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Case Report

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# Climate Smart Technological Solutions in Egypt: Hydropower Plant of the New Assiut Barrage Case Study

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**Abstract**

In Egypt, Hydropower sector plays a key role in Climate smart technological solutions to mitigate and adapt climate change. Egypt intends to replace the existing Assiut barrage in Nile River with a new one incorporating a hydropower plant. The technical and economical feasibility of the rehabilitation of the existing barrage including the installation of a low head hydropower plant of about 32 MW is proved. The electricity production of about 250 GWh annually is planed. The optimization of hydropower output will be achieved through mitigation of project-related environmental and social impacts. The implementation of measures to predict, monitor and mitigate or avoid construction and operation impacts is planned. This Paper sets out information relating to the contribution of Hydropower plant of New Assiut Barrage Project towards Adaptation and sustainability options. The Paper assesses the socio-economic and environmental impact of the project, the indicators applicable to the scheme / community in question, and details of the method used to diagnose and monitor social-environmental performance. Where applicable, the diagnostic for the community must be presented separately from that carried out for the scheme. The Paper concludes that the Hydropower plant of the New Assiut Barrage Project has very promising positive aspects in relation to climate change mitigation and adaptation and sustainable development in Egypt.

**Keywords:** Climate change; Hydropower; Assiut barrage; Mitigation; Egypt

## Introduction

UN Framework Convention on Climate Change (UNFCCC), first adopted in1992, established an international legal framework to address global climate change. Parties to Convention agreed to stabilize greenhouse gas (GHG) concentrations in earth's atmosphere by returning to 1990 GHG emission levels. Kyoto Protocol, adopted in 1997, commits industrialized countries to attaining legally binding GHG reduction targets during the period between 2008 and 2012. These commitments are an average of 5% below 1990 GHG emissions levels. In industrialized countries, where most GHG emissions are produced by private companies and individuals, each country will, therefore, have to either regulate or encourage large GHG emitters to reduce these emissions. Kyoto Protocol provides for a variety of measures to achieve GHG reductions through three special "Flexibility Mechanisms". These mechanisms are: Clean Development Mechanism, Joint Implementation and International Emissions Trading.

Clean Development Mechanism (CDM) has potential to assist in achieving sustainable development while contributing to the objective of stabilizing greenhouse gas levels in the atmosphere. As envisaged, the CDM will encourage additional capital flows to developing countries, accelerate technology transfer and facilitate cleaner technologies while assisting developed countries to achieve their emission reduction commitments at lower costs.

Renewable electricity may meet the increasing demand for commercial energy for those with access (mainly in cities), and provide access to modern, efficient and clean forms of energy for the majority of the population in isolated and rural areas, alleviating poverty. SD has tried to make this substantive approach operative through three major approaches: Sustainability as the maintenance of the stock of capital ; the triangular approach, which considers the three interrelated dimensions of sustainability (economic, social and environmental) and; the materials balance approach [1,2]. However, a given project should not only be sustainable according to the aforementioned three dimensions. It should also comply with the "procedural sustainability" approach. This is a participatory approach which takes into account the opinions and interests of all stakeholders [3]. Even though islands around the world have different landscapes and a diversity of natural resources, they share some common features that are relevant regarding the aforementioned triple dimension of SD. Scarcity of drinkable water is also often an important problem, which makes them dependant on external supplies from the mainland or, alternatively, on setting-up desalinization plants, which consume a significant amount of energy [4-6]. On one hand, access to energy has been highlighted as a major factor to reduce poverty levels of the local population, although both in islands and mainland [7,8]. According to the report from the UN on energy and environment, "The Energy Challenge for Achieving the Millennium Development Goals", there is a clear relationship between access to energy and achieving the Millennium Development Goals [7]. On the other hand, lack of adequate energy services is a constraint to development, which is probably more relevant in an island context than on the mainland [3,8]. Lack of energy limits the potentials of meeting basic needs of those who require energy to undertake essential domestic, agricultural and educational tasks, to support health and transport services, and to initiate or develop manufacturing or trading enterprises [8]. As stressed by Pérez and Ramos [9], small-sized electricity systems, which are not connected to other systems, present a series of characteristics that complicate and raise the costs of electricity supply: generation units cannot be too big as the loss of one generator would have a large effect on the overall system. Weisser [10] also argues that electricity supply in these territories is more expensive because there are high fuel transmission costs. These constraints require a different approach from that of mainland territories. Roper [11] notes that electricity prices in SIDS are generally between 20 and 35 cents (US) per kilowatt hour, which is much higher than prices in

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the USA or Europe. Secure supplies of affordable and reliable energy are an essential element of economic and social development. Security of supply has two main sides. As argued by Maria and Tsoutsos [12], the energy balance could be improved with the reinforcement of energy independence and safety and decentralization of energy production systems, simultaneously reducing losses of transferred energy and national energy dependence. Furthermore, they are usually tourist sites, receiving a significant, and often increasing, number of tourists, which aggravates the problems of energy and water supply with the existing capacity, especially during peak tourist periods [13]. The triple dimension of sustainability is presented [14-16]. The literature on renewable energy planning includes ex-ante assessments of the viability of different renewable energy options, considering the local RES [17-19]. Concerns about the environmental impact of RES plants and issues related to energy storage systems were other aspects studied in the renewable energy planning literature.

The environmental impacts of new RES plants (i.e., visual impact and land use) on tourism need to be taken explicitly into account. Tourism usually represents a large share of islands' total income, i.e., a conflict between tourism and RES may exist, although [20-23] suggest that this does not necessarily have to be the case. There is a surprising paucity of analysis both on the environmental impacts of RES in islands (with the exception of María and Tsoutsos [12]) and, more importantly, on the environmental problems that can be alleviated through the use of RES. The fact that most of papers deal with energy aspects of RES in islands, and much less with environmental aspects, might be a reflection of these aspects being significantly less relevant with respect to the mainland considerations, as argued by one of the reviewers of this paper. Renewable might not significantly improve the environmental dimension, since they use valuable land more inefficiently than imported fossil fuels. Since islands are usually rinsed by maritime winds and currents, emissions of local pollutants might not be a significant issue as on the mainland. Related to issues of public acceptability, but also to the application of new methodologies, there is a growing body of studies which try to infer the willingness to pay (WTP) for RES with either contingent valuation or choice experiments methodologies (see, for example, [24] and [2]). In addition, the contribution of RES to the transport systems in islands is hardly tackled, with the exception of [7] and [17]. The public policy dimension has been mostly absent, with the exception of [10] and [16]. A recent pioneering work in this direction is [9] for the case of the Canary Islands. It should also be analysed what are the differential barriers to RES with respect to the mainland. Roper [11] provides a preliminary analysis. Soil occupancy might be a more relevant barrier than on the mainland. Ratios of jobs created in all those stages per MW of installed capacity are provided, although these ratios differ across studies. In contrast, IO approaches calculate the direct and indirect employment as a result of induced effects from the project [25]. Selected studies on the contribution of renewable energy sources to the sustainable development of islands are presented in [26-31].

## New Assiut Barrage

Assiut Barrage was constructed between 1892 and 1902 to sustain a water level difference of about 4 m to feed Ibrahimia Canal is shown in Figure 1. Having length about 350 km, Ibrahimia Canal irrigates an area of almost 600.000 ha. By 1938, Assiut Barrage was remodeled to increase permissible headpond level difference to 4.2 m and thereby increasing capacity of Ibrahimia Canal. Civil works have been affected by age and by tail water erosion as a consequence of a modified river regime after construction of Aswan High Dam. Rehabilitation of existing barrage includes installation of a low head hydropower plant of about 32 MW. Corresponding measures would cover an increase of headpond level for improvement of water intake to Ibrahimia Canal, improvement of navigation conditions and optimization hydropower output, without serious environmental impacts. Assiut Hydropower plant has very promising positive aspects in relation to climate change mitigation and adaptation.

## Clean Development Mechanism In Egypt

Egypt Council for CDM (EC-CDM) has been appointed as the Designated National Authority (DNA) of Egypt. Egyptian Bureau for CDM (EB-CDM) acts as Permanent Secretariat of the EC-CDM.

**Figure 1:** Assiut Barrage.

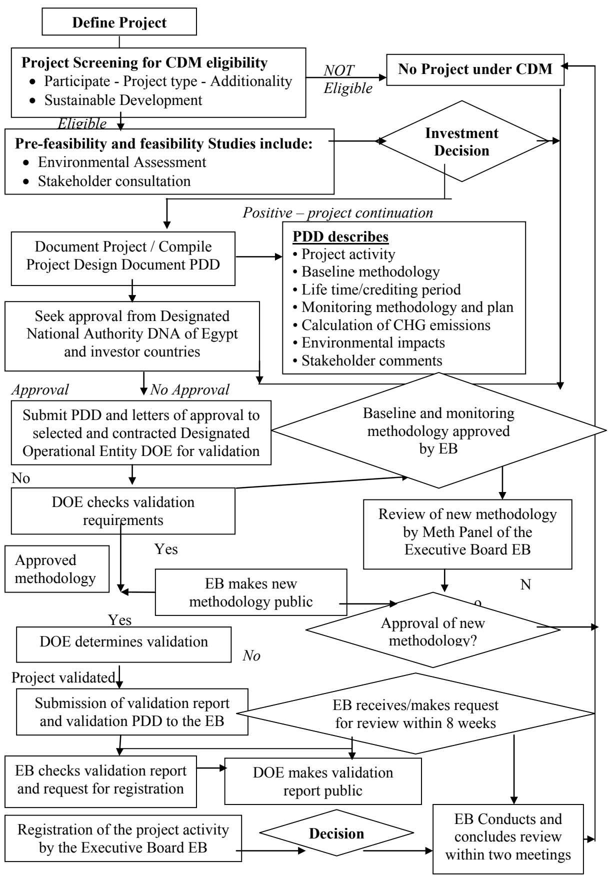


**Figure 2:** Submission of CDM Project.

The procedure for a typical submission of a CDM Project is shown in Figure 2. PDD consists of seven sections: (1) General description of the project activity, (2) Baseline methodology, (3) Identification of crediting period, (4) Monitoring methodology and plan, (5) Analysis of GHG emissions by sources, (6) Environmental impacts, and (7) Stakeholder comments. Regarding baseline methodology, a perceived financial barrier exists for the Assiut HPP project in respect of cost per kWh relative to comparison with alternative steam, thermal or power generation.

## Application of Carbon Methodology

Indicators applicable to Hydroelectric Power Plants, both if they are small scale ones, or big scale ones, and they are applicable to project activities which include: Implantation; Operation; and Amplification (i.e. Power upgrading). Application of the indicators can be done through Group Work, Interviews and Questionnaires. It is recommended that the application includes visits to the locals where the projects are developed, which will help characterizing the community and obtaining evidences.

## Barrage Operating Strategy

MWRI has defined a Target Operating Strategy for the barrage headpond which is guaranteed to be maintained for 80 % of the year. For the remaining 20% of the time, the headpond water levels may be reduced. Water levels shouldn't fall below the level required to adequately feed the Ibrahimia Canal. For the four summer months (June to September) the target operating level is 50.0 m, with varying target levels down to 48.8m for the remainder of the year. Figure 3 shows Design Flow Sequence at Assiut Barrage and Ibrahimia Canal. The absolute minimum headpond level is 48.0 m, for use during the January closure period of the Ibrahimia Canal, and a minimum head across the barrage structure of 3m. At any time of the year, headpond levels may rise in order to capture excess Nile flows. Where this "capture storage" is undertaken, the barrage headpond will be allowed to rise to a maximum level of 50.80 m. The downstream weir option at the rehabilitated lbrahimia Canal head regulator requires a barrage headpond level of around 50.25m to adequately discharge the design maximum canal flow of 40 $Mm^3/d$. The rise above the 50.0 m Summer Target Operating Level is likely to take place in July and August, but will only occur when flow situation in Ibrahimia Canal demands. Figure 4 shows Predicted Water Levels Downstream of Assiut Barrage.

## Barrage Operating Strategy and Energy Generation

The planned barrage-operating regime has been developed on the basis of a priority given to irrigation requirements; it also has significance for hydropower generation. Storing and releasing any excess Nile flows is a flexible whenever need downstream of Assiut barrage arises. During certain months to provide the maximum capture storage potential, a low target-operating level is specified. When storage is utilized at the barrage, headpond level will rise above target-operating regime. The increase in water level leads to a corresponding increase in energy generation from HPP. To calculate energy generation potential, we should know what time profile assumed for barrage headpond. Alternatively, the storage how frequently will be filled, to what level and for what duration. Definitive answers to which the energy generation is calculated will only be known after a period of operation of proposed barrage-operating regime. In the interim period it is clear that future storage operation will arise for the following reasons:

- Regulation of discharge is required in order that flows passing through the barrage and head regulator are adapted.
- Balancing of Nile flows is required to flow released 5 days earlier from HAD. Historical data recommend that this operation is most likely to be required during the primary planting season downstream.
- Capture of flood waters is planned to flood flows entering the Nile downstream of HAD, expected to occur around October.
- Multi-purpose operation increased head for energy generation, knowing that energy generation as a by-product.

## Potential Enhanced Multipurpose Operation

Barrage operating strategy has been used to determine the nature of proposed barrage operation and to calculate the head available for energy generation. The strategy is based on reducing the period of maximum headpond level to 4 months and requiring at least 80cm of storage availability throughout the year. A summary of the future policy for operating the barrage together with the corresponding discharge and headpond parameters is shown in Table 1. The "Base Case' operating strategy proposed by MWRI provides benefit to irrigation, and energy as by product. There is no requirement to investigate and optimize a barrage operating strategy. A detailed optimization process involving examination of both pit and bulb turbines have been undertaken. The conclusion of the study is that the optimum arrangement at Assiut is for an HPP with an installed capacity of 32 MW, provided by four 8MW bulb turbine units.

## Energy

A key aspect is the determination of the expected amount of annual energy generated by the HPP at Assiut. A hydropower optimization is based on principle that the main future function of the barrage will be for irrigation benefit. The optimization study identified the optimum rated capacity of a hydropower installation at Assiut to be 32 MW, with

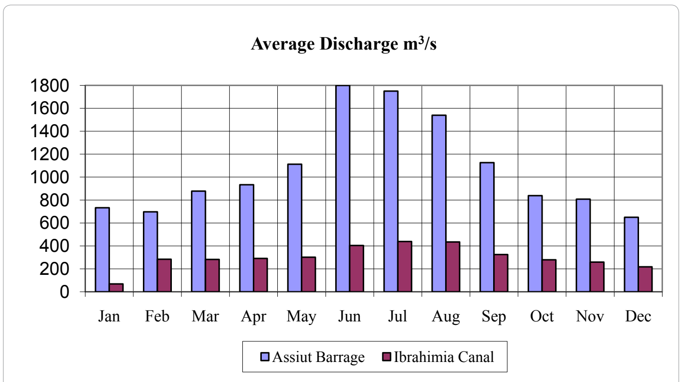


**Figure 3:** Design Flow Sequence at Assiut Barrage and Ibrahimia Canal.

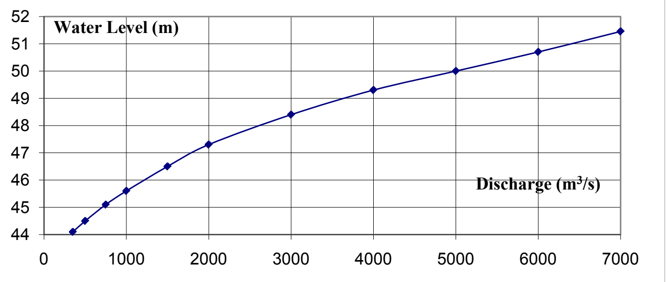


**Figure 4:** Predicted Water Levels Downstream of Assiut Barrage.

the plant made up of four 8MW bulb turbine units. Figure 5 shows Bulb Turbine optimization that occurs when minimum Relative Investment Cost / KWH Generated with respect to Installed Capacity [MW]. In addition to optimizing installed capacity of the plant, the financial and economic study of the associated costs and benefits of HPP is to detect the viability of hydropower at the site. Table 2 shows Main Powerhouse and Turbine Data.

## GHG and Carbon Emissions Analysis

Carbon analysis records, summarizes and reports the quantity of carbon emissions by sources and removals by sinks as a direct result of human activities or natural processes that have been affected by human activities. Emissions Analysis provide information on which to build an effective strategy to manage emissions, prerequisite for participation in GHG trading markets and demonstrate compliance with government regulations, if any are already in place. The analyst should be acquainted with the basics of climate change; proficient in basic mathematical operations; has a good computer literate; and familiar with activity or project process that results in carbon emissions.

Emissions Analysis Principles is summarized as Relevance, Completeness, Consistency, Transparency and Accuracy. Relevance clearly defines and reflects GHG emissions of the chosen boundary and the decision making needs of the users. Completeness such that all GHG emission sources and activities within chosen boundaries are analyzed and any specific exclusions are stated and justified. Consistency meaning that allows for meaningful comparison of emissions performance over time; clearly state any changes to the basis of reporting to enable continued valid comparison. Transparency meaning that relevant issues are addressed in a factual and coherent manner based on a clear audit trail; important assumptions are disclosed and appropriate references of methods used are made. Accuracy meaning that a credible analysis and reporting system with the precision needed for their intended use is practiced; and uncertainties which may arise from default assumptions and methods are kept at a minimum.

## GHG and Carbon Emissions Methodology

There are two types of boundaries; Organizational and Operational boundaries. Figure 6 shows Carbon Emissions Methodology. Organizational boundaries may be classified as Control based approach that responsible for the emissions of the project where it has direct control and Equity Share Based Approach that responsible for the emissions of the project in proportion to the amount of equity. Operational boundaries may be analyzed according to BASELINE and PROJECT cases to include Direct or indirect boundaries and On-site or Off-site boundaries. Table 3 shows Operational Boundary Matrix for baseline and project.

## Emissions Reduction Analysis

GHG emission sources are classified as Stationary combustion, Mobile combustion, Process emissions or Fugitive emissions. Stationary combustion is produced from fuels in stationary sources; e.g. boilers, furnaces, burners, turbines, and incinerators. Mobile combustion is produced from transportation devices; e.g. automobiles, trucks, ships, airplanes. Process emissions is produced from physical or chemical processes; e.g. $CO_2$ from calcinations, $CO_2$ from catalytic cracking, PFC from aluminum smelting. Fugitive emissions are produced from Releases such as equipment leaks from joints, seals, gaskets, etc. Also from coal piles, wastewater treatment, cooling towers, etc. Apply analysis tools in both Cross sector and Sector specific. Cross sector analysis tools e.g. stationary and mobile combustion, HFC use in air-conditioning and refrigeration. Sector specific analysis tools e.g. irrigation, building, agriculture, cement, and food industry.

Knowing that Activity data: the production or consumption activity responsible for the emission. (e.g. liters of gasoline, kWh of electricity, etc.), Emission factor: emissions per unit production or consumption associated with the particular activity (e.g. kg GHG per liter of gasoline or kg GHG per kWh of electricity, etc.).

***Select an emissions analysis approach***

| **Analysis approach** | **Inventory quality** | **Data Requirements** | **Cost** |
|---|---|---|---|
| Published emission factors | Fair-Good | Low | Low |
| Derived emission factors | High | Moderate | Moderate |
| Emission monitoring | Good-High | High | High |

***Collect activity data & mission factor***

| **Type of Emission** | **Activity Data** | **Emission Factor** |
|---|---|---|
| Scope 1 (Direct) | Purchased quantities of commercial fuel | Published |
| Scope 2 (Indirect) | Metered electricity consumption | Published |
| Scope 3 (Indirect) | Passenger miles | Published or 3rd party emission |

Objective is to define reference and project scenarios and determine the net difference in GHG emissions between two scenarios, Figure 7 presents emissions reduction due to existence of the project. CDM and Emissions Reduction Projects may be included; Renewable Energy Projects (Hydro, Wind, Biomass); Lower emission factor that leads to $CO_2$ savings; Landfill Gas and Energy Projects; such as capture and utilize methane from landfill; and displace fossil fuel used to generate electricity that leads to $CO_2$ and $CH_4$ savings; Energy Efficiency Projects such as Lower electricity consumption due to more efficient equipment or appliance that leads to $CO_2$ savings.

| **Description** | **Operating Regime** |
|---|---|
| Discharge | • Average discharge passing the barrage for the years 1986 to 1998 is used as representative of future barrage discharge.<br>• Barrage is designed to allow the emergency river discharge of 7,000 m³/s to be passed without raising the upstream water level above the maximum historical recorded level (52.8m asl, September 1964).<br>• Barrage is designed to allow passage of 350 Mm³/day without raising upstream water level above the Maximum Operating Level. |
| Water Level | MWRI is considering a commitment to:<br>• Maintaining operating level for 80% of the time.<br>• Ensuring, during remainder of time (maximum 20%) that headpond water level will not drop below lowest upstream water level recorded in 1995-2003.<br>• Maintaining a minimum head difference across the barrage of 3.0 m.<br>• Operating Level<br>Maximum Operating Level = 50.80 m<br>Minimum Operating Level = 48.00 m<br>Summer Target-Operating Level = 50.00 m (June to September). |

**Table 1:** Barrage Operating Policy.

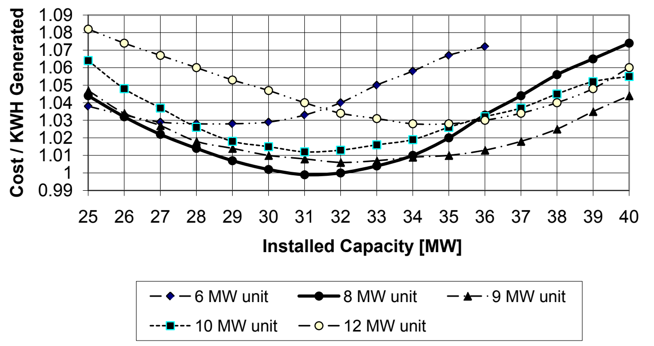


**Figure 5:** Bulb Turbine OPTIMIZATION.

| Item | Value |
|---|---|
| Maximum Operating Level | 50.8 |
| Minimum Tail water level | 43.65 m |
| Number of turbines | 4 |
| Installed powerhouse capacity | 32 MW |
| Rated power output per turbine | 8 MW |
| Rated powerhouse discharge | 908 m³/s |
| Rated head | 4.l0 m |
| Average annual power output | Between 24.4 and 34.0 MW |
| Average annual energy generated | Between 214 and 298 GWH |
| Number of blades per turbine | 3 |
| Runner diameter | 5.60 m |
| Axis setting level | 35.40 m |

**Table 2:** Main Powerhouse and Turbine Data.

| | On-site | Off-site |
|---|---|---|
| **Direct** | Electricity, Heat, Steam Production<br>Physical and/or chemical Processing | Project-owned Transportation |
| **Indirect** | Purchased Electricity,<br>Heat or Steam | Employee travel & commuting<br>Materials Extraction<br>Outsourced manufacturing |

**Table 3:** Operational Boundary Matrix.

$\Delta GHG_{reduction} = GHG_{base} - GHG_{project}$ = emissions reduction due to existence of the project

$GHG_{base}$ = an estimation of emissions assuming that no alternative project was implemented

$GHG_{project}$ = measures the GHG emissions following project implementation

Therefore,

**Greenhouse Gas Emission = (activity data) x (emission factor)**

**GHG = A x EF**

*Where*

GHG = emissions (amount of $CO_2$ or $CH_4$, etc)

A = activity data (liters of fuel)

EF = emission factor (kg $CO_2$/liter of fuel)

• To reduce the value of GHG emissions

– Lower A (e.g. decrease frequency or magnitude of activity)

– Lower EF (e.g. shift to more efficient, less carbon intensive technology)

– Lower both at the same time

In renewable energy projects, emission factors of the project are considered zero:

$$\Delta GHG_{reduction} = (A*EF)_{base} - (A*0)_{project}$$

$$= (A*EF)_{base}$$

$$\Delta GHG_{reduction} = GHG_{base}$$

Assuit Hydroelectric Project generates electricity using hydroelectric resources to sell to the power grid. Hydroelectric power with 4.2 MW installed capacity = 25,755 MWH/year. Hydro, solar, wind - excludes leakage and other direct and indirect emissions. Project activity included categorized as I-D (Renewable Energy Project - renewable electricity for a grid), baseline methodology - baseline is average of "operating margin" and "build margin"; and crediting period is 7 years. Table 4 shows Sources of emissions and project boundaries.

Expected annual electricity production of project (How much electricity the hydropower project will deliver annually, and how much electricity will be displaced from the grid).

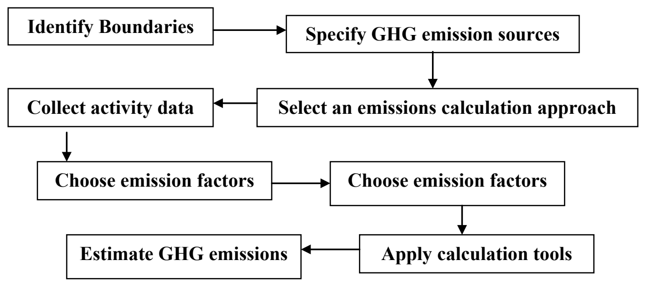


**Figure 6:** Carbon Emissions Methodology.

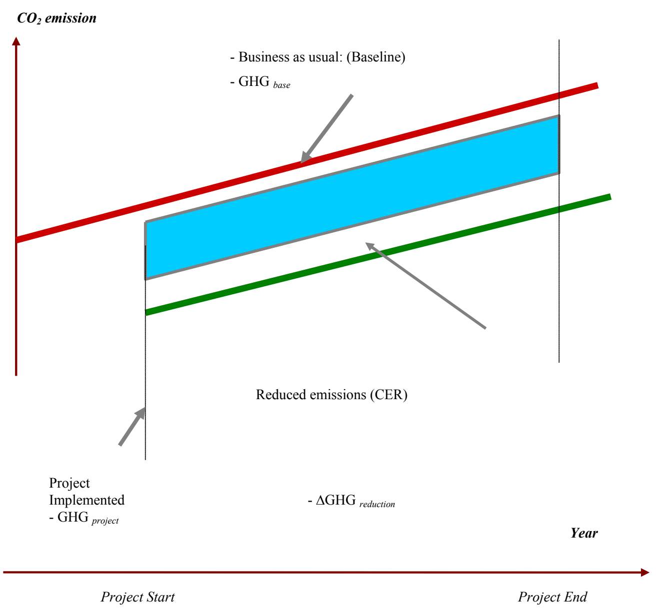


**Figure 7:** Emissions Reduction Analysis.

| Sources | On-Site | Off-Site |
|---|---|---|
| Direct | - $CO_2$ emissions during project construction - excluded<br>- emissions during operation (production of electricity from hydro power) – negligible = 0 | – *One-step upstream*: emissions due to transport of construction materials and equipment to project site- excluded<br>– *Downstream:* Transmissions and distribution losses |
| Indirect (leakage) | • None are expected | • Emissions from manufacture of parts, supplies and machinery required for building the project – excluded.<br>• emissions at the national grid that would be displaced by providing renewable power – baseline emissions |

**Table 4:** Sources of emissions and project boundaries.

| | | | | | | |
|---|---|---|---|---|---|---|
| Annual Plant Electricity Output | = | Installed Plant Capacity | * | Plant Capacity Factor | * | Hours |
| (MWH/yr) | | (MW) | | (%) | | year |
| Annual Plant Electricity Output | = | 4.2 | * | 70 | * | 8760 |
| (MWH/yr) | | (MW) | | (%) | | year |
| Annual Plant Electricity Output | = | 196,224 (MWH/yr) | | | | |

## Baseline emissions methodology

**Option 1:** "Operating margin" consider grid mix of all generating sources serving the system, Excluding hydro, geothermal, wind, low-cost biomass, nuclear and solar generation. "Build margin" consider grid mix of recent capacity additions (newly installed plants) defined as lower of most recent 20% of plants built or the 5 most recently built plants.

$$EF_{base} = (EF_{operating} + EF_{build})/2$$

**Option 2:** "Weighted average" considers grid mix of all generating sources serving the system, including, geothermal, wind, and low-cost biomass, nuclear and solar generation.

$$EF_{base} = EF_{Weighted\ average}$$

On Emissions from Power Plants:

| | | | | |
|---|---|---|---|---|
| GHG | = | A | * | EF |

| | | | | |
|---|---|---|---|---|
| $CO_2$ Emissions | = | Power Generation | * | Emission Factor |
| (tons $CO_2$) | | (MWH) | | (Tons $CO_2$/MWH) |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Emission Factor EF | = | Specific consumption | * | Calorific value | * | Carbon EF | * | Conversion factors |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Emission Factor | = | Vol. fuel consumed | * | Kg C | * | TJ | * | 1 ton C | * | 44g/ moleCO$_2$ |
| Tons $CO_2$/ MWh | | MWH output | | TJ | | Vol. unit of fuel | | 1 kgC | | 12g/moleC |

Notes:

Volume fuel consumed = Plant based-actual data

(Kg C/ TJ) = Carbon emission factor/fuel type – IPCC

(TJ / Volume unit of fuel) = Net calorific value, country specific/ fuel type - IPCC

(1 ton C / 1 kg C) = conversion factor

(44g/mole$CO_2$ / 12g/moleC) = conversion factor

***Compute emission factors***

| | | |
|---|---|---|
| Generation with diesel | 199.3 | GWH |
| Diesel consumption | 72,236 | Million liters/year |
| Specific consumption | 363 | Liter/kWh* |
| Calorific value (Diesel) | 10,700 | Kcal/liter |
| Diesel EF | 20.0 | Tons C/TJ |
| Emission factor | 1.190 | Kg$CO_2$/kWH |

EF for Diesel

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Conversion factors | = | 4.186J | 1000cal | TJ | 1MWH | 44g/mole$CO_2$ | 1000kg$CO_2$ |
| | | cal | kcal | $10^{12}$J | 1000kWh | 12g/moleC | tons$CO_2$ |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Emission Factor | = | Specific consumption | * | Calorific value | * | Carbon EF | * | Conversion factors |
| kgCO2/kWh | | L/MWH | | kcal/L | | Tons C/TJ | | |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Emission Factor EF | = | Specific consumption | * | Calorific value | * | Carbon EF | * | Conversion factors |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Emission Factor | = | 363 | * | 10,700 | * | 20 | * | Conversion factors |
| kgCO2/kWh | | L/MWH | | kcal/L | | Tons C/TJ | | |

| | | |
|---|---|---|
| Emission Factor | = | 363 |
| kg$CO_2$/kWh | | L/MWH |

| | | |
|---|---|---|
| Emission Factor EF | = | 1.1923 kg$CO_2$/kWh |

-composed of diesel-fueled (199.3 GWH) and natural gas-fueled (420.5 GWH) power plants

- therefore, a total of 619.8 GWH of electricity delivered to the grid

-Diesel EF = 1.190 kg $CO_2$/kWh (32%)

- Natural gas EF = 0.690 kg$CO_2$/kWh (68%)

- therefore, weighted EF = 0.851 kg$CO_2$/kWh

Compute for Baseline Emission

$$EF_{base} = (EF_{operating} + EF_{build})/2$$
$$= (0.851 + 0.310)/2$$

$EF_{base}$ = 0.580 kg$CO_2$/kWh

Compute for baseline emissions (annual)

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Annual $CO_2$ Emissions | = | 25,755 | * | 0.580 | * | 1000kWh | * | 1ton $CO_2$ |
| tons $CO_2$ | | MWH | | kg $CO_2$/ kWH | | 1MWh | | 1000kg $CO_2$ |

| | | |
|---|---|---|
| Annual $CO_2$ Emissions | = | 14,942 tons $CO_2$ |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Annual Plant Electricity Output (MWH/yr) | = | 4.2 (MW) | * | 70 (%) | * | 8760 year |

| | | |
|---|---|---|
| Annual Plant Electricity Output | = | 25,755 (MWH/yr) |

Annual emissions reduction

$E_{reduction} = E_{base} - E_{project}$

$=14,942 \text{ tons } CO_2 - 0$

$= 14,942 \text{ tons } CO_2$

## Conclusions

This review of potential HPP energy output has made the following conclusions: There is a significant, higher level of uncertainty regarding the nature of headpond levels rise above the 50.8m level. Operation of the headpond at MOL 50.8 m would likely be received by residents during pre-construction consultation as being similar to the existing barrage operating regime where headpond level has recently reached 50.4 m. Energy generated at Assiut Barrage HPP installation will result in national emissions reductions below the level that would have been the case without the project investment. These reductions can be applied for as Certified Emissions Reductions (CERs) and sold on the Carbon Market. Typically, process to certification involves identification of a CDM project, preparation of specific documentation as a CDM Project Design Document (CDM-PDD) and approvals via a Designated National Authority. A value of US$ 7.8 per ton of carbon in standard scenario is quoted in publication Opportunities and Prospects', Clean Development Mechanism in Egypt.

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