Notes for the Post-Retrofit Template for Co-Gen Systems:

1 The gas turbine model is based on data files created from running the Solar Turbines Microsoft Excel calculation program at various inlet air temperatures and various part load ratios. The turbine will attempt to meet the desired electrical load (input) up to its available capacity. To have the turbine run at full capacity all the time, simply set the desired electrical output (input) to a very large number.

2 The Type 201 weather component reads TMY, TMY-2, CWEC, IWEC, Energy+, and Meteonorm data files. Weather for most large cities in the world is usually available online. This weather model also does all the solar radiation processing so a separate radiation processor model is not required. In this example, ambient air will be pre-cooled before entering the gas turbine.

3 In this example, the electrical loads to be met by the system are read from a user-supplied external data file; although there are many ways to introduce electrical loads to the system (equations, forcing functions etc.). Care should be taken when reading in the loads as this is one of the more common errors found in simulations. Choose the data reader mode carefully; there are numerous options for reading in external files dealing with whether the data file has a line of initial values and whether the program should "skip" into the data file to find the correct place to start reading. Pay careful attention to the type of data that you have (instantaneous or average values), the conversion factors, the number of header lines, and whether or not you want the program to interpolate between data points. The data files that you create should be at even time intervals which must be integer multiples of the time step. The data should be arranged so that one row contains data for one time interval. The outputs from the model correspond to the column containing the data (for example if the ambient temperature is in column 2, the 2nd output from the model will contain the ambient temperature. The outputs from the model are <u>average</u> values over the timestep, not instantaneous values. The data will repeat after the last line of the data file has been read. Hint: Early on in the project use an online plotter to check the outputs from the data file and make sure that they are correct. In this example, the external data file contains the electrical load in kJ/h.

4 Using an EQUATIONs card is an excellent way to set common variables that will be used in several components. In this example, the specific heat of the turbine exhaust air is specified. The supplemental firing device and the heat recovery steam generator use this equation name in their parameter lists. Notice that the units for the parameter must be set to "string" im order to use a variable name.

5 In this EQUATION component, the electrical load (from the data file), the gs turbine power output, and the steam turbine power output are inputs. Using these variables, the load that the steam turbine should meet (Load_Left), and the total load met by the turbines (Load_Met). The load that the steam turbine must meet is sent to the steam turbine model and the total load met by the turbines is sent to an online plotter.

6 The supplemental firing device heats the air leaving the turbine up to a user-specified temperature (a constant 400 C in this case). The supplemental firing device outlet temperature may be below the user-specified setpoint if the device is capacity restrained, but the outlet temperature will never exceed the setpoint unless the inlet temperature is already above the setpoint.

7 There are several versions of a heat recovery steam generator available. In one version (the one used in this example), the generator will make as much steam at the user-specified condition as allowed by the current exhaust heat conditions. In another version, a known steam flow rate will attempt to be raised to the user-specified outlet steam condition.

In this example, the steam generator sets the steam flow rate for the system and, therefore, a condensate pump model that sets the flow rate is not required. Care should be taken when using other component models that set the steam flow rate for part, or all, of the steam loop so that mass balances are not destroyed.

In this example, the steam generator will attempt to make saturated steam at 1 MPA.

8 In this example, the heating loads to be met by the system are read from a user-supplied external data file; although there are many ways to introduce a heating load to the system. Refer to the sample projects “Template_BuildingLoads.tpf” and “Template_ConvertingLoadsToTemperatures.tpf” for more information on the different methods. Care should be taken when reading in the building loads as this is one of the more common errors found in simulations. Choose the data reader mode carefully; there are numerous options for reading in external files dealing with whether the data file has a line of initial values and whether the program should “skip” into the data file to find the correct place to start reading. Pay careful attention to the type of data that you have (instantaneous or average values), the conversion factors, the number of header lines, and whether or not you want the program to interpolate between data points. The data files that you create should be at even time intervals which must be integer multiples of the time

step. The data should be arranged so that one row contains data for one time interval. The outputs from the model correspond to the column containing the data (for example if the ambient temperature is in column 2, the 2^{nd} output from the model will contain the ambient temperature. The outputs from the model are <u>average</u> values over the timestep, not instantaneous values. The data will repeat after the last line of the data file has been read. Hint: Early on in the project use an online plotter to check the outputs from the data file and make sure that they are correct. In this example, the external data file contains the time of the day and the heating load in kJ/h.

9 In this EQUATIONs component, the steam flow from the heat recovery steam generator, and the steam flow required by the steam turbine to meet the electrical load are provided as inputs to the model. The diverting valve fractions and the maximum steam flow that the steam turbine can use are then calculated by the model.

10 Using diverting signals calculated from the attached EQUATIONs component, the diverting valve directs the inlet steam flow to the steam turbine and the thermal load. The pressure, temperature, and enthalpy at each outlet are set to the inlet values. The flow rate at each outlet port is calculated by multiplying the input fraction for that port (an INPUT) by the inlet flow rate. The sum of the input fractions should be one.

11 The thermal load, read from the external data file, is imposed on the steam flow. If the resulting outlet temperature of the steam is below 60 C (an input), a portion of the thermal load is not met and the steam outlet is set to 60 C. Excess steam energy (a low thermal load coupled with a large steam flow rate) is dumped in the downstream condenser. The pressure at which the steam condensate leaves the load is input to the model from the steam condenser model.

12 The steam turbine will attempt to meet the remaining electrical load (load – gas turbine power) given the steam back pressure (from the condenser model) and the available steam flow rate (from the heat recovery steam generator via an equation).

Several versions of the steam turbine model are available. One version calculates the resultant steam turbine power based on the inlet steam flow rate (multiple injection and extraction streams are allowed). Another version calculates the steam flow required to meet the inlet electrical load (multiple injection and extraction streams are allowed). The version used in this example attempts to meet the electrical load by varying the inlet steam flow rate; up to the maximum steam flow rate allowed (no injection or extraction streams are allowed).

13 The steam mixing valve allows multiple steam flows to be mixed together and the resultant outlet condition calculated. The enthalpy for the outlet stream is calculated from an energy balance on the device; where the device is assumed to be perfectly insulated. The outlet pressure from the device is set to the minimum pressure of all active flow streams (those with a positive flow rate). All flows entering above this minimum pressure will adiabatically expand to the minimum pressure. The outlet flow rate from the device is simply the sum of all the inlet flow rates.

14 At least one component model in <u>each</u> flow loop must definitively set the flow rate for that loop. In most simulations, this is the function of the pump model. In some circumstances, the flow rate can be set by another component. For example a load-following steam turbine (a device which meets an electrical load by varying the steam flow rate) or a heat recovery steam generator operating in the "Make as much as possible" mode are examples of other devices that can set the flow rate. In these cases (as in this example), a pump model which does not set the flow rate, but instead just calculates the pump power should be used. The condensate pump will generate an error and the simulation will stop if two-phase or superheat steam is provided at the inlet. The pump model calculates the required pump power and heat transfer to the fluid and ambient by imposing the overall pump and motor efficiencies on the theoretical pump power (incompressible fluid v * dP).

15 In this example, a simple steam condenser is used to reject heat from the steam loop to the ambient. In this model, a fixed amount of subcooling and an outlet pressure are specified by the user. In other more detailed condenser models, the outlet steam conditions are calculated using a pinch-point temperature difference approach and an inlet cooling stream.

16 Layers can be used inside the studio to help the user visualize what's happening in the projects. Layers containing models and links may be turned on and off throughout the simulation process. Use the View menu in the studio to control which layers are currently being displayed.

17 Make sure and check the component order before running your simulations. Besides a likely increase in speed, many convergence problems can be avoided by simply changing the order. The best order seems to correspond to the natural flow of information via pipes and wires of the real system. The component order can be modified using the control cards under the assembly menu.

18 Before running the simulation, and usually before any of the models are connected, the user should set the values for the control cards. The control

cards set the simulation start and stop times, the timestep, the convergence tolerances and many other simulation-specific values.

19 After every simulation, the TRNSYS list file should be checked for warnings and/or errors that were found. The list file can be accessed from a small button on the left side of the studio or through the Calculate menu of the studio.

20 Every input that is left unconnected in a project will assume it's specified initial value for the duration of the simulation; so be sure and set the initial values carefully.

21 One of the best ways to avoid problems when creating a complicated project is to run the simulation, with an online plotter watching the variables, after each component has been added to the system.

22 While the temperature, pressure, and enthalpy of the steam are passed from component to component in TRNSYS, only the pressure and enthalpy are used to set the state of the steam for any component.

23 Make sure and carefully read the detailed description of each model you are considering using in the project. The proforma for each model contains all the assumptions, limitations, and a description on how the model is intended to operate.

24 This example utilizes an evaporative cooling device which cools the inlet air stream to the gas turbine by injecting tiny droplets of water into the air stream - causing the water to evaporate and removing sensible energy from the flow stream. There are many ways to provide gas turbine inlet air cooling; including the use of a steam-driven absorption chiller as described in the example project: Template_PostRetrofit_InletAirCooling.tpf