APPENDIX A: Component Characteristics

Microgas Turbines

Capstone C30, C65, C200 and Turbec T100 have been selected as Microgas Turbine. The most important parameters are reporter in Table A1, including also the investment costs. Maintenance costs have been assumed equal for all MGTs and equal to 0.005€/kWh. Similar trends can be found for each one of the machines identified. The parameters related to the MGTs have been evaluated for each time interval through a linear regression of the performance curves, considering also the effect of the ambient temperature. Each MGT is equipped with a heat exchanger to produce thermal energy at 85°C.

TABLE A1 - Microgas Turbine Technical data [1-4]

	Capstone C30	Capstone C65	Turbec T100	Capstone C200
Electric output [kW]	30	65	100	200
Thermal output @90°C[kW]	58	119	167	315
Electric efficiency at full load	26%	29%	30%	30.2%
Thermal efficiency at full load	50%	53%	50%	52%
Cost [k€]	50	100	140	230

Internal Combustion Engines

Viessmann Vitobloc 200 EM 50/81, EM 70/115, EM 140/207 and EM 200/264 have been selected as internal combustion engines. Table A2 reports the most important data related to the ICEs. In this case the influence of the ambient temperature is negligible so that it has not been taken into account. The thermal energy is recovered at a temperature of 85°C Through a heat exchanger from exhaust gases and engine cooling circuit (0.02€/kWh has been considered as maintenance cost).

TABLE A2 - Internal Combustion Engine data [5]

	EM 50	EM 70/115	EM 140/207	EM 200/264
Electric output [kW]	50	70	140	200
Thermal output @90°C [kW]	81	115	207	264
Electric efficiency at full load	34.5%	34.3%	36%	37%
Thermal efficiency at full load	55.9%	56.4%	54%	48.9%
Cost [k€]	60	70	125	165

Absorption Chillers

Maya Yazaky WFC-SC 10, 20 and 30 has been selected as absorption chillers. Each one of them can be installed only if at least one cogenerator is installed, and they can operate only if the related cogenerator is operating. They are connected at the cogenerators through direct water circuits in order to reduce thermal losses. Table A3 reports the technical data of the absorption machines considered (0.001€/kWh has been considered as maintenance cost).

TABLE A3 - Absorption chillers data [6]

	WFC-SC10	WFC-SC20	WFC-SC30
Cooling capacity [kW]	35	70	105
COP	0.7	0.7	0.7
Cost [k€]	21	40.6	60

Heat Pumps

Daikin air source heat pumps have been selected for this study. They can produce hot water at a temperature of 65°C. The table A4 reports the main important data related to the heat pumps. The technical parameters are evaluated at ISO conditions (0.001€/kWh has been considered as maintenance cost).

TABLE A4 - Heat pumps data [7]

	EWYQ 35	EWYQ 70	EWYQ 105
Total power input [kW]	35	70	105
EER	3.1	3.1	3.1
COP	3.4	3.4	3.4
Cost [k€]	20.5	36	52.5

Boilers

The boilers which can be installed either inside the production units or in the central unit are described through a single parameter which is the boiler efficiency. It is reported in table A5 together with the variable and fixed investment costs (0.001€/kWh has been considered as maintenance cost). The cost of boilers which can be installed to the production unit is proportional with respect to its size (so that the fixed cost is null), while the cost of the central unit boiler is linear with respect to the size.

TABLE A5 - Boilers data [8]

	Production unit boilers	Central unit boiler
Efficiency	92%	95,5%
Variable Cost [€/kW]	c_{boi}= 70	$c_{boi,v}$= 30
Fixed Cost [k€]		$c_{boi,f}$=195

Compression Chillers

Compression chillers are described through a single parameter which is the COP equal to 3. The variable investment cost has been chosen to be 230 [€/kW] (0.002€/kWh has been considered the maintenance cost)

Solar Thermal and Photovoltaic Panels

The hourly production per surface unit of solar thermal and photovoltaic panels is the input parameter considered in the optimization model. Hourly solar radiation of a south oriented and 30° inclined surface, is obtained through a certified model called SOLTERM® distributed by ENEA [9]. Table A6 reports the cost of a square meter of panel and the average annual production obtained by the average daily solar radiation for the considered site. Flat plate collectors have been chosen as solar thermal panels, while polycrystalline silicon panels as photovoltaic panels. Table A6 reports the solar thermal panels which can be installed to the unit and in the solar field. The different costs are related to scale economies. In the case study, 200 m^2 per unit has been considered as a maximum surface available for the installation of ST panels or PV panels.

TABLE A6 - Solar Thermal and Photovoltaic Panels data

	Solar thermal panels	Solar field panels	Photovoltaic panels
Average Annual production [kWh]	800	800	1,150
Cost [e/m^2]	350	180	250

District Heating and Cooling network

The technical parameter which describes the pipelines of the DHCN is the thermal loss coefficient per unit length. This parameter is reported in Table A7 together with the cost proportional only to the length and the cost proportional to the size and to the length of the pipeline. The costs of the central pipeline different as they have been linearized for larger sizes, as the central pipe can be larger than the others.

TABLE A7 - District heating and cooling network data [10]

	Cooling pipeline	Thermal pipeline	Central pipeline
Percentage loss per unit length (%/km)	5%	8%	8%
Fixed cost $c_{net,f,c}$, $c_{net,f,c}$ € /m	215	215	470
Variable cost $c_{net,f,c}$, $c_{net,f,c}$ € /kW m	0.17	0.17	0.03

Thermal/cooling storages

The characteristic parameters of the thermal/cooling storages considered in the optimization model are the thermal loss percentage (Klos,ts) and the cost per cubic meter. Table A9 reports also the real thermal loss coefficient which have been used to calculate the thermal loss percentage. The Klosts represent the percentage of thermal energy lost in a time interval (1 hour). The thermal losses in the central storages which can be installed in the production units are greater due to the different technologies adopted.

TABLE A9 - Thermal storage data [11]

	Thermal storage	Cooling storage	Central storage
Themal losses ($K_{los,ts}$)	0.1%	0.2%	0.001%
Real Thermal losses [kj/hm^2K]	1.6	1.6	0.5
Cost [€/m^3]	300	300	80

Appendix References:

[1] Capstone. Capstone C65-Technical Reference, 2008.

[2] Capstone. Capstone C30-Technical Reference, 2008.

[3] Capstone. Capstone C200-Technical Reference, 2008.

[4] Turbec. Microgas Turbine Turbec T100-Technical Manual, 2002.

[5] Viessmann-Group. Vitobloc 200, 2009.

[6] Yazaky. Maya Yazaky WFC-SC 10, 20 & 30 - Technical Manual, 2002.

[7] Daikin. EWYQ-DAYN Heat pumps, 2010.

[8] D Chinese. Optimal size and layout planning for district heating and cooling net- works with distributed generation options. International Journal of Energy Sector Management, 2(3):385–419, 2008.

[9] ENEA. SOLTERM. Calculation model for the definition of diffuse and global solar radiation.

[10] Kemal Çomakl, Bedri Yüksel, and Ömer Çomakl. Evaluation of energy and exergy losses in district heating network. Applied Thermal Engineering, 24(7):1009–1017, May 2004.

[11] MA Lozano, A Anastasia, LM Serra, and V Verda. Thermoeconomic cost analysis of central solar heating plants. In IMECE2010, pages 1–11, 2010.