COMPLEX HEATING, COOLING, AND HEAT RECOVERY PLANT MODELING

Affiliated Engineers

Energy Trust of Oregon

Building Energy Simulation Forum

04/18/2018

Lyle Keck, PE, LEED AP BD+C

Building Performance Consultant

Agenda

Plant modeling basics using EnergyPlus (E+)

- ‘Complex’ hydronic plant modeling
- E+ plant loop structure and equipment
- E+ plant loop controls & Energy Management System (EMS)

Simulation workflow approach

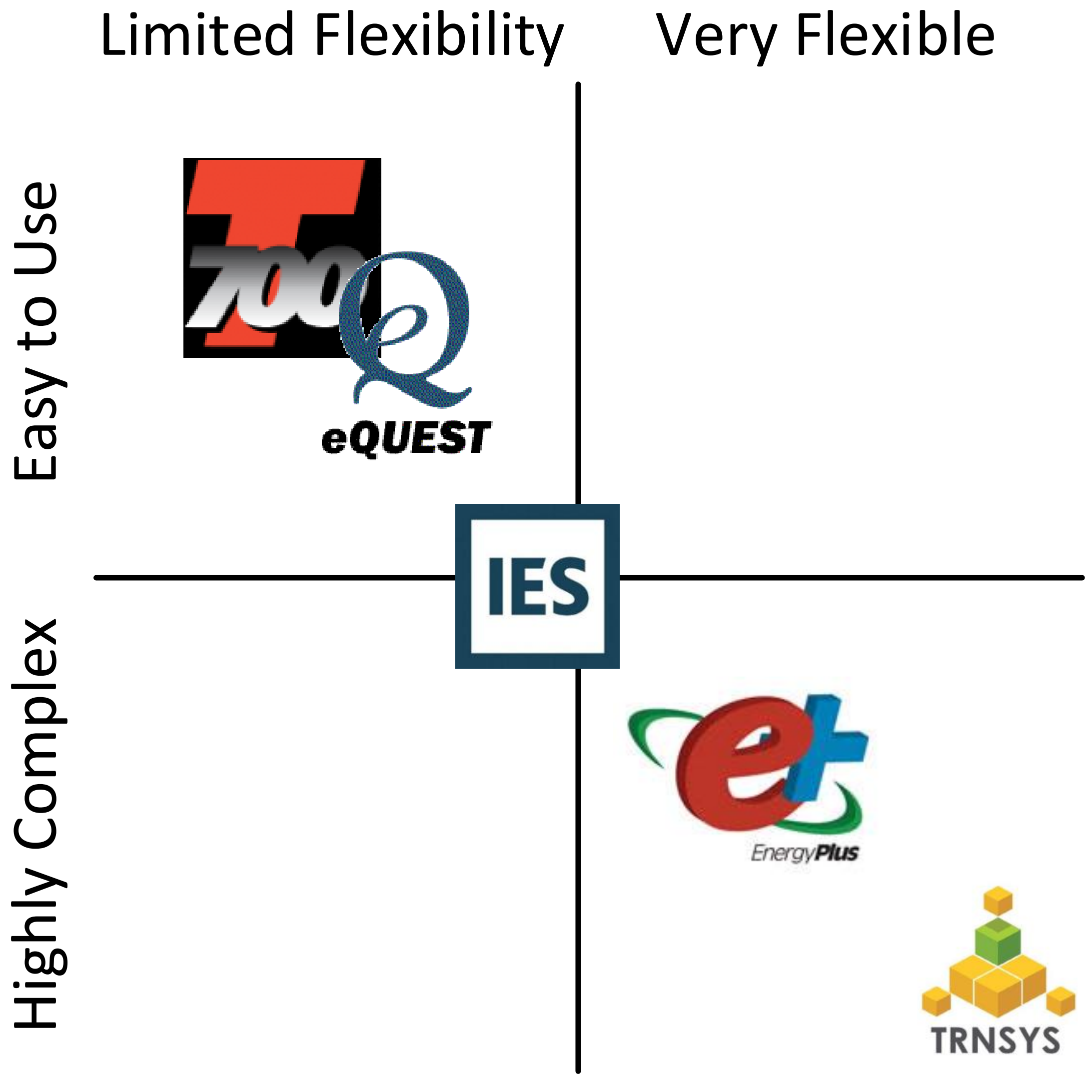
- Model setup and input file creation
- Pre/post processing, model diagnostics

Case studies

- OHSU – CHH South, Block 28 & 29 (Portland, OR)
- PHSA – Teck Acute Care Centre (Vancouver, BC)
- Seattle Children’s Hospital – Building CARE (Seattle, WA)

EnergyPlus Plant Loop Modeling

Why EnergyPlus?



Why EnergyPlus?

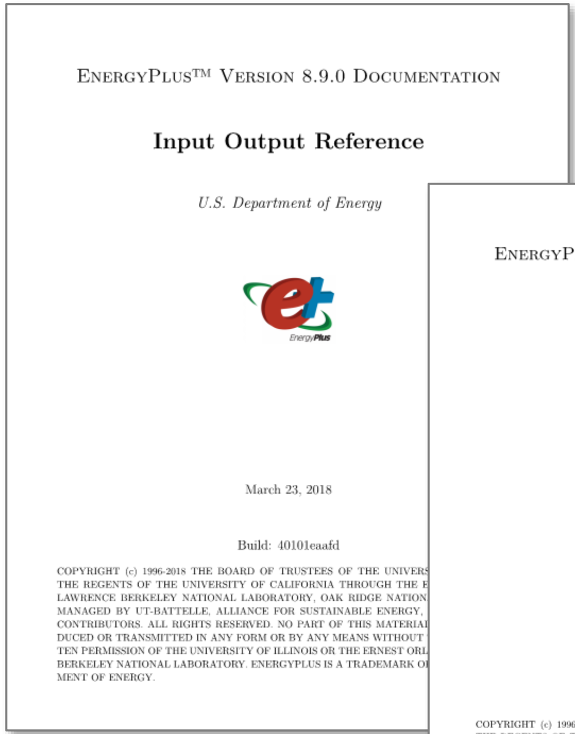
Flexibility to build hydronic loops <u>to simulate the energy performance</u> as designed and engineered

Detailed objects for many real world equipment and components

- Boilers, chillers, heat pumps
- Thermal storage tanks (HW, CHW, mixed/stratified, ice)
- Loop-to-loop objects, heat exchangers and heat pumps

Robust controls

- Many types of setpoint managers, load operation schemes
- Custom EMS controls



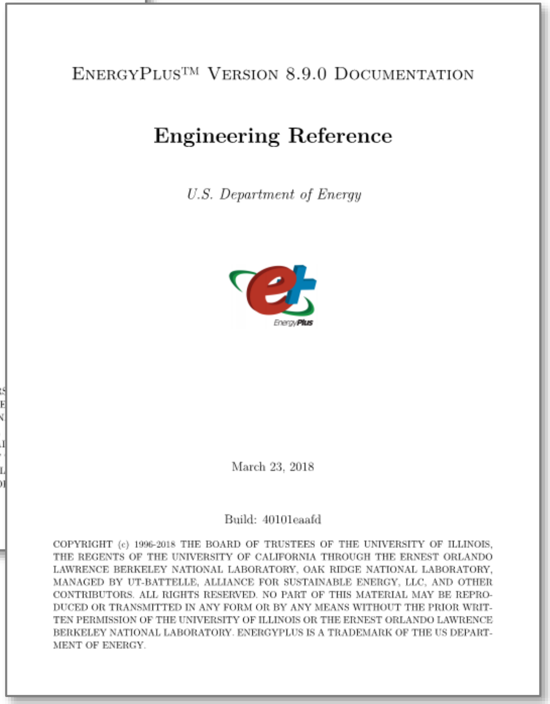
ENERGYPLUS™ VERSION 8.9.0 DOCUMENTATION

Input Output Reference

U.S. Department of Energy

March 23, 2018

Build: 40101eaafd



ENERGYPLUS™ VERSION 8.9.0 DOCUMENTATION

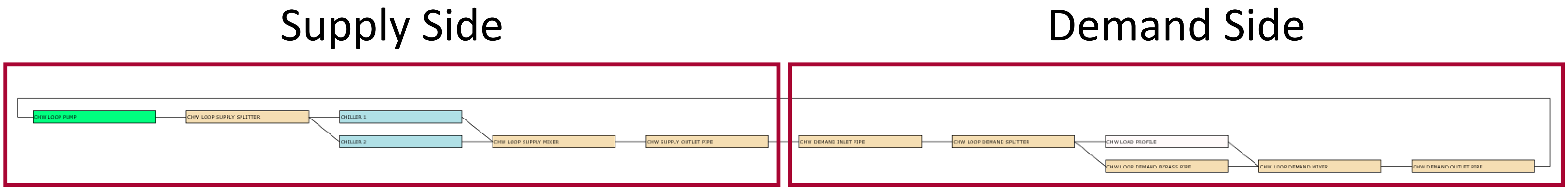
Engineering Reference

U.S. Department of Energy

March 23, 2018

Build: 40101eaafd

Plant Loop - Structure



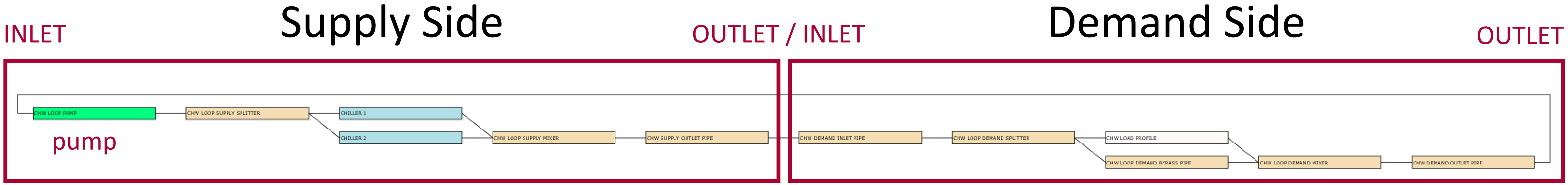
EnergyPlus has 2 main types of loops in the HVAC simulation

- Air loop and plant loop
- Plant loop uses a liquid fluid as the transport medium

Each loop is broken up into 2 half-loops

- Supply side and demand side
- Demand side equipment places a load on the supply side primary equipment
- The supply side operates to meet a specific load and flow condition
- User specified rules for how that load is distributed to supply side equipment

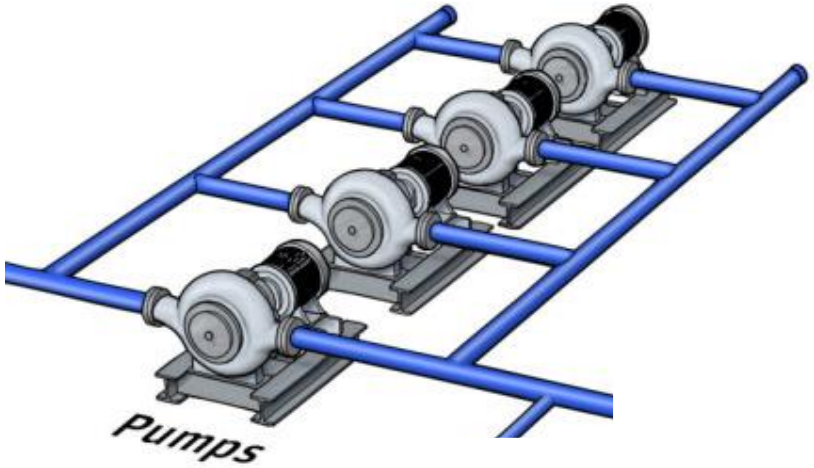
Plant Loop - Structure



Each half-loop has an inlet and outlet

Loop pump is typically placed as first object on supply side inlet

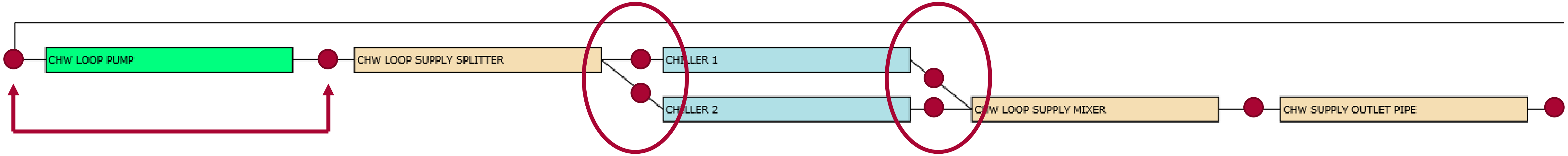
- Placing a pump on the demand side inlet will simulate primary-secondary systems
- ‘Branch pump’ can be placed in parallel section of a branch (chiller/boiler pump, etc.)



Plant Loop Basics - Structure

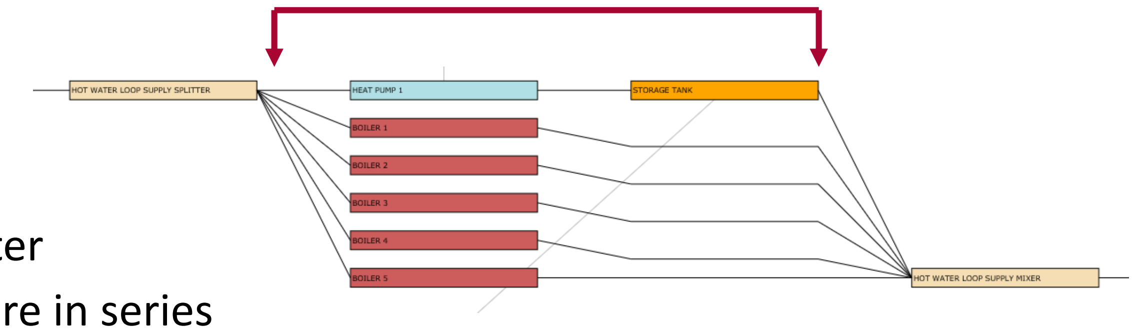
Components

- Nodes (stores properties of the loop at that location)
- Branches (one or more objects linked together in series)
- Splitter/mixer (allow branches to be setup in parallel)



Structure

- Within any single branch, objects can only be in series
- Each half-loop may only have 1 splitter and 1 mixer
- Branches may be in parallel only between the mixer and splitter
- Good practice to have a splitter and mixer even if all objects are in series



Plant Equipment – Commonly Used Objects

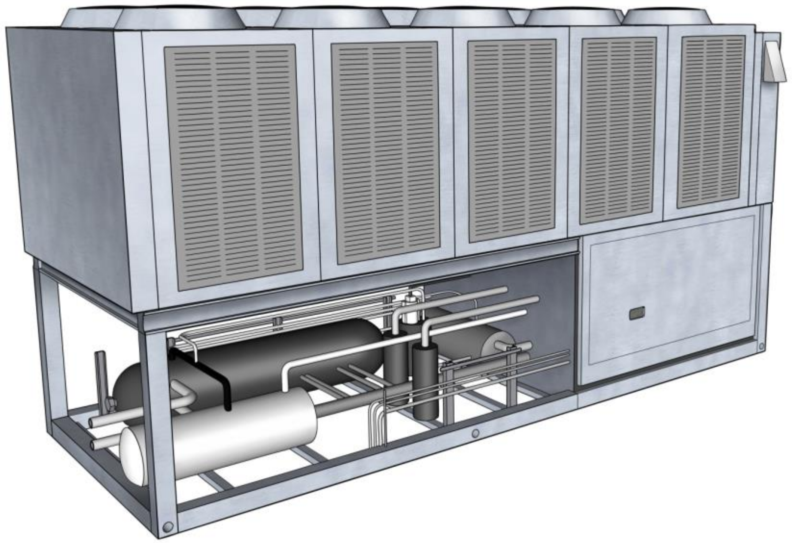
Chiller:Electric:EIR

- Air-cooled or water-cooled
- Heat recovery only available with water-cooled condenser*

Boiler:HotWater

DistrictCooling

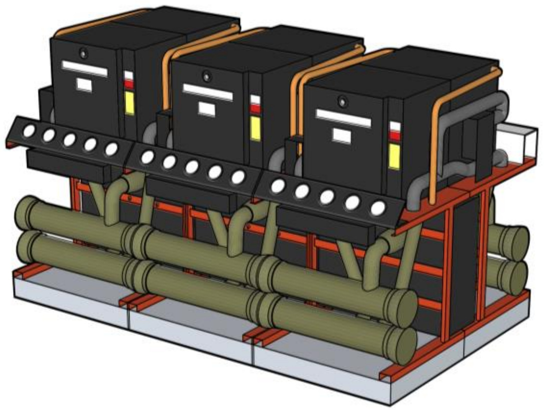
DistrictHeating



Plant Equipment – Commonly Used Objects

HeatPump:WaterToWater

- 4-pipe hydronic (hot, cold)
- Two models, EquationFit:Cooling and EquationFit:Heating
- Object only controls to one mode (heating or cooling), other mode is always passive



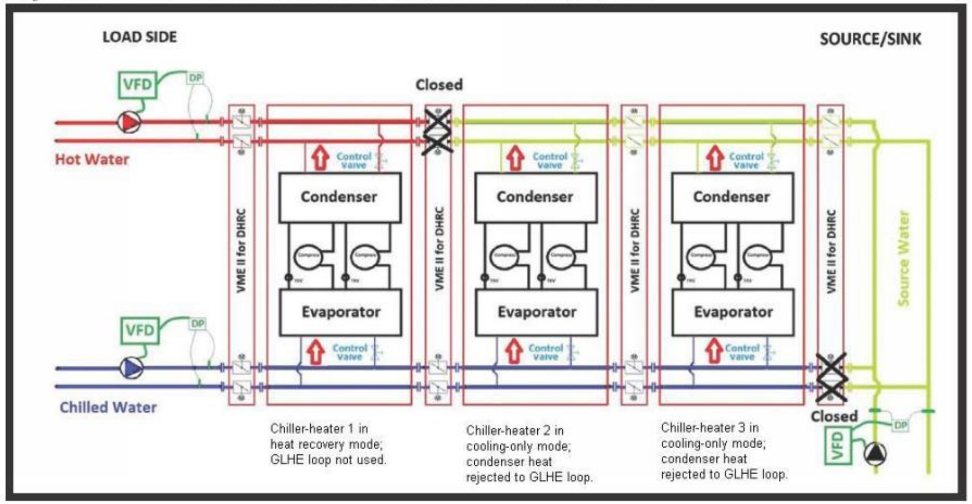
CentralHeatPumpSystem

- 6-pipe hydronic (hot, cold, source)
- Made of multiple ChillerHeater objects
- 5 modes of operation

  → Heating only, cooling only, balanced heat recovery, heat recovery with trim cooling, heat recovery with trim heating

  → User not able to actively control mode of operation*

Diagram of chiller-heater bank with one module in heat recovery mode, two in cooling only mode.



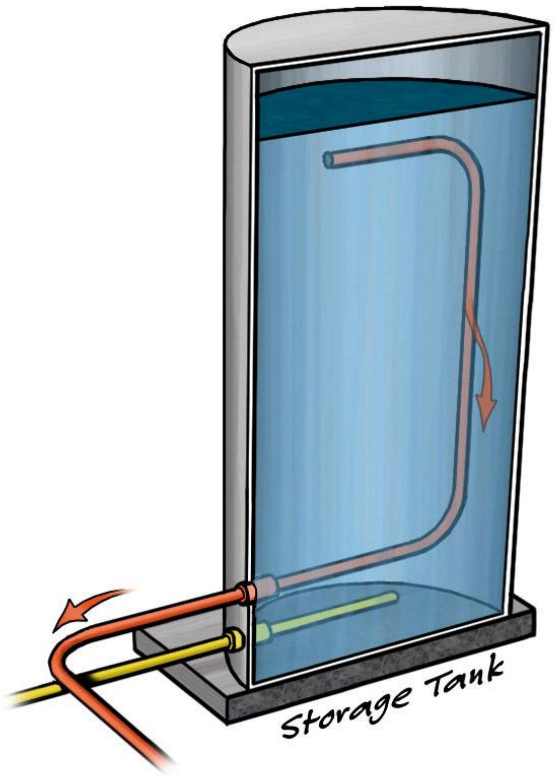
Plant Equipment – Commonly Used Objects

WaterHeater:Mixed

- Hot water storage tank
- Can be standalone or coupled with other objects…
    - WaterHeater:HeatPump (often used to approximate plant loop air-to-water HPs by minimizing tank volume)
    - Energy storage for solar hot water or waste heat recovery

ThermalStorage:ChilledWater

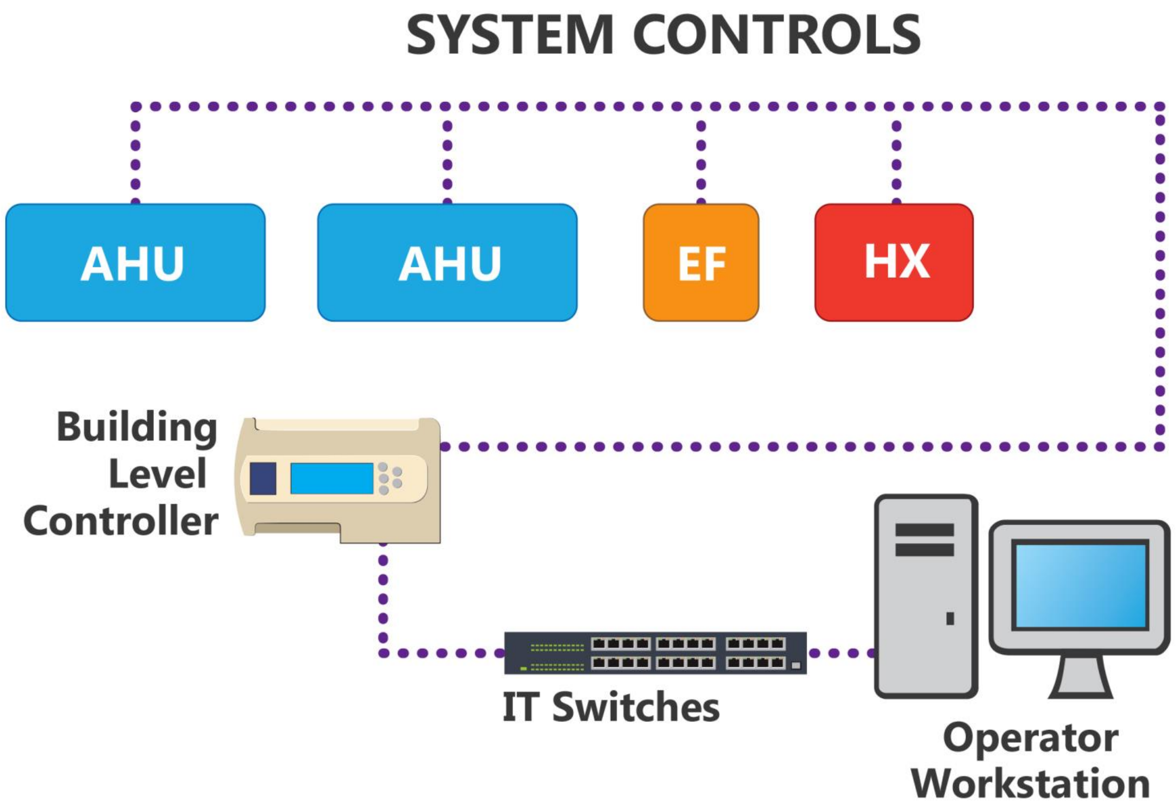
ThermalStorage:Ice



Plant Loop Controls

Control Objects

- SetpointManagers
- AvailabilityManagers
- PlantEquipmentOperationSchemes
- Energy Management System (EMS)



Plant Loop Controls

<u>Control Objects</u>

- SetpointManagers
- AvailabilityManagers
- PlantEquipmentOperationSchemes
- Energy Management System (EMS)

<u>Examples</u>

- SetpointManager:Scheduled
- SetpointManager:OutdoorAirReset
- SetpointManager:ReturnTemperature

<u>Description</u>

Place a calculated or scheduled setpoint value on the setpoint node

Setpoints are then used by plant loops as a goal for their control actions

Plant Loop Controls

Control Objects

- SetpointManagers
- AvailabilityManagers
- PlantEquipmentOperationSchemes
- Energy Management System (EMS)

Examples

- AvailabilityManager:Scheduled
- AvailabilityManager:DifferentialThermostat
- “ ”:High/Low Temperature Turn On/Off

Description

Access data from node and make a decision on whether a plant loop or equipment should be on or off

Output is an availability status flag

Loop pump then takes action of turning loop on or off – availability manager will overrule the pump on/off schedule

Plant Loop Controls

<u>Control Objects</u>

- SetpointManagers
- AvailabilityManagers
- PlantEquipmentOperationSchemes
- Energy Management System (EMS)

<u>Description</u>

Once loop load is calculated from demand side and loop setpoint, the load needs to be allocated to the supply equipment according to user input.

Overall operation scheme assigns priorities to multiple control schemes that may be assigned to a loop (list order defines priority)

If control scheme is unavailable, control will move to the next highest priority

Operation scheme links to a list of equipment and uses the plant loop load distribution scheme to dispatch load to equipment

Plant Loop Controls

Control Objects

- SetpointManagers
- AvailabilityManagers
- PlantEquipmentOperationSchemes
- Energy Management System (EMS)

Uncontrolled

- If the loop runs, the equipment will also run to full capacity

Load based control schemes

- HeatingLoad, CoolingLoad
- Defines load range and which equipment can operate for each range
- Load is dispatched according to load distribution scheme (sequential, uniform, PLR or load range)

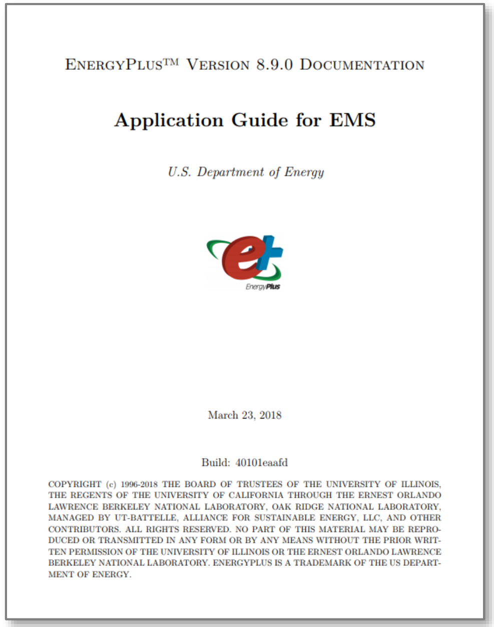
ComponentSetpoint

- Sequences plant components based on the outlet temperature of individual equipment
- Each piece of equipment must have its own setpoint that is different from loop setpoint

Plant Loop Controls

Control Objects

- SetpointManagers
- AvailabilityManagers
- PlantEquipmentOperationSchemes
- Energy Management System (EMS)



EnergyPlus™ Version 8.9.0 Documentation

Application Guide for EMS

U.S. Department of Energy

March 23, 2018

Build: 40101eaafd

"The Book of Erl"

Description

EMS provides a way to develop custom control and modeling routines for E+

Provides high-level supervisory control to override selected aspects of E+ simulations

Access sensor data and use this data to direct control actions

Concept is to emulate the types of control possible with DDC building automation systems in real buildings

Plant Loop Controls - EMS

EMS:Sensor

- Declares a variable. Used to get information from somewhere else in the model to use in control calculations.
- Generally uses normal E+ output variables

EMS:Actuator

- EMS initiates control actions by changing the value of this variable.
- Actuators override things in E+. Normal operation resumes when actuator is set to Null.
- Can be scheduled value, on/off status, flow rate, load dispatch, node property, etc.

EMS:Program

- Contains control logic (code) to be executed
- Uses simple if/then/else/set statements, functions and expressions to

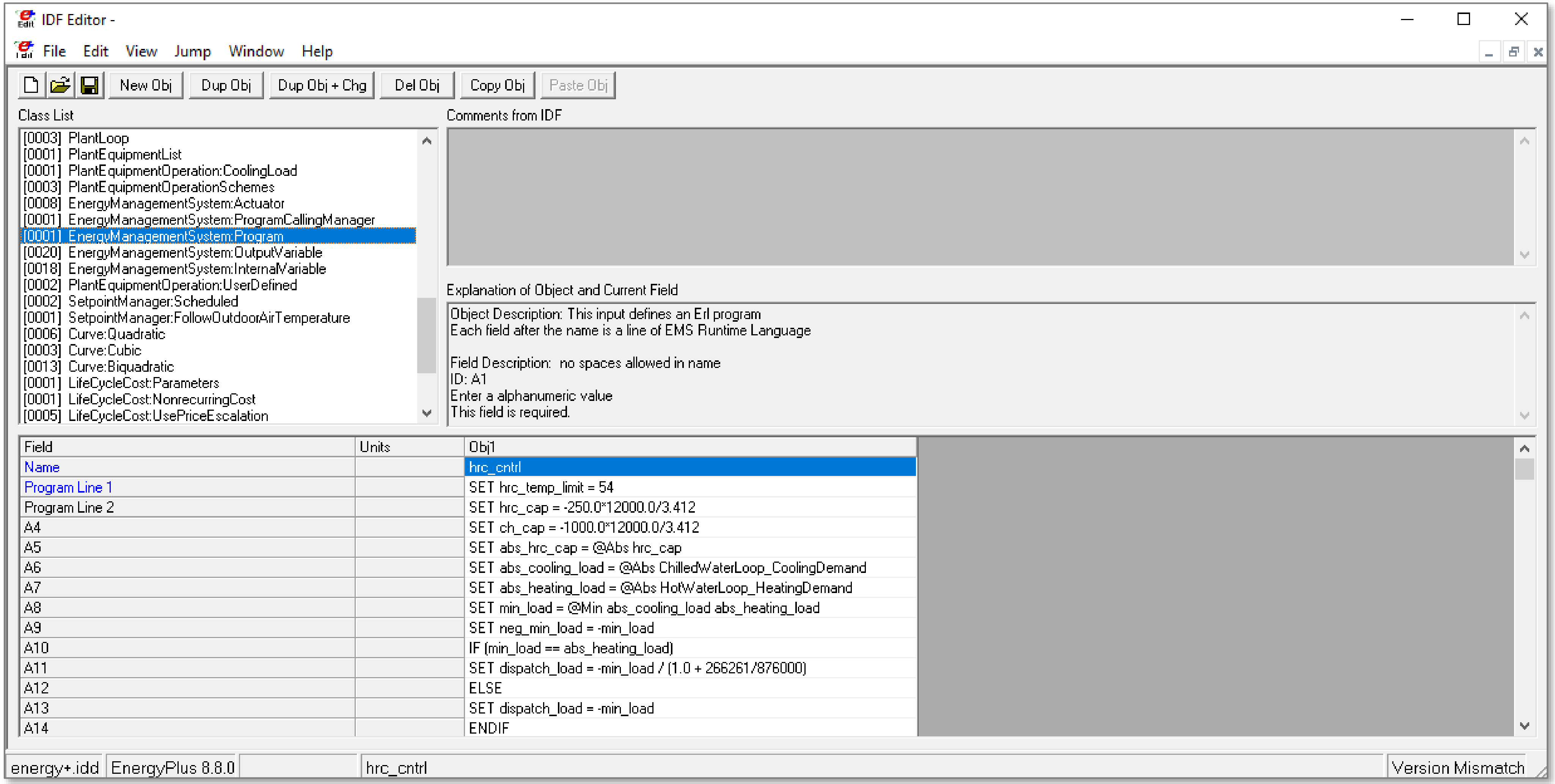
EMS:ProgramCallingManager

- Defines when in the simulation, and/or timestep, EMS programs are executed
- Also defines when EMS programs are executed relative to other EMS programs

Global/Output/Internal Variables

- Another means of accessing and reporting variables for use in EMS

Plant Loop Controls - EMS



Simulation Workflow

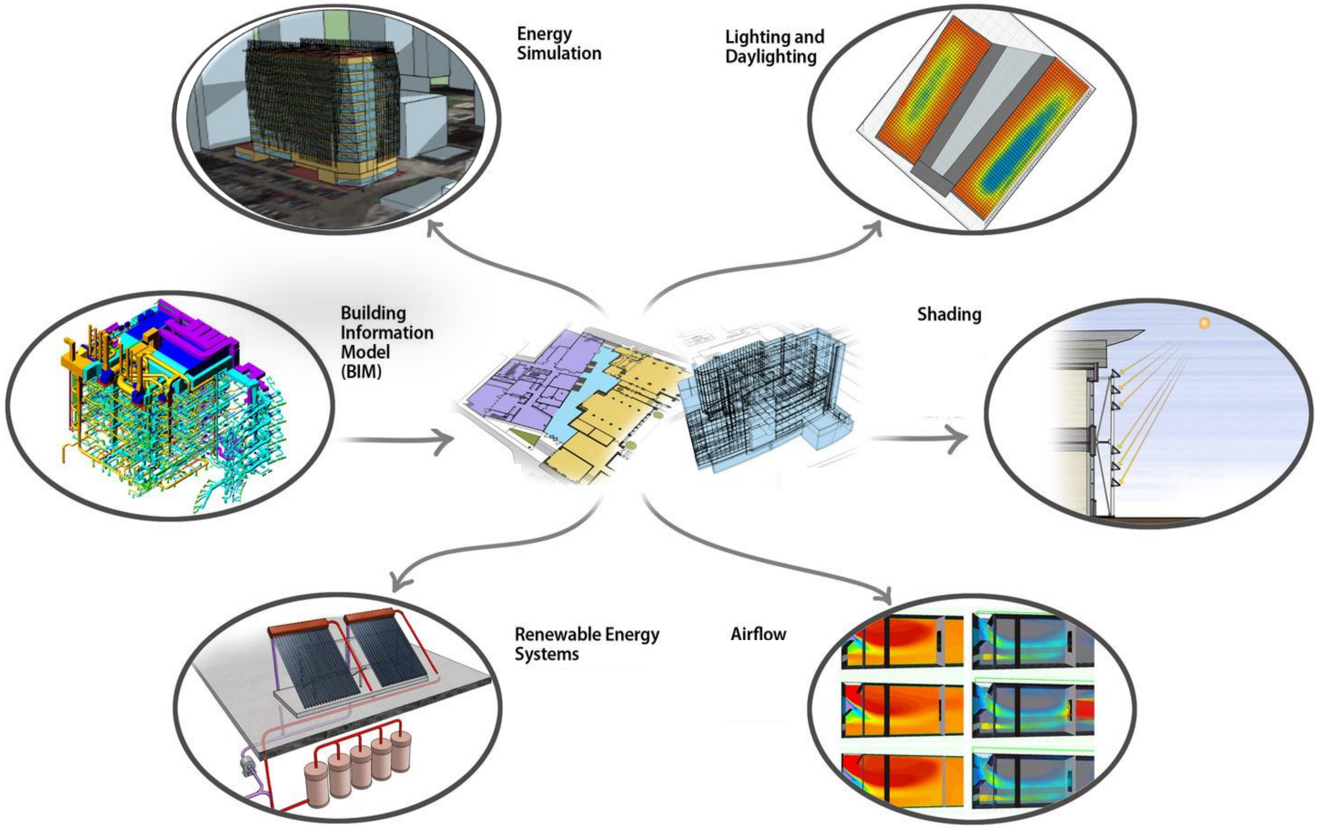
Simulation Workflow Approaches

Model setup and input file creation

- EnergyPlus IDF Editor
- OpenStudio

Pre & Post Processing

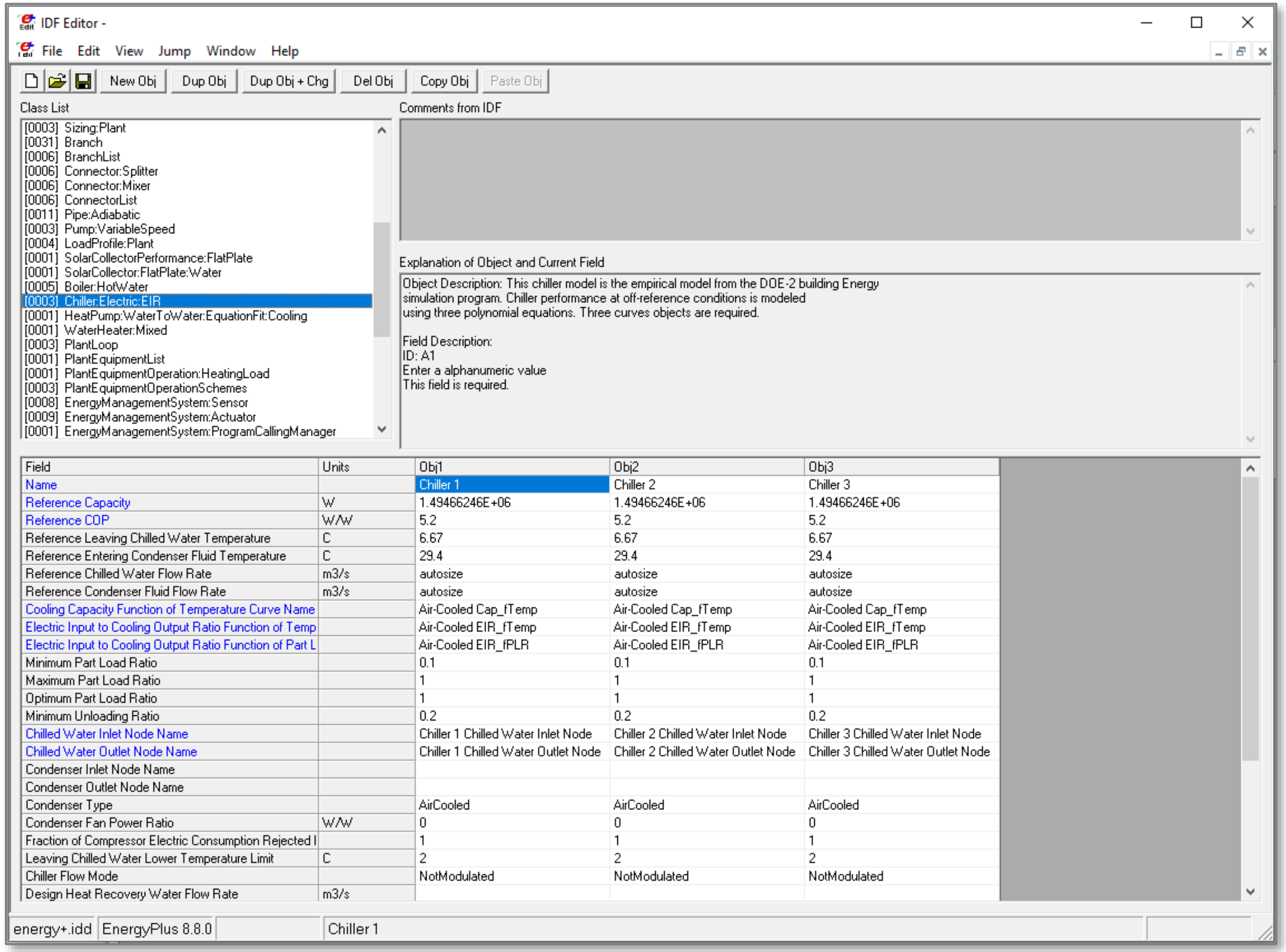
- Data transfer and calculation
- Model diagnostics

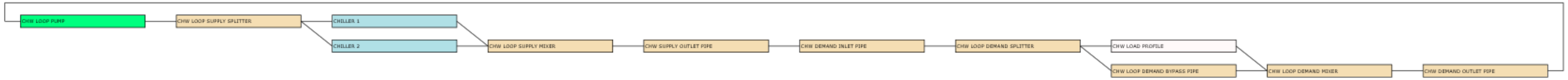


Simulation Workflow – Model Setup

EnergyPlus IDF Editor

- ‘GUI’ that is distributed with E+
- No visual representation of system layout until successful setup and simulation
- Many objects to manage for each piece of equipment….

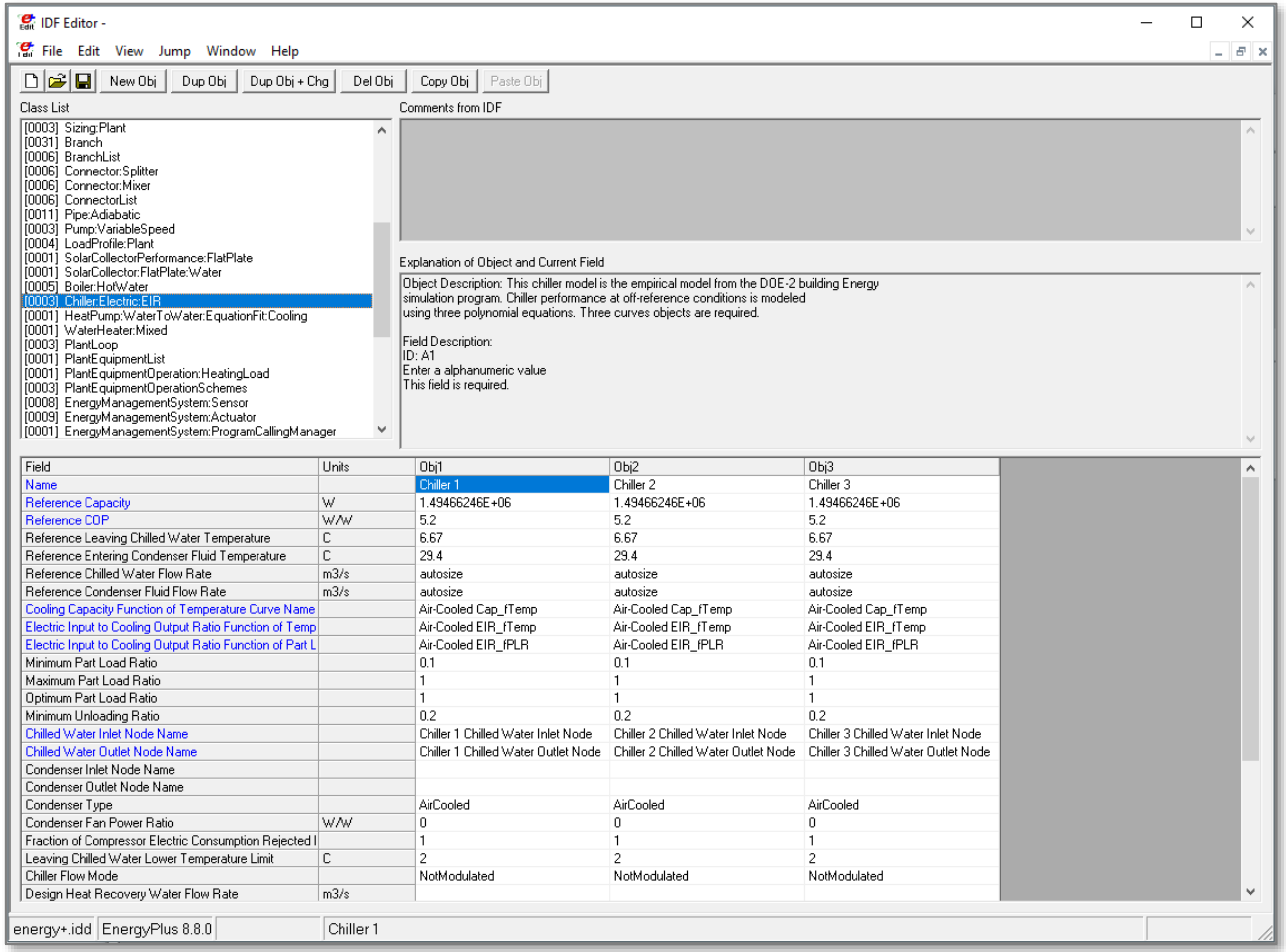


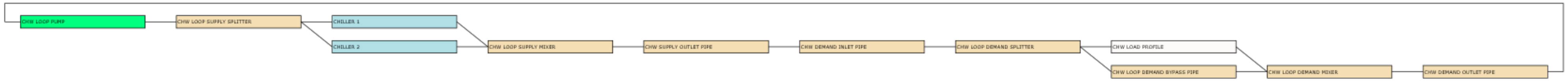


Simulation Workflow – Model Setup

<u>To add 1 boiler in IDF editor:</u>

- Boiler:HotWater
- Inlet Node, Outlet Node
- Branch
- BranchList
- Connector:Splitter
- Connector:Mixer
- PlantEquipmentList
- May require more….

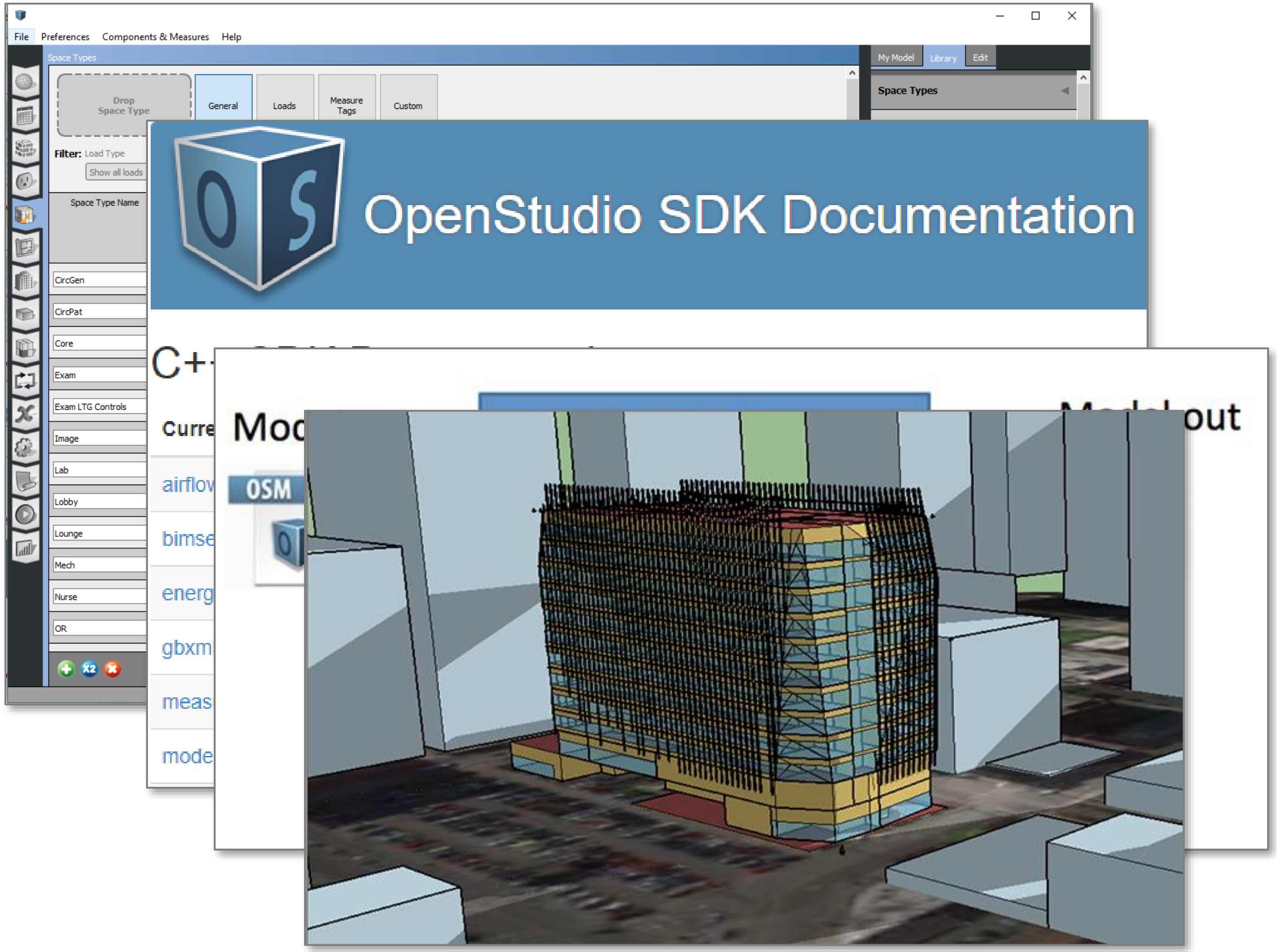




Simulation Workflow – Model Setup

OpenStudio (OS)

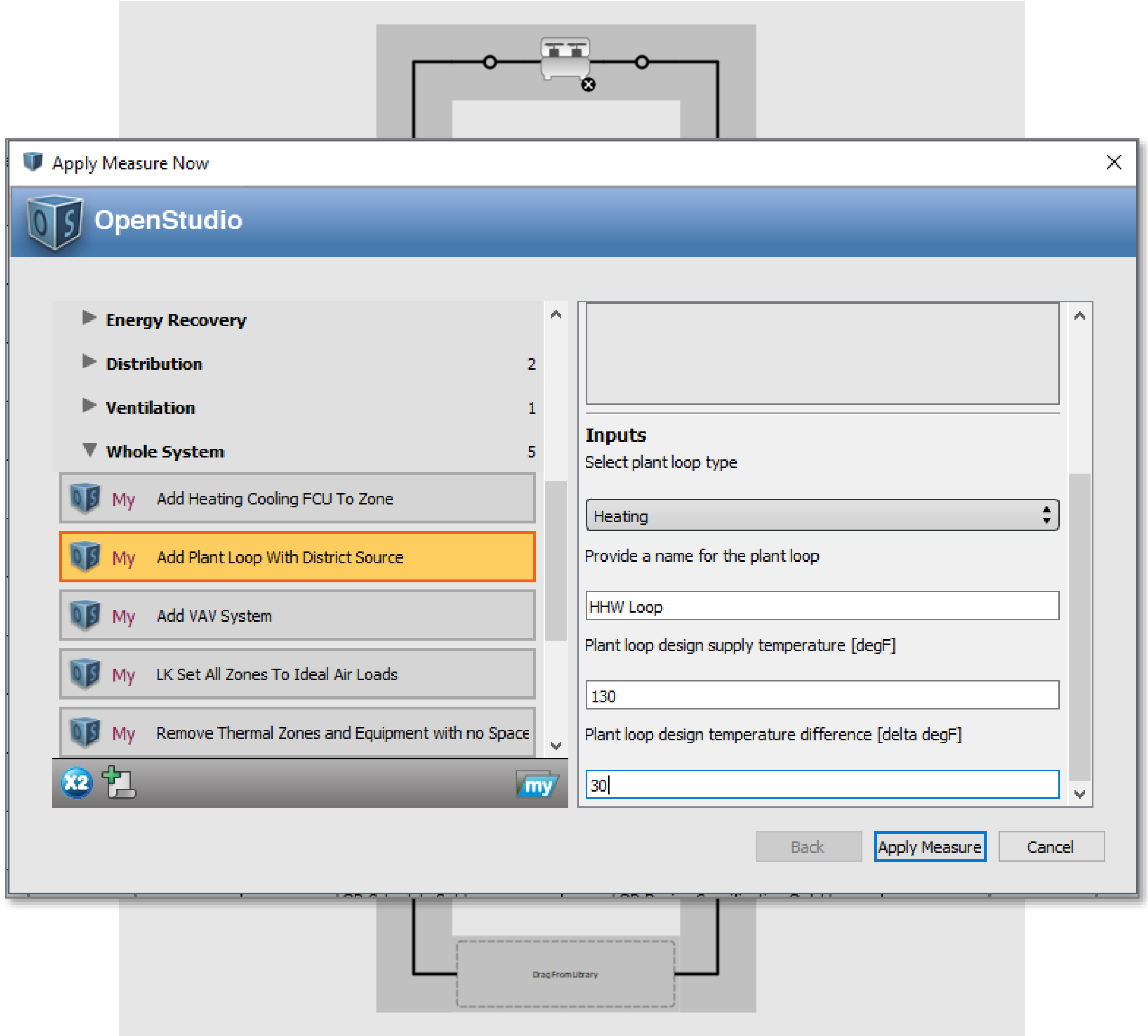
- Collection of tools to support whole building modeling using E+ simulation engine
- OS Application (GUI)
- OS Software Development Kit (SDK / API)
- OS Measures (scripts)
- Other tools including SketchUp plugin for geometry, parametric analysis tool, Radiance



Simulation Workflow – Model Setup

<u>OpenStudio (OS)</u>

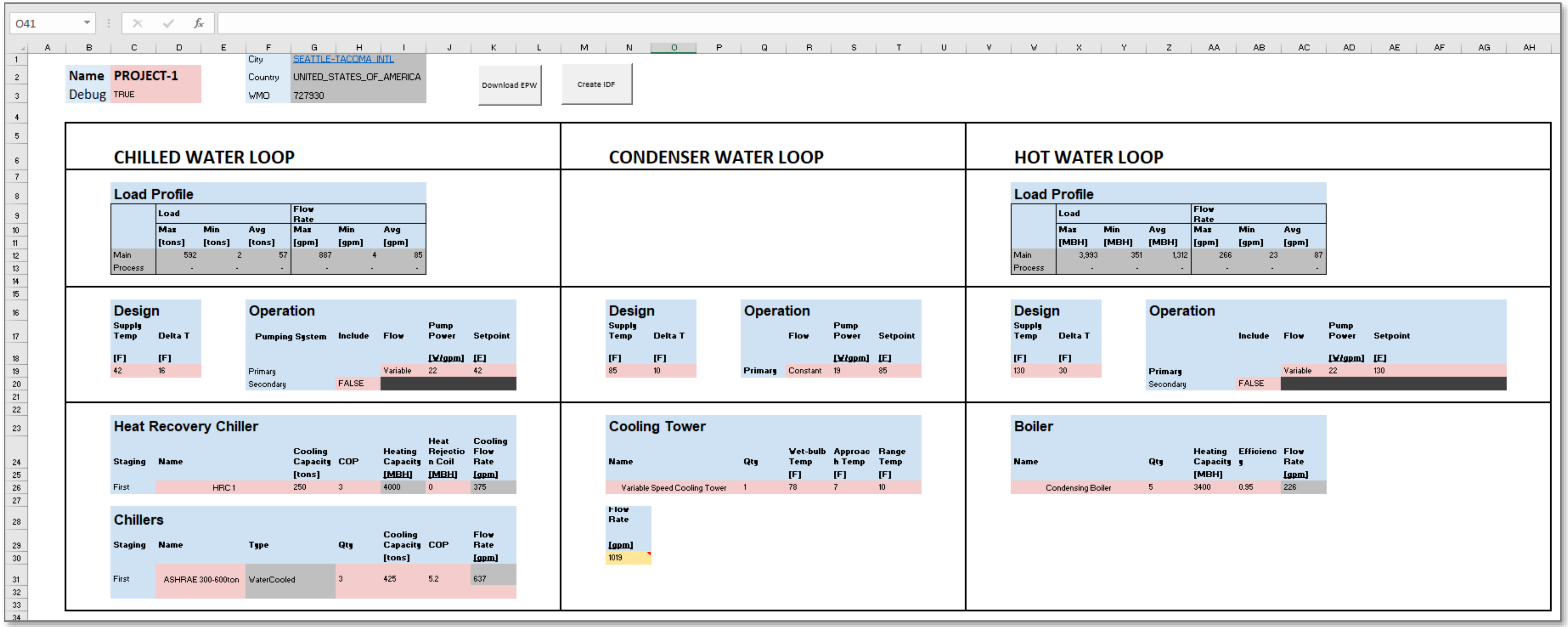
- Use OS Application to quickly setup plant loops
- Visual interface that holds E+ loop structure and general ruleset
- Adding components to loop does a lot of the 'heavy lifting' setup and coordination/management
- Export E+ input file (IDF) for further manipulation if needed
- Measure to automate setup and bake-in best practices



Simulation Workflow – Model Setup

Custom workflows with OpenStudio API

- Use OS SDK to create custom tools that quickly generate E+ plant models



Simulation Workflow – Pre Processing

Plant model can be separate model from whole building model

- Multiple buildings fed by a central district or campus plant
- OpenStudio (or other) whole building model and EnergyPlus plant model
- May be easier to setup and troubleshoot plant model in isolation, faster simulation time
- Preference and discretion of modeler

LoadProfile:Plant Object

- Used to transfer loop load/flow information from whole building model to plant model
- Can reference hourly CSV file, or reference manual schedules in E+
- Hourly data for Load [W], Flow Rate [m3/s], Flow Rate Fraction [0-1]
  - → Create hourly variables in whole building model
  - → Use loop design temperature difference and peak hourly load to define flow rates (peak & hourly)
  - → Flow rate fraction is a normalized value of hourly flow rate to peak flow rate

Simulation Workflow – Pre Processing

python™

Data Transfer

Use custom python script to automate this process, which does the following…

- Run OS whole building simulation
- Query results file (SQL) to pull out hourly loop variables
- Calculate peak/hourly/normalized flow rates based on loop design temperature difference
- Write hourly loop information to CSV file referenced by LoadProfile:Plant object
- Run E+ plant simulation
- Query results file (SQL) and combine results from whole building model and plant model as desired

Database Connections

```
In [5]: con = sqlite3.connect(os.path.join(path, filename))
```

Heating Loop

```
In [6]: loopname = heating_loop_name
In [7]: heat_loop_df = aei.create_plant_loop_df(con, loopname)
In [8]: heat_loop_df.head()
```

Out[8]:

	Cooling Demand Rate [W]	Heating Demand Rate [W]	Supply Flow Rate [GPM]	Supply Temp [F]	Return Temp [F]	Delta T [F]	Unmet Demand [W]
0	0.0	578384.698937	107.655573	130.0	93.330434	36.669566	0.0
1	0.0	572482.271080	108.387765	130.0	93.949834	36.050166	0.0
2							
3							
4							

```
In [9]: heat_loop_summ
        heat_loop_summ
```

Out[9]:

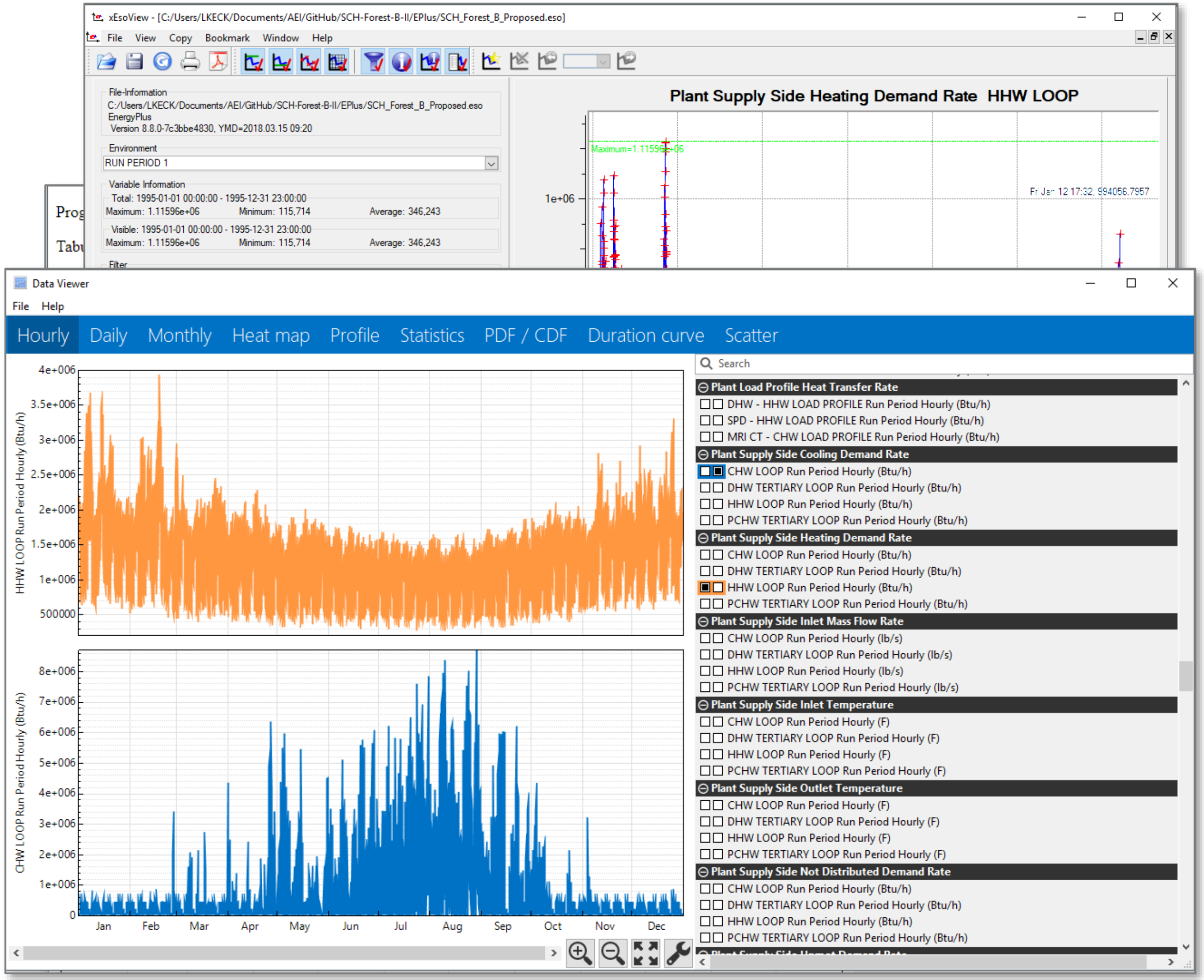
	Total Cooling
0	

```
In [10]: total_heating
         print 'Total H
Total Heating
```

T1

	A	B	C	D	E	F	G	H	I	J	K	L	M
1	Hour	Main CHW Load	Main CHW Flow Rate	Main CHW Norm Flow Rate	Process CHW Load	Process CHW Flow Rate	Process CHW Norm Flow Rate	Main HHW Load	Main HHW Flow Rate	Main HHW Norm Flow Rate	Process HHW Load	Process HHW Flow Rate	Process HHW Norm Flow Rate
2		[W]	[m3/s]	[]	[W]	[m3/s]	[]	[W]	[m3/s]	[]	[W]	[m3/s]	[]
3	1	-8329.42	0.000249	0.003331	-379836	0.011342	1	578384.7	0.008636	0.521254	0	0	0
4	2	-8328.78	0.000249	0.003331	-379836	0.011342	1	572482.3	0.008548	0.515935	0	0	0
5	3	-8328.72	0.000249	0.003331	-379836	0.011342	1	565126.8	0.008438	0.509306	0	0	0
6	4	-8331.19	0.000249	0.003332	-379836	0.011342	1	547353.8	0.008172	0.493288	0	0	0
7	5	-8331.95	0.000249	0.003332	-379836	0.011342	1	540047.1	0.008063	0.486703	0	0	0
8	6	-8328.27	0.000249	0.003331	-379836	0.011342	1	519574.9	0.007758	0.468253	0	0	0
9	7	-8327.87	0.000249	0.00333	-379836	0.011342	1	562800.7	0.008403	0.50721	0	0	0
10	8	-8335.41	0.000249	0.003333	-379836	0.011342	1	566341.9	0.008456	0.510401	0	0	0
11	9	-12611.8	0.000377	0.005044	-350589	0.010469	0.923001	484267.8	0.00723	0.436434	0	0	0
12	10	-14950.5	0.000446	0.005979	-328430	0.009807	0.864663	457840.9	0.006836	0.412617	0	0	0
13	11	-15161.5	0.000453	0.006063	-322158	0.00962	0.848152	449759.9	0.006715	0.405334	0	0	0
14	12	-15184.9	0.000453	0.006073	-351226	0.010488	0.924678	488547.8	0.007294	0.440291	0	0	0
15	13	-15192.7	0.000454	0.006076	-346644	0.010351	0.912615	482449	0.007203	0.434795	0	0	0
16	14	-15193.3	0.000454	0.006076	-339238	0.01013	0.893116	472574.4	0.007056	0.425895	0	0	0

Simulation Workflow – Post Processing



Model Diagnostics

Model results are used to ensure the model is operating as intended and support design

EnergyPlus tabular results

- HTML file and web browser
- CSV / excel

EnergyPlus hourly results

- xEsoView
- DView
- CSV / excel

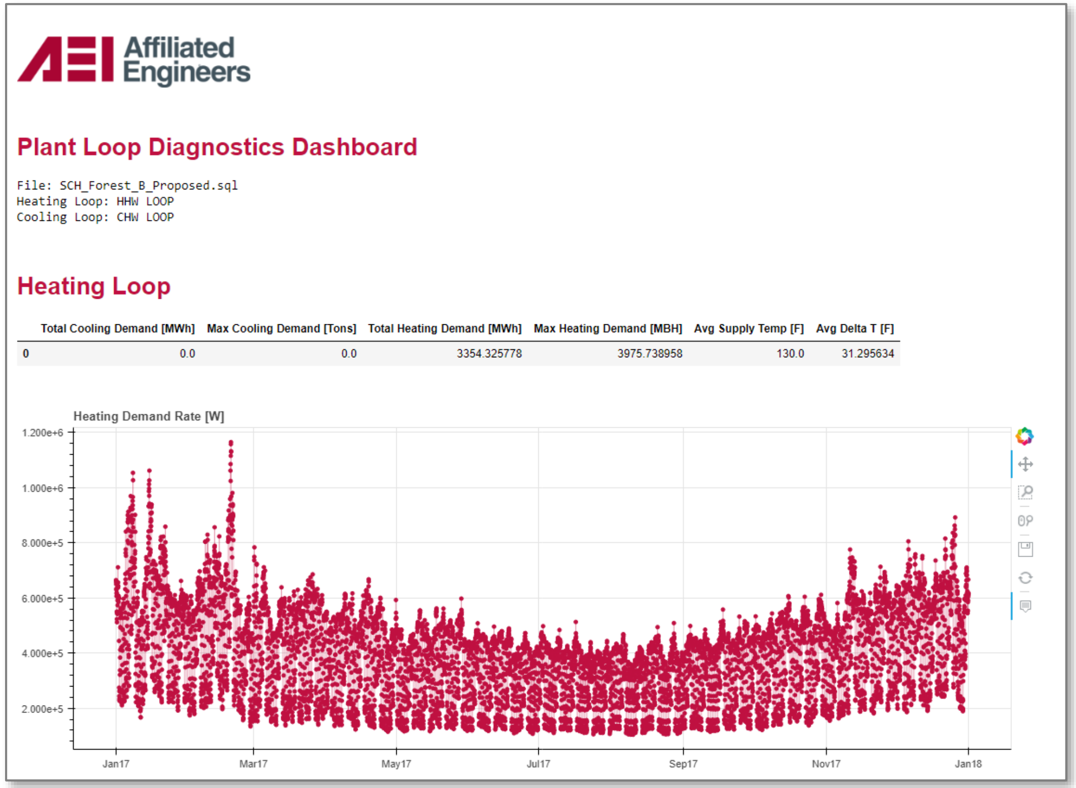
OpenStudio results

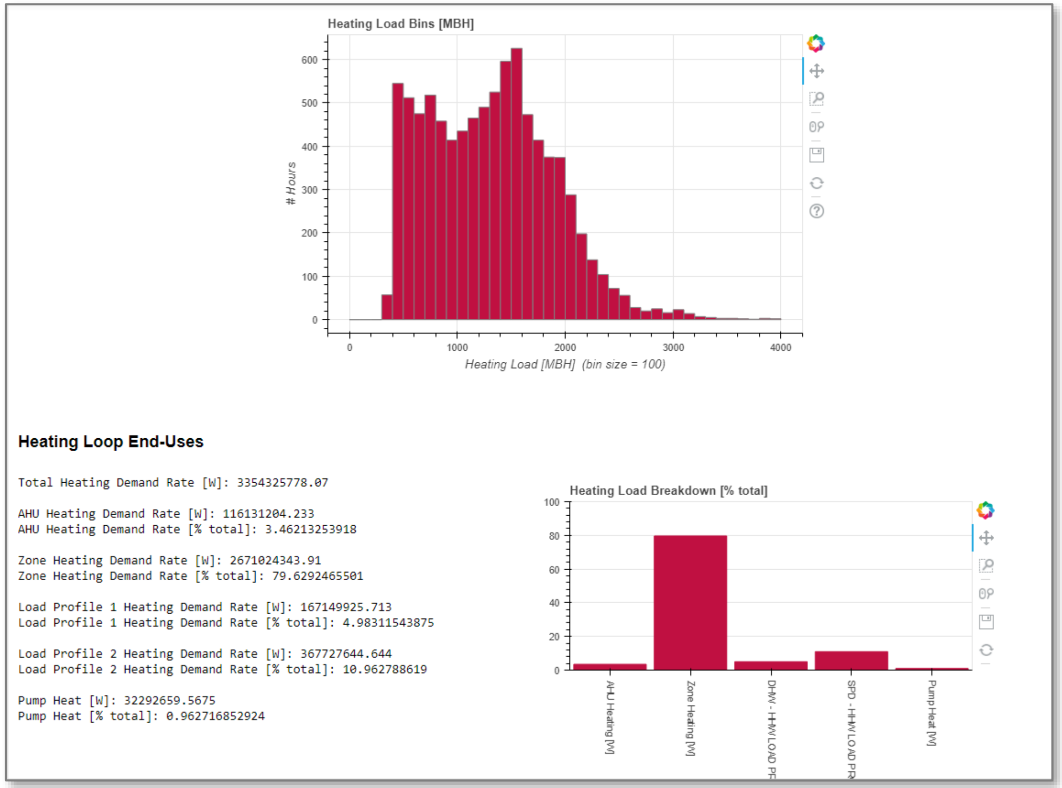
- E+ output files (above)
- OS application
- DView now packaged w/ OS

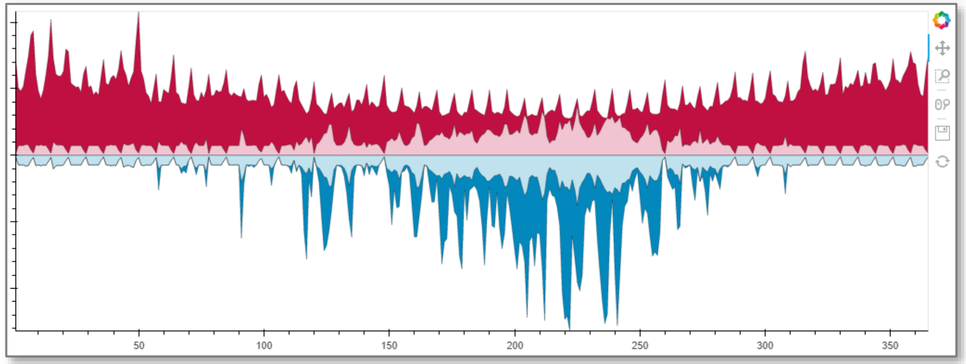
Simulation Workflow – Post Processing

Model Diagnostics

- Custom python based dashboards
- Query tabular and hourly results from E+ output file (SQL) and create model diagnostic reports



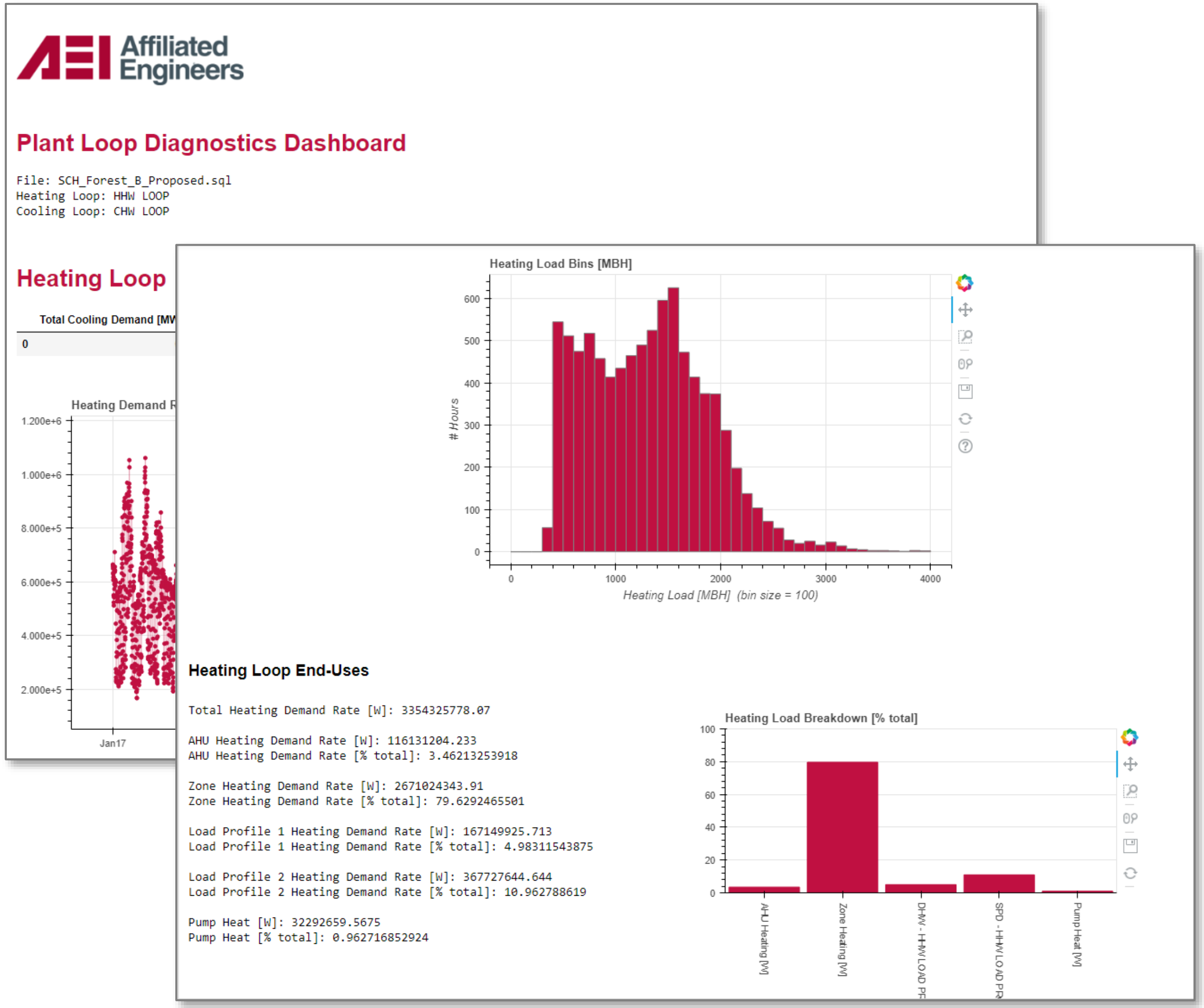




Simulation Workflow – Post Processing

Model Diagnostics

- Visualize design inputs, sizing inputs & results, tabular results and hourly data side-by-side
- Calculate key performance metrics to assess operational efficiency
- Report key metrics to inform design and write results to integrate with design workflow tools
- Intelligent sorting and binning of data
- Flexible – query model and grab appropriate results, automatically adapts to changes in number of objects & components
- Interactive – scale, zoom, hover, save image with a single click



Plant Modeling Case Studies

Case Studies

Oregon Health & Sciences University – Center for Health and Healing South (OHSU CHH South)

- Portland, OR
- Two buildings (B28 & B29) with common central plant
- Heat recovery chiller, exhaust air heat recovery
- ETO incentive modeling

Provincial Health Services Authority – Teck Acute Care Centre (TACC)

- Vancouver, BC
- Air source heat pump
- BC Hyrdo incentive modeling

Seattle Children's Hospital – Building CARE (SCH CARE)

- Seattle, WA
- Thermal storage
- Solar hot water collectors

OHSU - Center for Health & Healing South (CHH South)

Client:

- Oregon Health & Sciences University

Location:

- Portland, OR

Size:

- 330,000 ft^2 (Block 29)
- 120,000 ft^2 (Block 28)

Building Program:

- Outpatient ambulatory surgery center, outpatient clinical services, medical office (Block 29)
- Conference center, patient family lodging, parking (Block 28)

Status:

- Under construction

ZGF Architects

OHSU – Center For Health & Healing South

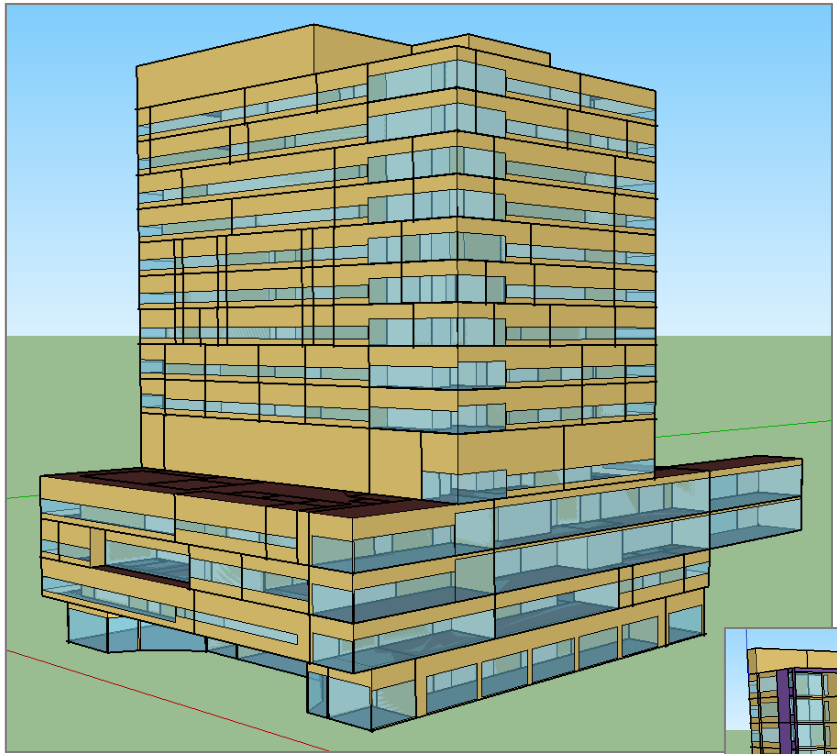
<u>Modeling Services:</u>

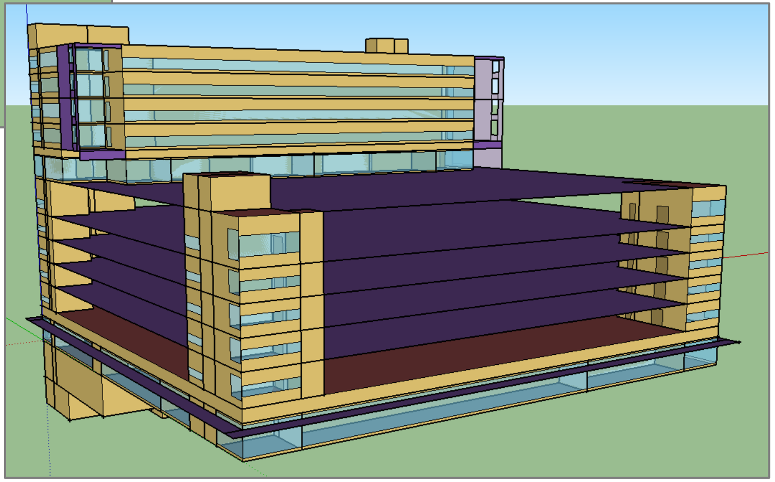
- Design performance analysis
- Utility incentives (ETO)
- LEED certification

<u>Central Plant:</u>

Located in B29, provides HHW and CHW to B28 & B29, also provides CHW to B25 (CHH North)

- Condensing gas fired boilers
  - (4x) 5,600 MBH
- High efficiency water-cooled chillers & cooling towers
  - (2x) 1,000 ton centrifugal chillers
- Water-to-water heat recovery chillers (HRCs) w/ exhaust air heat recovery coils
  - (2x) 250 ton
  - 90,000 CFM of exhaust air recovery coils


BLOCK 29

BLOCK 28


OHSU – Center For Health & Healing South

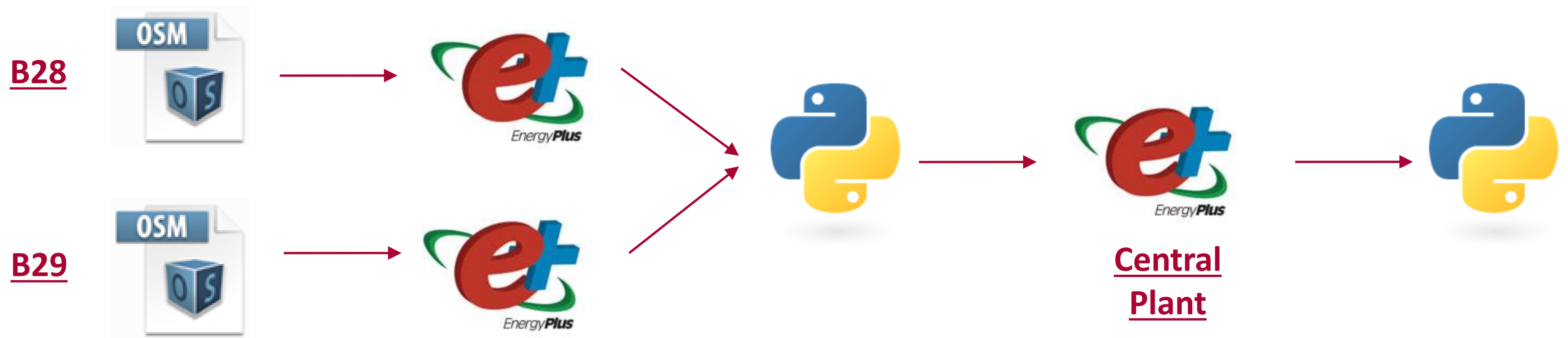
<u>Modeling approach</u>

Separate whole building models for B28 and B29

Combined plant model with hourly load profiles from B28, B29 and B25

Python script to…

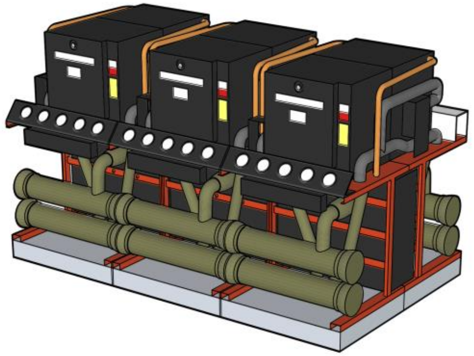
- automatically create HHW and CHW load profiles from whole building models
- calculate and create 'false cooling' heat recovery load profile based on design inputs and hourly results
- Runs whole building models, creates load profiles, runs plant model, combine results

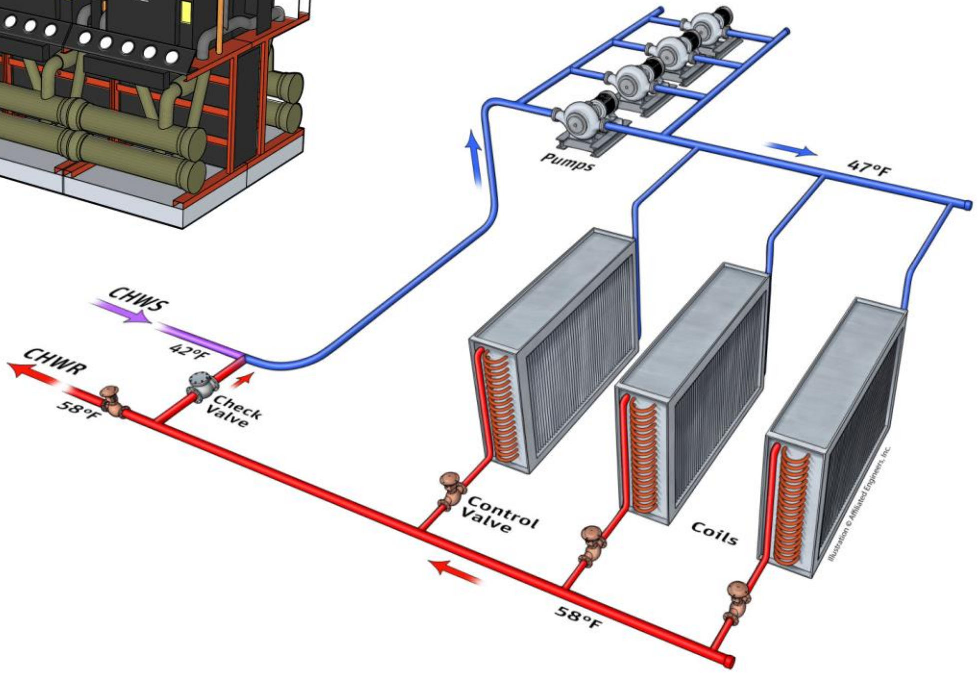


OHSU – Center For Health & Healing South

<u>Exhaust Air Heat Recovery w/ HRCs:</u>

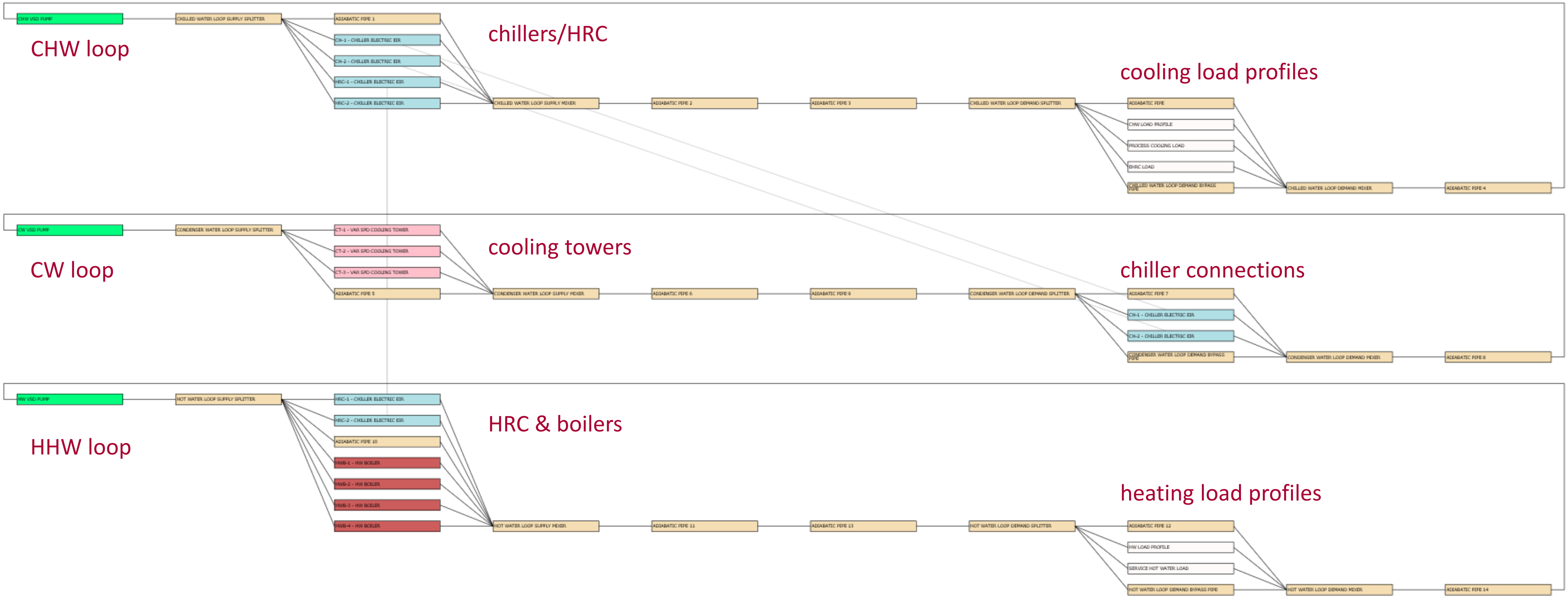
- Utilize building exhaust as a heat source (70-75F) for a super efficient form of heat pump heating
  - → ~3X more efficient than gas-fired boilers
  - → Boiler COP = 0.9
  - → HRC Heating COP = 3.0 - 3.5
- Capture heat leaving the building and transfer/reuse that heat at a higher grade to HHW loop
- Ability to meet preheat, reheat, and domestic water heating demands
- Operate when heating dominant:
  - → HRC meets simultaneous heating/cooling demand first
  - → Then engage 'false cooling' heat recovery coils to provide trim heating





OHSU – Center For Health & Healing South

EnergyPlus Plant Model



OHSU – Center For Health & Healing South

<u>EnergyPlus Objects:</u>

- Boiler:HotWater
- Chiller:Electric:EIR
- CoolingTower:VariableSpeed
- HeatPump:WaterToWater:EquationFit:Cooling
- EnergyManagementSystem:Program (and associated components)

<u>EMS Control Logic:</u>

- HeatPump:WaterToWater:EquationFit:Cooling only controls to cooling demand, condenser heat is passively dumped to HHW loop regardless of demand (results in overheating of loop)
- EMS is used to optimize and control HeatPump based on both CHW and HHW loop demands. Intelligently dispatch loads to HRC, chillers, and boilers.

At every time step…

- EMS reads HHW and CHW loop demands, calculates simultaneous load
- Calculates heating and cooling output of HeatPump based on load and input power at that operating point
- Determines load to be placed on HeatPump based on limiting factor (heating/cooling output)
- Calculates 'cooling' dispatch to HeatPump based on desired heating/cooling output
- Takes remaining HHW and CHW demands and dispatches to trim boilers and chillers

OHSU – Center For Health & Healing South

<u>ETO Incentive Modeling Approach:</u>

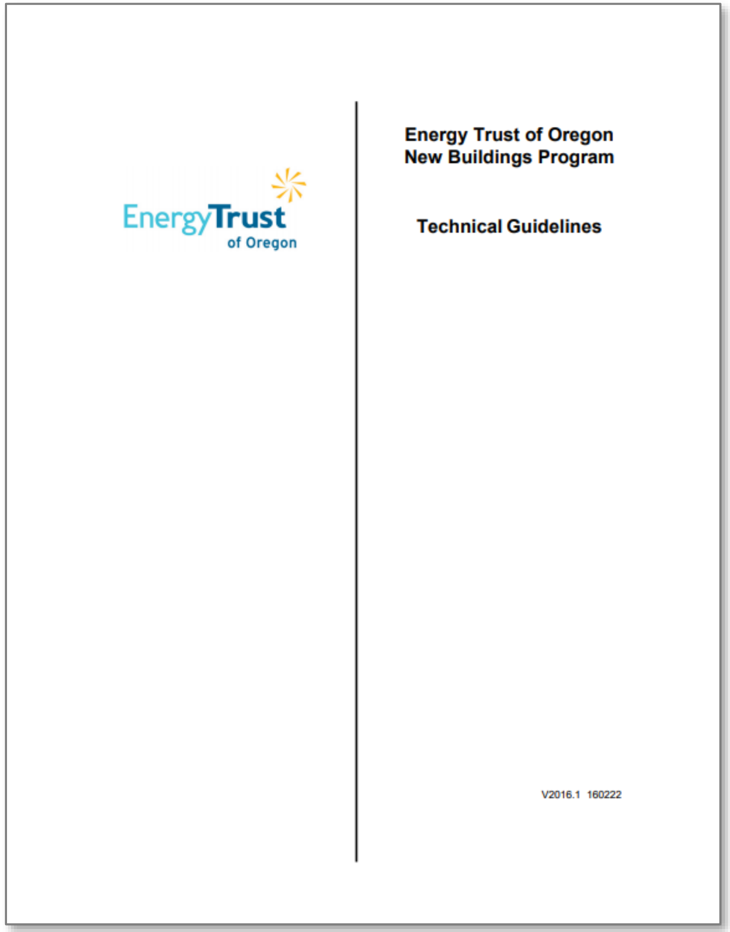
B28 and B29 as 2 separate ETO projects

Plant savings captured under B29 project

Gas as 'primary' heating source with heat recovery in both models.

Baseline plant:

- Boilers
- Water-cooled chillers
- Condenser water heat recovery (sized for 30% of peak heat rejection load at design conditions)


EnergyTrust of Oregon

Energy Trust of Oregon
New Buildings Program

Technical Guidelines

V2016.1 160222

OHSU – Center For Health & Healing South

Plant Modeling Takeaways

- Python script to integrate whole building models with separate plant model
- Python script to create hourly profile for HRC exhaust air heat recovery
- EnergyPlus EMS program to control operation of HRC and optimize based on heating demand and cooling demand simultaneously

Plant Modeling Results

- Energy savings: 49 EUI [kBtu/sf-yr]
- Annual energy cost savings: $210,000
- ETO measure incentive: $170,000
- Annual water savings: 1.7M gallons

Teck Acute Care Centre

Client:

- Provincial Health Services Authority

Location:

- Vancouver, BC

Size:

- 675,000 ft^2

Building Program:

- Acute care inpatient & outpatient services
- Emergency department, med/surg inpatient units, medical imaging, oncology/hematology, PICU/NICU, labor & delivery

Status:

- Open & operating as of Fall 2017
- Monitoring & verification of energy target

Affiliated Engineers, Inc.

Teck Acute Care Centre

Modeling Services:

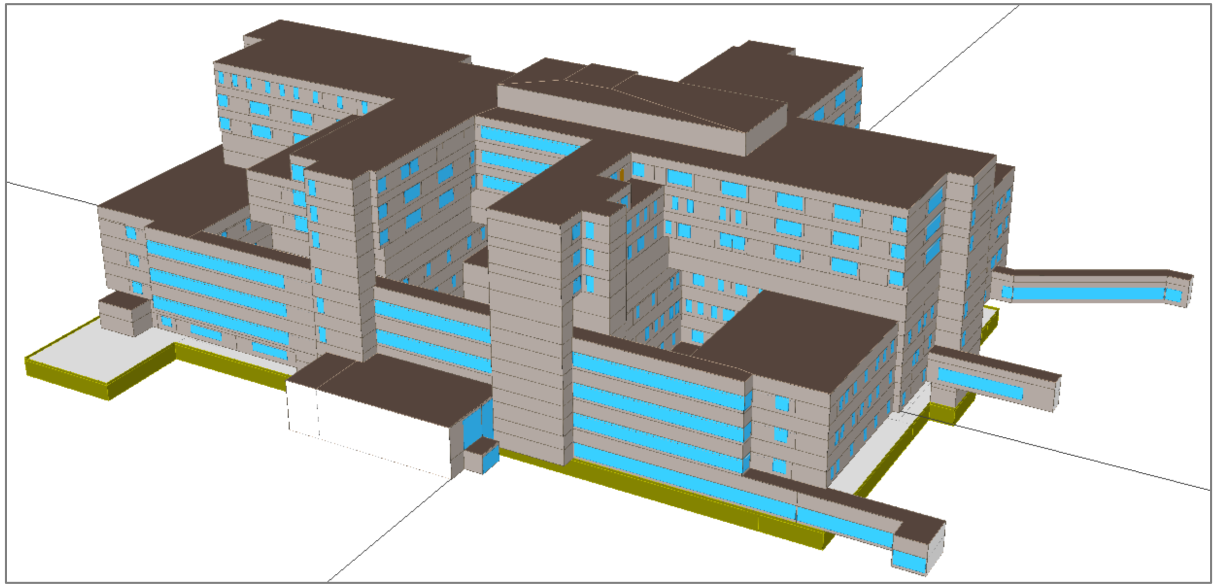
Design performance analysis (energy target)

Utility incentives (BC Hydro)

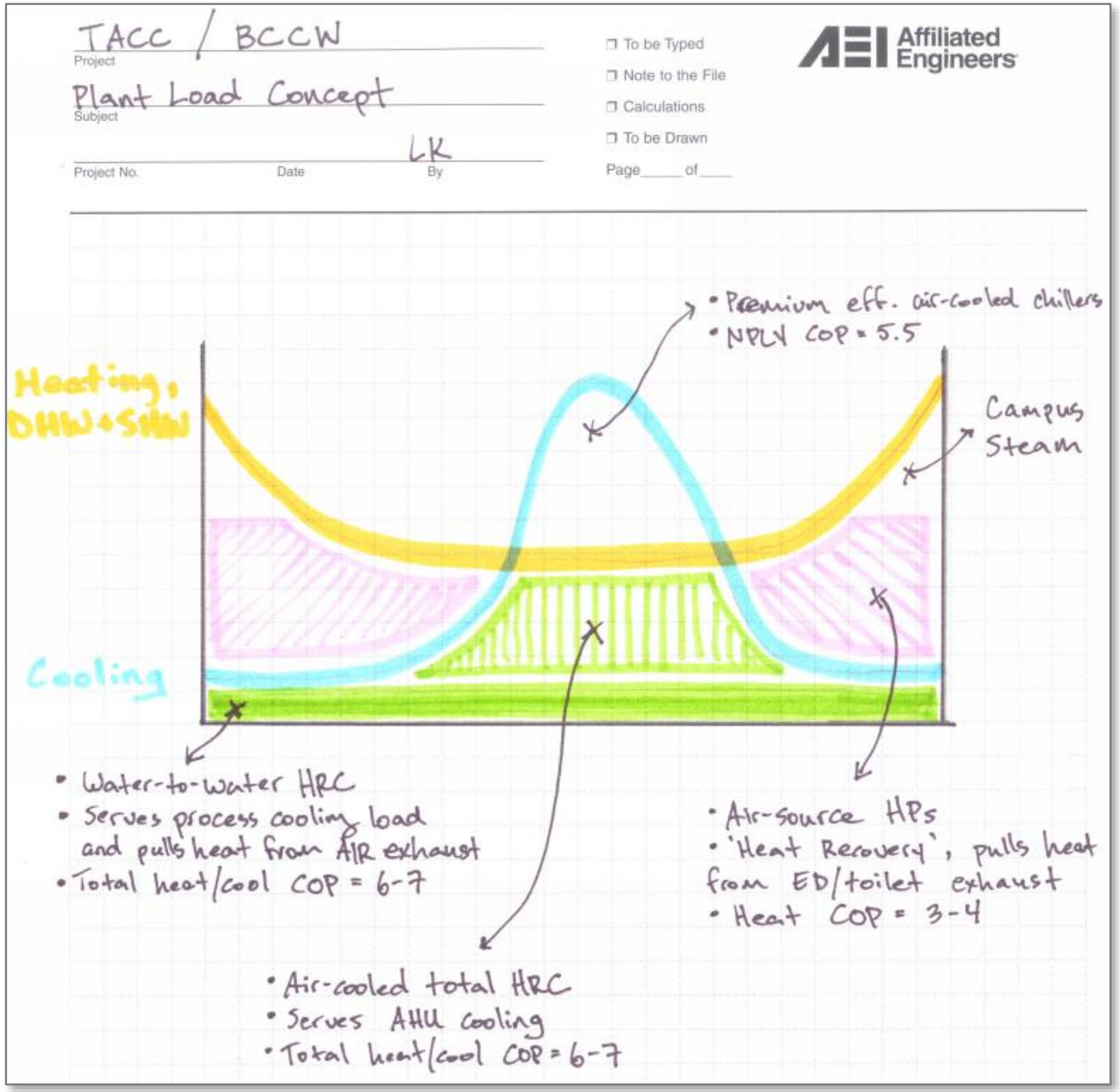
LEED certification

Central Plant:

- Water-to-water heat recovery chillers w/ exhaust air heat recovery coils
  - (4x) 85-ton modules
- Air-cooled heat recovery chillers
  - (1x) 275-ton
- Air-source heat pump
  - (8x) 30-ton modules
- High efficiency air-cooled chillers
  - (3x) 400-ton
- District heating



Teck Acute Care Centre



Plant Order of Operations:

Cooling

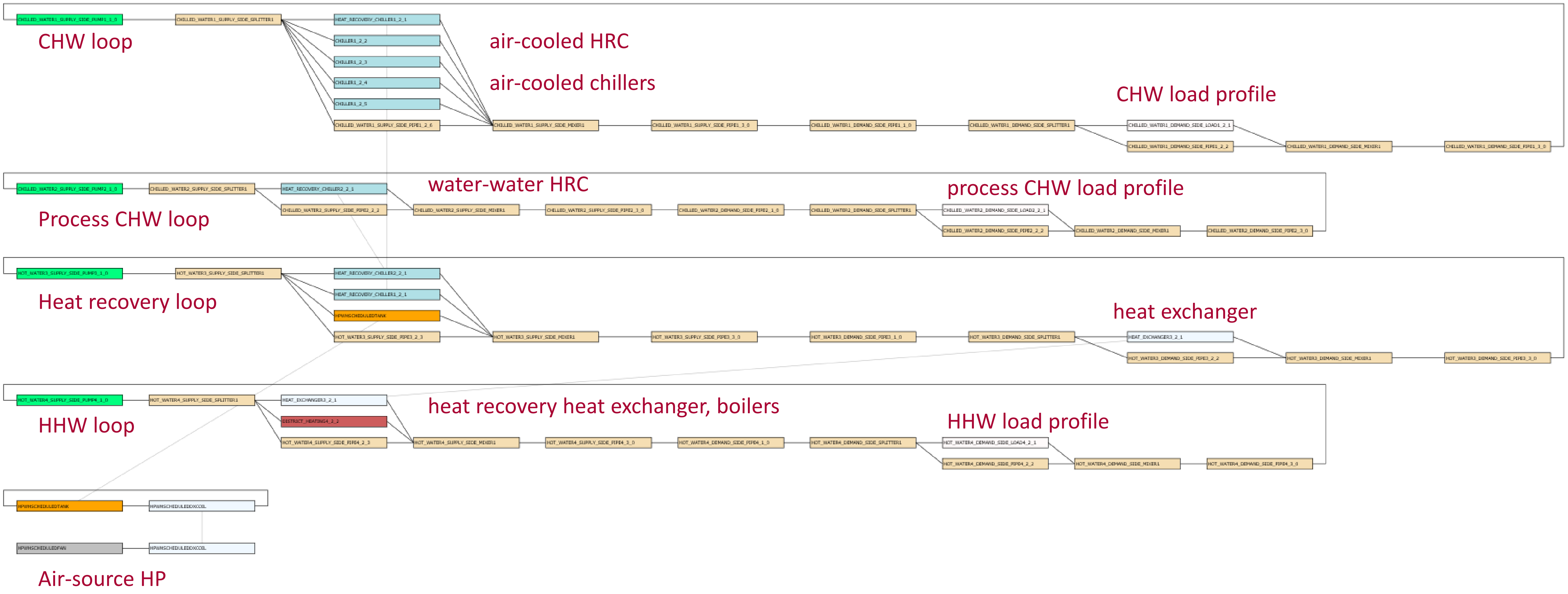
- Process cooling met by water-water HRC
- First stage of AHU cooling provided by air-cooled HRC (simul. heating/cooling)
- Second stage AHU cooling provided by air-cooled chillers (trim)

Heating

- First stage provided by water-water HRC and air-cooled HRC (simul. heating/cooling)
- Second stage provided by air-source heat pumps located in building relief (heat pump heating)
- Third stage provided by district heat (trim)

Teck Acute Care Centre

EnergyPlus Plant Model:



Teck Acute Care Centre

<u>EnergyPlus Objects:</u>

- District:Heating
- Chiller:Electric:EIR
- HeatPump:WaterToWater:EquationFit:Cooling
- WaterHeater:Mixed
    - WaterHeater:HeatPump:PumpedCondenser
    - Coil:WaterHeating:AirToWaterHeatPump:Pumped
- HeatExchanger:FluidToFluid
- EnergyManagementSystem:Program (and associated components)

<u>WaterHeater:Mixed Object:</u>

Used to approximate air-to-water heat pumps located in building relief airstream*

- Set storage tank volume to 1 gallon (virtually no thermal storage)
- Use heat pump with air-to-water coil
- Schedule evaporator nodes of heat pump coil to equal relief air conditions

**native EnergyPlus air-to-water HP is only for Zone HVAC use, not plant loop*

Teck Acute Care Centre

BC Hydro Incentive Modeling Approach:

Unique methodology to baseline plant regarding fuel switching

- Baseline heating plant includes a mix of electric air-to-water heat pumps and gas-fired boilers (matches fuel source mix of proposed heating equipment)
- Baseline heat pumps sized and controlled to match the *proportion of annual load* met by electricity vs. gas in the proposed model.

Great energy modeling guidelines including detailed modeling procedures and equipment performance tables that are not well defined in reference codes/standards

APPENDIX A:
AIR-COOLED HEAT PUMP SUPPLEMENT PERFORMANCE TABLES

COOLED PERFORMANCE TABLE: Single Module ASP20 Entering Condenser Air Temperature

Leaving Chilled Water □F	85 □F			95 □F			105 □F		
	Tons	kW	EER	Tons	kW	EER	Tons	kW	EER
40	18.1	21.0	10.3	16.7	23.3	8.6	16.3	26.0	7.5
42	18.8	21.0	10.8	17.4	23.3	9.0	17.0	26.0	7.9
44	19.6	21.0	11.2	18.2	23.3	9.4	17.7	26.0	8.2
45	20.0	21.0	11.4	18.5	23.3	9.6	18.0	26.0	8.3
46	20.4	21.0	11.6	18.9	23.3	9.7	18.4	26.0	8.5
48	21.2	21.0	12.1	19.7	23.3	10.1	19.1	[illegible]	[illegible]
50	22.0	21.0	12.6	20.5	23.3	10.6	19.9	[illegible]	[illegible]

HEATING PERFORMANCE TABLES: ASP-20 Entering Source Air Temperature

Leaving Hot Water □F	0 □F			10 □F			20□F		
	MBH	kW	COP	MBH	kW	COP	MBH	kW	COP
80	105.7	17.2	1.8	126.1	17.1	2.2	151.3	17.1	2.6
90	106.4	19.8	1.6	124.3	19.4	1.9	147.4	19.2	2.3
100				126.3	22.3	1.7	146.5	21.8	2.0
105							147.2	23.3	1.9
110							148.8	24.9	1.8
115							151.4	26.7	1.7
120									
125									
130									
135									
140									

Teck Acute Care Centre

BC Hydro Power Smart
New Construction Program
Whole Building Design Energy Study

Prepared For: BC Hydro, Provincial Health Services Authority

04/06/2015 - SUBMITTAL 1
08/05/2015 - SUBMITTAL 2

Prepared By: AEI Affiliated Engineers

4.11 BASELINE MODEL CENTRAL HEAT PUMP TYPE AND SIZING

BC Hydro NC Program's baseline heat pump type is by default an air source heat pump with two variations (if proposed heating/cooling plant is heat pump based):

- Air to air heat pump for all-air proposed HVAC systems (i.e. air source VRF system, PTHPs and CV rooftop air source heat pumps)
- Air to water heat pump for all hydronic proposed HVAC systems.

To avoid excessive fuel switching, the same heat pump/boiler sizing strategy used in the proposed design shall be applied to baseline plant sizing. Here is one example how it should be done:

- Concept Proposed Plant Design Assumption (P1)
  - o Mechanical design engineer proposes heat pump capacity to be (for example) 75% of peak building heating load. Proposed backup gas boiler capacity is (for example) 90% of peak building heating load.
- Concept Baseline Model (B1)
  - o Modeller runs the first baseline loads simulation and gets the peak building heating load
  - o Modeller applies the proposed sizing concept from P1 step, inputs the sizes of baseline heat pump and boiler in the model and run the baseline energy simulation.
  - o Modeller use baseline B1 model to run all ECMs (including the different, more efficient heat pump type).
- Final Proposed Model/Design (P2)
  - o Modeller creates the proposed model based on selected bundle of the most cost effective ECMs, which now becomes a final model/design.
  - o The results of the final model simulation run may show that proposed heat pump and backup gas boiler handle now 60% and 40% of annual heating load respectively.
- Final Baseline Model (B2)
  - o To avoid excessive fuel switching modeller adjusts capacities of baseline model heat pump and boiler iteratively to match annual load proportions of P2 model (60% and 40%).
  - o The final bundle of ECMs energy savings entered in BC Hydro's Life Cycle Cost (LCC) analysis spreadsheet will represent a difference between B2 and P2 models energy consumptions.

Note that with some proposed heat pump configuration some fuel switching may happen using this procedure, which is acceptable as long as the final bundle saving result does not show any gas consumption increase.

Heating plant oversizing in B1 and B2 models not to exceed 25% as per ASHRAE 90.1 Appendix G requirement.

Teck Acute Care Centre

Plant Modeling Takeaways

- Use of WaterHeater:Mixed object to approximate air-to-water heat pumps connected to plant loop
- For complex equipment control and heat recovery, consider using a separate plant loop as intermediate between CHW and HHW loops
- Innovative approach to fuel switching and baseline heating plant modeling for BC Hydro

Plant Modeling Results

- Annual energy cost savings: $185,000
- BC Hydro measure incentive: $600,000

Seattle Children's Hospital – Building CARE

Client:

- Seattle Children's Hospital

Location:

- Seattle, WA

Size:

- 300,000 ft^2

Building Program:

- Acute care inpatient & outpatient services
- Operating rooms/interventional suites, diagnostic and therapeutic services, inpatient unit, ambulatory clinics, infusion, sterile processing, admin/support

Status:

- In design

ZGF Architects

Seattle Children's Hospital – Building CARE

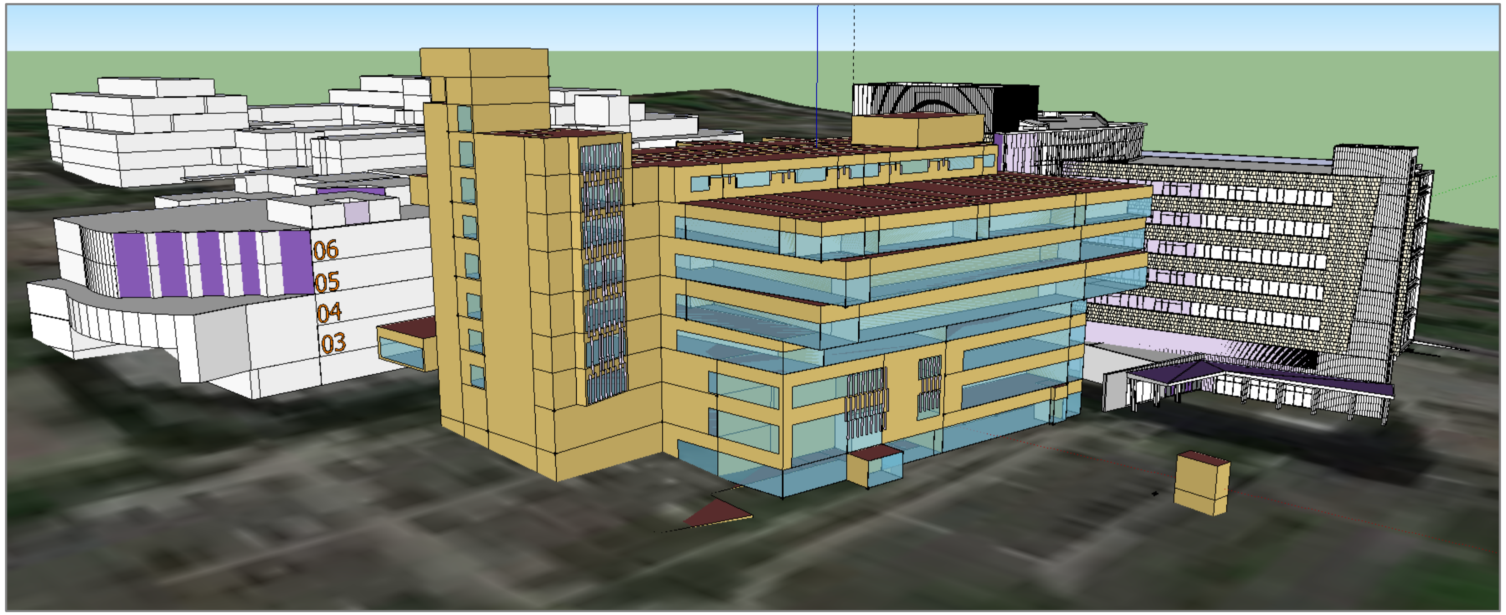
<u>Modeling Services:</u>

Design performance analysis (energy target)

Code compliance (City of Seattle)

Utility incentives (SCL/PSE)

LEED certification

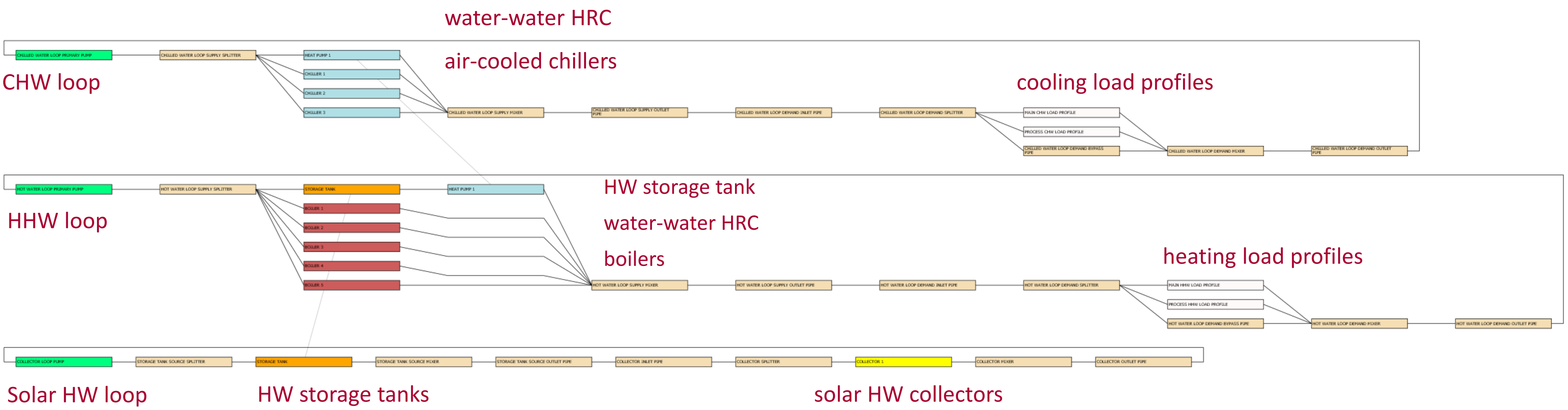


<u>Central Plant:</u>

- Water-to-water heat recovery chillers w/ exhaust air heat recovery coils
  - (1x) 250-ton
- Air-cooled chillers
  - (5x) 525-ton
- Solar thermal array & HW storage
  - (95) Evacuated tube collectors
  - (4x) 1,250 gallon HW storage tanks
- Condensing gas-fired boilers
  - (5x) 3,400 MBH

Seattle Children's Hospital – Building CARE

EnergyPlus Plant Model:



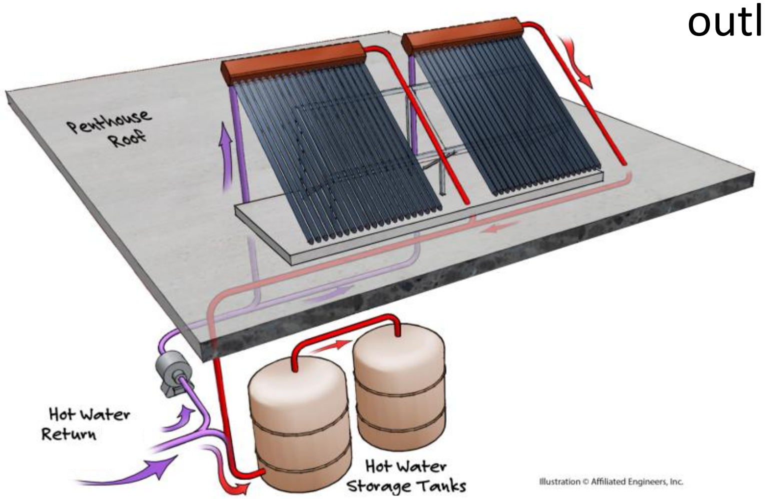
Seattle Children's Hospital – Building CARE

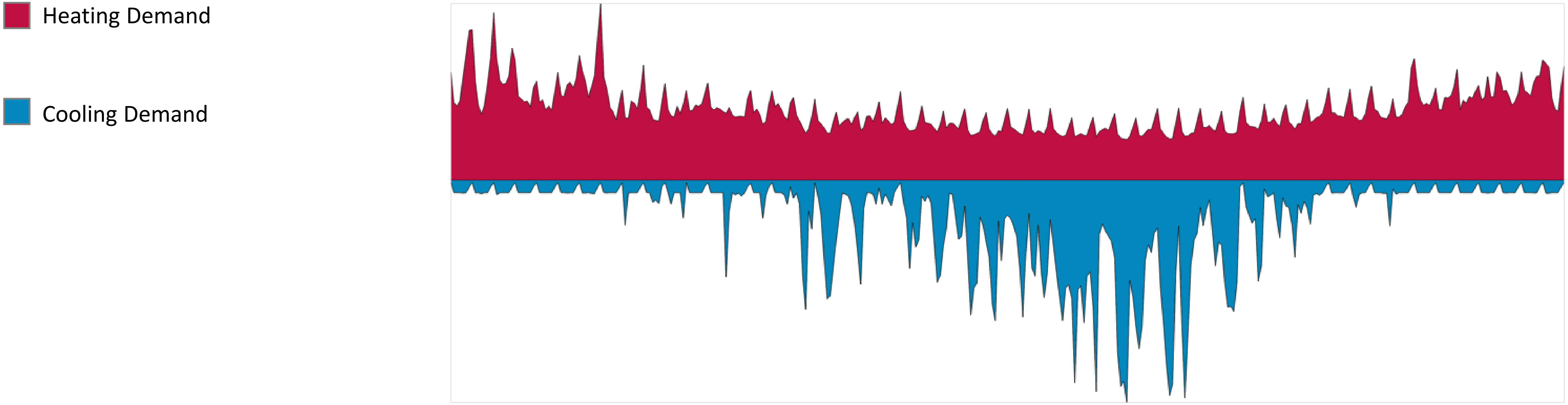
EnergyPlus Objects:

- Chiller:Electric:EIR
- Boiler:HotWater
- HeatPump:WaterToWater:EquationFit:Cooling
- WaterHeater:Mixed
- SolarCollector:FlatPlate:Water
- EnergyManagementSystem:Program (and associated components)

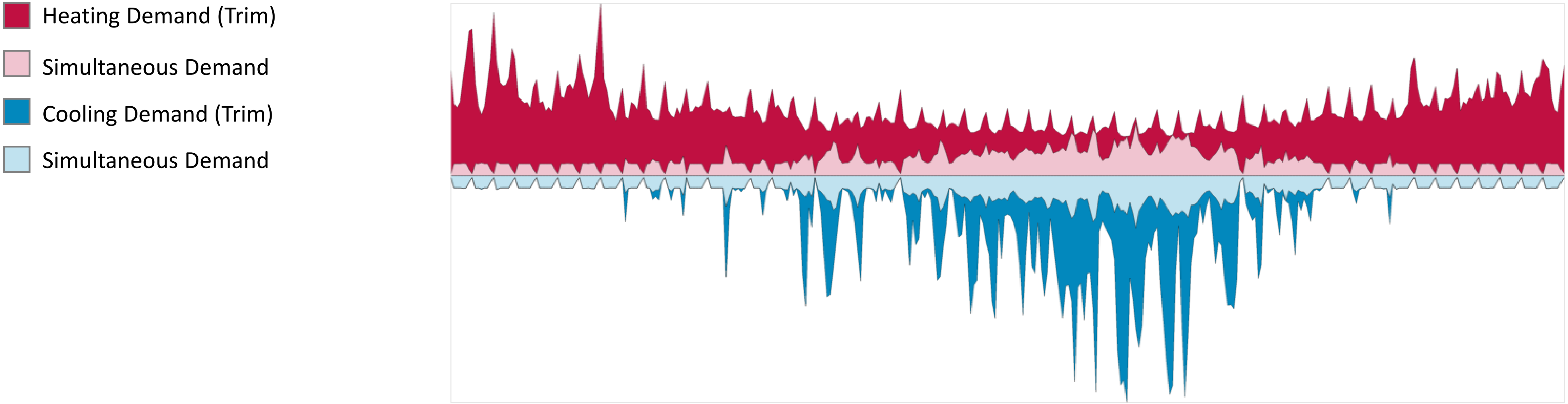
WaterHeater:Mixed and Thermal Storage:

- Storage tank 'use' size typically autosizes reasonably, but 'source' side is bad for autosizing because there is no demand (hard sizing is best here)
- AvailabilityManager:DifferentialThermostat can be used to schedule equipment ON/OFF based on temperature difference between 2 nodes
- PlantEquipmentOperation:ComponentSetpoint can be used to sequence plant equipment based on outlet temperatures for individual equipment

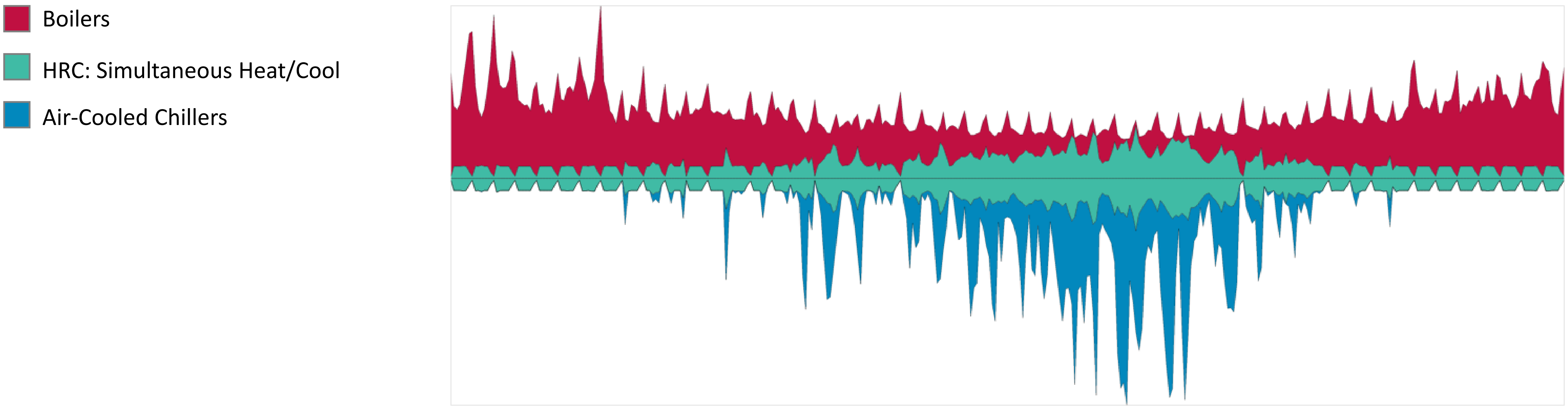


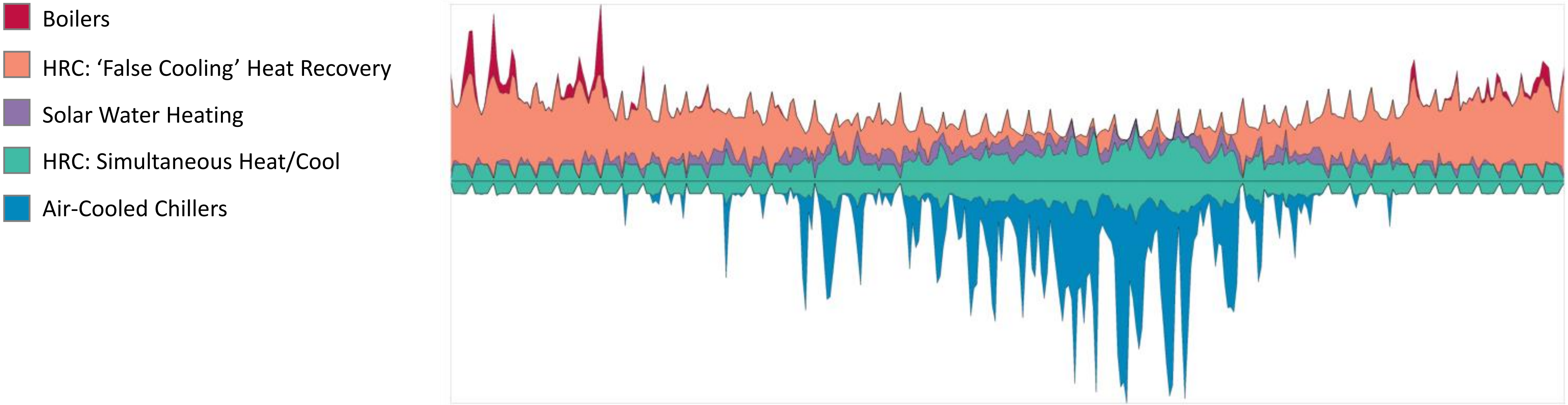


Heating Demand
Cooling Demand



Heating Demand (Trim)
Simultaneous Demand
Cooling Demand (Trim)
Simultaneous Demand


Boilers
HRC: Simultaneous Heat/Cool
Air-Cooled Chillers


Boilers
HRC: 'False Cooling' Heat Recovery
Solar Water Heating
HRC: Simultaneous Heat/Cool
Air-Cooled Chillers

Seattle Children's Hospital – Building CARE

Plant Modeling Takeaways

- WaterHeater:Mixed and SolarCollector:FlatPlate:Water used to simulate evacuated tube solar HW panels with HW thermal storage
- Good practice to hard-size EnergyPlus 'source' side components
- Explore different combinations of availability managers, operation schemes, and EMS controls to achieve desired operation

Plant Modeling Results

Boilers & Chillers

- 43 EUI [kBtu/sf-yr]

Condensing gas boilers & premium efficiency air-cooled chillers

Boilers, Chillers, HRC (simul. only)

- 33 EUI [kBtu/sf-yr]
- 23% savings

Boilers, Chillers, HRC (simul. + false cooling), solar HW

- 11 EUI [kBtu/sf-yr]
- 74% savings

QUESTIONS?

Lyle Keck, PE, LEED AP BD+C
Lkeck@aeieng.com

aeieng.com

AEI/Affiliated Engineers, Inc.

@AEITweets