CMU Models for the IW_s, ESS, ED^2S and BAPP Systems

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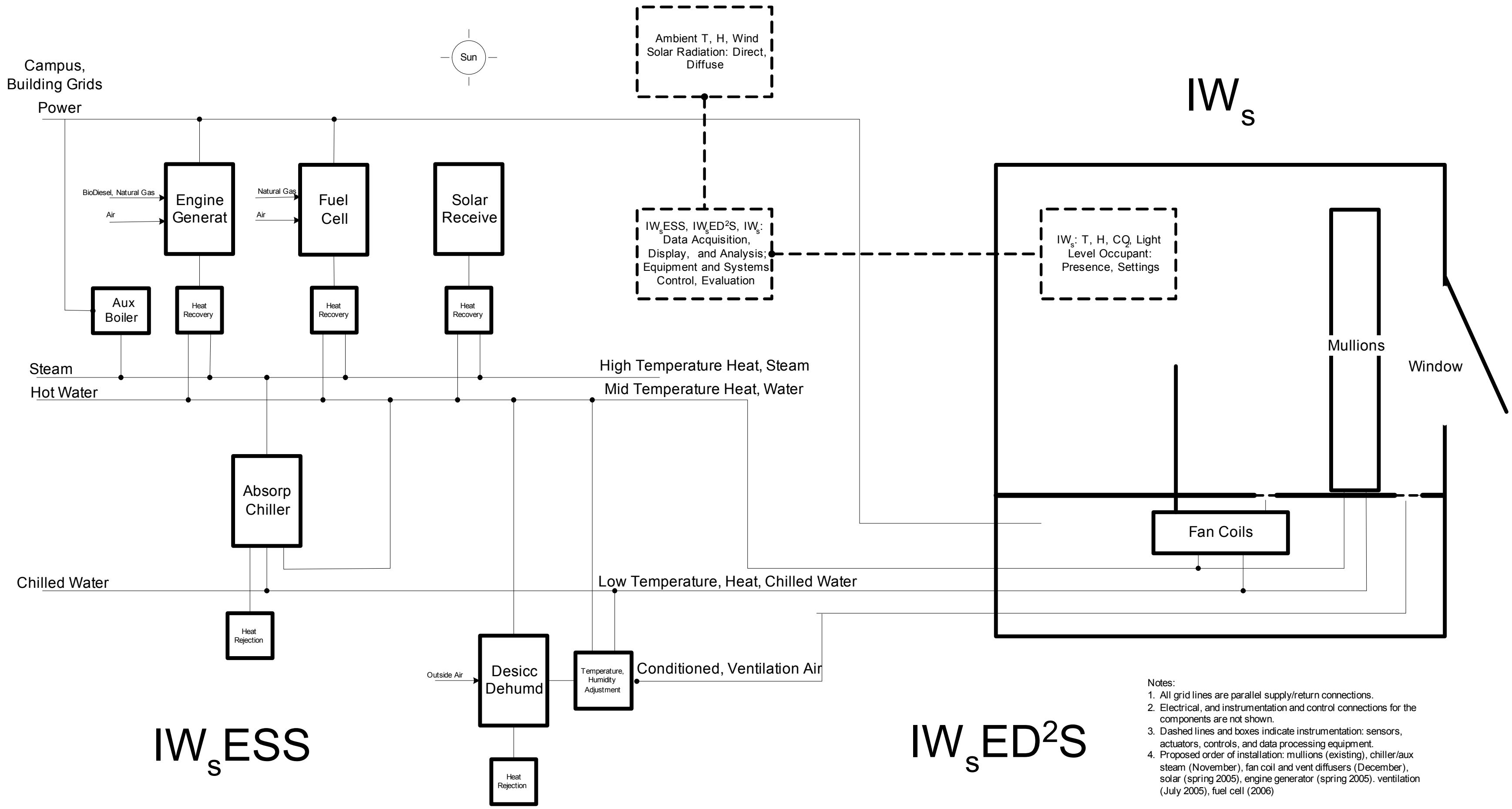
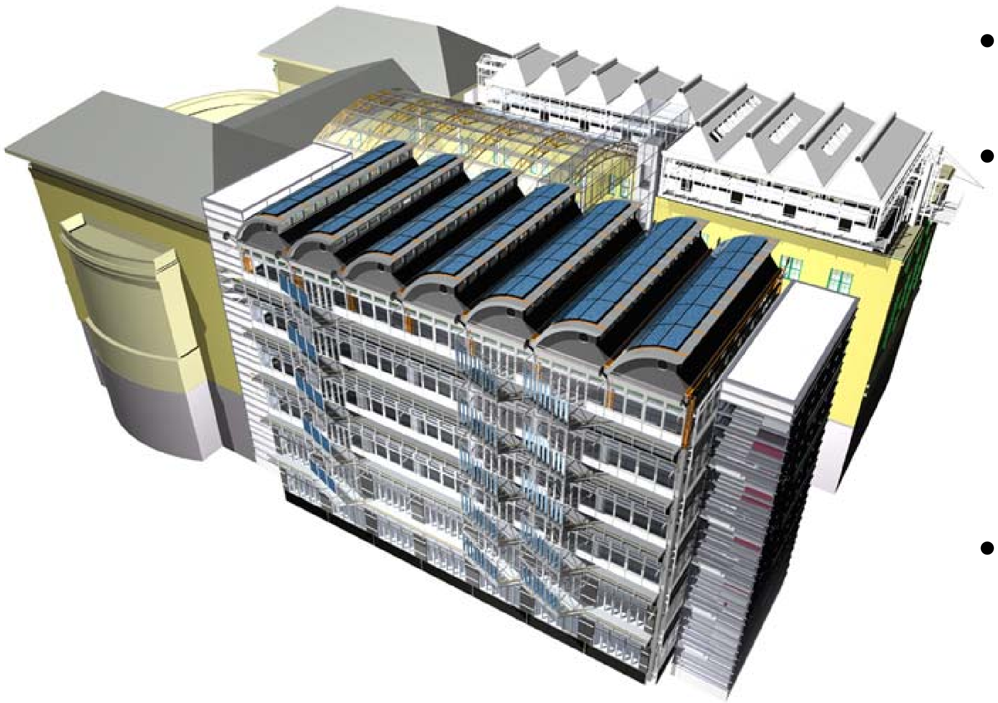
IW_s, ESS, ED^2S Systems



Notes:
1. All grid lines are parallel supply/return connections.
2. Electrical, and instrumentation and control connections for the components are not shown.
3. Dashed lines and boxes indicate instrumentation: sensors, actuators, controls, and data processing equipment.
4. Proposed order of installation: mullions (existing), chiller/aux steam (November), fan coil and vent diffusers (December), solar (spring 2005), engine generator (spring 2005). ventilation (July 2005), fuel cell (2006)

BAPP, Building as Power Plant



- 6000 m2, 6 storey, projected building on CMU campus
- offices, class rooms, laboratories
- architectural features demonstrated in the IW
  - natural lighting, ventilation.
  - underfloor delivery of utilities
  - flexible interior arrangements
  - factory produced, site assembled
- integrated, distributed CHP+ventilation, grid connected
- mechanical rooms at ends of each floor

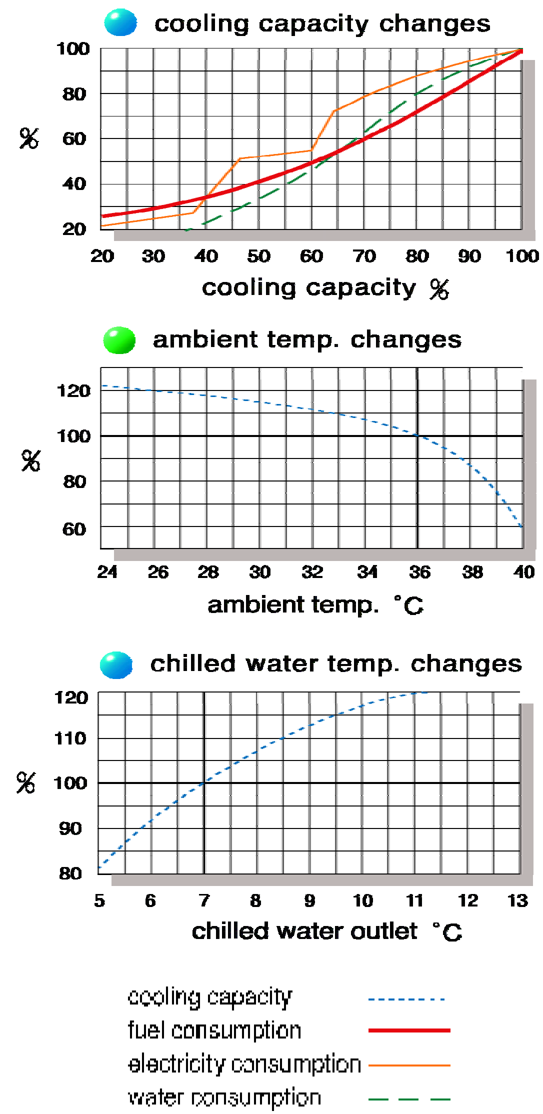
IW$_s$ESS Model Characterization

model: mathematical representation that mimics the performance of component or systems

- *fundamental*: based equations expressing scientific, engineering principles plus assumptions
  - material and energy balances
  - heat, work computations
  - property relations
  - phase, chemical equilibria
  - heat, mass, momentum transport
- *empirical*: correlations, based on operating, performance data (or possibly from fundamental models)

Eg: Empirical Model of the BCT 16 Absorption Chiller

Model		BCT 16
Cooling capacity	kW	16
Chilled water O/I temp.	°C	7/14
Flow rate	m3/hr	2.0
External head	mH2O	8
Maximum fuel consumption (full load)		
Cooling, natural gas Diesel oil	m3/hr kg/h	1.5 1.24
Max. electric & water consumption (full load)		
Electricity (cooling)	kW	1.00
Water (cooling)	m^3/h	0.05
Noise	dB(A)	62
Shipping weight	kg	440



IW_sESS Model Charactization

- *steady state*: time independent, algebraic equations; all variables remain constant with time
- *dynamic*: time dependent, differential equations

- *lumped parameter*: independent of spatial dimensions, algebraic or differential equations
- *distributed parameter*: dependent on spatial dimensions, partial differential equations

choice of model approach depends on system to be modeled and the question or application to be addressed

IW_sESS Component Model Applications

- design: fundamental, steady state, lumped parameter model calculates consistent set of operating conditions, UA and KA values, pump and valve requirements
- performance projection (variable load, ambients, controlled operating conditions): fundamental, steady state, lumped parameter model calculates consistent set of operating conditions for a given design and control configuration
- data analysis: fundamental, steady state, lumped parameter with least squares solution assesses data consistency, model accuracy
- control tuning, stability: fundamental, dynamic, lumped parameter model characterizes the dynamic performance of the component for a given feed back, feed forward, etc control system

IW_sESS System Model Applications

- system equipment, operations design and performance evaluation: empirical, steady state, “platform” with lumped parameter models of components, ambient inputs, and operational algorithms calculates effectiveness, efficiency, economics, and environmental impacts

IW_sESS Component and System Model Platforms

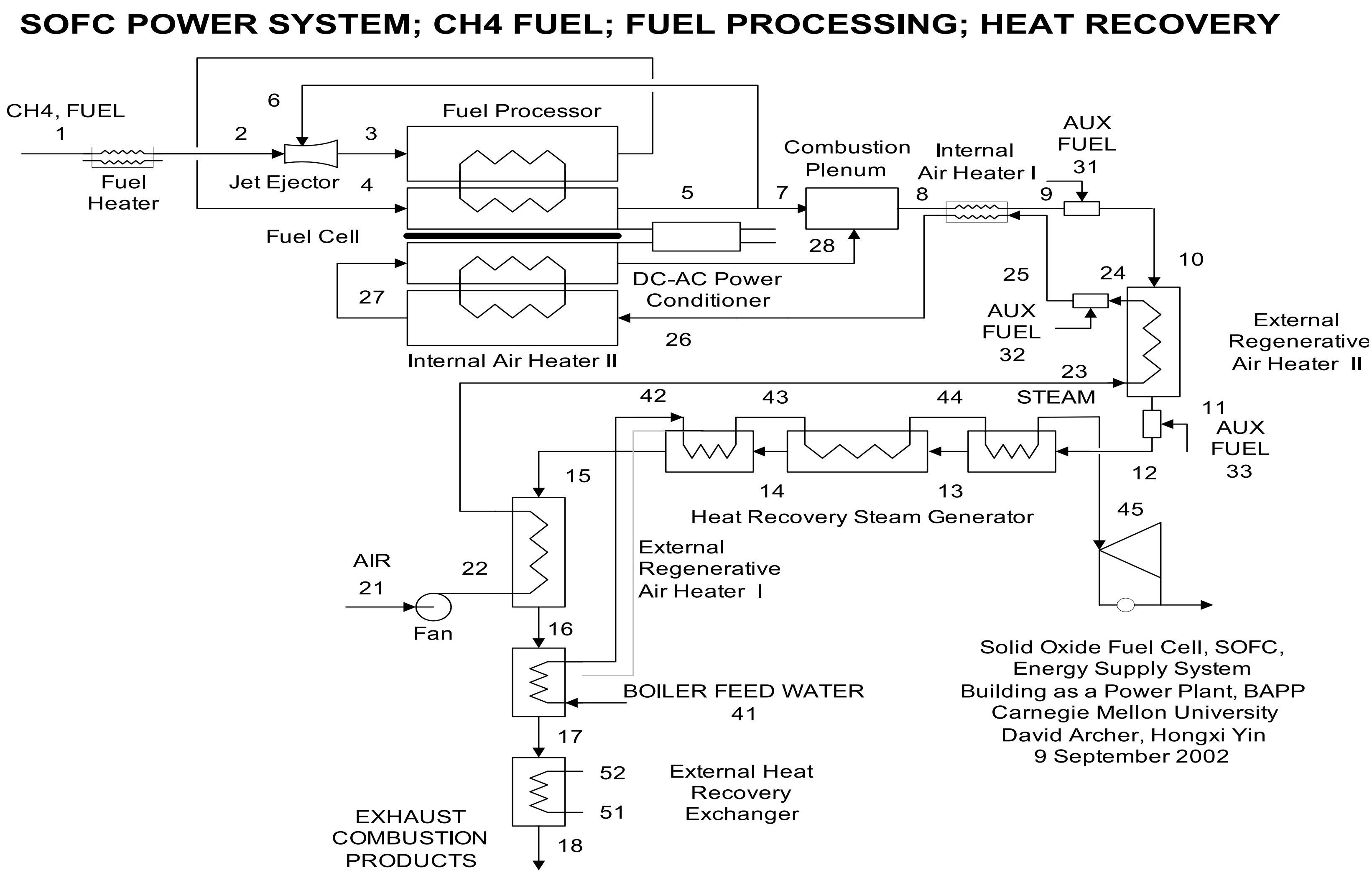
- spread sheets
- equation solvers: EES, Matlab
- systems simulators: Thermoflex, Trnsys, ASPEN
- building system simulators: EnergyPlus, DOE 2

CMU ESS Component Models

Energy Supply System, ESS, Components

Component		Models Programmed (Steady State)		
Model Tool	Spread Sheet,Excel	Numerical, EES		Matlab
Model Purpose	basis, design	design	performance	data analysis
Broad Chiller, Auxiliary Steam Supply	√	√	√	√
Solar Thermal Steam/Heat Supply	√			
AIL Liquid Desiccant Ventilation Supply	√	√		
Engine Generator Power/Heat Supply				
Solid Oxide Fuel Cell Power/Heat Supply	√			

Spread Sheet Model: SOFC Power Heat Supply System



Spread Sheet Model:
SOFC Power/Heat Supply System

Stream Number	Description	Pressure atm	Temperature K	CH4	CO	CO2	H2	H2O	O2	N2	Sum n	Sum nCp	Sum nhf	Work	Heat	UA, Ht Trans	E, voltage	Water Gas delta	Water Gas constant	Carbon Deposition constant	CH4 Reforming constant
				Mol Quantities														Equilibrium			
	Therm Prop @ 1300 K																				
	hf, enthalpy, kJ/mol			-91.713	-113.870	-395.257	0.000	-249.473	0.000	0.000											
	Cp, sp ht, J/mol K			60.919	34.572	57.137	31.423	44.945	35.988	34.147											
								-43.99936 (Condensation)													
1	Fuel into preheater	1.00	300	0.029							0.03	1.78	-4.45								
															0.00						
2	Fuel into ejector	1.00	300	0.029							0.03	1.78	-4.45								
															0.00						
3	Fuel mix into processor	1.00	1083	0.0291	0.0126	0.0343	0.0156	0.0783			0.17	8.18	-38.98								#DIV/0!
			351		0.0417	0.0343	0.1030	0.0491			0.23	8.85	-38.98								
		1.00	354		0.0409	0.0351	0.1038	0.0483			0.23	8.86	-38.98					0.0008	1.84575		#DIV/0!
															6.0412						
4	Fuel mix into fuel cell	1.00	1023		0.0417	0.0343	0.1030	0.0491			0.23	8.85	-33.03				0.896		0.83584		
		1.00	1023		0.0444	0.0316	0.1003	0.0518			0.23	8.82	-32.93				0.904	-0.0027	1.3794	3.661 No Depo	
															23.0397						
														13.00	0.0036					If Fuel Processor and Int Air Htr II are added	
5	Spent fuel from fuel cell	1.00	1300		0.0204	0.0557	0.0253	0.1269			0.23	10.38	-55.97								
															-21.4462						
6	Recycle to processor	1.00	1300		0.0126	0.0343	0.0156	0.0783			0.14	6.40	-34.53								
															-13.0822						
7	Spent fuel to combustor	1.00	1300		0.0000	0.0291	0.0175	0.0408			0.09				0.0000				0.00039		
		1.00	1300		0.0078	0.0213	0.0097	0.0486			0.09	3.98	-21.45				0.777	-0.0078	0.54396		
															0.0000	0.00					
8	Comb prods to heater I	1.00	1398		0.0000	0.0291		0.0583	0.2535	0.987	1.33	47.10	-21.45								
															-12.9472	0.00					
9	Comb prods to burner	1.00	1123	(-1000*((G45*$G	0.000	0.029		0.058	0.254	0.987	1.33	47.10	-34.39								
																0.00					
10	Comb prods to regen air htr	1.00	1123		0.000	0.029		0.058	0.254	0.987	1.33	47.10	-34.39								
															-17.5530	0.00					
11	Comb prods to hrsg burner	1.00	750		0.000	0.029		0.058	0.254	0.987	1.33	47.10	-51.95								
															-1.8316	0.00					
12	Comb prods to hrsg	1.00	946		0.000	0.041		0.082	0.230	0.987	1.34	48.00	-53.78								
															0.0000	0.00					
13	Comb prods to hrsg evap	1.00	946		0.000	0.041		0.082	0.230	0.987	1.34	48.00	-53.78								
															-15.7404	0.00					
14	Comb prods to hrsg fd water	1.00	618		0.000	0.041		0.082	0.230	0.987	1.34	48.00	-69.52								
															-1.5831	0.00					
15	Comb prods to regen air htr	1.00	585		0.000	0.041		0.082	0.230	0.987	1.34	48.00	-71.10								
																0.00					
16	Comb prods to hrsg fd water	1.00	405		0.000	0.041		0.082	0.230	0.987	1.34	48.00	-79.73								
															-1.5312	0.00					
17	Comb prods to ht recov exch	1.00	373		0.000	0.041		0.082	0.230	0.987	1.34	48.00	-81.26								
															-1.8854	0.00					
18	Exhaust comb prods	1.00	334		0.000	0.041		0.082	0.230	0.987	1.34	48.00	-83.14								

Possible Model Applications in the Advanced BuildingTestbed Program

- IW_s, ESS, ED^2S components
  - selection/design
  - testing: performance, data consistency, model accuracy
  - design, operation optimization
  - diagnostics
- IW_sESS/ED^2S system
  - component integration, system design
  - system operation
  - system evaluation: effectiveness (occupant satisfaction), efficiency, economics (capital, operation costs), environmental benefits
- BAPP, ESS, ED^2S components, systems
  - component identification, integration (centralized/distributed, uniform/varied)
  - operations definition
  - systems, operation evaluation: effectiveness, efficiency, economics, environment

Define: design, operation, effectiveness, efficiency, environment