NEW WASTEWATER DISPOSAL RULES AIMED AT PROTECTING THE ENVIRONMENT COULD HAVE DRASTIC CLIMATE CHANGE IMPACTS

Enrique Vadiveloo, Hazen and Sawyer, P.C., Hollywood, FL
George A. Brown, Hazen and Sawyer, P.C., Hollywood, FL
Gary W. Bors, Hazen and Sawyer, P.C., Hollywood, FL
Janeen M. Wietgrefe, Hazen and Sawyer, P.C., Hollywood, FL
Bert J. Vidal, Hazen and Sawyer, P.C., Hollywood, FL
Vin Morello, Broward County Office of Environmental Services, Pompano Beach, FL

Introduction

Recent regulatory agency initiatives in Southeast Florida will inevitably result in significant increased energy consumption as treatment levels necessitate highly energy dependent technologies. For the regional wastewater system, increased energy consumption is expected primarily from rule changes requiring phased elimination of open ocean discharge (with related reuse mandates), increased reuse requirements, as well as a separate rule change requiring high-level disinfection for future Class I Injection Wells.

These regulatory initiatives occur at a time of acute focus on climate change, with specific attention to the role of greenhouse gas emissions as a cause of global warming. In South Florida, some experts say the effects of warming and sea level rise are likely to be dramatic. National and global climate change initiatives aimed at leveling-off and decreasing greenhouse gas emissions, such as cap and trade, are expected to affect both electricity production and cost.

The intent of this paper is to examine each of the alternatives available to Broward County (as well as combinations) in the context of feasibility, associated cost and energy consumption/carbon footprint impact in order to arrive at the best long term solution to comply with the ocean outfall rule.

Existing Facility

Broward County Florida operates the North Regional Wastewater Treatment Plant (NRWWTP), a nominal 95 mgd secondary treatment facility. The utility currently uses a series of treatment processes to achieve carbonaceous treatment. Raw wastewater is screened then flows to the activated sludge treatment process for completion of carbonaceous biochemical oxygen demand reduction. The biological treatment modules are referred to as Modules A, B, C, D and E. Treatment modules A, B and D are each equipped with three surface aerators. Modules C and E use fine bubble diffusers to aerate the mixed liquor. Each treatment module has a capacity of 20 mgd AADF; the overall capacity of the biological treatment facilities is 100 mgd AADF.

Effluent disposal is accomplished by pumping treated effluent via an ocean outfall pump station, an injection well pump station or by an effluent reuse pump station. The ocean outfall is a 54-inch diameter ductile iron pipeline that discharges 7,300 feet from shore in about 110 feet of water. The ocean outfall has a permittable design capacity of 66 mgd AADF. The existing Outfall Pump Station conveys water to the ocean outfall. The Outfall Pump Station includes 1 low head and 4 high head pumps.

There are currently six existing Class I injection wells at the NRWWTP. The wells are designated as IW-1 through IW-6. The system also includes four monitor wells, designated MW-1 through MW-4. IW-1 through IW-4 were constructed between 1990 and 1991. IW-5 and IW-6 were constructed between 2000 and 2001. All deep injection wells were completed before recent changes to the Underground Injection Control rules in 2005 which now required high level disinfection treatment prior to injection well disposal.

Current Effluent Disposal and Reclaimed Water Practices

During the 2003 through 2007 operating period, the NRWWTP discharged about 37.4 million gallons per day (mgd) of effluent to the Atlantic Ocean via a 54-inch diameter ocean outfall pipeline on a daily average basis. Additionally, the utility currently disposed of an average of about 31 mgd of effluent to Class I deep injection wells.

About 4.75 mgd of treated effluent was reclaimed and reused for non-potable purposes. These non-potable purposes include on-site irrigation, process water and supply to offsite users for various irrigation and industrial process purposes. A significant portion of this non-potable flow is recaptured through the existing WWTP process with a "net" reuse consumption of approximately 1.1 mgd.

Additionally, an average of about 1.65 mgd of treated effluent is currently removed from the ocean outfall at the Pompano Beach Reuse Plant, treated to reuse standards, and then utilized. Regulations presently allow discharge of secondary treated effluent with basic disinfection to the open ocean outfall and secondary effluent to existing Class I deep injection wells. These two disposal methods have historically proven to be the most reliable and permittable effluent disposal means in southeast Florida. Both methods were originally viewed as protective of human health by virtue of separating of the treated effluent from the local potable water supply source, the Biscayne Aquifer. Both methods were also initially viewed as protective of the environment by separating the treated effluent from the inland and near shore ecosystems. The open ocean outfall discharges in the western boundary of the Florida Current; a tributary of the Gulf Stream which flows north along the Atlantic coast of Florida. The receiving waters are classified as Class III waters by the state of Florida. The NRWWTP outfall discharge is operating in full compliance with current regulations and permitted limits.

Over time, the increased reliance on these two disposal methods to support the region's population growth led to opposition by certain special interest groups and, in the case of ocean outfalls, by the Florida Department of Environmental Protection.

During prior permitting efforts, Clean Water Act compliance concerns were addressed through a series of studies. Two large scale evaluations were performed under the Southeast Florida Ocean Outfalls Experiment (SEFLOE) studies completed through a cooperative effort of several governmental agencies in 1988 and 1994. The studies developed extensive data relative to the receiving waters and the impact of the discharge on the marine environment. Monitoring and testing over the past decades demonstrated that the discharge is not toxic and that plume dispersion characteristics are such that background water quality is met within currently allowable mixing zones.

However, recurrent questions relative to the possible impact of nutrients on the receiving waters ultimately led to passage of Senate Bill 1302. This legislation requires a reduction in nutrients discharged via the outfall by the year 2018 and the elimination of ocean outfalls by the year 2025.

Regulatory Changes

Ocean Outfall Rule

House Bill (HB) 7139 and Senate Bill (SB) 1302 were proposed to eliminate the use of ocean outfalls for wastewater effluent disposal and require expansion of effluent reuse. The Governor of Florida signed Chapter 2008-232, a consolidated bill, into law on June 30, 2008 with an effective date of July 1, 2008. The legislation is referred to herein as the Outfall Rule.

The Outfall Rule mandates that the discharge of domestic wastewater through ocean outfalls will be required to meet advanced wastewater treatment and management requirements no later than December 31, 2018.

These requirements and compliance pathways were defined by the new legislation as meeting the following conditions:

- **Path 1**: Advanced waste treatment (AWT) standards; or

- **Path 2**: A reduction in cumulative outfall loadings of TN and TP occurring between December 31, 2008 and December 31, 2025, which is equivalent to that which would be achieved if the AWT requirements were fully implemented beginning December 31, 2018, and continued through December 31, 2025.

Advanced waste treatment standards are defined by Florida Statute 403.086(4) as treatment that contains not more, on a permitted annual average basis, than the following concentrations:

- Biochemical Oxygen Demand ($CBOD_5$) 5 mg/L
- Total Suspended Solids (TSS) 5 mg/L
- Total Nitrogen, expressed as N 3 mg/L
- Total Phosphorus, expressed as P 1 mg/L
- High level disinfection (HLD) of the effluent

Construction of an AWT facility at the NRWWTP site has been viewed as not economically or technically feasible due to a number of limiting factors and therefore excluded from the scope of this paper.

Based upon the Outfall Rule Part 2 cumulative loading requirements, the resultant allowable cumulative load of TN is 14,020 tons; the allowable cumulative load of TP is 1,400 tons; as illustrated below.

Table 1. Broward NRWWTP
Maximum Allowable Cumulative Nutrient Loading – Years 2009 through 2025

	Total Nitrogen	**Total Phosphorus**
Annual Load 2009 - 2018	1,282.4 tons/year	100.2 tons/year
Annual Load 2019 - 2025	170.8 tons/year	56.9 tons/year
Cumulative Load 2009 - 2018	12,824 tons	1002 tons
Cumulative Load 2019 - 2025	1,196 tons	398 tons
Total Cumulative Load 2009 - 2025	**14,020 tons**	**1,400 tons**

The Outfall Rule mandates that the discharge of domestic wastewater through ocean outfalls be prohibited after December 31, 2025, except as a backup discharge that is part of a "functioning reuse system" authorized by FDEP. A backup discharge to the ocean would only be allowed during periods of reduced demand for reclaimed water, such as wet weather, and such discharges are to comply with the advanced wastewater treatment and management requirements. The maximum annual loading allowable through the outfall after 2025 has been interpreted to be less than or equivalent to that mass loading which would correspond to the AWT nutrient standards (3 mg/L TN and 1 mg/L TP) at the facility's established baseline allowable outfall flow.

Based upon recent interpretation of this requirement by FDEP it is reasonable to assume for the NRWWTP that at the facility's established baseline allowable outfall flow rate of 37.4 mgd, approximately 171 tons/year of TN and 57 tons/year of TP could be released assuming management of equivalent AWT treatment standards.

For backup disposal of secondary effluent through the outfall, this would represent approximately 2 billion gallons of allowable backup discharge per year. For example, at the established baseline allowable AADF outfall flow rate of 37.4 mgd, this would be equivalent to approximately 53 days of backup discharge in any given 365 day period.

The interpretation of the Outfall Rule will require further clarification with FDEP relative to the intent of the language as it may be specifically applied to the NRWWTP as the County continues to move forward.

For purposes of this paper, all facilities shall be sufficient to provide up to 200 mgd of peak hour injection well system primary backup disposal capacity of high level disinfection process (HLD) effluent. This flow rate is equivalent to 100% peak hour disposal capacity under severe weather conditions (hurricane, flooding, etc.) when there is minimal, if any, water demand by the "functioning reuse system".

The ocean outfall is anticipated to remain as a secondary means of partial backup disposal as a contingency. The outfall will only provide partial relief since its capacity is limited to the existing outfall pipeline and pumping system peak flow rate capacity.

The Outfall Rule defined a "functioning reuse system" as "an environmentally, economically and technically feasible system that provides a minimum of 60 percent of the facility's actual flow on an annual basis for irrigation of public access reuse areas, residential properties, or agricultural crops, aquifer recharge, groundwater recharge, industrial cooling, or other acceptable reuse purposes authorized by

FDEP". The term "facility's actual flow on an annual basis" is defined as the annual average flow of domestic wastewater discharging through the facility's ocean outfall using monitoring data available for calendar years 2003 through 2007.

For the NRWWTP this outfall flow rate has been established at 37.4 mgd; the corresponding reclaimed water flow would be computed as 22.5 mgd (60 percent of 37.4 mgd).

New HLD Requirements for Class I Injection Wells

As discussed above, any new Class I injection well (that was submitted for permitting after December 2005) will need to meet the requirements for HLD to comply with the new Federal Underground Injection Control (UIC) Requirements for Class I Municipal Disposal Wells in Florida.

HLD regulations require additional TSS control beyond secondary treatment to maximize disinfection effectiveness. The rule also requires that HLD facilities be designed to result in an effluent in which fecal coliform values are below detectable limits.

Table 2 lists a brief summary of the main HLD requirements.

Table 2. High Level Disinfection Requirements

Parameter	**Limitation**
Peak filter loading rate	6.0 gpm/ft^2
Fecal Coliform	75% of Samples Below Detectable Limits
TSS before Disinfection	≤ 5 mg/L
Minimum Chlorine Residual	1 mg/L
Minimum Contact Time	15 minutes at peak hourly flow rate

For the NRWWTP, to meet increased disinfection needs to achieve HLD treatment levels for reuse and to provide high level disinfection prior to disposal through any new Class I injection wells, the following key elements are anticipated:

1. Filter feed pump station
2. Deep bed filters
3. New chlorine contact tanks
4. Hypochlorite generation (optional) or commercial bulk hypochlorite storage and feed system to replace existing gaseous chlorine facility
5. Electrical upgrades including new FPL service feeders

High level disinfection (HLD) requires a minimum of 15 minutes of chlorine contact time at peak flows with a minimum free chlorine residual of 1.0 mg/L at all times. Additionally, new chlorine contact tanks are required to provide adequate detention time and chlorine residual to meet CT (concentration-contact time) requirements without reliance on downstream facilities. New chlorine contact tank facilities should be designed to provide a minimum detention time of 15 minutes at peak hour flow, and chlorine feed should be adjusted to meet the required CT requirements.

The County's long term goal is to eliminate gaseous chlorine in favor of liquid bleach systems to reduce risk and address heightened security concerns. Several facilities have begun or have completed conversion from gaseous chlorine to bleach systems. Based upon cost analyses prepared for other similarly sized facilities, an on-site sodium hypochlorite generation system, a commercial bulk sodium hypochlorite storage facility, or a commercial bulk sodium hypochlorite storage facility with provisions for the future addition of an on-site system may prove to be the most cost effective.

Long Term Effluent Disposal Options

The primary effluent disposal method shall be through deep injection wells. The deep injection wells shall also be used as backup to the reuse system. It is assumed that the primary method of the reclaimed water utilization will be large-user (e.g., golf courses) irrigation. The reclaimed water demand available from the potential large users is insufficient, by itself, to meet the 60 percent reuse requirement of the Outfall Rule. Hence, supplemental reuse would be needed. The supplemental reuse methods considered in this paper include Biscayne aquifer recharge and dual distribution residential irrigation.

Based on these assumptions two viable long term effluent disposal alternatives were chosen:

- **Alternate LT-1**: Module E Full BNR - Biscayne Aquifer Recharge / HLD Facility / Offsite Large User Reuse - Injection Well Backup Disposal

- **Alternate LT-2**: Conventional Activated Sludge / Offsite Large User and Residential Reuse - Injection Well Backup Disposal

Alternative LT-1

Wastewater reclamation and reuse requirements contained within the language of the Outfall Rule can be achieved through high level disinfection followed by reclaimed water pumping and distribution to large user customers for irrigation purposes. However, due to the seasonal variations in reclaimed water irrigation demands and available large user acreage; supplemental wastewater reclamation facilities will be required. One option to supplement reclaimed water irrigation is Biscayne Aquifer recharge. Potential recharge mechanisms include: Biscayne aquifer recharge wells, canal discharge or treatment wetlands (if permitted under BC Chapter 27). The scope of this evaluation is limited to considering Biscayne aquifer recharge through canal discharge.

Advanced wastewater treatment processes are required to meet the Broward County surface water discharge TN and TP limits of 1.5 mg/L and 0.02 mg/L, respectively. Biological nutrient removal followed by ultrafiltration (UF) and reverse osmosis (RO) membrane processes are capable of reducing particulate and soluble nitrogen and phosphorus sufficiently to meet these very strict standards, which are at the limits of technology (LOT) for nutrient removal.

This alternative returns operation of Modules A through D to the conventional activated sludge process or partial nutrient removal (PNR) operation can remain, if desired. Effluent from Modules A through D as well as excess flow from Module E would receive filtration and high level disinfection prior to pumping to reuse distribution and injection well systems.

Module E would be converted to a full biological nutrient removal (BNR) process followed by UF membranes, RO and ultraviolet (UV) disinfection with advanced oxidation processes (AOP) to provide reclaimed water for Biscayne aquifer recharge.

For the purposes of this evaluation the following assumptions have been applied:

- ♦ It is assumed that FDEP will allow concentrate from the RO facility to be disposed of via the NRWWTP's effluent injection well system. If a dedicated disposal well is required by FDEP, then the cost of an injection well pump station, electrical facilities, monitor well and ancillary facilities must be added to this alternative.

- ♦ Future regulations may require AOP for disinfection and emerging contaminant removal for indirect potable reuse applications such as direct recharge of the Biscayne aquifer. Therefore, UV disinfection with hydrogen peroxide addition was assumed downstream of the RO facilities.

It should be noted that recent pilot testing of a wastewater reuse system using RO membranes for nutrient polishing indicates the final effluent may not pass the effluent toxicity testing, due to a possible ionic imbalance in the effluent. This technology must be pilot tested and toxicity issues resolved prior to implementing this alternative.

Overall, Alternate LT-1 would produce an additional 22.5 mgd of reuse on an annual average basis via a combination of 7.8 mgd of large-user reuse irrigation via the proposed HLD facilities at the NRWWTP plus 14.7 mgd of Biscayne aquifer recharge at proposed RO facilities at the NRWWTP.

Alternative LT-2

Under Alternate LT-2, compliance with the Outfall Rule reuse requirement would be accomplished through a combination of large user irrigation along with conveying reclaimed water to include individual residential and small commercial customers for irrigation.

This treatment strategy includes the return of Modules A through E to the conventional activated sludge process. A 200 mgd (peak) high level disinfection facility would be constructed to serve all off site reuse customers including large users as well as individual residential and commercial customers. The high level disinfection facility would also provide HLD treatment prior to injection well disposal of all effluent not delivered by the reuse system. The effluent transfer and high level disinfection facilities would be identical to those described for Alternate LT-1.

A new electrical distribution, emergency power and fuel storage facility would be required to serve the HLD facility and transfer pump station. A detailed electrical power load study will be required to confirm the viability of the existing system and integration with the proposed power system.

Overall, Alternate LT-2 would produce a an additional 22.5 mgd of reuse on an annual average basis using a combination of 7.8 mgd AADF of large-user reuse irrigation plus 14.7 mgd AADF of residential irrigation of HLD facility product from the NRWWTP.

Opinion of Probable Costs

Table 3 summarizes order-of-magnitude construction cost estimates for the above described long term alternates. The project cost presented includes construction cost along with contingency and fees for engineering services. The project cost of each includes the cost for the large-user reclaimed water transmission system plus the cost for the supplemental reuse facilities.

This table also includes an estimate of the annual operations and maintenance costs (O&M) and 20-year present worth for each alternate. The annual O&M costs were based upon power consumption estimates and a power cost of $0.09 per kilowatt-hour. The O&M costs associated with operating labor, spare parts and chemicals were not included.

Table 3. 20-Year Present Worth (millions of 2009 dollars)
Long-Term Alternatives for Compliance with the Outfall Rule

Cost Item	**Long Term Alternates**	
	LT-1	**LT-2**
Project Cost[1] (2009 $M)	$815	$850
Annual O&M Cost ($M/year)	$7.0	$5.1
20-Year O&M Cost[2] (2009 $M)	$140	$101
20-Year Present Worth (2009 $M)	$955	$951

[1] *The project cost includes the following: construction cost, land acquisition, contractor overhead, contractor profit, contingencies together with engineering services during design, permitting, and construction. Project costs are in 2009 dollars.*

[2] *The escalation of power cost was disregarded since the annual operating costs for the long-term alternatives would not begin until the year 2026. Therefore, the 20-Year O&M cost was estimated as simply 20 times the annual O&M cost.*

Carbon Footprint Impacts

Carbon footprint assessment is a methodology for accounting for greenhouse gas (GHG) emissions and is gaining acceptance as a measure of long-term sustainability for water treatment projects. Reports published by the International Panel on Climate Change (IPCC) and the World Resources Institute (WRI) serve as the accepted guidelines for the preparation of GHG inventories, where all emissions contributing to climate change for a given process are identified and quantified. The global warming potential (GWP) is a measure of the amount that a gas will contribute to global warming over a certain period of time, relative to carbon dioxide. Standard values for GWP are established in the IPCC Third Assessment Report, shown in Table 4, where values for the 100-year time horizon are used in accordance with common practice. The GWP allows for the conversion of emissions outlined in the GHG inventory to carbon dioxide equivalents (CO2e), allowing for the development of a carbon footprint (IPCC, 2001).

Table 4. Direct Global Warming Potentials (IPCC, 2001)

Gas	**Global Warming Potential Time Horizon in Years**		
	20 yrs	100 yrs	500 yrs
Carbon dioxide	1	1	1
Methane	62	23	7
Nitrous Oxide	275	296	156

The WRI GHG protocol (WRI, 2004) has identified three distinct groups in which to categorize emissions which cause global warming. These classifications are identified as follows:

- Scope 1 emissions are those released into the atmosphere directly from a given process. This could include methane released in the case of decomposition of biosolids or nitrous oxide released in an activated sludge process. The present analysis for the City of Plantation is based on the addition of select process components to those already in place at the existing water and wastewater treatment facilities. Therefore, a system boundary was constructed to include existing facilities at the City of Plantation. Since the processes proposed to meet future water supply needs are primarily separation and chemical-based systems which are not known to produce appreciable GHG emissions, it is assumed that Scope 1 emissions are negligible for purposes of this analysis.

- Scope 2 emissions are those released into the atmosphere indirectly from a given process as a result of the purchase of energy. The present study is principally based on Scope 2 emissions as the alternatives proposed for the City contain energy consumptive processes.

- Scope 3 emissions are those released into the atmosphere indirectly from a given process as a result of the transport or manufacture of a given process component. This could include the emissions associated with electricity required for the off-site generation of bulk hypochlorite solution or the carbon dioxide released during the delivery of bulk antiscalant to a plant site. Scope 3 is generally considered an optional reporting category as emissions data must often times be provided by outside sources and GHG emissions can be difficult to quantify. The present study does not consider Scope 3 emissions, however it is recommended for future study.

Note also that the present analysis considers only the carbon footprint resulting from the operation of wastewater treatment systems, and does not account for GHS emissions relating to the construction or decommission of the proposed facilities.

The annual power consumption associated with each of the conceptual design alternatives was determined through summing individual process contributions, allowing for the application of emissions factors to calculate the mass of emissions released annually. Greenhouse gasses emitted from power utilities generally include carbon dioxide, methane, and nitrous oxide. Emission factors for these gasses were obtained from the US Environmental Protection Agency (USEPA) Emissions and Generation Resource Integrated Database (eGRID), where values for GWP were used in the conversion to CO_2e. The theoretical amount, in terms of mass, of CO_2e produced for each of the project alternatives could then computed for comparison in the carbon footprint assessment (USEPA, 2005; WRI, 2007).

Results

Based on liquid treatment and effluent disposal, the NRWWTP currently has an average annual electrical consumption of 52 million kWh for an annual electrical cost of $4.7 Million with a composite electricity cost of 9-cents per kWh and an annual average treatment of 100 mgd. As mentioned above, the NRWWTP currently has relatively inefficient mechanical aerators in Modules A, B and D. The NRWWTP is planning to convert those modules to fine bubble diffusers within the next five years. Those enhancements would reduce the average annual electrical consumption to 40 million kwh with an annual electrical cost of $3.6 Million.

Table 5 shows the carbon footprint impacts of each alternative in comparison to the existing operating conditions.

Table 5. Carbon Footprint Impacts

Alternative	Annual Power Consumption (MWh)	Carbon Dioxide Equivalents Emitted (1000 lbs/year)	Additional 1000 lbs of eCO_2/Yr
1. Existing System w/Enhancements[1]	40,000	53,900	-
2. LT-1	77,800	104,800	50,900
3. LT-2	56,300	75,800	21,900

[1]*Assumes mechanical aerators will be converted to fine bubble diffusers*

As can be seen, the ocean outfall while aimed at protecting the environment could add up to 51 million lbs of carbon dioxide equivalents (eCO_2) to the atmosphere annually.

Conclusions

A preliminary evaluation of the impacts related to the implementation of the ocean outfall rule indicates a present worth cost of almost 1 billion dollars and a carbon footprint increase equal to 51 million eCO_2 annually due to electrical consumption of electricity produced from typical fossil fuels. This rule while aimed at protecting the coastal reefs and increasing wastewater reuse could create larger global warming issues, especially since there are currently six wastewater treatment plants in southeast Florida that currently dispose of their treated effluent through open ocean outfalls. These results suggest that further dialog between the regulatory agencies, the regulated communities and the public at large should be pursued.

References

International Panel on Climate Change (2001) Climate Change 2001: The Scientific Basis; IPCC Third Assessment Report; Cambridge University Press: New York
http://www.grida.no/publications/other/ipcc_tar/?src=/climate/ipcc_tar/wg1/index.htm

Scanlan, P.; Elmendorf, H.; Shaw, A.; Tarallo, S. (2009) Evaluating Greenhouse Gas Emissions: An Inventory of Greenhouse Gasses is an Important Piece of the Sustainability Puzzle. Water Environment and Technology, 21 (4), 31-35.

Strutt, J.;Wilson, S.; Shorney-Barby, H.; Shaw, A.; Byers, A. (2008). Assessing the Carbon Footprint of Water Production. Journal AWWA, 100 (6), 80-91.

USEPA (2005) Emissions and Generation Resource Integrated Database (eGRID)
http://www.epa.gov/RDEE/energy-resources/egrid/index.html

World Resources Institute (2004) The Greenhouse Gas Protocol: A Corporate Accounting and Reporting Standard; World Resources Institute: Washington, DC
http://www.ghgprotocol.org/files/ghg-protocol-revised.pdf

World Resources Institute (2005) The Greenhouse Gas Protocol: The GHG Protocol for Project Accounting; World Resources Institute: Washington, DC
http://www.ghgprotocol.org/files/ghg_project_protocol.pdf

World Resources Institute (2007) The Greenhouse Gas Protocol: Guidelines for Quantifying GHG Reductions from Grid-Connected Electricity Projects; World Resources Institute: Washington, DC
http://www.ghgprotocol.org/files/electricity_final.pdf