CHP Capacity Optimizer Maximizes Economic Benefit by Determining Optimum Size of DE Components

Project description and goals:

Current cooling, heating and power (CHP) project analysis tools define installed capacities as either single-point values or as lists of discrete, candidate combinations of prime mover and absorption chiller. As such, the component capacities that would maximize the economic benefit of the project are not known. The purpose of this project is to develop an automated tool that can be used by system developers and end-users to determine the most appropriate capacities for prime mover and chiller that will:

- Maximize net present value savings produced by a CHP system
- Reflect the non-coincidence of electric and thermal loads
- Perform operation simulation on an hourly basis
- Recognize part-load performance, multi-year operation, tax and depreciation effects
- Find the economic balance between the energy provided by a CHP system and that provided by the utility grid/on-site boiler

Project synopsis:

Electric and thermal demands vary by type of end use, building size, location, and time. In addition, prices of grid-based electricity and on-site fuel vary considerably by location. As a result, each potential CHP application has a unique optimal solution. As the operation of a CHP system represents an hourly make-or-buy decision that can span many years, annual operating savings and initial investment costs must be combined to form a life-cycle, net present value (NPV) savings. Using nonlinear optimization techniques, the optimum capacities for prime mover and absorption chiller are determined by maximizing the NPV savings of the CHP system.

DE Program benefits:

- Maximizes potential economic benefit of integrated energy systems
- Helps to define the amount of load relief for the electric grid provided by a DE/CHP system
- Indicates the degree of cost-competitiveness of DE/CHP systems

Implementation:

- Contained in a Microsoft Excel spreadsheet file
- Represents a complementary extension to existing DE software tools (e.g., BCHP Screening Tool)
- Development in FY05; distribution in FY06
- Available from ORNL

Example application:

Consider a 500,000 sq.ft. hospital in Boston

Maximum electric load: 2.3 MW; maximum heat demand: 17 MMBtu/hour; maximum cooling demand: 808 RT.

CHP alternative: natural gas-fired recip engine generator with absorption chiller.

Electricity rates: Boston Edison T-2 tariff; natural gas price: $11/MMBtu (2005$)

General Data

On-site boiler efficiency	82.0%
Conventional chiller COP	3.54
DG electric efficiency (full output)	29.0%
DG unit minimum output	50%
Absorption chiller COP	0.70
Absorption chiller min. output	25%
Abs chiller sys elec req (kW/RT)	0.20
CHP O&M cost ($/kWh)	0.011
DG power/heat ratio	0.65
Number of DG units	1
Type of prime mover	Recip
Discount rate	8.0%
Effective income tax rate	38.0%
DG capital cost ($/net kW installed)	1500
AC capital cost ($/RT installed)	1000
Planning horizon (years)	16

Solution summary identifies optimal capacities and CHP contributions

Results

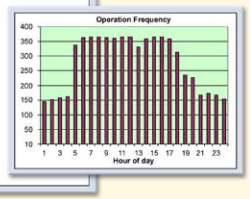
Demands	Electricity		Heating		Cooling	
Annual	12,406,742	kWh	37,074	MMBtu	1,617,306	RT-hr
Maximum	2275	kW	17.0	MMBtu/hr	808	RT
Minimum	934	kW	0.51	MMBtu/hr	0	RT

Installed DG capacity:	1130.1	kW (net)
Installed AC capacity:	210.5	RT
Installed capital cost:	$1,905,607	
Hours of DG operation	6,717	hours/year
DG generated electricity	7,422,145	kWh/year
DG supplied heating	27,839	MMBtu/year
AC supplied cooling	535,793	RT-hr/year

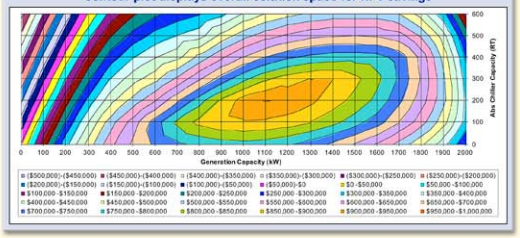
Annual costs (before tax)	With CHP	No CHP
CHP system	$1,056,647	$0
Utility elec	$661,305	$1,785,547
Non-CHP fuel	$125,137	$502,367
Total	$1,843,290	$2,287,913

Annual operating savings (after tax):	$275,666
NPV savings:	$954,175

Optimum DG capacity:	1130.1	kW
Optimum AC capacity:	210.5	RT
NPV savings:	$954,175	



Contour plot displays overall solution space for NPV savings



Potential CHP applications have distinct parameters (e.g., electric and thermal loads, location) that result in unique optimal installed capacities. In order to maximize economic benefit, capacities appropriate to the specific application must be selected.

In the examples below, note that optimal capacity values vary across both application and location.

City	Parameter	Hospital	Hotel	Retail Store	Supermarket
Boston	Peak elec load (kW)	2275	1185	337	260
	Peak chiller load (RT)	808	492	147	40
	Optimal DG capacity (kW)	1130.1	417.2	118.3	117.7
	Optimal AC capacity (RT)	210.5	88.3	35.9	6.9
	NPV savings	$954,175	$341,877	$57,945	$67,611
	DG capacity % of peak load	50	35	35	45
	AC capacity % of peak load	26	18	24	17
San Francisco	Peak elec load (kW)	1949	1004	433	248
	Peak chiller load (RT)	452	334	131	17
	Optimal DG capacity (kW)	513.8	257.2	63.9	54.6
	Optimal AC capacity (RT)	30.9	36.2	19.1	5.0
	NPV savings	$431,123	$212,726	$15,954	$42,666
	DG capacity % of peak load	26	26	15	22
	AC capacity % of peak load	7	11	15	29

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