CARICOM

# Caribbean Renewable Energy Development Programme (CREDP)

*CARICOM Secretariat*

# Cogeneration Technology Brief

*Creating Value for Early Stage, High-risk Financing, RET Projects*

## MAJOR FEATURES AND BENEFITS

- Makes more efficient use of fuel resources by using the energy in the streams of air, exhaust gases, and liquids that exit the system and enter the environment as waste products.
- The high temperature rejected heat usually represent an energy flow of up to 65% of the fuel input.
- Buy using a cogeneration system the overall efficiency (electrical plus thermal) of the total system can be increased from around 30% to over 80%.
- CHP offers significant, economy-wide energy efficiency improvement and emissions reductions.
- Besides saving energy and reducing emissions, distributed generation also addresses capacity constraints and reduces losses within the electricity transmission and distribution grid.

CREDP

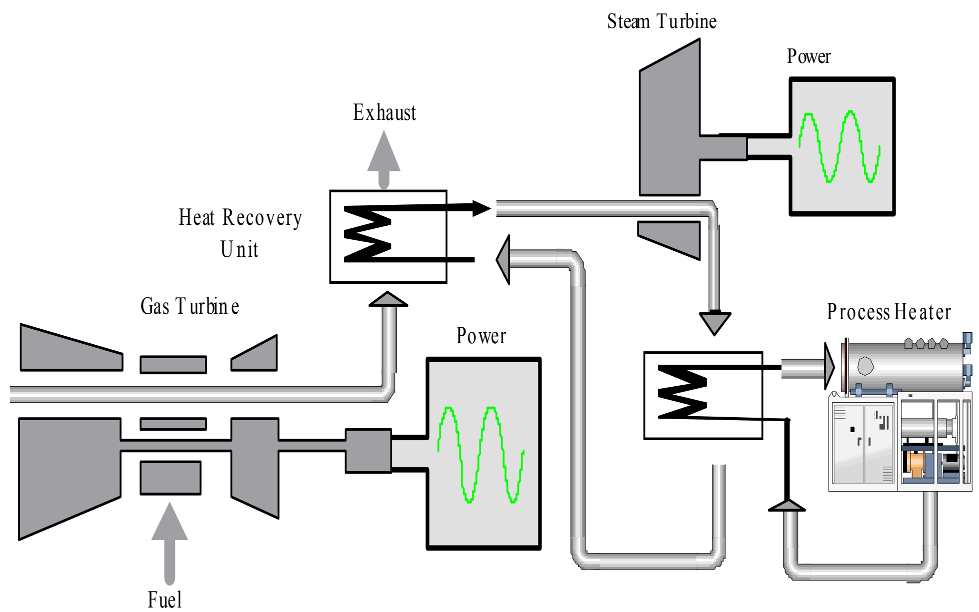


Figure 1: Cogeneration Combined Cycle plant—with Gas and Steam turbines

## Cogeneration or Combined Heat and Power (CHP):

- Cogeneration is the sequential use of fuel energy to produce more than one finished energy product, such as steam, electricity, cooling, thermal drying, heating, etc.
- CHP technology is not new and has been widely used in industrial applications such as sugar, paper and other mills.
- Small scale CHP units are becoming increasingly popular in commercial applications for meeting heating, cooling and power loads. These CHP systems primarily make use of reciprocating engines—gas fired, diesel or dual fuel systems.
- When considering an investment in a cogeneration system, the analysis is based not only on the potential output and efficiency of the system, but the match of the potential output of the facility's internal requirements or ability to sell outputs.
- CHP units can most effectively be installed where there is a certain minimum demand for heat and electricity and where economic evaluations indicate profitability.



CARICOM

Caribbean Renewable Energy Development Programme (CREDP)

CARICOM Secretariat

Cogeneration Technology Brief

## Environmental Issues:

- The significant increase in efficiency with CHP results in lower fuel consumption and reduced emissions compared with separate generation of heat and power.
- When natural gas is used in CHP systems (as is the practice for small-scale systems) the only major environmental problem arising is the emissions of oxides of nitrogen, compared to conventional power plants.
- The amount of NOx formed in reciprocating engines depends on the type and capacity of the engine, the temperature of the combustion process, on the type of fuel and on the condition of the engine.
- Catalytic converters are effective in reducing the NOx present in the exhaust gases and can also be used to reduce the levels of carbon monoxide and unburned hydrocarbons.

CREDP

## Fuels for Cogeneration:

Combined Heat and power systems use a variety of fuels, including:

***Renewable Fuels for CHP:***

- Geothermal
- Biomass (solid combustion fuel)
- Biogas (gaseous combustion fuel)
- Animal Wastes (manure & bedding):
  - ⇒ Swine
  - ⇒ Cattle
  - ⇒ Poultry
- Human Wastes (Sewage & sludge)
- Agricultural Wastes or Energy Crops:
  - ⇒ Straw, Baggasse, Food Processing Residues
  - ⇒ Forest products Industry Residues
  - ⇒ Short-Rotation Coppice (e.g. Willow, Poplar), Grasses
- Municipal Solid Waste (incl. Landfills)

***None-Renewable Fuels;***

- Natural Gas
- Coal
- Fuel oils—diesel

| System Arrangement | Fuel Efficiency (%) | Net Electrical Efficiency (%) | Electrical-to-Thermal Ratio |
|---|---|---|---|
| Simple Cycle | 76 | 60 | 0.68 |
| Combined Cycle with Extraction Steam Turbine | 58 | 38 | 1.88 |
| Supplementary-fired Combined Cycle with Duct Burner | 85 | 79 | 0.26 |
| Supplementary-Fired Combined Cycle with Duct Burner and Back-pressure Steam Turbine | 84 | 79 | 0.43 |
| Supplementary-Fired Combined Cycle with Duct Burner and Back-pressure Steam Turbine and Condensing Steam Turbine | 62 | 49 | 1.09 |

Figure 1: Comparison of CHP (Gas Turbine Topping Cycle) System Configurations

# Caribbean Renewable Energy Development Programme (CREDP)

*CARICOM Secretariat*

CARICOM

# Cogeneration Technology Brief

## Policy Issues:

- Reform of environmental permitting regulations and the permitting process to provide credit for the inherent efficiency of CHP systems.
- Reform electric utility regulations to provide fair and open access to the grid for procurement of standby power and excess generation sales.
- Modernize the depreciation schedules for CHP equipment to reflect current markets and technologies.
- Provide financing opportunities and incentives, such as tax credit, to spur interest in CHP systems.
- Develop educational and technical assistance programs to increase awareness of CHP opportunities and technologies.
- Installation of CHP systems in government facilities to demonstrate the benefits and provide market leadership.

CREDP

## POWER CYCLE PERFORMANCE INDICATORS:

*Thermal Efficiency:*

$$\eta_{th} = \left(\frac{Net\ Work\ Output}{Heat\ Energy\ Input}\right) \times 100\,\%$$

*Heat Rate:*

$$Heat\ rate = \frac{Heat\ energy\ input}{Net\ work\ output}$$

*Net Thermal Efficiency:*

$$\eta_{th} = \left(\frac{Net\ Work\ Output}{Heat\ Energy\ Input - Heat\ recoverd}\right) \times 100\%$$

*Net Heat Rate:*

$$Net\ Heat\ rate = \frac{Heat\ energy\ input - Heat\ recovered}{Net\ work\ output}$$

*Energy-Chargeable-to Power (ECP):*

$$ECP = \frac{Total\ energy\ input - Displaced\ energy}{TC_{output} + BC_{output} - Auxiliary\ power\ input}$$

*Where:*

*TC = Topping Cycle*

*BC = Bottoming Cycle*

### *Note:*

- Other important factors include Load Factor and Capacitor Factor
- To express true fuel-specific thermal efficiency, when heat added is expressed on a LHV basis, the thermal efficiency $\eta_{th}$ becomes:

$$\eta_{th}(HHV) = \left\{\frac{Net\ Work\ Output}{Heat\ Energy\ Input\ (LHV)}\right\} \times (LHV/HHV) \times 100\,\%$$



# Caribbean Renewable Energy Development Programme (CREDP)

*CARICOM Secretariat*

CARICOM

# Cogeneration Technology Brief

## PROJECT DEVELOPMENT ISSUES:

- Each prime mover system to be considered will have a different: heat rate; combination of power and thermal outputs: available temperatures and pressures; emissions rates for different pollutants; space requirement; different expected service lives.
- Translating performance into cost and values requires a detailed analysis of the site conditions, the equipment performance under these conditions, and the interaction of all factors for each alternative.

**CARICOM SECRETARIAT**
**CARIBBEAN RENEWABLE ENERGY DEVELOPMENT POJECT (CREDP)**
**Bank of Guyana Building**
**P.O. Box 10827**
**Georgetown, Guyana**

**Phone: 592-226-9281 thru 9**
**Fax: 592-225-0972**
**E-mail: rclarke@caricom.org**
**URL: www.caricom.org/credp/homepage.htm**

CREDP

## COGENERATION SYSTEM SELECTION:

Given the wide array of drives, and system configuration options, it is necessary to evaluate and define baseline conditions at the facility and, perform detailed electricity and thermal energy requirements in a feasibility study that compares all potentially viable system application options.

We therefore strongly recommend the following approach:

- A pre-screening process should be used to limit the number of options to be studied in detail
- A rigorous technical and economic performance analysis will be required to make a reliable financial investment decision
- Rules of thumb should not bias the selection process
- Site-specific conditions must be carefully identified and applied to system performance evaluation
- Technology applications should be viewed within an integrated approach that considers the interactive effects of other viable facility improvement options.

## Economics:

The development of CHP depends very much on the relationship between kWh costs at Cogen and kWh price bought or sold to the grid. The following may be used as a guide:

- Avoided Cost > Retail Price > Cogen Cost
  - ⇒ Maximize capacity for CHP system
  - ⇒ Sell back a large portion of electric power
  - ⇒ Cogen project extremely attractive
- Retail Price > Cogen cost > Avoided Cost
  - ⇒ Cogen project sized to meet demand
  - ⇒ Self-generating with little or no electricity sales
  - ⇒ Cogen project is feasible
- Cogen Cost > Retail Price > Avoided Cost
  - ⇒ Cogen project is not feasible