important to agriculture, animal and human excreta contains three important nutrients – nitrogen (N), phosphorus (P) and potassium (K). Phosphorus is particularly important in plant growth. The supply is quickly becoming exhausted as it is being mined unsustainably for production of artificial fertilizers. Urine has 50% of the excreted phosphorus. It can be captured by toilets that separate liquid and solid excreta. Research into new technologies for resource recovery is continuing. It represents a larger paradigm shift taking place within the movement toward a sustainable society.

Advanced wastewater treatment systems can offer enormous benefits to the environment and the world by reducing GHG emissions and recovering resource nutrients. When Biological Nutrient Removal (BNR) is applied in secondary wastewater treatment, it

sequesters carbon as inert biomass and can recover biogas energy to reduce costs and avoid uncontrolled carbon discharge. Appropriate use of the biomass either in landfills, or in biosolids recycling (wastewater solids that meet government approval as fertilizer) create a carbon sink with little emissions risk because the methane potential is largely eliminated. This creates a significant carbon savings that can be measured and traded as proposed by Rosso and Stenstrom at the Water Environment Federation Technical Exhibition and Conference (WEFTEC™) in 2007.

CLEAN DEVELOPMENT MECHANISM

What is it?

The CDM is one of three market provisions within the Kyoto Protocol designed to engage non-Annex 1 (developing) countries while providing market driven efficiencies to reduce costs to Annex 1 (developed) counties. Developed countries have the opportunity to invest in developing countries with sustainable development technologies that reduce emissions and obtain CER credits (Figure 1).

Although the CDM doesn't have an explicit goal to meet technology transfer objectives, there is evidence that new technology projects are being introduced in host countries as a result of financing emission reduction projects. Roughly 39% of all CDM projects accounting for 64% of the annual emission reductions claim to involve technology.[14]

Projects were only begun in 2006, but already more than 1,000 projects are registered. An anticipated 2.7 billion tons of CERs will be generated for the first commitment period of the Kyoto agreement[15]. In 2008, the CDM administration at UNFCCC reported a $22 million dollar surplus.[16] Although there are issues questioning the validity of some credits and the efficiency of the mechanism, the increasing popularity of the tool makes it likely that it will be included in the next generation climate agreement.

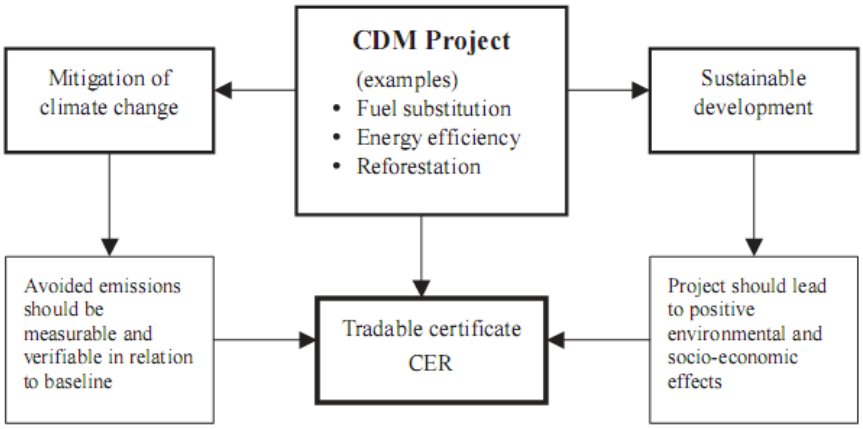

Figure 1 Characteristics of CDM projects[17]

Why is it needed?

The CDM can be looked at as a subsidy, a market, and a political mechanism.[18] It is a subsidy in that it pays developing countries to pollute less than they otherwise would. It is a market in that its subsidy is delivered through the creation of CERs. And, it is a political mechanism in that it induces developing world participation in the Kyoto Protocol.

There is an inverse relationship between those countries that have responsibility for the accumulation of GHGs in the atmosphere and those who are least prepared for its most dramatic effects – the poor in developing countries. The accumulation of GHG in the atmosphere has been generated by now developed nations that have reaped the benefits of industrialization over the last 150 years. However, the effect of temperature increases and sea-level rise will be felt by all countries. Poorer nations have less ability to adapt to its effects based on limited resources. Fair and global solutions are a necessity. Everyone is served by a distribution of sustainable technologies which results in equitable economic opportunity amongst all countries.

The United States and the European countries are responsible for the abundance of accumulated GHG in the atmosphere as well as some of the highest current generation rates. Creating market mechanisms to give industrialized countries less expensive options for meeting reductions was an important measure for making the Kyoto protocol politically feasible to the developed world. (The CDM and market mechanisms were negotiated by the most infamous non-signatory of Kyoto - the United States.) The trading of credits allows developed countries to reduce global emissions at the least price. Theoretically, abatement costs in developing countries should be less expensive than in developed countries because new technologies can be put in place rather than retrofitting current infrastructure. This creates a market efficiently leading to the less expensive options for the same carbon saving results.

The success of the Kyoto Protocol also depends on its ability to engage the developing and middle income countries. Although Middle income countries, such as China, India, or South Africa, don't have the same carbon debt as developed countries, there rate of growth and demand for cheap energy sources have made them a significant player and the largest potential emitter for increases in GHG emissions. Their need for cheap, available energy sources is easily met with the most carbon dioxide (CO_2) intensive of them all – coal. Forests are often stripped for basic human necessity to provide energy needs and wood products without regard for their value as carbon sinks and ecological habitat. The CDM gives them an incentive to engage in the GHG reduction process. By subsidy of the CDM, developing or middle income countries can pursue sustainable development and position themselves with advanced technologies so that future GHG restrictions don't hinder their economic growth. Interestingly, CDM participation is also perceived to have a positive impact on GHG emissions and technologies awareness thus educating and preparing host countries[19] (GAO 2008) for their own emissions reductions in future agreements.

How does it work?

The United Nations Framework Convention on Climate Change formed an international treaty in 1994 to consider how to reduce GHG emissions. The treaty was signed by most countries. However, it doesn't compel signatories to take action. There are no penalties attached to the agreement. The Kyoto Protocol was created with specific commitments to reduce emissions in most cases 5% below 1990 levels in the first commitment period 2008-2012. The detailed rules of the agreement were adopted in Marrakesh in 1997 and go by the same name, "Marrakesh Accords" (UNFCC). It includes the steps of the CDM process as outlined below.

1. A Project Design Document (PDD) is submitted by the project applicant.

2. The Designated National Authority (DNA) that has been authorized through the national government has the prerogative to approve or reject the project based on whether it creates "additionality" and meets sustainable development goals. Additionality establishes that the project would not have been implemented had incentives not been provided through the CDM. Therefore, the GHG savings are additional to what would otherwise have occurred.

3. A Designated Operational Entity approved by the CDM Executive Board gives the project independent validation. They also monitor progress and confirm CER credits.

4. Once approved by the CDM Executive Board, projects are registered and placed on the International Registry for trade.

What are the issues related to Sanitation Projects?

Negotiations for the next generation agreement will be held in Copenhagen in December 2009. It is understood that the first commitment period has been an opportunity to trial and test provisions of the agreement so that they can be amended and improved or displaced by better ideas. A number of issues in regard to the CDMs have presented themselves and adaptations will need to be made. However, significant infrastructure for building capacity has also developed with promise for the market mechanism and its important objectives.

Building Capacity

The Kyoto Protocol is giving birth to a whole new set of skill-sets and institutions that will prove invaluable in ultimately meeting the challenges of climate change (Wara 2006). However, as in many things, developing countries have limited resources for developing this infrastructure. The CDM project approval process is extensive and demanding. Because the CDM concept is new, host country capability to evaluate project proposals, validate, and monitor results is only now developing. To be effective institutional structures must be in place with complex rules for implementation. This has resulted in lesser participation for those countries with the greatest needs. Middle income countries have been more likely to be beneficiaries (Figure 2). For example, Africa accounts for only 2.6% of the CDM projects registered.[20]

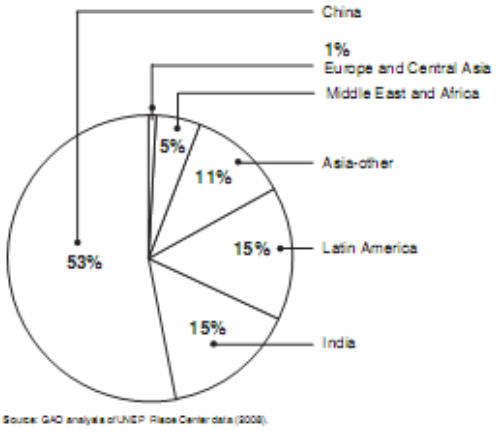

Figure 2 CERs by Host Country

The United Nations Development Program (UNDP), United Nations Environmental Program (UNEP), World Bank Group, African Development Bank, and UNFCC launched the

Nairobi framework agreement in 2006 to provide assistance and build capacity so that developing countries can more widely reap the benefits of the CDM.[21] Its goal is to establish collaboration and partnerships with the private sector for CDM projects. As a part of the Framework, an Africa Carbon Forum was conducted in Senegal last September. It attracted attention and declarations from development banks as well as encouraged host nations to develop infrastructure for managing projects. By initial accounts, it has sparked interest and commitments that may result in an increased interest in CDM projects that specifically address Millennium Goals for Africa.

Sustainable Development vs. Cost Effectiveness

The origination of the CDM concept has its roots in the linkages between climate change and sustainable development (SD). Only 10 years ago, the two areas were debated in separate disciplines. Climate change was largely considered natural science and sustainable development social science. They became framed together after the 2001 IPCC Third Assessment Report (TAR) and the World Summit on Sustainable Development both concluded that they are interconnected. An understanding of one contributes to the understanding of the other.[22]

In the Kyoto negotiations, developing countries argued that an international standard for SD would impinge on their sovereignty.[23] SD criteria vary because different countries set different priorities. However, when power relations between stakeholders are uneven, it is those resource-strong stakeholders who define the terms of the carbon trade.[24] Discrepancies are created as countries compete to offer projects for credit. In an effort to attract investment, countries may offer incentives with lower sustainability standards.[25] Since there is no monetary value placed on sustainable development in the carbon marketplace, there will be an emphasis on GHG reduction where CERs are most abundant.

Will the CDM's SD objective become a victim of its market mechanism? Should non-carbon benefits be considered for the CDM? Doing so would enhance feasibility for projects that target Millennium Development Goals. It would create an incentive to fulfill the original CDM intention of SD.

Additionality

CDM projects must reasonably demonstrate that the emissions reductions would not have been implemented in the absence of the project. This is important to be able to validate a real reduction over the baseline emissions. To help host countries establish "additionality" the UNFCC established the tool in (Figure 3 - EB 39 Report Annex 10 p. 1).

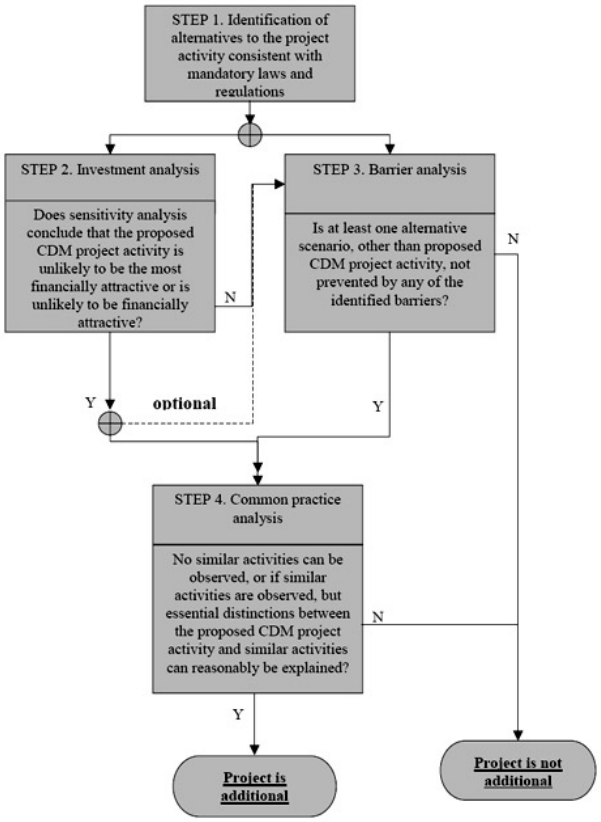

Figure 3 UNFCC Additionality Tool Test

Additionality has proven to be a contentious issue for some host countries. The question is whether a project that is implemented in response to a national policy is additional. A stringent interpretation might say that if the government mandates a particular change that it would have occurred without CDM intervention. Therefore, it wouldn't be eligible for the credit. The interpretation becomes particularly important when considering the idea of a regional or sectoral CDM approach. This has been proposed for the next generation agreement. As it is currently defined, additionality would prove a significant roadblock.

Sectoral CDM

To date the vast majority of CDM proposals have been for specific and relatively small scale projects. A Sectoral CDM (S-CDM) approach would also allow for the development of projects in a specific region or across an entire sector (e.g. electricity, transport, wastewater). They could be the result of a specific SD policy. The project would measure the carbon savings that occur and be able to trade them for CERs. For example, the modernization of the entire cement industry in a country might be eligible. Or, advanced wastewater treatment with biogas capture might be considered in a particular municipality. The emissions savings would be eligible for CER credit.

Low Hanging Fruit

As a matter of equity in a carbon market driven world, the CDM has the weakness referred to as "Low Hanging Fruit." Theoretically, those projects with the highest CER credits and the lowest costs will be implemented first. Currently, developing countries have no emissions ceiling. However, in a post Kyoto agreement it is highly likely they will graduate into commitments. CDM projects that resolve all of the low hanging fruit will leave them with few lesser expensive abatement options when they must meet reduction commitments.[26]

Host countries must keep in mind their future emission reduction requirements. Climate change science is becoming more sophisticated and evidence even from the last IPCC report has shown dramatic rates of change driving worst case scenarios. It is difficult to estimate future value of credits to insure equity in the CDM exchange.

What is the CDM process in South Africa?

As one of the most economically developed nations within Africa, South Africa has been in a position to take full advantage of the Nairobi Framework and provide leadership on the continent. Its Designated National Authority is the Department of Minerals and Energy (DME) established in 2004 and has developed a comprehensive process (Figure 4) along with considerable guidance. For the last two years, they have been conducting a proactive promotion and capacity building campaign. A series of workshops has been organized to attract stakeholders and reveal opportunities for interested parties. A workshop for Kwa-Zulu-Natal Province is scheduled in Durban, June 23, 2009.

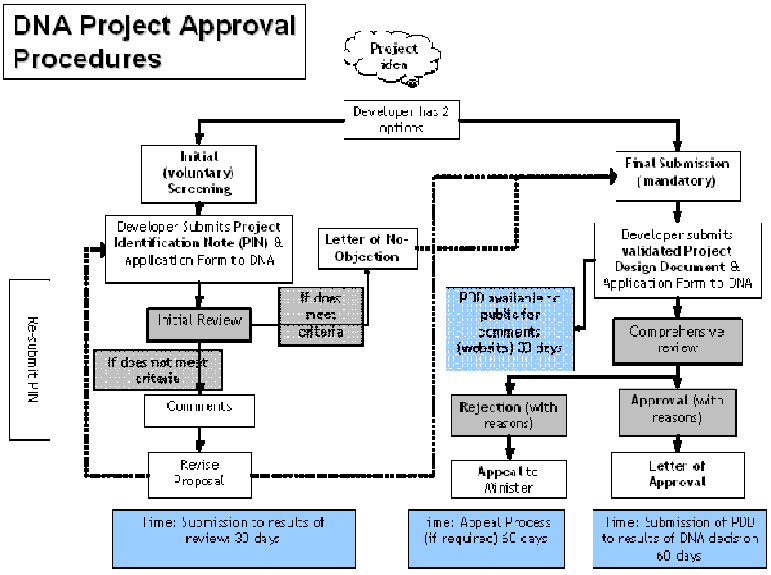

Figure 4 South Africa CDM process[27]

In addition to a developed process, South Africa's CDM has the significant advantage of having specifically defined criteria for project sustainability (Appendix I). This acts as an insurance policy against the low hanging fruit and baseline issues discussed earlier.

By virtue of its coal-based economy and an extensive industrial sector, South Africa has significant CDM potential. The country ranks 12 for CO_2 emissions worldwide.[28] Because electricity is so inexpensive, there are significant inefficiencies and waste that could be capitalized on for CERs earned through CDM projects. However, the low price on electricity also creates less of an incentive for investment in emission reduction technologies. For example, eThekwini Municipality was one of the first organizations to participate in a CDM project when they established an electricity-from-biogas project in the Marianhill landfill. The total cost of generating electricity was US $.042 per kWh; however the cost of electricity from Eskom over the lifetime of the project was estimated at almost half that $.0225 per kWh.[29] The project was only viable through the CDM and World Bank funding.

WASTEWATER TREATMENT GHG EMISSIONS

Wastewater treatment plants (WWTP) are significant generators of GHG emissions. Carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O) from waste handling and management represent 4% of the world's total anthropogenic greenhouse gas (GHG) emissions worldwide.[30] Based on this accounting, the Kyoto Protocol includes "wastewater handling" as a target sector for emissions reductions. Under current and anticipated air emissions regulations, large wastewater treatment plants, 100 MGD (million gallons per day) or larger, are potential major emission sources (100 tons CO_2 ~ per year or greater).[31]

Energy use, primarily electricity, is the biggest indirect source of GHG emissions in wastewater operations (Figure 5). It also represents the largest uncontrollable cost of providing wastewater services. Within developed countries, and in South Africa, most facilities were built when energy costs were not a major concern. The pumps, motors, and large equipment operate 24 hours per day, seven days a week. The U.S. EPA estimates 3% of U.S. electricity consumption goes to the pumping, treatment and distribution of water. Approximately 30% of the average U.S. wastewater treatment plants operations and maintenance costs go toward paying the electric bill thereby increasing the cost of water service to customers. In many cases, WWTPs are the largest electricity user in their community.

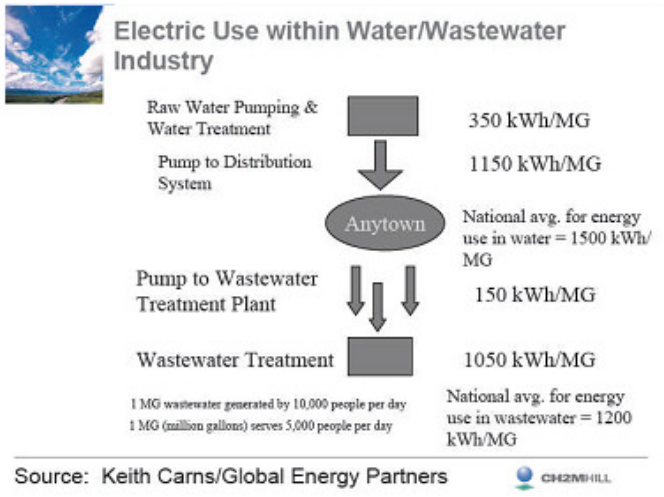

Figure 5 WWT Electricity Use

Although significant efficiencies are possible, overall WWTP energy use is driven by the level of treatment implemented. Within developed countries, the trend has been increasing water quality and therefore energy consumption per unit of wastewater treated. Over the next decade, electricity use is anticipated to increase by 20% due to a growing population and higher treatment standards.[32]

Wastewater operations are a direct source of N_2O and CH_4 emissions. Although CO_2 receives most of the attention when it comes to the greenhouse effect, N_2O causes 300 times, and CH_4 20 times, the warming effect of comparable CO_2 amounts in the atmosphere. As a result of Biological Nutrient Removal (BNR) and other processes, fugitive (not from a pipe) GHG emissions are released, primarily CH_4 and N_2O. The Water Environment Research Foundation is conducting on-going research led by Kartik Chandran, Ph.D., Columbia University, to develop an inventory and mathematical model for characterizing N-GHG emissions from wastewater treatment operations. Results are anticipated in the summer of 2010. At this time, there is no accurate accounting for N_20 emissions. In the current IPCC guidelines, fugitive emissions are not addressed other than for anaerobic digestion. The calculations for N_2O were based on a final effluent emissions factor and population that came from a small treatment plant in New Hampshire, resulting in a gross simplification.[33]

> "Even using the best available data from literature sources, large uncertainties (in the order of approximately 10% to more than 100%) exist in the estimation of GHG emissions from WWTPs, particularly due to so-called "fugitive" emissions of N_2O and CH_4 from either the raw sewage entering the plant, secondary off-gases, or treatment and disposal of biosolids."[34]

However, it is important to note that preliminary research based on U.S. EPA and IPCC methodology, determined "unequivocally that biological wastewater treatment, with BNR or

without BNR, actually result in a net reduction in N_2O emissions relative to discharging untreated effluent to receiving water bodies"[35] Ammonia discarded to the aquatic environment produces more nitrous oxide than ammonia oxidized in WWTPs. In fact, GHG emissions reductions were one of the arguments made by the National Resources Defense Council in their 2007 proposal to require nitrogen removal in all U.S. WWTP. Wastewater treatment can be seen as part of an overall GHG emissions reductions strategy.

The anaerobic digestion method commonly used to treat biosolids produces substantial amounts of CH_4, considered biogenic (in balance with nature.) However, wastewater treatment plants (WWTP) can reduce their total GHG emissions by reducing methane flaring and instead directing the methane to energy producing options such as engines, boilers and fuel cells (Figure 6). Within the United States, there are approximately 1,600 wastewater treatment plants sized at 5 MGD. Roughly 500 use the anaerobic digestion process and only an estimated 20% of those produce biogas at this point.[36] The potential for methane capture represents a large potential GHG savings.

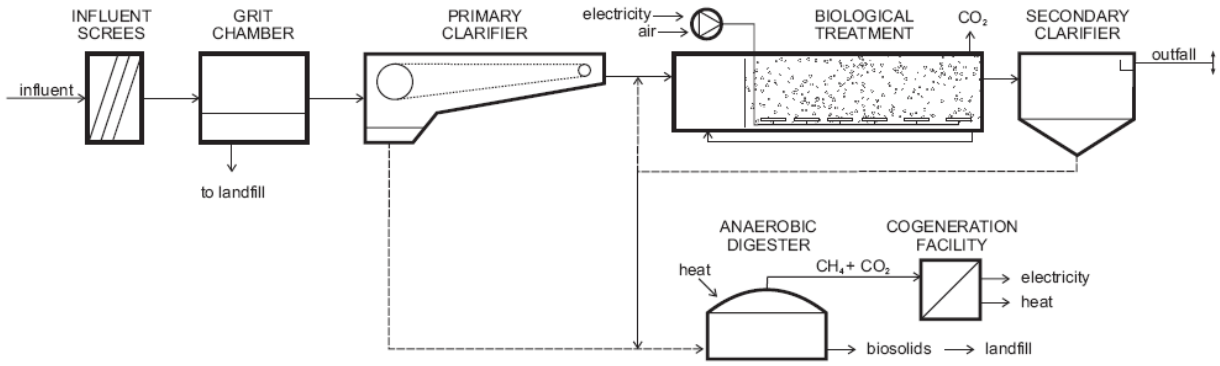

Figure 6 Advanced Wastewater Treatment Process with Biogas Capture[37]

Currently, there is an environmental management trade-off between reducing GHG emissions and nutrient removal (treatment level) for water quality. If N_2O fugitive emissions

prove to be as significant as suspected, more advanced WWTPs do not necessarily offer lower environmental foot-prints. If fugitive N_2O prove to be as much of a factor as suspected, new methods that by-pass the secondary aerobic part of the process would become important to consider. Thus my interest in algae based systems.

Algae for Wastewater Treatment

Advanced treatment with algae based technologies for nutrient removal is of particular interest. The algae treatment process replaces the aerobic (secondary) treatment process which is the greatest user of energy and emitter of N_2O emissions. Secondary and tertiary treatment processes represent roughly 70% of the costs for operating a WWTP.[38] As noted earlier, N_2O has global warming potential some 300 times that of CO_2. Algae treatment actually has the potential to create a carbon-negative situation since algae use CO_2 to grow.

The basic technology for algae cultivation requires nutrients (N and P), CO_2, light, and a non-toxic liquid medium maintained at pH of 6 to 9 with a temperature range between 10 and 20^0 C.[39] Filtered, primary treated wastewater works well as a nutrient rich liquid medium. The biomass can be harvested and processed to produce biofuel and/or fertilizers. The oil in the algae can be converted to biodiesel. The carbohydrate content can be fermented into ethanol. (Both are much cleaner-burning fuels than petroleum-based diesel or gas.[40])

Algae treatment for wastewater leverages the mutually beneficial relationship between bacteria and algae. Bacteria convert organic matter and oxygen (O_2) into CO_2 during growth. Algae convert CO_2 (and other nutrients) into O_2 during photosynthesis growth. Traditional wastewater treatment plants are bacteria only. They require energy intensive pumps to infuse oxygen into the process. Algae, on the other hand, take advantage of solar energy to produce O_2. The result is 40-60% less energy use in the treatment process.[41] Not only is it not

producing GHG, but using algae in the treatment process substantially decreases energy needs and thus prevents other fossil fuel use. Furthermore, CO_2 that is produced by burning methane (usually released into the air) in the thermal process can be "bubbled" into rapidly growing algal to increase yield and capture the majority of CO_2.

Conventional treatment doesn't remove N from wastewater but converts it to nitrate. Additional steps are needed to reduce N and P from effluent. They either involve biological or chemical precipitation processes. Algae require N and P as essential elements for growth. Generating algae from wastewater effectively removes Biological Oxygen Demand (BOD), Total Suspended Solids (TSS), N and P in one step without additional chemicals thereby producing a cleaner effluent and improving water quality.

Another benefit of algae is that it produces natural polymers which capture organic matter as a food source. This creates a heavier biomass and enhances the settling process which in turn avoids the need for manufactured polymer chemicals. The solids are collected using clarification tanks and can be processed into energy products or fertilizer.

Lastly, conventional treatment maximizes the amount of wastewater solids produced in order to clean water. Producing a higher grade water quality generates a large amount of wastewater solids with additional issues of processing and disposal. Not uncommonly, the solids present real or perceived human health and environmental risks that are costly to correct or resolve.

Research is on-going into optimal design and operations. The photo (Figure 7) is for algae fuel production that isn't using wastewater. However, it gives a visual perspective of the potential scale of production.

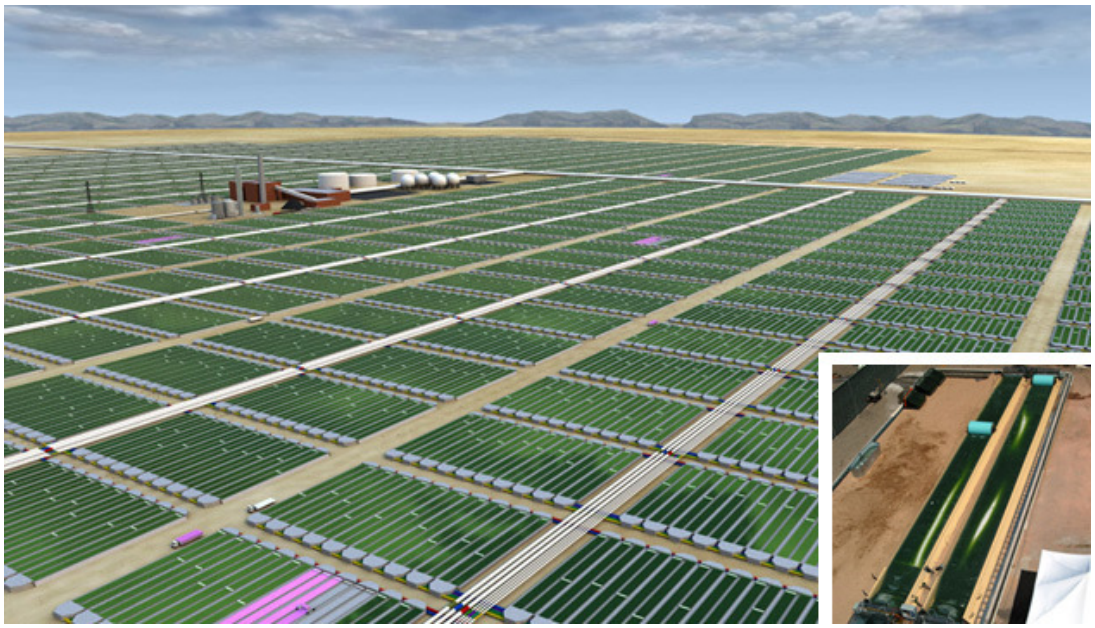

Figure 7 Colorado's Solix Biofuel's field of bioreactors (Popular Mechanics, 2007)

For small rural conventional wastewater treatment plants, there is the potential to retrofit relatively easily for the algae process. Locations with suitable climate and land can use algal high rate ponds (HRP) in combination with algae harvesting and anaerobic digestion at much less expense than currently used mechanical treatment processes, such as BNR.[42] These plants could potentially become energy exporters. Researchers at Cal Poly State University have identified several technical improvements that could be made to realize the full benefits of algal HRP:

1. Development of low-cost algae harvesting methods
2. Minimizing land use while achieving nutrient removal objectives
3. Improving the currently rather low methane yields from anaerobic digestion of algal biomass.

Rhodes University has conducted significant research into the efficacy of an “Integrated Algal Ponding System”. For nine years they monitored an experimental field station in Grahamstown, South Africa seeking a less expensive and energy intensive treatment option for wastewater (Figure 8). The algal pond system was found to achieve levels of nutrient and organic removal comparable with conventional wastewater treatment works.[43]

Figure 8 Algae HRP in South Africa (Wells, 2006)

Below is a flow diagram for the production of tertiary effluent, biodiesel, phytochemicals, electricity via cogeneration and capture of GHG. The model was developed by Dr. Stephen Lyon (Figure 9). The concept seeks to retrofit small rural conventional wastewater treatment plants (.5 – 10 MGD) that are overburdened or more than 30 years of age and in need of upgrading. The tertiary effluent could serve multiple functions for water reuse, biodiesel, electricity derived from a co-generation system and capture of the waste gases produced by a

co-generation system.[44] Boxes with double lines indicate a usable end product or benefit. Each raceway requires approximately two acres of land.

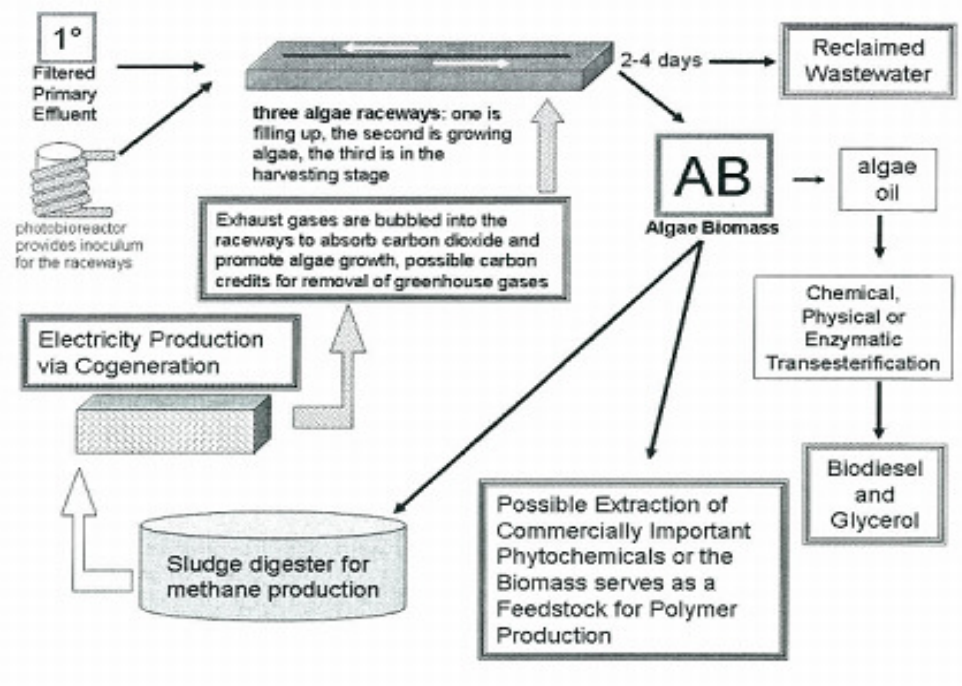

Figure 9 Flow diagram of an algae-based WWTP (Lyon, 2009)

Urban facilities would find the cost of land prohibitive. However, several patented processes are currently being tested that will potentially be operated on a much larger scale. One system, the "Algaewheel" was recently permitted for operation in Cedar Lake, Indiana (41).

Algae production for fuels has been under research since the 1950s. It peaked in the 70's amid the middle-east oil crisis. Since 1978, the U.S. Department of Energy's Office of Fuels Development invested $25 million in research called the Aquatic Species Program. Its goal was to develop renewable transportation fuels from algae. Program scientists developed production of biodiesel from high lipid-content algae grown in ponds, utilizing waste CO_2 from coal fired power plants. During the studies' two decades they made tremendous advances by

manipulating the metabolism of algae and engineering the production systems. Unfortunately, they were shut down in 1996, largely due to low crude oil prices that were considered too competitive to make biodiesel from algae a viable fuel source. The research was reopened again in 2008 when oil topped $100 per barrel.

The volatility of fuel prices and the demands of climate change to mitigate GHG emissions make the potential for algal to fuel technology compelling. Large scale "algaculture" provides the potential for a second generation biofuel that unlike the first generation of corn based ethanol products, doesn't compete with agriculture needs. Its production under climatically favorable conditions doesn't rely on irrigation waters or favored lands. Its most advantageous host is the wastewater treatment plant. There energy production becomes a side benefit to water quality.

The concept of algal wastewater treatment systems attracted standing room only attention when it was introduced in a special session at WEFTEC™ '08 in Chicago. A number of companies within the water sector and in the larger business sector called on the Water Environment Federation (WEF) to take leadership in pursuing research and best management practices for implementing wastewater algae technology. WEF has since formed a community of practice including several companies with patent processes and universities testing other processes for wastewater generated algae to fuel technologies. Another special session is being planned at WEFTEC™ in 2009. The topic has generated a great deal of excitement within the water sector as it is another step in the paradigm shift from simply managing waste disposal to producing added value from waste in a sustainable process.

SOUTH AFRICA

South Africa's current condition, its infrastructure and social situation developed out of Apartheid and the struggle for liberation. While it enjoys one of the wealthier economies in Africa and is the third most bio-diverse country in the world, the challenge of alleviating poverty and raising the quality of life for the previously disenfranchised black population remains a major challenge. This can be clearly evidenced in its water and sanitation situation. Despite progressive water policies and international accolades, the legacy of apartheid hangs on. Reports estimate 15 and 20 million people still lack safe drinking water and adequate sanitation, respectively.[45]

After Apartheid (1948-94), South Africa became one of the few countries in the world to incorporate the right to water in its constitution. The National Water Act of 1998 was founded on two pillars: sustainability (long-term protection of the resource) and equity (sharing of scarce resource in terms of quantity and quality).[46]

The water policy in South Africa is considered by many in the water sector to be the most progressive in the world. In 2000, Professor Kadar Asmal was credited for many of these advances and recognized with the Stockholm Water Prize, considered the Nobel Prize for water science. At the World Water Forum in Istanbul this March, South Africa was referred to as an example of how to do things right, "there, laws guarantee a basic water supply, protect water-based ecosystems and allow people a say in how the resource is used at the community level," commented a representative from the Union for Conservation of Nature.[47]

A distinguishing feature of the South African water sector is the role of Water Boards in providing an interface between the national government in setting policy and the municipal government that actually provides services. Water Boards oversee the operation of dams and

play an important role in water resource management. They are responsive to and seek public participation in water decisions. (Umgeni Water is the Board that serves Kwa-Zulu Natal.)

South Africa is estimated to have a total water credit of 34 billion m^3 with an annual consumption of 19 billion m^3 in 1990 and this is rapidly rising.[48] The arid climate exacerbates the challenge. South Africa's rainfall of 500 mm is only about half the world's average, and it has above average evapotranspiration rates. This means that only 8% of the rainfall is carried in the rivers, compared to the world mean of 31%.[49] The combined effects of climate, rapid population growth and inefficient water infrastructure increase the pressure on river ecosystems. At the current rate of consumption and with anticipated population growth, it is estimated that there will not be enough water to meet demand.

The government recognizes it as an ever more scarce strategic resource and has legislated that water used for industrial and municipal purposes must be returned to its stream of origin, if it is practical, possible and purified to meet certain standards. Therefore, treated wastewater represents a significant source of water, but of deteriorated quality.

Durban

The city of Durban is located in KwaZulu-Natal, a major province amongst 10 in South Africa. The name KwaZulu-Natal tells the story of its roots. KwaZulu means "Zululand," home of the Zulu nation. Natal derived from Natalia, means "Christmas". This was the coincidence of the calendar year when a Dutch explorer decided to land on its shores. Two civilizations collided and eventually combined into its present-day state.[50]

Durban's 3.5 million people are relatively racially diverse due to the way it evolved. The native Zulu population had no interest in working on plantations for low wages. They were

satisfied with the abundance and dignity of living off the land. The British were forced to import indentured servants from India. Many stayed and today the population is almost 20% of the total. The white population is 9% and mixed race almost 3%. Blacks (mostly Zulu's) are the largest segment of the population at 68%. Durban's unemployment rate is a staggering 28%; almost 90% of this unemployment is shouldered by the Black population.[51]

Durban sits on the west coast and is the third largest metropolitan area in South Africa. It enjoys a subtropical climate and beautiful beaches making it a tourist and vacation destination for Africans which accounts for close to 25% of the economy. Most of Durban's development has been activity through its port location which is the busiest in all of Africa. Early Dutch settlers founded large sugar plantations creating a food and sugar processing center that were well served by the distribution point. Later petro-chemical industries that are dependent on port facilities for imports and exports arrived. The port gave rise to Durban as a manufacturing center making up 30% of the economy.[52]

Durban is part of the eThekwini Municipality created in 2000. (Ethekwini means Bay which came to refer to Durban in the Zulu language.) Most government services including water and wastewater treatment are through the municipality. Although it occupies only 1.4% of the total land mass, the eThekwini service area accounts for over a third of the population and 60% of all economic activity in KwaZulu-Natal province. It contains four of the country's eight biomes and has over 2,000 plant species with open-space of more than 63,000 hectares.[53]

Textiles and metal finishing are currently the two most important industries overall in South Africa both for the labor market and for the economy. More than 40% of those textile companies are located in the eThekwini service area. There are also a significant number of metal finishing factories.[54] Both use large quantities of water and their wastewaters negatively impact receiving waters.

eThekwini Wastewater Treatment

In the eThekwini service area there are 14 rivers (Figure 10). Most are used for recreation and in some poorly serviced areas; some are used for daily water supply. The municipal potable supply is from a high quality source on the upper Umgeni River. There are 32 wastewater treatment plants (Figure 11). Twenty-one of these with a total design capacity of 320 million m^3 discharge their final treated effluent into the nearest river. Even when meeting legislative requirements, these waters are degraded through nutrient enrichment. The general discharge standard addresses ammonium, but not nitrogen and phosphorus.

Figure 10 Map showing rivers & terrain

Rivers suffer from eutrophication to a greater or lesser extent depending on the time of year.

Winter has less rainfall and therefore results in a more concentrated nutrient load as the effluent is a greater percentage of the overall water flow. Poulsen (2005) estimates that in half of the rivers the final treated effluent make up approximately 90% of the base flow during winter and about 50% of the flow during summer. In addition, the rivers may be polluted by untreated sewage from poorly serviced settlements or broken sewer pipes. Estuaries are heavily impacted and, at times, unfit for contact recreation. The two largest wastewater treatment plants dispose of effluent to the sea through submarine pipelines. Algae blooms may result and pose risks to the marine environment.

Much of eThekwini Municipality's wastewater treatment infrastructure is aged and overburdened. Largely developed under apartheid, it only serves portions of the city. Large areas of impoverished populations and informal settlements were left without proper sanitation. In 2002, approximately 140,000 households were not served by the wastewater treatment system. As a cost effective measure and to protect groundwater, the municipality has installed 57,000 urine diversion (UD) toilet and a 200 liter yard tank as of 2007.[55] There are plans to fulfill the remaining need with UD sanitation systems as well. On-site systems such as this in peri-urban areas can eventually be connected to the central collection and wastewater treatment system.

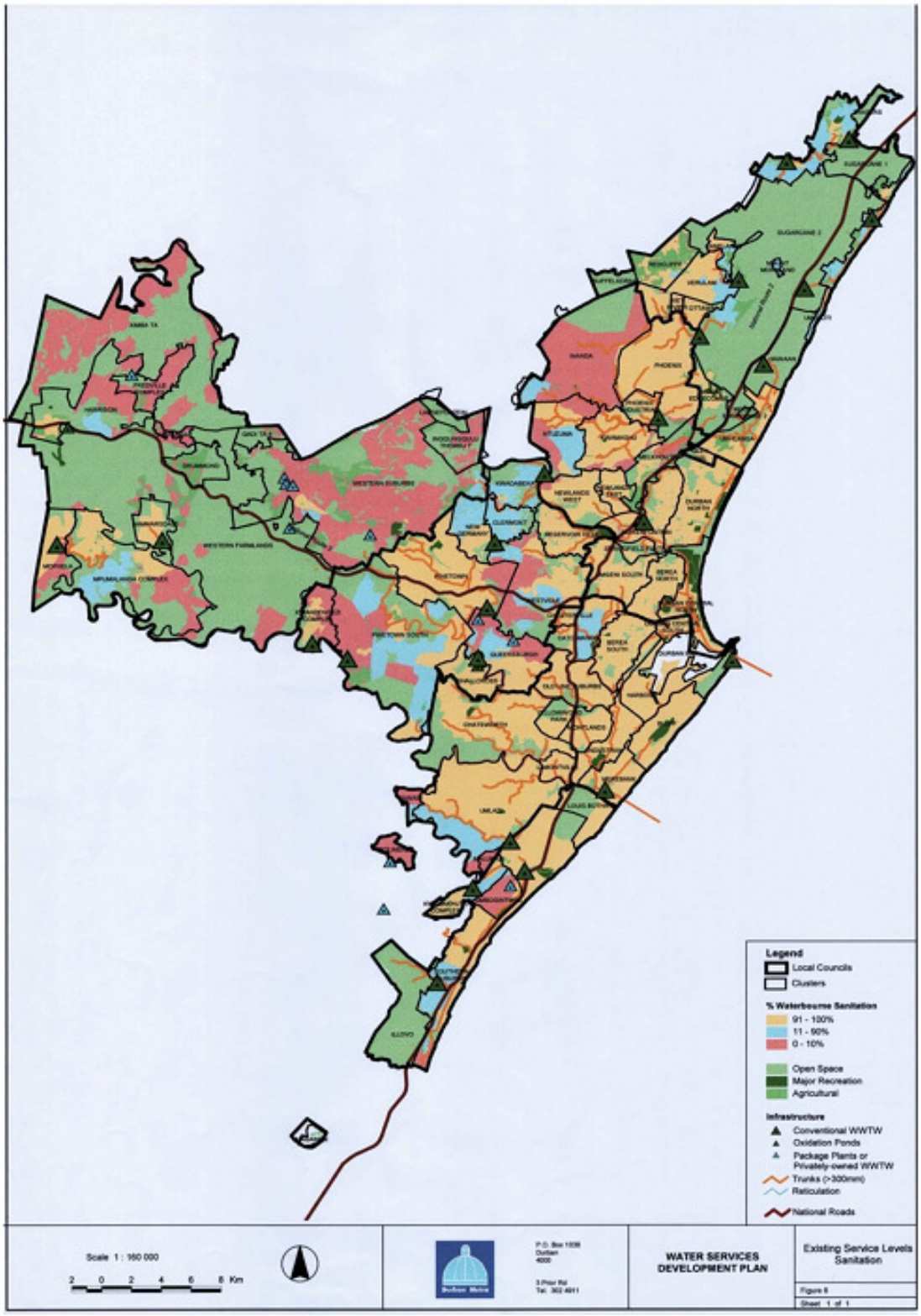

Figure 11 Map of eThekwini Wastewater Services

eThekwini GHG inventory

In 2005, a GHG emissions audit was commissioned by eThekwini municipality. Emissions from the water and wastewater sector were estimated at 6.2% (

Figure 12) primarily indirect from electricity intensive operations and pumping. The direct emissions were mostly from biogas (methane) generated in wastewater treatment operations. [N_2O is also a significant factor from aerobic treatment processes, but not identified in this inventory.] They estimated the water/wastewater sector's contribution at 6.2% of eThekwini's overall output or 69,341$_t$ CO_2 ~. Energy usage is estimated at 220,594 GJ (a measure of energy use equivalent to 10^9 Joules).[56]

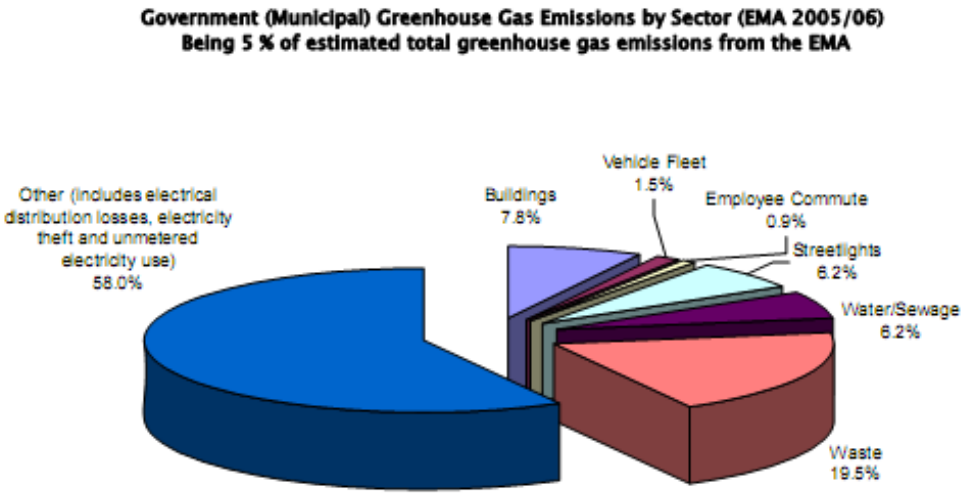

Figure 12

Municipal GHG emissions for 2005/06 total: 1,118,061t CO2~

FINANCING INFRASTRUCTURE INVESTMENT

The purpose of the World Bank, International Monetary Fund, and their regional counterparts such as the Development Bank of South Africa, is for social welfare, to create capacity and support infrastructure in developing countries. The Development Finance Institutions (DFI) have their mission in social development, but all need to show a productive cost benefit analysis to have sustainable operations. Some of the DFIs such as the Development Bank of South Africa are self-financed through capital markets.

DFIs have tremendous potential impact on the CDM. Since they have a similar mission to build infrastructure and alleviate poverty, they are well positioned to promote and fund projects by their financing. Blended within the CDM framework, DFI funds can leverage the benefits of receiving CERs to entice funding. CDM in Africa could be an opportunity to attract foreign investment and build the role of DFIs for developing partnerships and building capacity to leverage resources.

Because DFIs function as advisors, they are in a position to facilitate the sometimes difficult process through the Designated National Authority (DNA) proposal approval process. By doing so, they build institutional capacity. In addition, the DFI mission complements the sustainable development goal of CDM projects to ensure the implementation of best practices.

> "The Development Bank of South Africa has emerged as a knowledge-based DFI and a key change agent for socio-economic development. It is self-financed, not dependent on subsidies from government and emphasizes partnership and advisory services. They assist or facilitate the CDM process through the DNA and by doing so help to encourage best practices."[57]

Global Sanitation Fund

The Water Supply & Sanitation Collaborative Council (WSSCC) was established in 1990 by the United Nations to enhance collaboration in the sector, generating, sharing knowledge, and advocating the importance of water and sanitation. To meet the 2015 Millennium Development Goal for Sanitation, WSSCC formed the Global Sanitation Fund. It is a financing mechanism that offers grants from a pooled global fund to selected organizations in eligible countries. It may be able to leverage additional benefits to the cause of sanitation by finding projects eligible for CERs through the CDM.

KwaZulu-Natal Business Partners for Development

The KwaZulu-Natal Business Partners for Development was started in 1999 by Vivendi Water. They are part of the world-wide Business Partners for Development program that was organized by the World Bank to bring together partnerships from the business sector, public sector, and non-governmental organizations (NGOs). In KwaZulu-Natal, the partners include Vivendi Environnement, Durban and Pietermaritzburg municipalities, and Umgeni Water, the KwaZulu-Natal regional Water Board. Also, the Water Research Commission and The Mvula Trust, a leading independent charitable Trust in South Africa whose mission is the improvement of water and services for poor communities are partners.[58] Certainly, the mission of this partnership would be served well by sanitation projects that generate CERs through the CDM.

Venture Capital

The surge of oil prices in 2008 and the desire to move toward energy independence for security reasons has renewed interest in algae as a fuel source all over the source. Three years ago the investment in research grants was about $3 million. In 2007, it increased to $32

million. As of November 2008, the investment by venture capital and academic grants has exponentially grown to $350 million (44). Roughly 50 start-up companies are now rushing to see who can produce the first viable product. Clearly, at the current price of $20 per gallon[59], there are production challenges that must be overcome. However, the growing pressures to reduce GHG emissions and the increase in research dollars from multiple national governments make it an attractive consideration for venture capital. In addition, algae to fuel, particularly using wastewater represents a second generation biofuel without the negative impacts as were suffered upon the world food supply by the first generation of corn, soy, etc.

As an example, last year a German company Phytolutions signed a memorandum of understanding with the Nelson Mandela Metropolitan University to form a joint-venture company called Phytolutions Africa to develop and promote the technology in Africa.[60] This March they announced that the Eastern Cape of South Africa was selected for an algae-to-power pilot project due to its ideal climate and mix of industry (similar to Durban). The marine algae photo-bioreactors (Figure 13) will be set up at industrial locations to capture CO_2 and convert it into dry biomass for biofuels, glycerin and protein for fish or animal food.

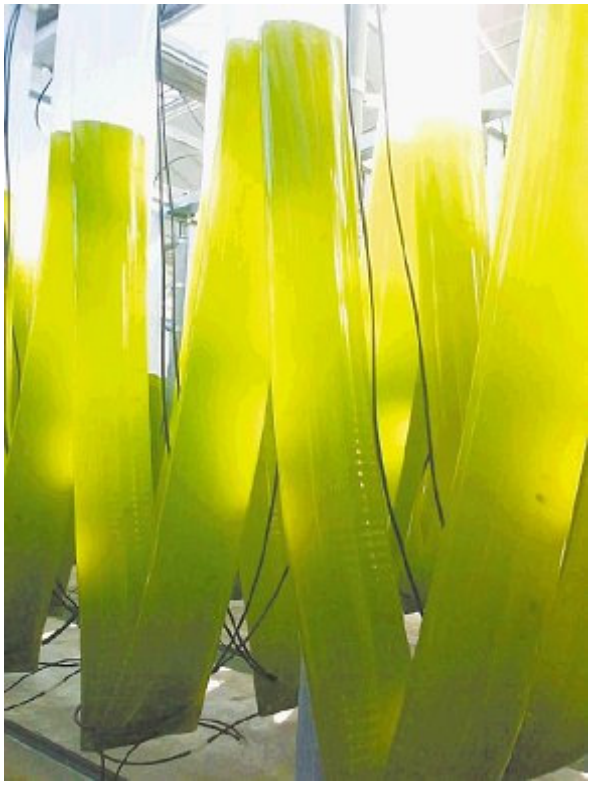

Figure 13 Marine algae photo-bioreactors (Willemse, 2009)

The incorporation of utilizing wastewater in the process with its municipal benefits is another potential opportunity for venture capital. Promotion of the investment could even provide positive public relations through publicizing public health and environmental benefits. The municipal benefits of higher grade water quality, lower costs, and financial incentives from the CDM plus potential partnerships with Development Finance Institutions should increase venture capital's attention.

FEASIBILITY ANALYSIS

Can the CDM be used to improve water quality in eThekwini Municipality by incorporating algae based wastewater treatment systems? There are five questions central to the criteria.

1. Viable and Appropriate Technology

The first criterion is to ensure that algae for wastewater to biofuels are a viable technology. Is it scientifically sound? Does it make sense given the particular conditions of Durban, South Africa?

Algae are a second and better generation biofuel because it doesn't compete with food production and has much more available energy. Some species of algae are so rich in oil that it accounts for over 50% of their mass.[61] The oil-per-acre production rate is 100-300 times the amount of soybeans, and offers the highest yield feedstock for biodiesel.[62] Using wastewater for production increases the efficiencies as water resources aren't depleted for algae biofuel production.

The alga to biofuel model is not wishful thinking. Multiple large-scale combustion-fired power plants are in the process of developing algae-based biofuel production facilities that will absorb their CO_2. In addition to reducing power plant overall emissions by recycling them into the algae production, a new revenue stream can be created by producing biofuels. This could underwrite the cost of CO_2 abatement. What's really cutting edge here is combining algae for biofuel with wastewater treatment as a source of water, nutrients, and CO_2.

Algal systems for wastewater treatment systems have been in practice for several decades. They provide a low-cost and effective method for nutrient and organics removal.

Previously, they've been applied primarily in more rural areas where land is available for settling ponds and drying beds. They have been used most commonly in developing countries. However, with the pressures to reduce GHG emissions and the rising prices of fossil fuel, algae systems are attracting attention from water industry leaders and research investment for implementation in larger population areas as well. There are several promising innovations that are being researched and tested, however at this point, they are still conceptual. Most experts agree they are 3-5 years from full-scale implementation.

Climatically, South Africa overall has good conditions for the algae processes considering its aridity and temperature range. KwaZulu Natal is a little less arid with more rainfall. Even with twice the rainfall of South Africa overall (an average of 1,000 mm) it still offers hospitable conditions for algal technology. It has an abundance of sunny days, 320 per year. The temperature range is from the minimum of 17°C to the maximum of 25°C. The high range of this is ideal and the low range could easily be managed by heating ponds through solar photovoltaic panels.

South Africa is already familiar with the Integrated Algal Ponding System. They have significant experience and research through the Rhodes University study (43). These systems are less expensive to build and operate because they involve less mechanical processes, less energy use, and fewer chemicals than conventional WWTPs. They have been practiced and continue to be an appropriate technology in developing countries. Given the newly appreciated benefits of reduced emissions and energy use, as well as the recent surge in research, it is reasonable to assume algal treatment technologies will become much more popular in developing and developed countries.

eThekwini Municipality will be well prepared to construct and operate algal wastewater treatment processes. The Kingsburgh Wastewater Works has been the pilot site for 300,000

liter volume raceway[63] since 2006. Dr. Manjinder Singh of Durban University Technology has been conducting the study working in collaboration with the municipality on a joint project of testing the technology for biodiesel production. The training of graduate and postgraduate students involved in the study will help develop the human resource capital needed to successfully implement the technology.

2. South Africa as a CDM Host

Secondly, even if it is viable, are South Africa and particularly eThekwini Municipality, in a position to leverage the CDM? Do they have the organizational capacity and political will to participate in the complex process of the mechanism?

The Department of Minerals and Energy's campaign to promote the CDM appears to be meeting its objectives. As of June 2008, there were 80 CDM projects submitted for initial review and approval. The project types cover a wide scope: bio-fuels, energy efficiency, waste management, cogeneration, fuel switching, and hydro-power. Major sectors of the economy have become engaged including manufacturing, mining, agriculture, energy, waste management, housing and residential.

Because South Africa relies on coal sources for energy it is relatively easy to net a carbon savings when switching fuel sources. Projects range in abatement of CO_2 t ~ from 7,000 at the low end for home solar water heaters and CFL bulbs in housing projects to 20,170,000 CO_2t ~for the replacing of an old coal-fired power plant with a gas fired station to produce electricity. [64]

Although, all of the projects by their project descriptions will contribute to sustainability in South Africa mostly through energy efficiencies and transfer into non fossil fuel sources, none

addresses UN millennium goals or contribute to water quality. As noted earlier, South Africa is particularly conscious of meeting its sustainability goals and unlike many countries, has established sustainable development criteria to guide the DNA in its approval process. Given the emphasis placed on equity and plans of South Africa to provide and protect water quality, I would anticipate the Department of Minerals and Energy to provide support and welcome projects using algae to treat wastewater.

The eThekwini Municipality is sensitive to its role and that of South Africa's as one of the highest emitters of CO_2 per capita in the world. The combination of heavy industry, particularly in Durban, and its historical reliance on indigenous coal supplies have made it a concentrated source of GHG emissions. eThekwini Municipality has taken a proactive position as reflected in the vision statement of their Integrated Development Plan. They intend to reduce GHG emissions and encourage "sustainability in energy sector development and energy use through efficient supply-side and demand-side practices and increased uptake of renewable energy sources." The eThekwini Municipality Energy Strategy (53) contains a plan to develop a diverse portfolio of renewable energy and energy efficiency projects to meet target goals. Their collaborative effort with the Durban University of Technology at Kingsburgh wastewater treatment plant is evidence that they are already considering and open to the concept of algae to biofuel using wastewater.

3. Financing

The third consideration is about the availability of capital for investment in a new technology? This could be a disruptive transition because it involves a different treatment process and therefore poses risks. It also involves unusual partnerships between municipalities, power and/or petrochemical companies.

At the recent World Water Forum in Istanbul, Turkey, World Bank representatives lamented the economic downturn and its impact on progress in meeting sanitation goals. Jamal Saghir, director of energy, transport and water at the World Bank, pleaded for countries to apply greater efficiencies in water management since stimulus packages by developed countries include little funds for water investment. "We will have to do more with less," he concluded (AP, 2009). Obviously, depressed economies will have fewer opportunities for investment, but what money is available will more easily be channeled to those projects that present the greatest efficiencies and sustainable development benefits such as algae wastewater treatment.

As a result of the UNFCC's Nairobi Framework international banking institutions have become more sensitized to serving the African continent. Through the work of the Department of Minerals and Energy in South Africa, regional banks have been mobilized and are spearheading CDM projects. It is reasonable to expect that they would welcome wastewater treatment projects using algae.

Again, the exponential growth in research and venture capital is very promising. Since I've been following this topic, there are new algae to fuel pilot plants announced each week. Particularly relevant to using wastewater for algae, is the announcement that a Dutch biotechnology firm will open a plant in September 2009 that will use sewage waste to supply 20% of a city's energy needs and use leftover nutrients for algae production.[65] Several others are planned for Malaysia and in Brazil. As mentioned previously, a German company has selected KwaZulu Natal Province's neighbor, the Eastern Cape, as the pilot location for numerous algae to power projects.

4. Water Quality

The issue of whether it enhances water quality overall and therefore helps meet sanitation objectives is the fourth criteria and fundamental to the thesis of this paper. Is water quality enhanced for public health, the environment, and the business environment?

A primary water quality problem for eThekwini Municipality is eutrophication in its rivers. Depending on the time of the year (determining the amount of rainfall) the concentrated nutrient load can overwhelm the river systems. In some cases, WWTP effluent dominates the base flow (50-90%). Algae based wastewater systems are particularly effective in reducing nitrogen and phosphorus. Building small systems or retrofitting aged and ineffective systems could have a significant impact on water quality overall in Durban.

Also, it's important to note that these plants will be much less expensive to operate. Algae for wastewater treatment replace secondary treatment which has the most energy and chemical demand of the entire process. In the United States, it is some 70% of operational expense. It is reasonable to assume that less expensive treatment options will allow for increased wastewater treatment facilities and service throughout the municipality resulting in higher water quality and increased sanitation.

The algae wastewater treatment to biofuel has potential for many industrial applications. Development of Durban industry may look toward the models being created in the neighboring Eastern Cape Province. It is quite possible that these models will spread to KwaZulu-Natal and lighten the municipal industrial load for wastewater treatment.

5. Value of CERs

Lastly - but potentially the most important criterion to the proposal of this paper - What is the value of CERs from GHG emissions savings and is it adequate to provide an incentive for instituting the technology.

Generating CERs through the CDM to build or retrofit algae wastewater treatment systems would create a financial incentive and attract funding institutions and private industry to provide initial capital provided the credits are substantial enough. Based on a survey of current projects, this is a very broad range (7,000-22$M_t CO_2$~). However, recent discussion about the CDM put the future potential of smaller scale projects in doubt.

Because of controversies surrounding the validity and "additionality" of some CDM projects, more stringent guidelines and monitoring are being required from independent Designated Operational Entities (DOEs). There are only a handful of these companies and as their expenses go up due to increased investigative needs they have increased prices three-fold. Currently, a validation can cost as much as $33,100.[66] The cost- benefit ratio for a smaller scale project becomes very weak.

In addition, the recent downturn in the market has also flooded EU Emissions Trading Scheme with CERs reducing their value to as low as €8 this year.[67] Of course, this removes incentives particularly for smaller scale projects. Low carbon prices make the market completely ineffective under a cap and trade scheme.

The CER potential for an algae based wastewater project would have a broad range depending upon whether it is a new WWTP or the retrofitting of a conventional WWTP. A credit analysis should take into account the following potential abatements and energy savings.

- N_2O fugitive emissions that would normally take place during the secondary treatment in a conventional WWTP will be prevented.

- CH_4 emissions will be recycled in the treatment process to feed and increase the photosynthesis process. (Flue gasses that are normally GHG waste could be diverted to feed algal.)

- Energy offsets will be created by the capture of waste gases and cogeneration to operate WWTP.

- Electricity and its GHG emissions will be saved by using a less mechanical and energy intensive system.

- Energy exports may be produced for biogas or power to the electric grid.

- Nutrients from dried algal can be used to produce fertilizers and/or bioplastics thereby creating offsets from energy that would be used to produce these energy intensive products.

The largest GHG reduction would be from the biofuel created by the algae. However, unless the biofuel, fertilizer and/or bioplastics were being used by eThekwini Municipality, replacing a more carbon intensive energy form or product, they could not be claimed for offset credit. The biofuel and other byproducts would provide revenues and therefore an economic incentive. However, the credits for reductions could only be claimed by the organization using them.

CONCLUSIONS & RECOMMENDATIONS

Algal processes for wastewater treatment aren't new. They have been successfully employed since the 50s in the form of high rate pond systems. Algae to biofuel is relatively new but has been researched since the 70s with tremendous advances in technology and identification of advantageous species for production. The technology is still somewhat conceptual for wastewater treatment but there are several models and prototypes being operated with predictions that it will be implemented within 3-5 years. The real challenge is partnering the wastewater industry with the petrochemical industry. Both need the other to be able to scale up production for water quality benefits and profitability for algae biofuel and other byproducts such as fertilizer, and bioplastics. In the literature reviewed for this project, the cost of producing biofuel ranged from $20 to $35 per gallon. However, the anticipated price, once scale is mastered, was speculated by several experts at $1.50 per gallon.

There is potential for sanitation objectives to receive economic incentive through the CDM for algae treating wastewater. However, it is not in the large scale and more urban treatment plants as was originally envisioned when I started this master's project. Given the level of enthusiasm within the water sector for this technology, and the reliability of the currently applied algae HRPs, it is plausible these processes could be scaled up and available to larger treatment plants in only a few years.

However, in the meantime, there is still substantial benefit to be claimed, particularly in the eThekwini municipality, for upgrading the operations of small conventional WWTP .5 - 10 MGD (6,000 to 120,000 population served equivalents) by retrofitting the secondary treatment process to algae based treatment system as in the Lyon's model (44). Given the nutrient discharge issues of rivers throughout the eThekwini service area, this may provide a viable and least expensive option for improving water quality while generating energy. It's attraction as an

innovative technology that also addresses GHG emissions could draw the necessary funding to meet its implementation challenges.

In order to make these projects more attractive from a CER credit perspective, they will need to be grouped together in a “Sectoral” approach for the CDM proposal. eThekwini Municipality would be served by a process biofuels facility for its own use. In that way, it can gain credit for the offset of more fossil fuel intensive oils used and maximize the CERs available.

A Sectoral approach would group all of the emissions reductions within the water and sanitation unit of eThekwini Municipality. In addition, to the retrofits for algae wastewater treatment, CH4 can be captured from plants with anaerobic digesters and used as a fuel source in other parts of the plant. This has become a relatively common practice and will generate CERs that added to the algae treatment savings will increase the value of the financial incentives and therefore increase the ability to enhance water quality and sanitation overall.

APPENDIX

Acronyms & Explanations

AAUs – Assigned Amount Units, Joint Implementation allows trade of assigned allowable emissions.

Annex 1 Countries – are the 36 countries listed in Annex 1 of the UNFCCC that ratified the Kyoto Protocol and have specific emission reduction targets.

BOD – Biological Oxygen Demand

BNR – Biological Nutrient Removal

CDM – Clean Development Mechanism

CER – Certified Emission Reduction

CPR – Common Pool Resource

DFI – Development Financial Institution

DBSA - Development Bank of South Africa

DNA – Designated National Authority

GHG – Greenhouse Gas

GWP – Global Warming Potential, conversion to CO_2 ~ based on 100 year global warming potential.

IPCC – Intergovernmental Panel on Climate Change

MGD – Million Gallons of water per day

Non-Annex 1 Countries – developing and middle income countries that ratified the Kyoto Protocol and will eventually have reduction targets but for now can reduce emissions and generate CER credits.

PDD – Project Design Document

SD – Sustainable Development

TAR – (IPCC) Third Assessment Report

TSS – Total Suspended Solids

UD – Urine Diversion toilets, on-site sanitation system

VIP - Ventilated Improved Pit Latrine, on-site sanitation system

WEFTEC – Water Environment Federation's Technical Exhibition and Conference

WWTP – Wastewater Treatment Plant

South Africa – Sustainable Development Criteria

Sustainable development is defined in the National Environmental Management Act (NEMA) as "the integration of social, economic and environmental factors into planning, implementation and decision making so as to ensure that development serves present and future generations".
This definition of sustainable development informs the decisions of the Designated National Authority of the Clean Development Mechanism

Criteria

In accordance with the NEMA definition of sustainable development, three core criteria are used to assess the contribution of proposed projects to sustainable development in South Africa. These are supported by additional indicators to allow the DNA to effectively regulate CDM project activity in South Africa.
The DNA evaluates CDM projects submitted to it through consideration of the following three criteria:

- Economic: Does the project contribute to national economic development?
- Social: Does the project contribute to social development in South Africa?
- Environmental: Does the project conform to the National Environmental Management Act principles of sustainable development?

These principles are that "sustainable development requires the consideration of all relevant factors", including the following:

- That the disturbance of ecosystems and loss of biological diversity are avoided, or where they cannot be avoided, are minimized and remedied;

- That pollution and degradation of the environment are avoided, or where they cannot be altogether avoided, are minimized and remedied;
- That the disturbance of landscapes and sites that constitute the nation's cultural heritage is avoided, or where it cannot be altogether avoided, is minimized and remedied;
- That waste is avoided, or where it cannot be altogether avoided, minimized and reused or recycled where possible and otherwise disposed of in a responsible manner;
- That the use and exploitation of non-renewable resources is responsible and equitable, and takes into account the consequences of the depletion of the resource;
- That the development, use and exploitation of renewable resources and the ecosystems of which they are part do not exceed the level beyond which their integrity is jeopardized;
- That a risk averse and cautious approach is applied, which takes into account the limits of current knowledge about the consequences of decisions and actions; and
- That negative impacts on the environment and on people's environmental rights be anticipated and prevented, and where they cannot be altogether prevented, are minimized and remedied.

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