Thermal Energy Network Modeling Tools

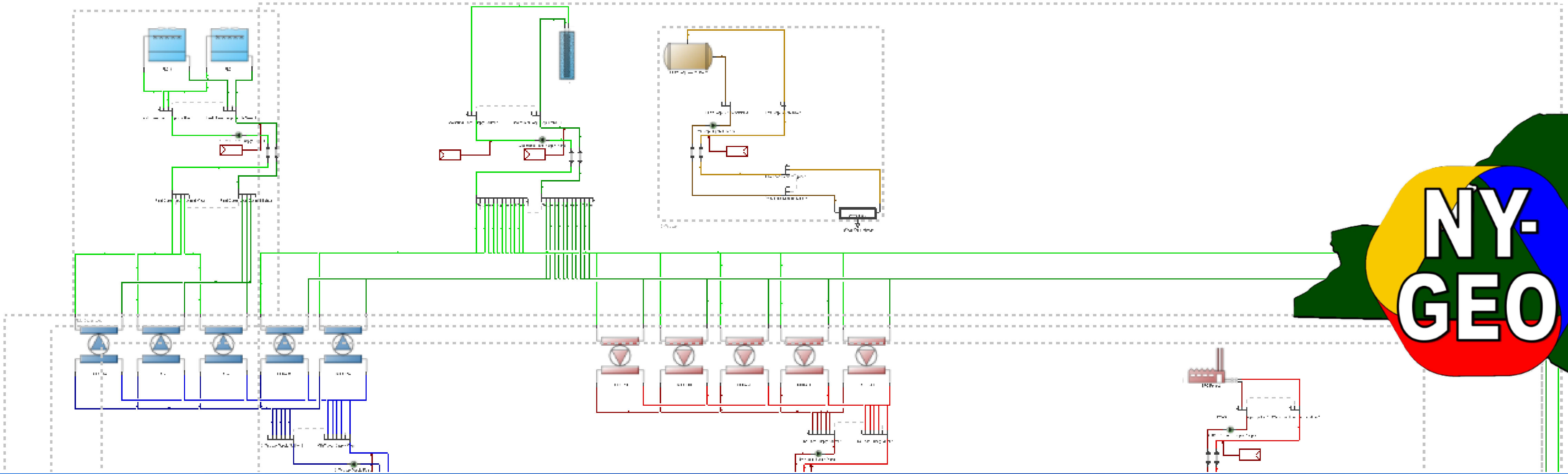
Moderator: Aeowyn Kendall / *Aztech Geothermal, LLC*

Panel: Brendan Hall / *CHA Solutions*

Jason Willeford / *Jacobs*

Victor Braciszewski / *SmithGroup*

Brian Urlaub / *Salas O'Brien*



Thermal Energy Network Modeling Tools

Brendan Hall, PE, BEMP

April 23, 2025

Obligatory Log Rolling Slide

- ASHRAE Building Energy Modeling Professional (BEMP)
- Designbuilder Webinars (2022)
  - Design and Modelling of Ground Source Heat Pump Systems
    - https://www.youtube.com/watch?v=MsuNGGb26VQ
  - Using Energy Modelling to Optimize GSHP System Design
    - https://www.youtube.com/watch?v=VEJ_3vdpk1I

Network Modeling Categories

Scoping / Feasibility Tools	• High level assessment of potential. • Excel and GIS Based Tools
Building Level Modeling	• Whole Building Energy Modeling, Load Forecasting • EnergyPlus , eQuest
Component Level	• Ground Heat Exchanger Design Tools • GLD, GLHEPro
Urban Scale Modeling	• Object Oriented modeling • Powerful, complex, flexible tools

Find the right hammer for the right nail.

Scoping Tools

Data Collection
Site Selection
Economic Potential
Urban Planning
Master Planning

Building Modeling

Site specific energy use

Reconciling existing buildings to utility usage.

Quantifying energy use, cost and savings

Component Level

Sizing of GHX

Evaluation of effect of options on sizing.

Energy Usage Estimate

Urban Scale

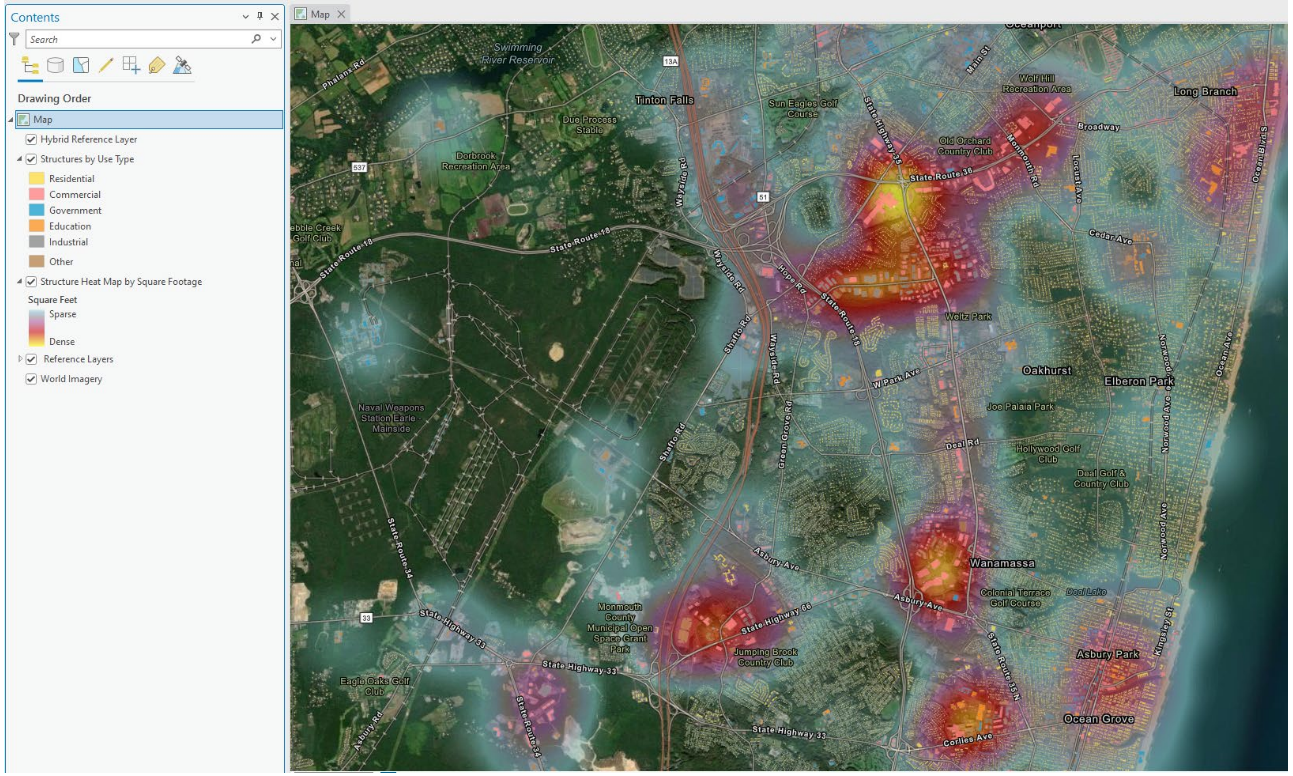
Multiple Building Dynamics

Pipe Network Dynamics

Energy Sharing

Scoping and Feasibility Tools

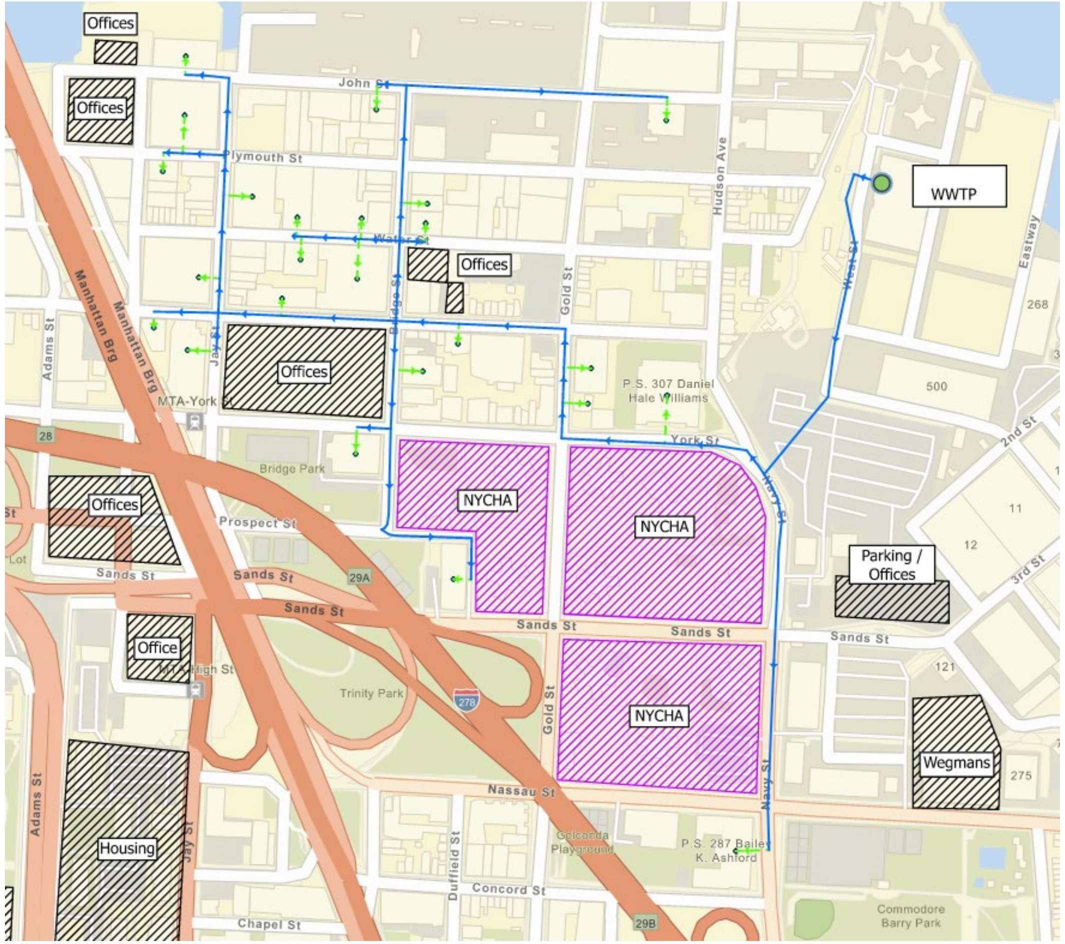
- Custom Spreadsheets
  - Load Estimation
  - Load Aggregation
  - Scoring Rubrics
  - Financial Models
- GIS Tools
  - Data mapping
  - Layering available data sets
- Purpose Built Commercial Software Tools



Sample ArcGIS Heat Map of Building Area

Commercial Tools

- Data Collection
- Data Visualization
- Cost Estimating
- Economic Analysis
- Examples:
  - nPro (Web-Based Tool)
  - Comsof Heat (ArcGIS Plug-In)
- Municipal Level District Heating systems are much more common in Europe so many of the tools are created toward that market.



Sample System layout in Comsof Heat

Data Sources

- Property Tax Records
  - Many municipalities have property tax records in GIS format.
  - Building area, usage, and age.
  - Formatting various, making universal sorting of data difficult.
- Economic Development Organizations
- Field Surveys
- Utility Bills
- DOE Reference Building Sets
- Energy Information Agency (EIA.gov)
- NIST Life Cycle Analysis Guidelines

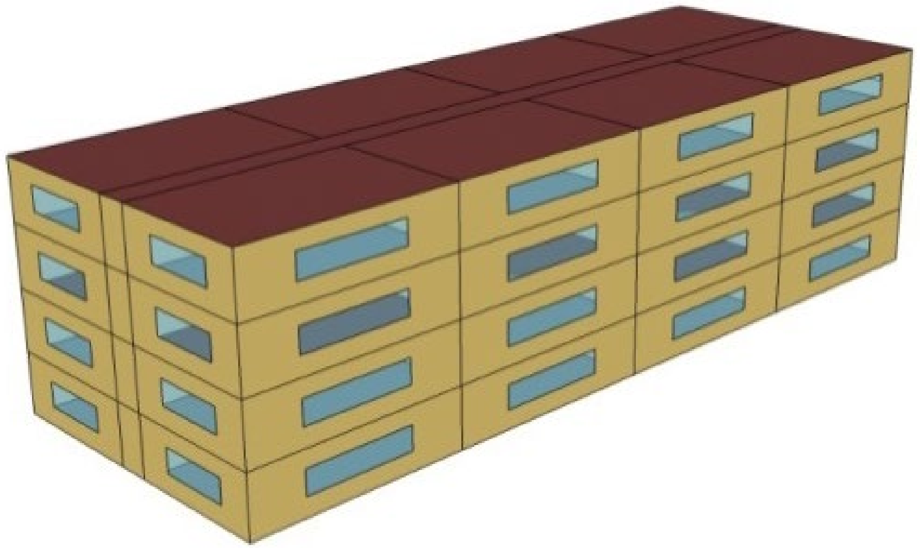
DOE Protype Building Set

•Developed by the U.S. Department of Energy (DOE) in collaboration with national laboratories and maintained by the Pacific Northwest National Laboratory (PNNL), to represent typical commercial building types in the U.S.

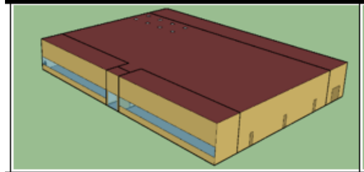
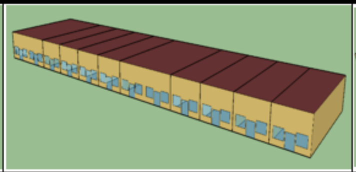
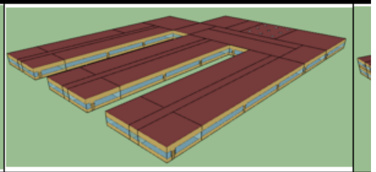
•Provide standardized building energy models for use in energy simulations, helping to assess new technologies and support the development of energy codes.

•Include 16 building types that cover approximately 70% of the commercial building stock in the U.S., across all climate zones

•Regularly updated to comply with newer versions of energy standards like ASHRAE Standard 90.1 and the International Energy Conservation Code (IECC)



Reference Building Scope

Stand-alone Retail	Strip Mall	Primary School
		
1	1	1
7.1%	10.5%	35.0%
Concrete Block Wall 8 in. CMU+Wall Insulation+0.5 in. gypsum board	Steel-framed Wall 1 in. Stucco + 0.625 in. gypsum board + wall insulation + 0.625 in. gypsum board	Steel-framed Walls (2x4, 16" OC) 0.75" stucco + 0.625" gypsum board + cavity insulation + 0.625" gypsum board
Nonresidential	Nonresidential	Nonresidential
Built-up roof: Roof membrane+roof insulation+metal decking	Built-up Roof: Roof membrane+Roof insulation+metal decking	Built-up roof Roof membrane + roof insulation + metal decking
Nonresidential	Nonresidential	Nonresidential

All Parameters are defined in a spreadsheet for review and simulation files are available as *.eps files (Energy Plus Format)

https://www.energycodes.gov/prototype-building-models#Commercial

Building Types

1. Large Office
2. Medium Office
3. Small Office
4. Warehouse
5. Stand-alone Retail
6. Strip Mall
7. Primary School
8. Secondary School
9. Supermarket
10. Quick Service Restaurant
11. Full Service Restaurant
12. Hospital
13. Outpatient Health Care
14. Small Hotel
15. Large Hotel
16. Midrise Apartment

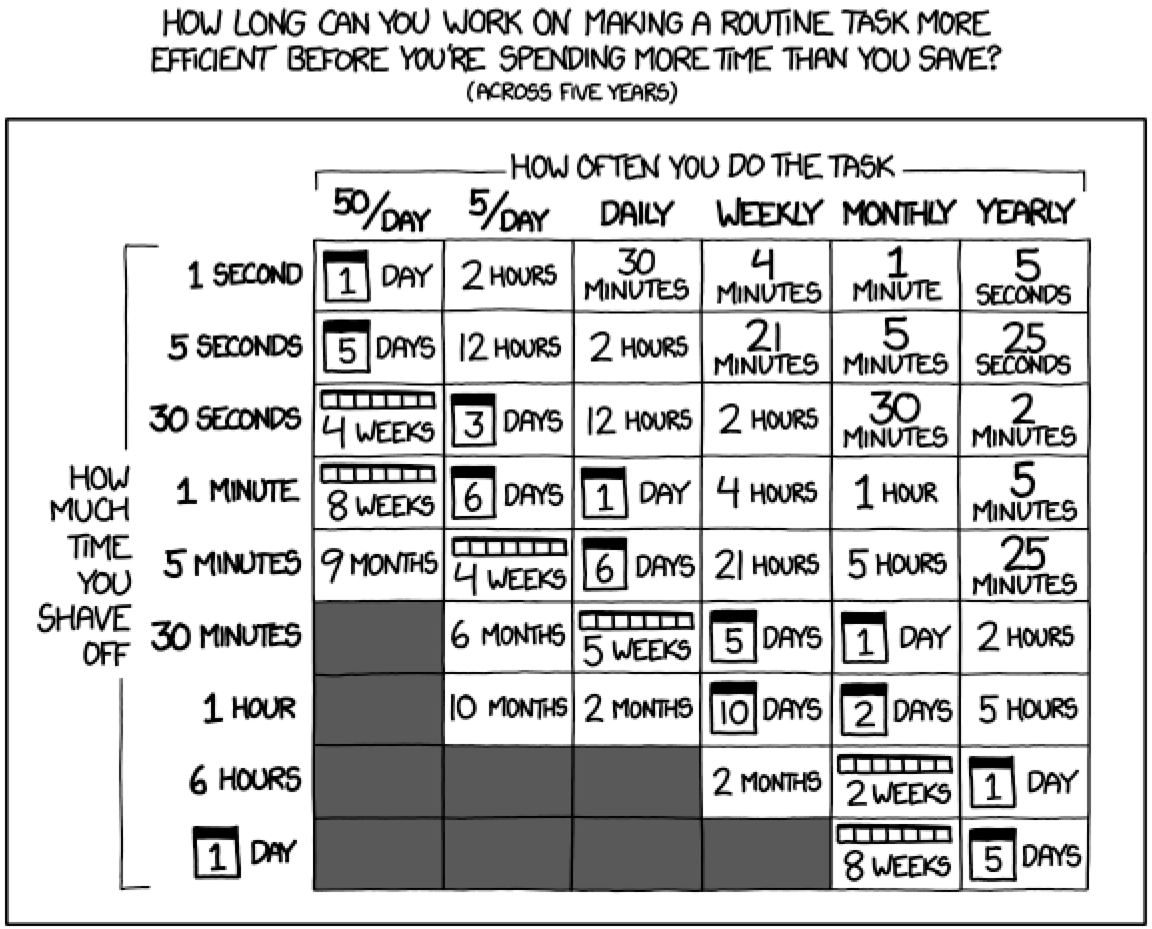
Building Vintage

- Pre-1980 (Before Energy Codes)
- Post-1980
- New Construction
- Any energy code version since 2004

- HVAC Systems – Set based on 90.1 modeling guidelines
- Envelope – Code minimum for the specified timeframe
- Usage are either by code min or defined based on usage research for that building type.

Custom vs Commercial Tools

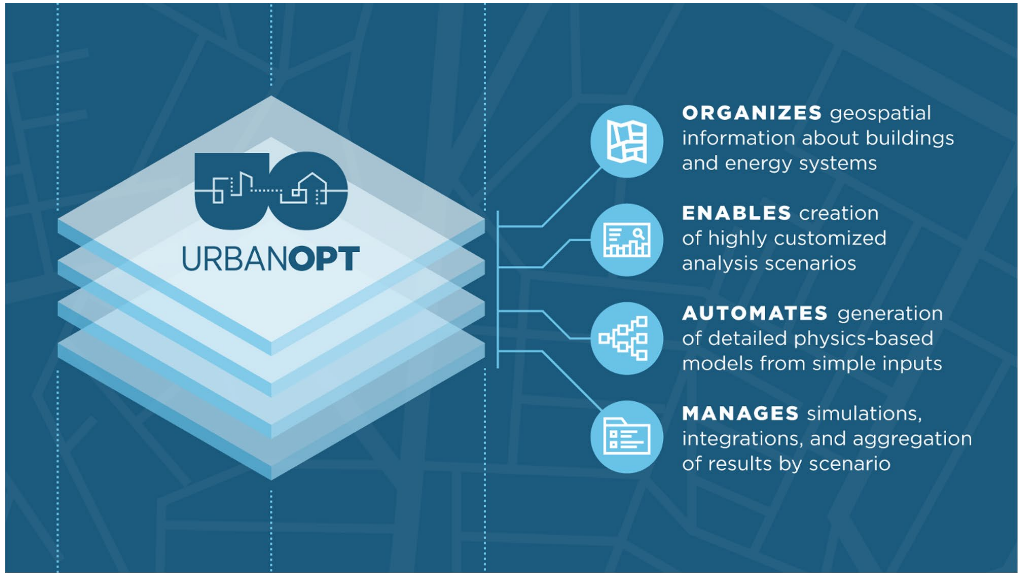
- Most current tools are custom excel or GIS tools within firms that are doing projects.
- As US/CAN market grows there will be more room for commercial tools and GUIs for this project type.



Room for Development

URBAN OPT

- NREL Development Platform
  - Open Source
  - Modeling Shared Thermal Systems
  - Grid and Distributed Resource Integration
  - Integrations over a variety of software platforms.



Challenging today.
Reinventing tomorrow.

Thermal Energy Network Modeling Tools

Masterplans

Jason Willeford

Jacobs Challenging today. Reinventing tomorrow.

- Jacobs, Energy & Power
- Senior Mechanical Engineer and Manager
- Austin, Texas
- Campus heating and cooling systems for universities, utilities, national labs, data centers
- Decarbonizing district energy through geothermal exchange systems and associated thermal energy networks

BY THE NUMBERS

40+ COUNTRIES

400 OFFICES

45K+ TALENT FORCE

$27.9B BILLION IN BACKLOG

$2.5B BILLION IN CLIENT SAVINGS

$16B ANNUAL REVENUE

Net Zero
Carbon for operations and business travel

Engineering News-Record 2023 Rankings

Overall

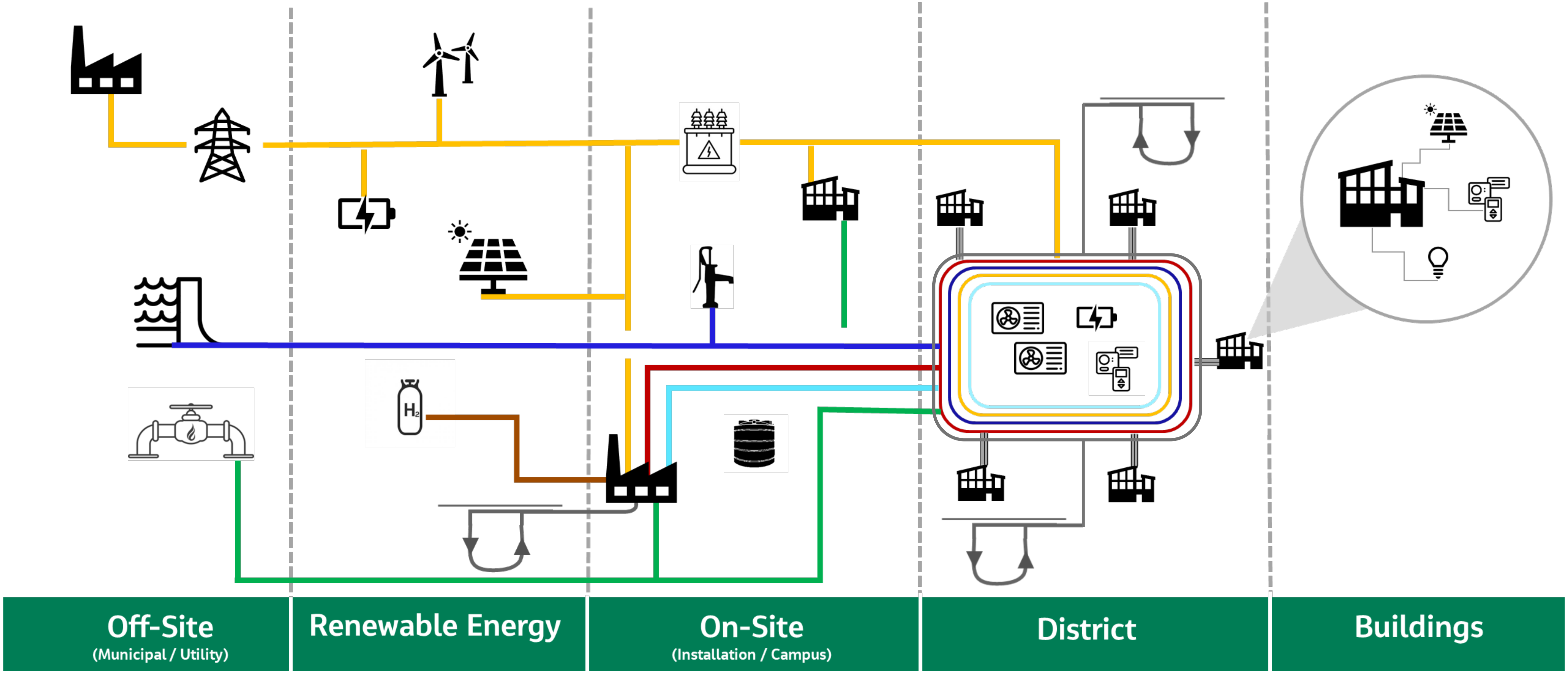
#1
- Top 500 Design Firms
- Top 100 Pure Designers
- Top 50 Program Management Firms

Relevant Disciplines

#1
- Solar Power
- Environmental Consulting and Clean Air Compliance

Top 10
- Transmission Lines & Cabling
- Transmission & Distribution
- Wind Power
- Co-Generation Power
- Marine & Port Facilities
- Transportation

Planning Complex, Interdependent Energy Infrastructure



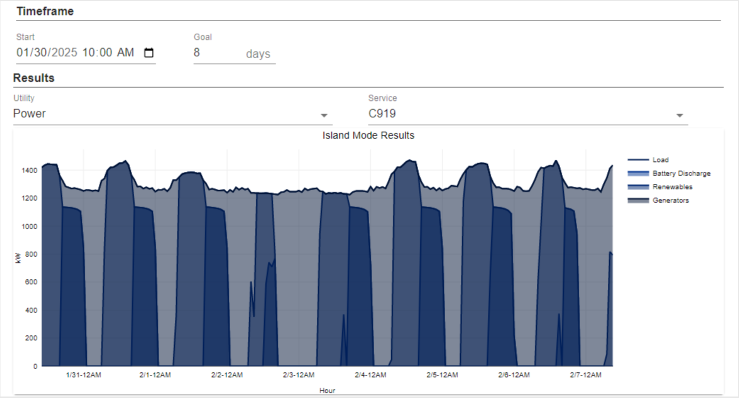
Virtual Infrastructure (VI)

Virtual Infrastructure is a utility infrastructure digital twin that provides dynamic, data driven solutions which are easily digestible to efficiently and accurately inform stakeholders on complex challenges including ***decarbonization, resiliency, and cost optimization*** while offering a holistic modeling engine that is fluid with future development

VI allows a clear and comprehensive path to goals

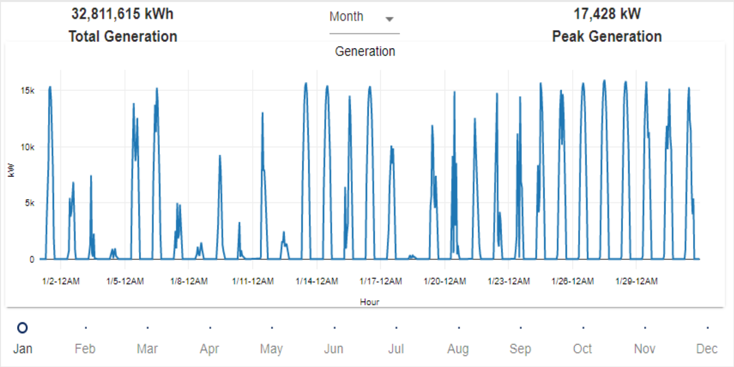
Improve Reliability

- Project system performance and resources for any utility outage during the analysis timeframe.
- Anticipate how growth will affect sitewide resiliency



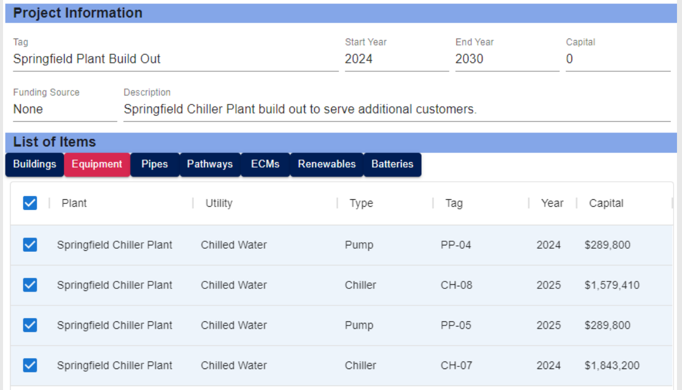
Increase Sustainability

- Measure goals related to NetZero Emissions (onsite renewables, energy storage, hourly emissions calculations, etc.)
- Analyze performance enhancements from building to production levels



Reduce Expenses

- Plan for future build out with organized equipment capital management
- Develop CapEx, OpEx, or TOC optimized scenarios



Project Information

Tag: Springfield Plant Build Out | Start Year: 2024 | End Year: 2030 | Capital: 0

Funding Source: None | Description: Springfield Chiller Plant build out to serve additional customers.

List of Items

Buildings | Equipment | Pipes | Pathways | ECMs | Renewables | Batteries

Plant	Utility	Type	Tag	Year	Capital
Springfield Chiller Plant	Chilled Water	Pump	PP-04	2024	$289,800
Springfield Chiller Plant	Chilled Water	Chiller	CH-08	2025	$1,579,410
Springfield Chiller Plant	Chilled Water	Pump	PP-05	2025	$289,800
Springfield Chiller Plant	Chilled Water	Chiller	CH-07	2024	$1,843,200

Modeling Capabilities

Physical Assets

- Generation
- Distribution
- Thermal Storage
- Electrical Storage
- Renewables
- Geothermal Heat Pumps
- 3rd party data
- GIS Integration/Export

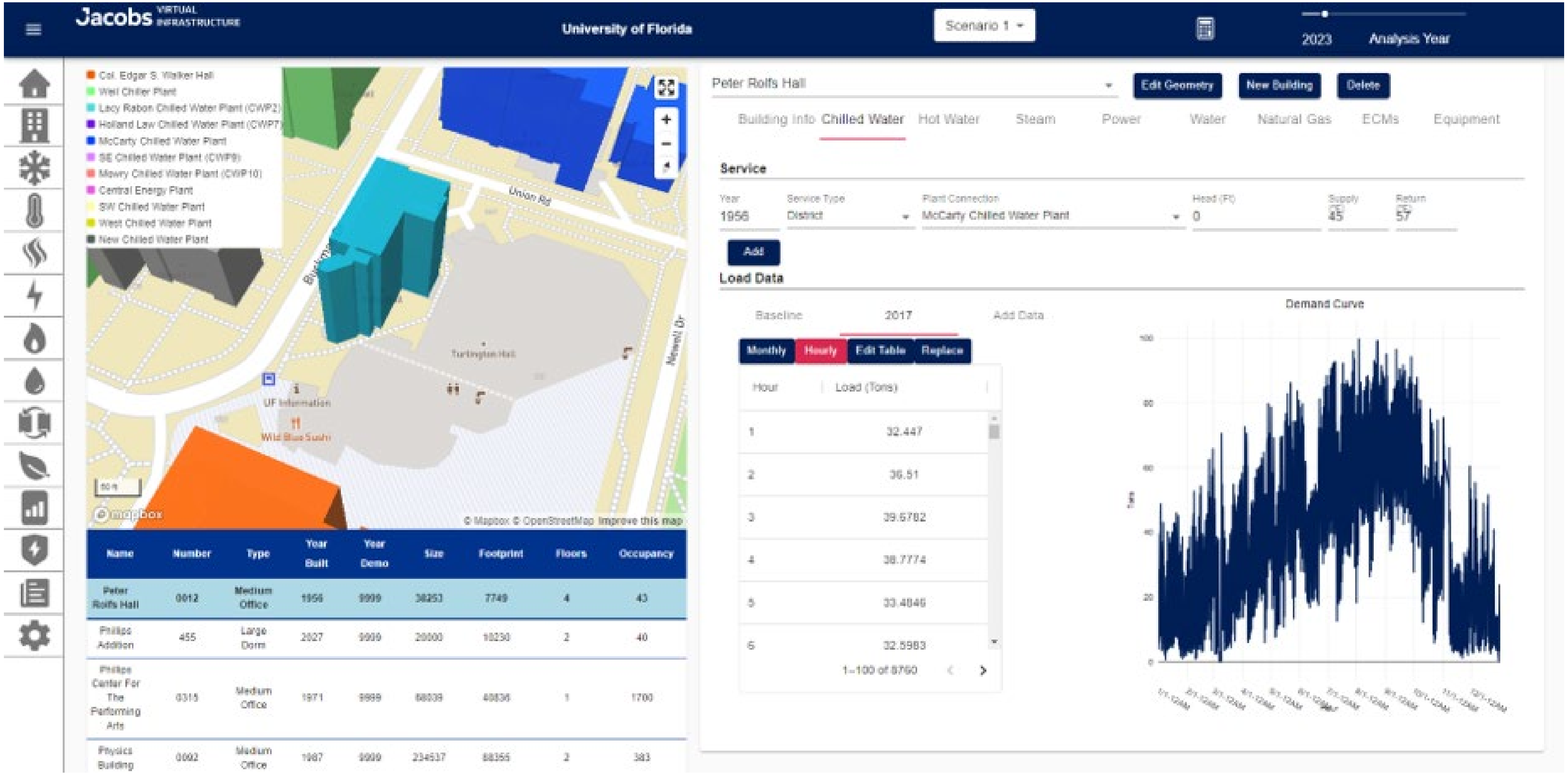
Operations

- Emissions
- Heat Recovery
- Ambient/5th Generation Thermal Systems
- Hourly Hydronic Flow Analysis
- Hourly Feeder Utilization
- Utility bills/meter data
- Island Mode Operations

Financial

- Unlimited Scenario Modeling
- Full LCCA
- Real Time Pricing & Demand Charges
- Renewable Energy Credits
- Physical Asset Bundling
- Funding Sources

Detailed Building Utility Demands

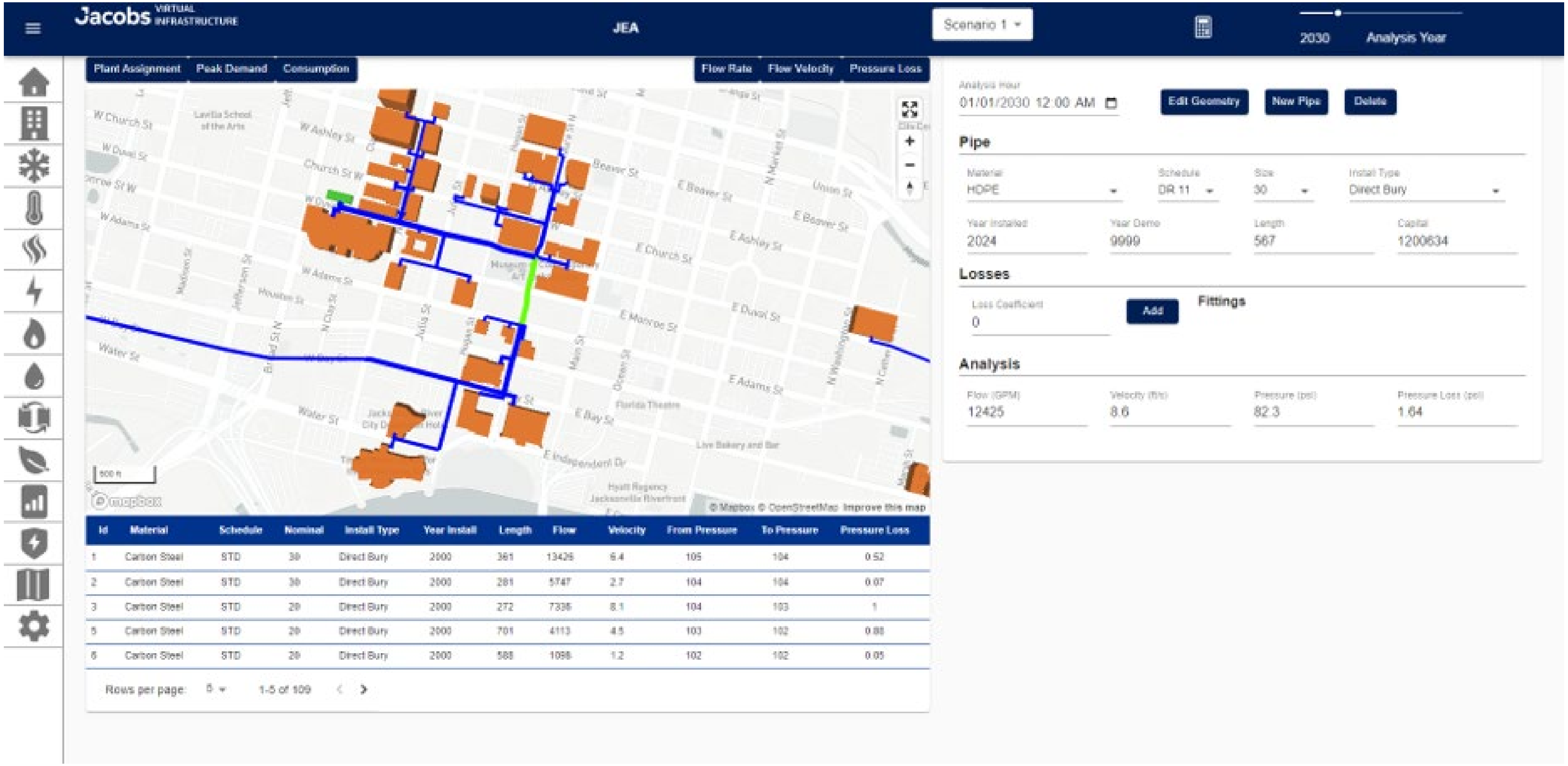


Name	Number	Type	Year Built	Year Demo	Size	Footprint	Floors	Occupancy
Peter Rolfs Hall	0012	Medium Office	1956	9999	38253	7749	4	43
Phillips Addition	455	Large Dorm	2027	9999	20000	10250	2	40
Phillips Center For The Performing Arts	0315	Medium Office	1971	9999	68039	40836	1	1700
Physics Building	0092	Medium Office	1987	9999	234537	88355	2	383

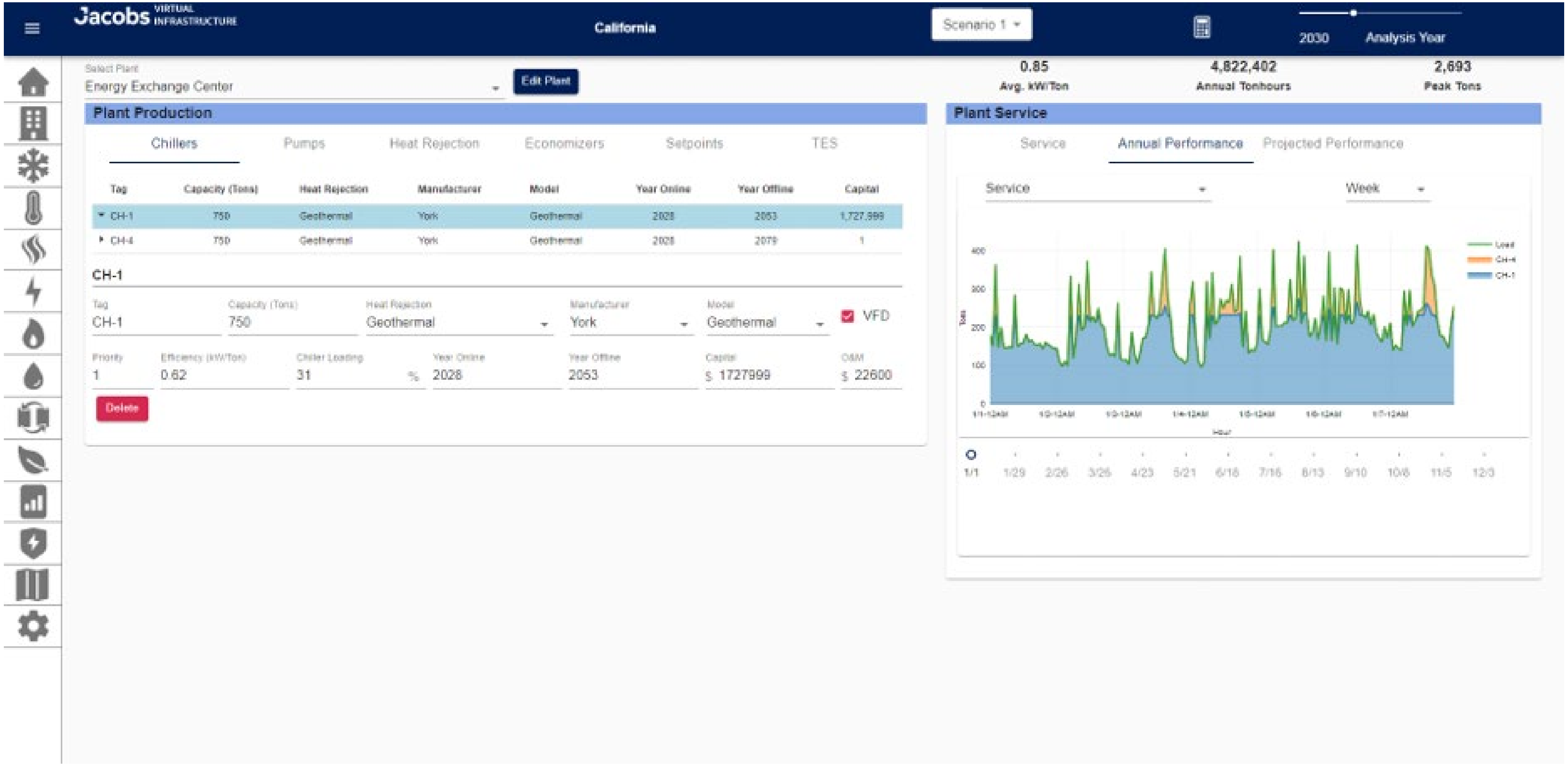
Hour	Load (Tons)
1	32.447
2	36.51
3	39.6782
4	38.7774
5	33.4846
6	32.5983

1–100 of 8760

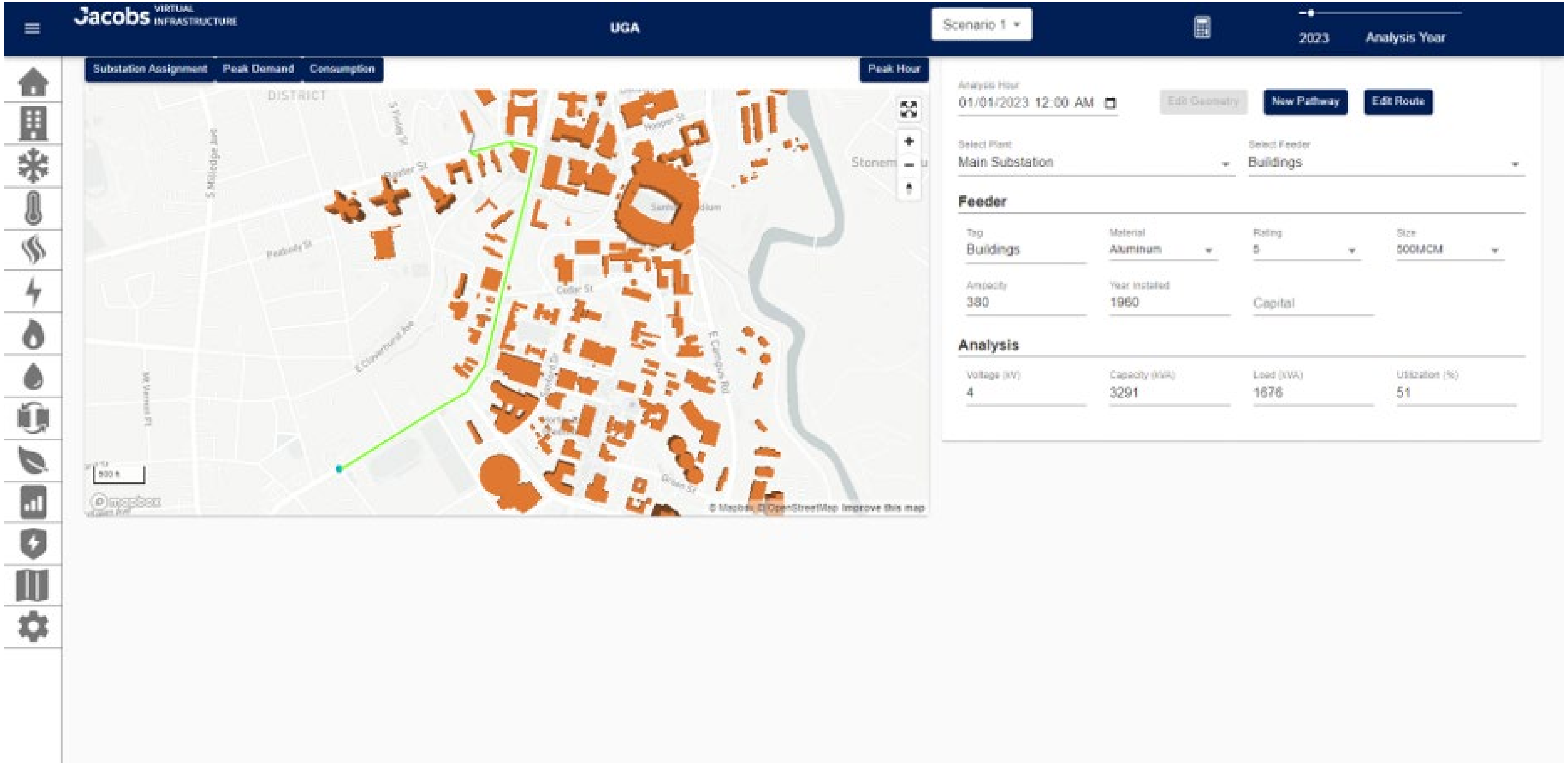
Hourly Hydronic Flow Analysis



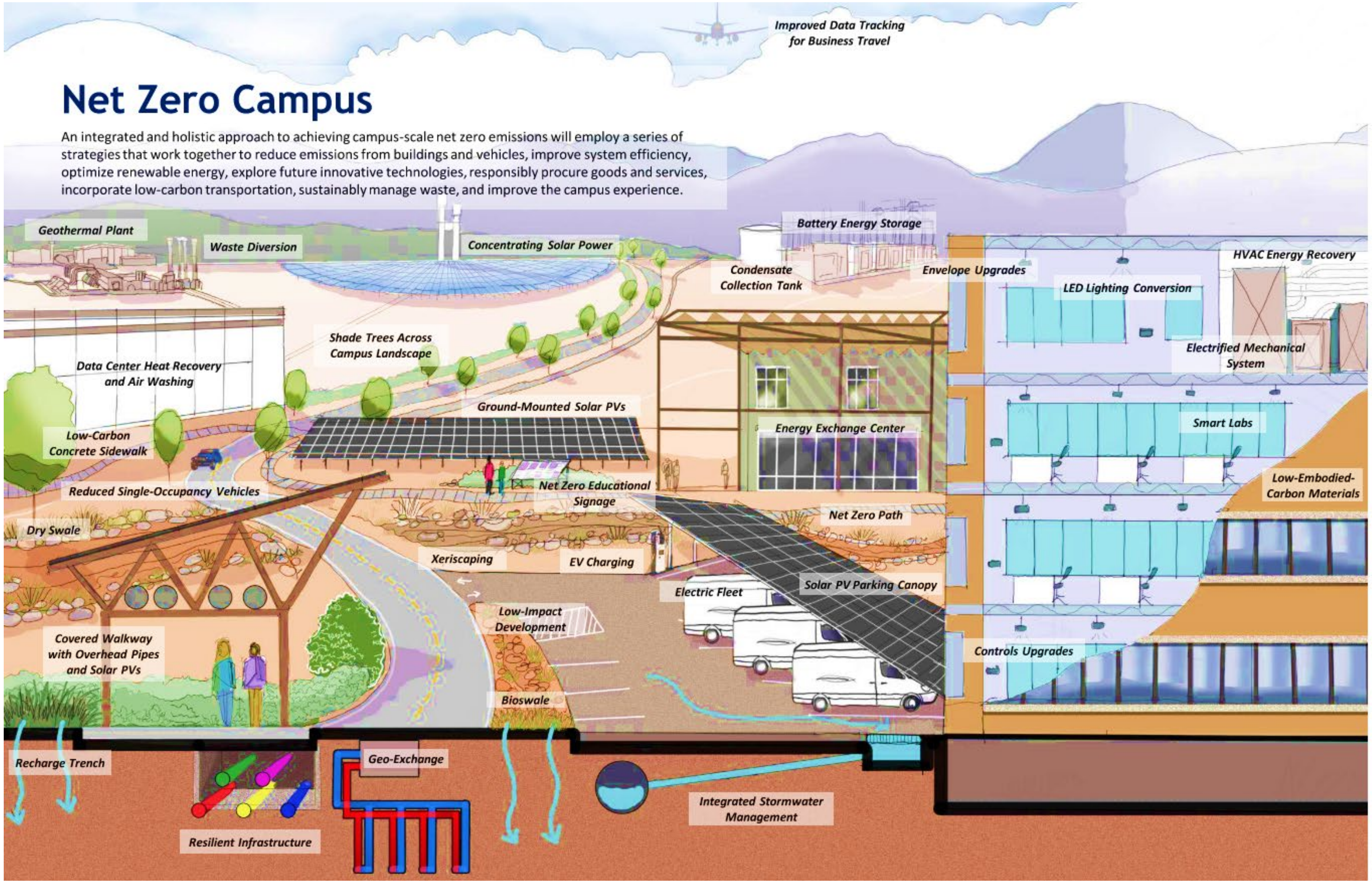
Equipment Operation and Sequencing



Visualization of Electrical Systems



Universities and Research Centers



Copyright notice

Important

Let's connect!

jason.willeford@jacobs.com

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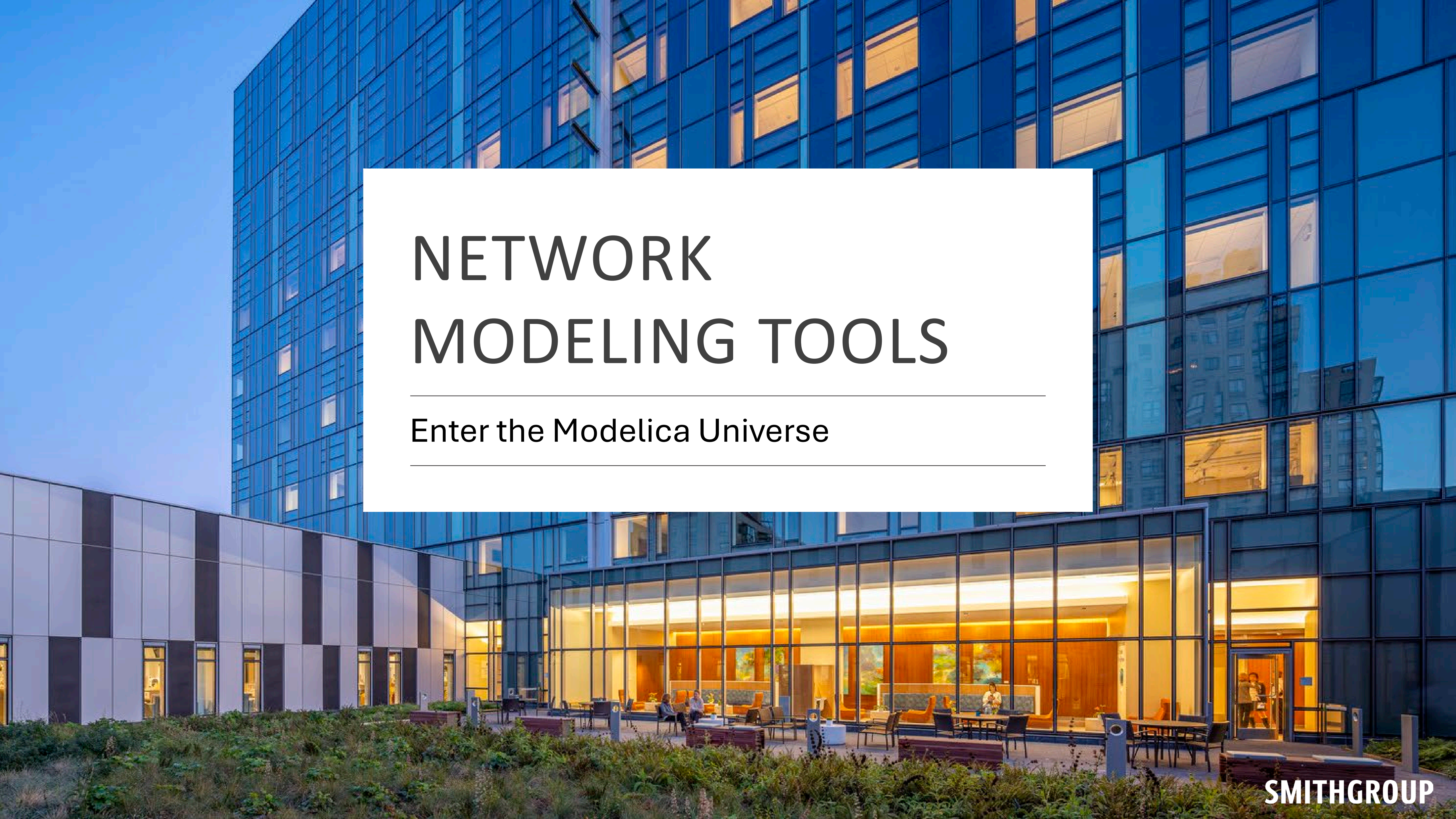
Challenging today.
Reinventing tomorrow.



NETWORK MODELING TOOLS

Enter the Modelica Universe

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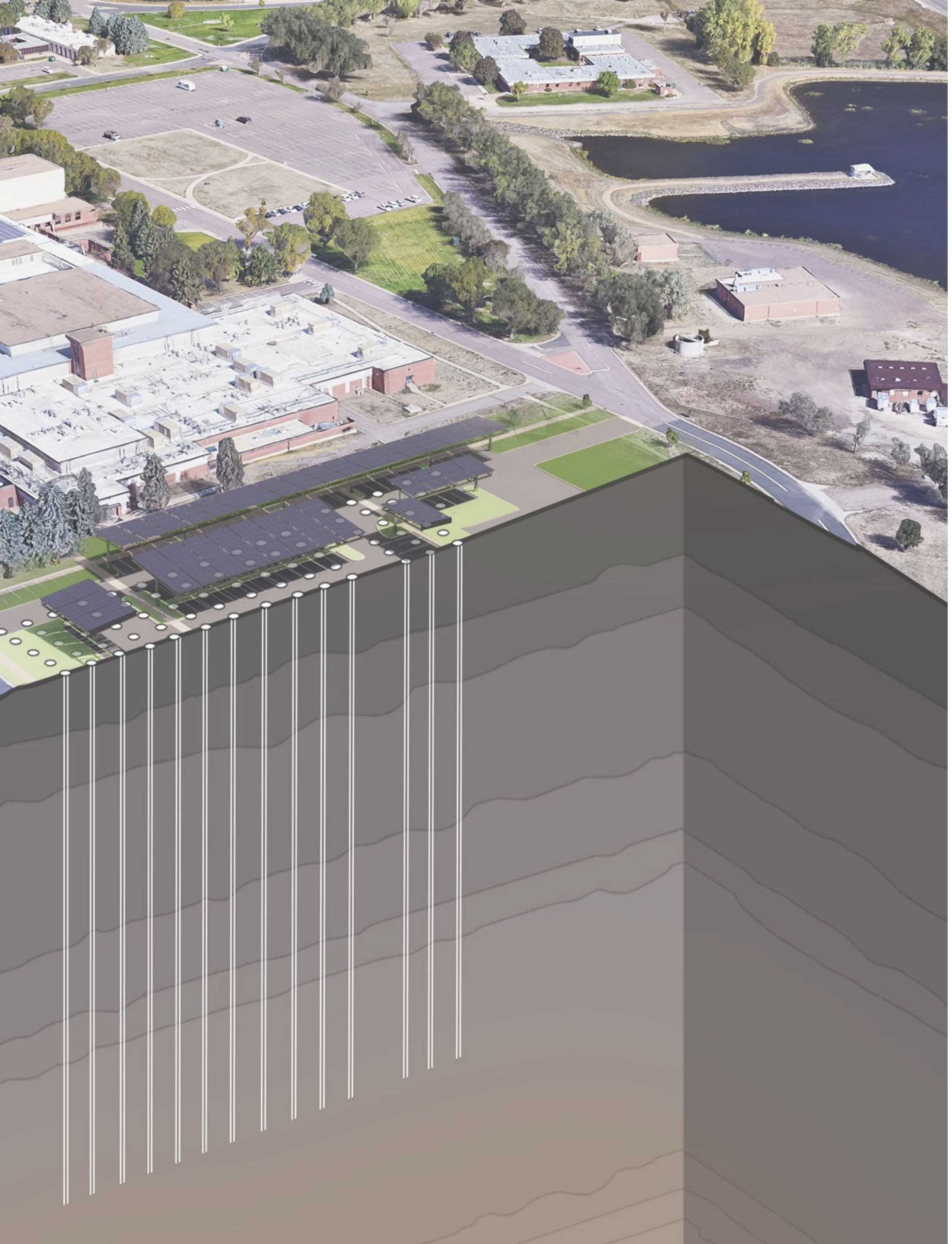

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Associate | Mechanical Engineer | IMPACT

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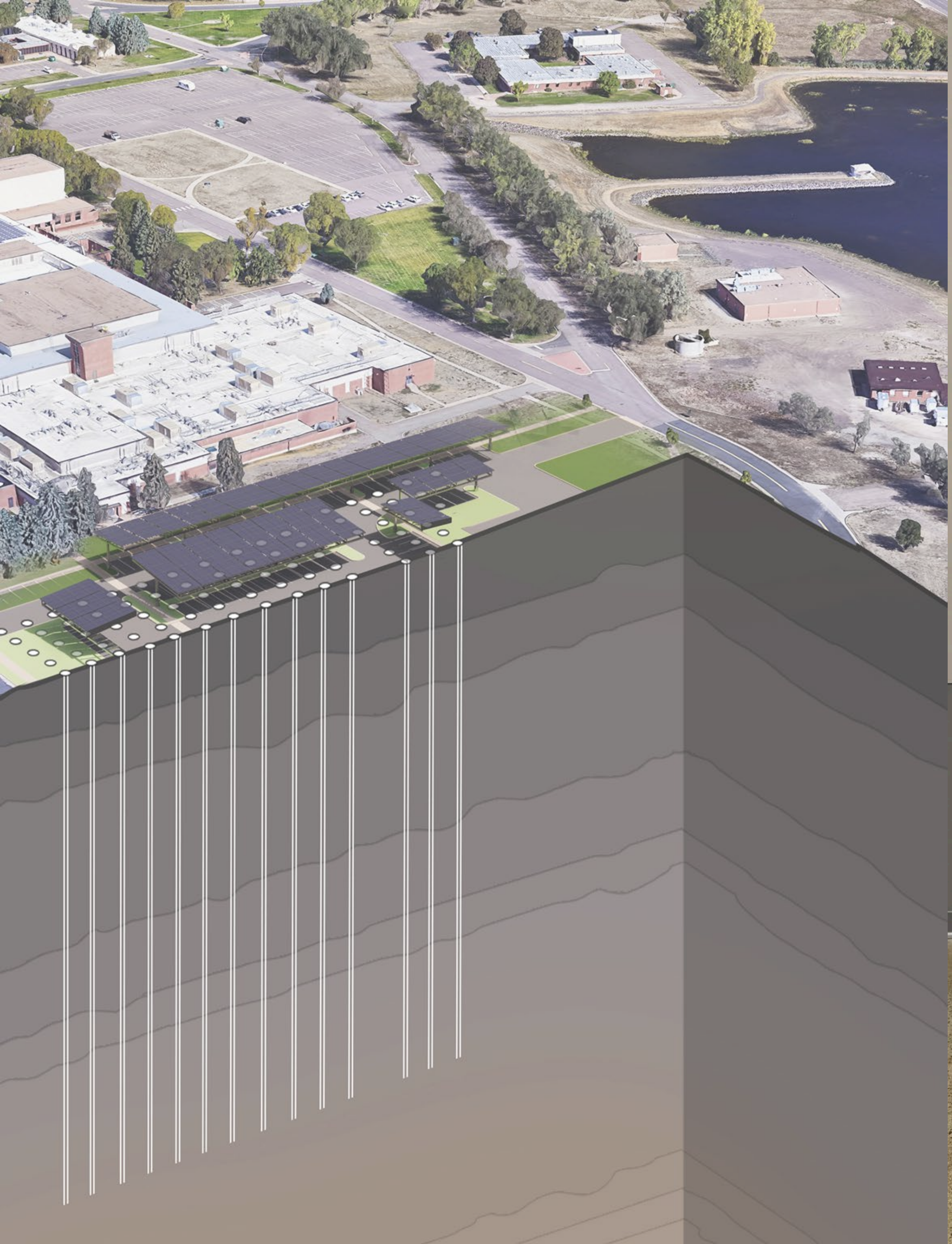
Design a Better Future




UC / LAWRENCE BERKELEY NATIONAL LABORATORY
CHU HALL - SOLAR ENERGY RESEARCH CENTER
UNIVERSITY OF THE PACIFIC
ARTHUR A. DUGONI SCHOOL OF DENTISTRY
GEO
ROCKS

DEFINING IMPACT

Building Scale

Campus Scale

Energy/Carbon Performance Modeling

- Energy Shoebox
- Customized performance models
- Compliance Modelling

Sustainable Design & Strategy

- Integrated Design Analytics
- Advanced Engineering
- Sustainable Design Recommendations
- Sustainable Design Tracking Support

Infrastructure & Systems Analysis

- Portfolio Energy Analysis
- District Energy Analysis
- Microgrids

Climate and Resilience Planning & Design

- Climate Action Planning
- Resilience/disaster planning
- Resilient Design Recommendations

Equity and Economic Impact

- Socioeconomic Analysis
- Job and industry analysis
- Utility impact analysis
- Equitable Design Recommendations

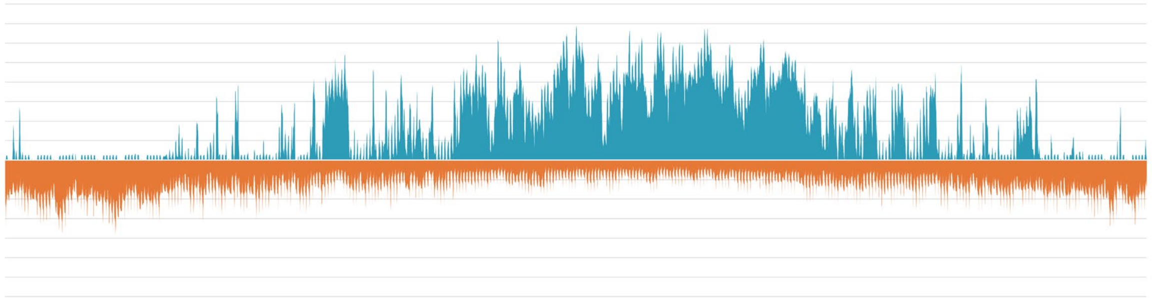
R&D

- Direct R&D Grants
- USDOE
- CEC
- Utility Work
- Controls

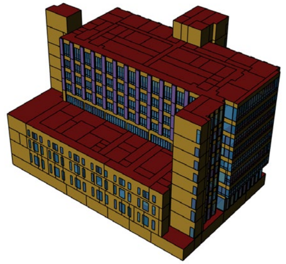
TYPICAL DISTRICT MODELING PROCESS

BUILDING HEATING AND COOLING LOA

HISTORICAL LOADS



BUILDING ENERGY MODEL



DISTRICT MODELING PLATFORM

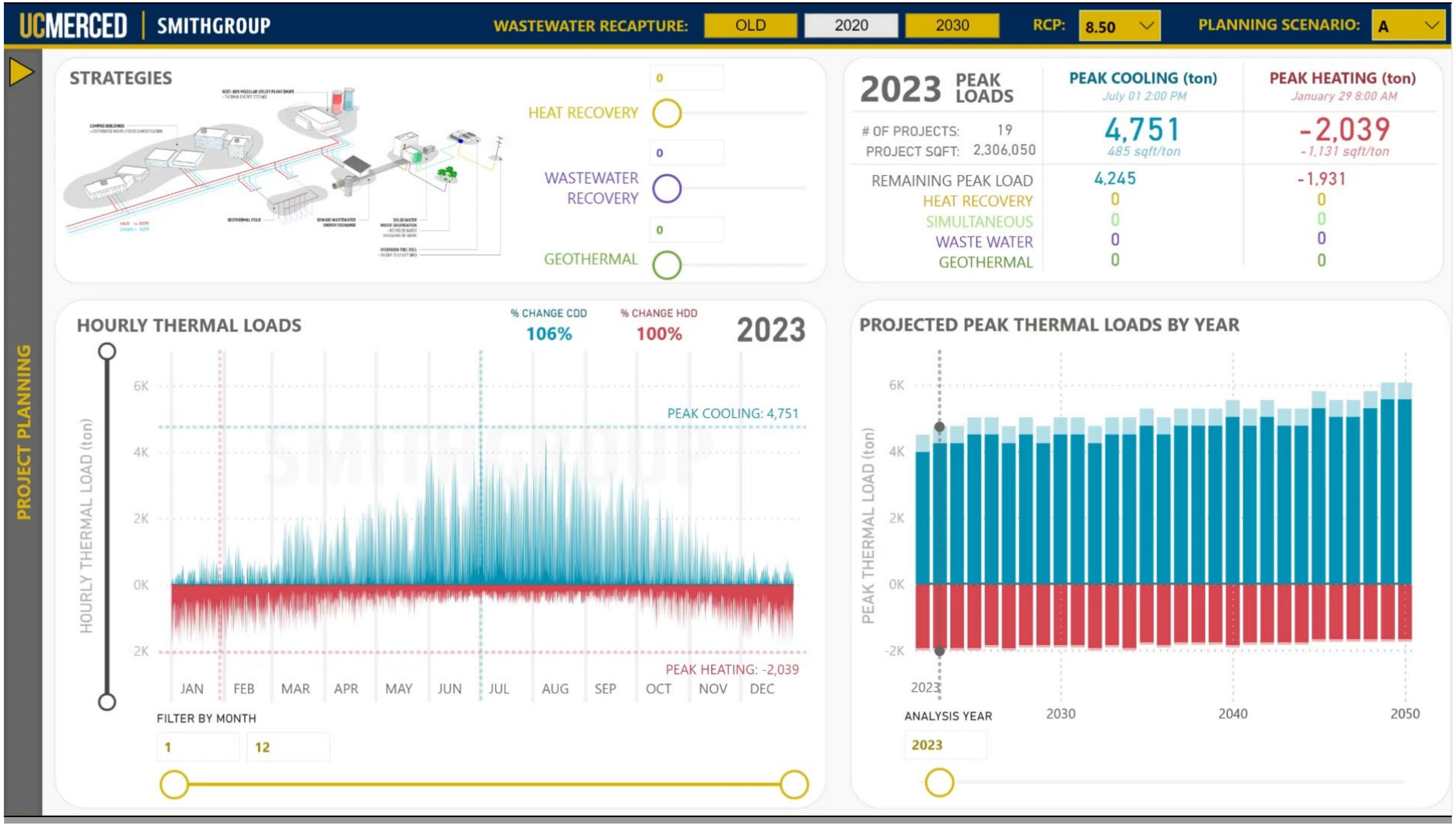
RESULTS

SCENARIO & INFRASTRUCTURE PLANNING

ENERGY USE / COST / EMISSIONS

CONTROLS VALIDATION/OPTIMIZATION

DISTRICT MODELING



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WHAT ABOUT….

COMPLEX PLANT DESIGNS?

CONTROLS TESTING?

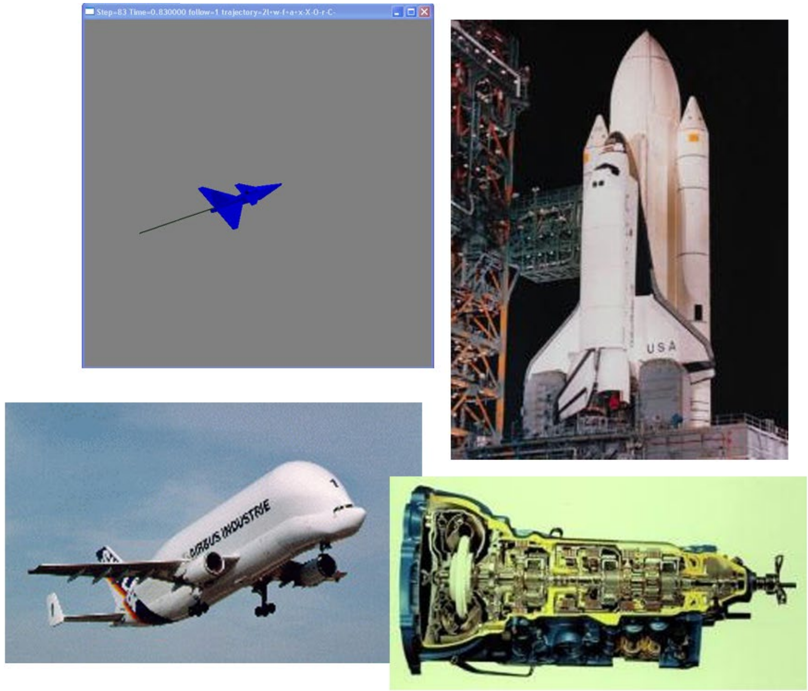
AMBIENT LOOPS?

MORE ACCURACY?

MODELICA

MODELICA MODELING

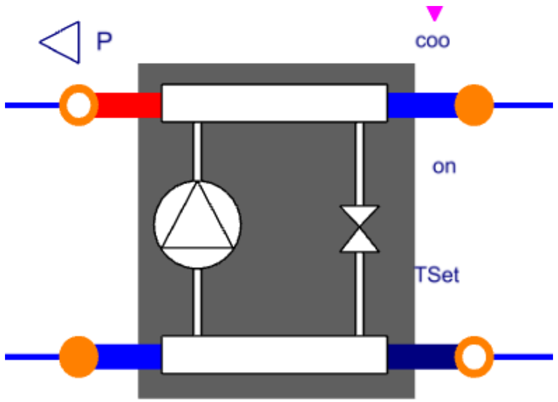
- **Modelica** > ~~tool~~ language for modeling
  - **Building systems**
  - **District energy systems**
  - Power plants
  - Robotics
  - Automotive
  - Aircraft
  - Satellites
- **First released in 1997** > Gen Z



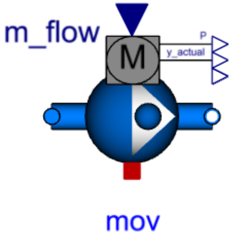
Source: openmodelica.org (April 2025)

MODELICA MODELING

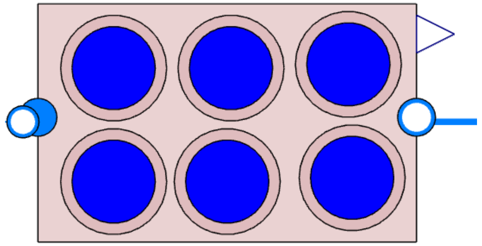
- **Object oriented** > **Connect realistic components to create a system**
- Acausal > **Pipe doesn't need to know direction of flow**
- Multidomain > **Combine Electrical + Mechanical**
  - Mechanical
  - Hydraulic
  - Electrical
  - Thermodynamic
  - Controls



HEAT PUMP



PUMP



BOREFIELD

MODELICA MODELING

- Object oriented > Connect realistic components to create a system
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FLOW IN PIPE

MODELICA MODELING

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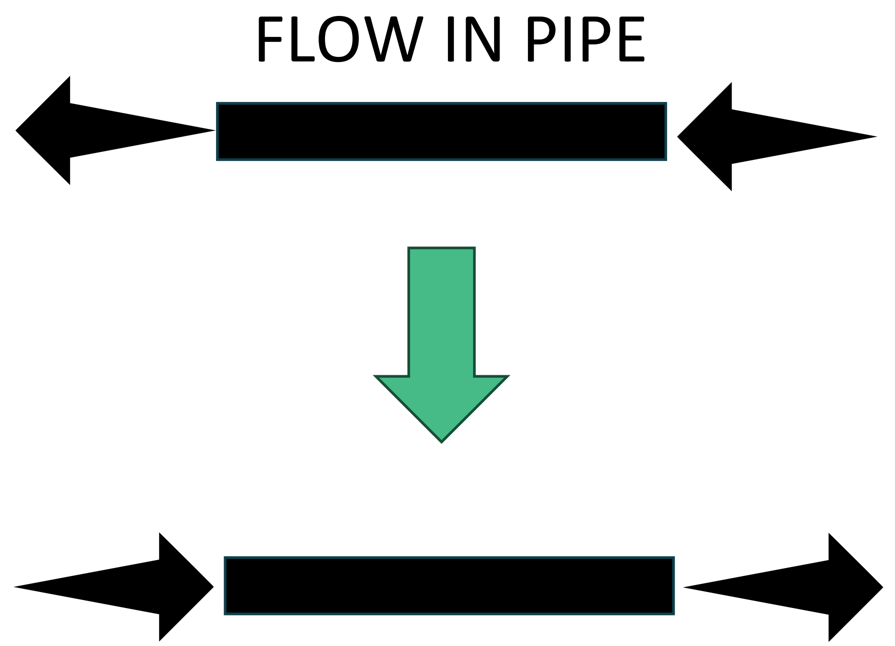

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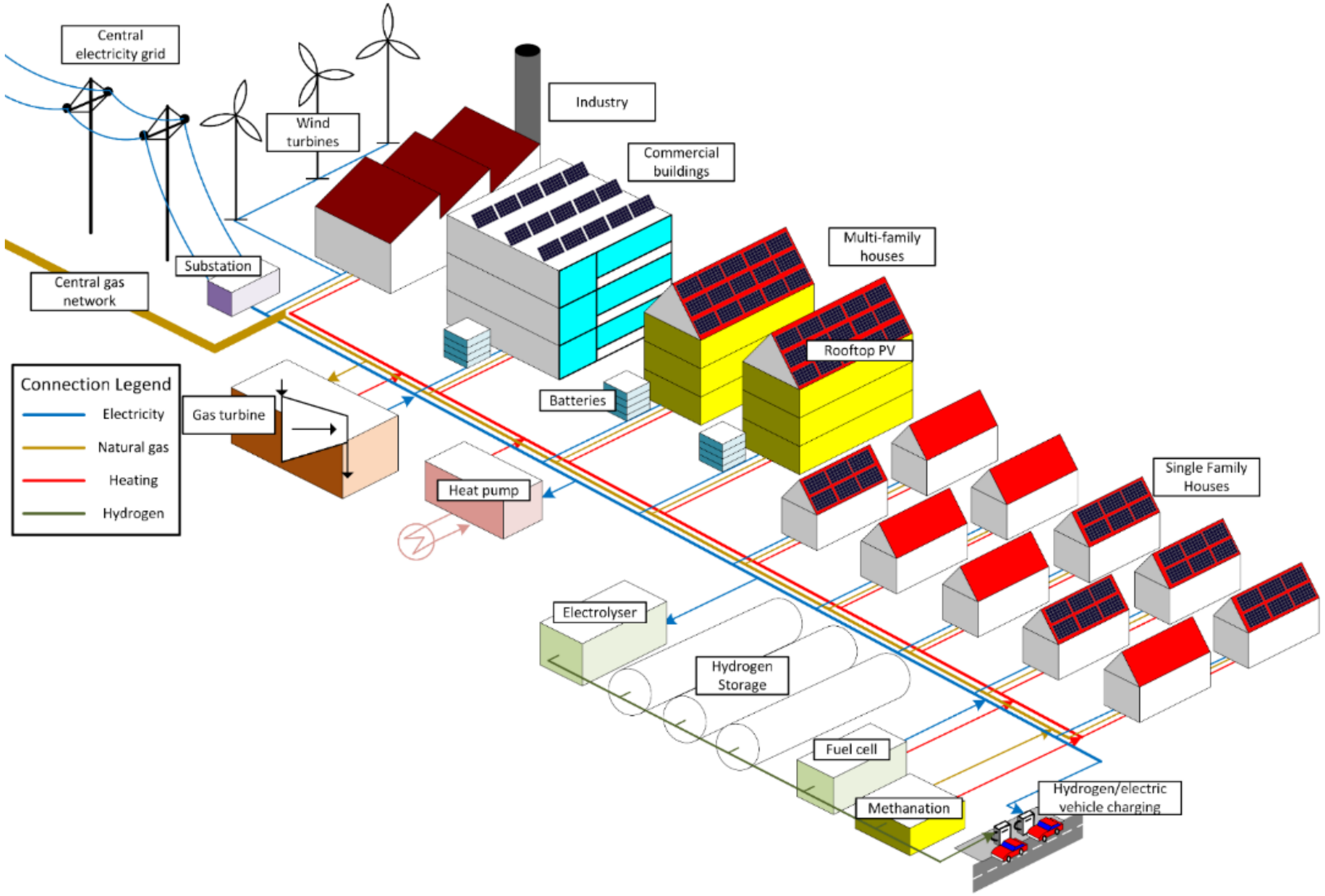


Figure: EMPA

TRADITIONAL ENERGY MODELING VS MODELICA

Traditional Energy Modeling

“I think you’ll find my management style pretty direct”

Modelica Modeling

TRADITIONAL ENERGY MODELING VS MODELICA

Traditional Energy Modeling

- **Pros**
  - **“Simple”**
  - **Building loads**
- **Cons**
  - **Single building**
  - **Simple controls**
  - Less flexible system customization
  - Less open-source
  - Less data access
  - Limited hydraulic/flow analysis

Modelica Modeling

- **Pros**
  - **More flexibility: model atypical systems**
  - **Single building plant or district**
  - **Advanced controls**: Real life control 1:1 translation options between digital twin and BAS control
  - **Expanded Hydraulics / flow analysis**
  - **Multi-domain**: thermal + electrical + controls
  - More open-source
  - More data accessible
- **Cons**
  - **Generating building loads**
  - Limited CAD and BIM integration (e.g., for piping takeoffs)
  - Learning curve

MEET THE MODELICA FAMILY

MODELING LANGUAGE

Modelica

MODELING ENVIRONMENTS

Modelon Impact | Dymola | OpenModelica

LIBRARIES

Open Source | Proprietary

MEET THE MODELICA FAMILY

MODELING LANGUAGE

Modelica

MODELING ENVIRONMENTS

Modelon Impact

LIBRARIES

Open Source

Modelica Buildings Library

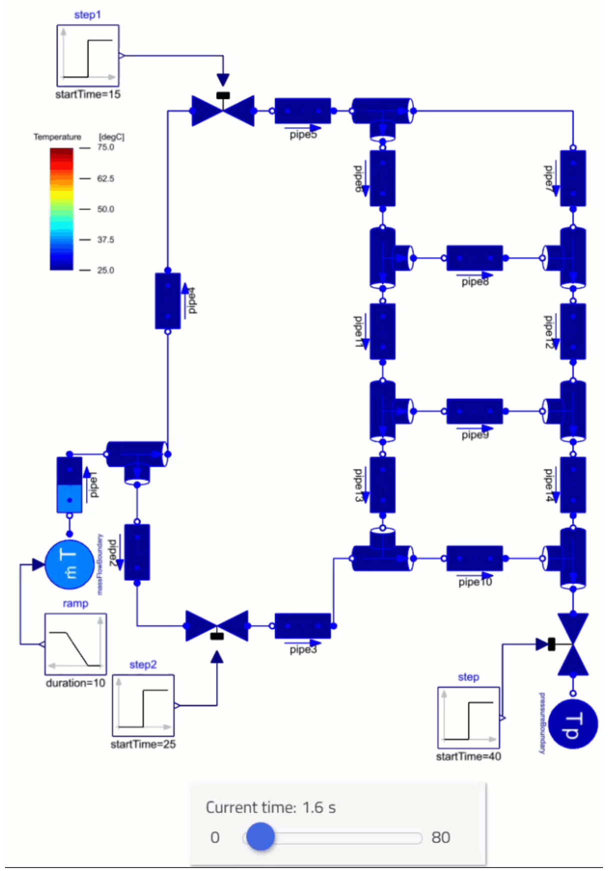
Proprietary

Modelon

MODELING ENVIRONMENT: MODELON IMPACT

- **Cloud Platform**
  - Ease of collaboration
  - Rapid simulation
  - Multiple deployment options
- **Includes Libraries**
- **Includes Support**

Modelon Impact



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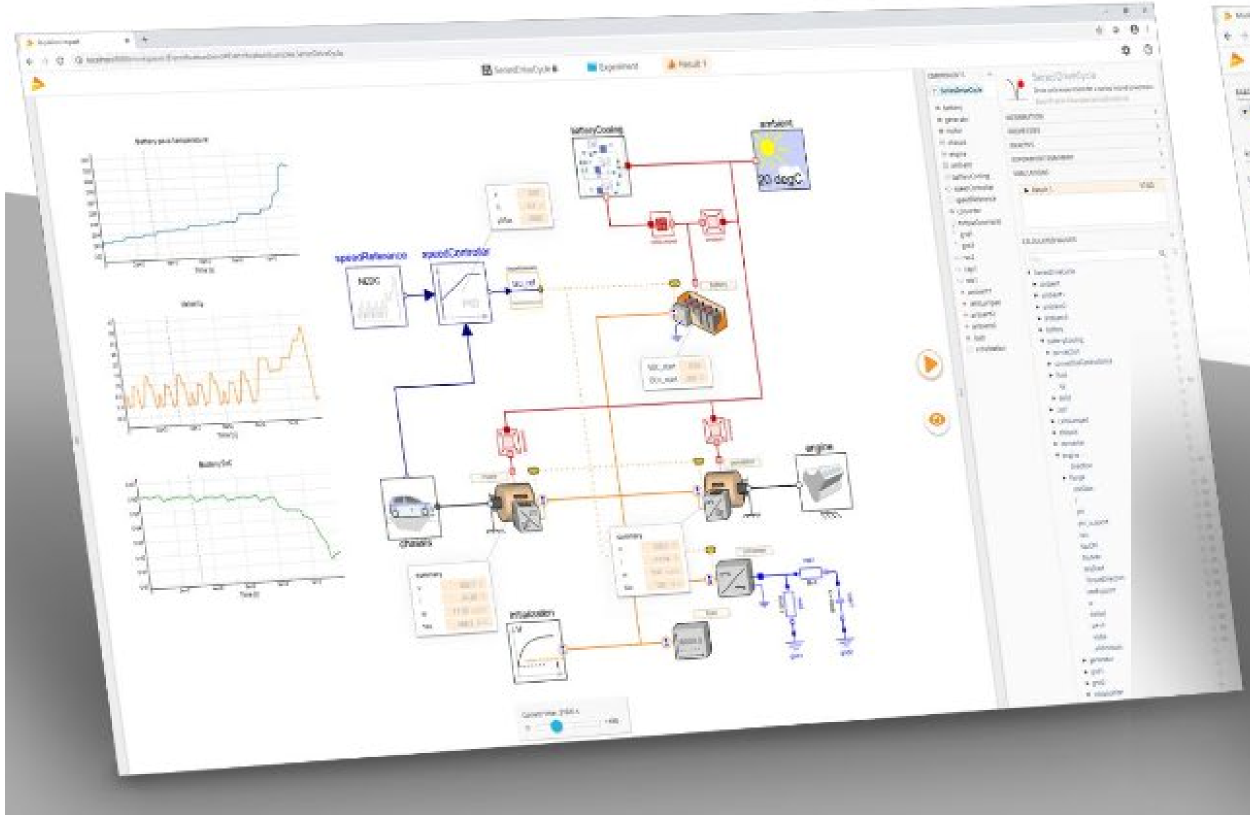
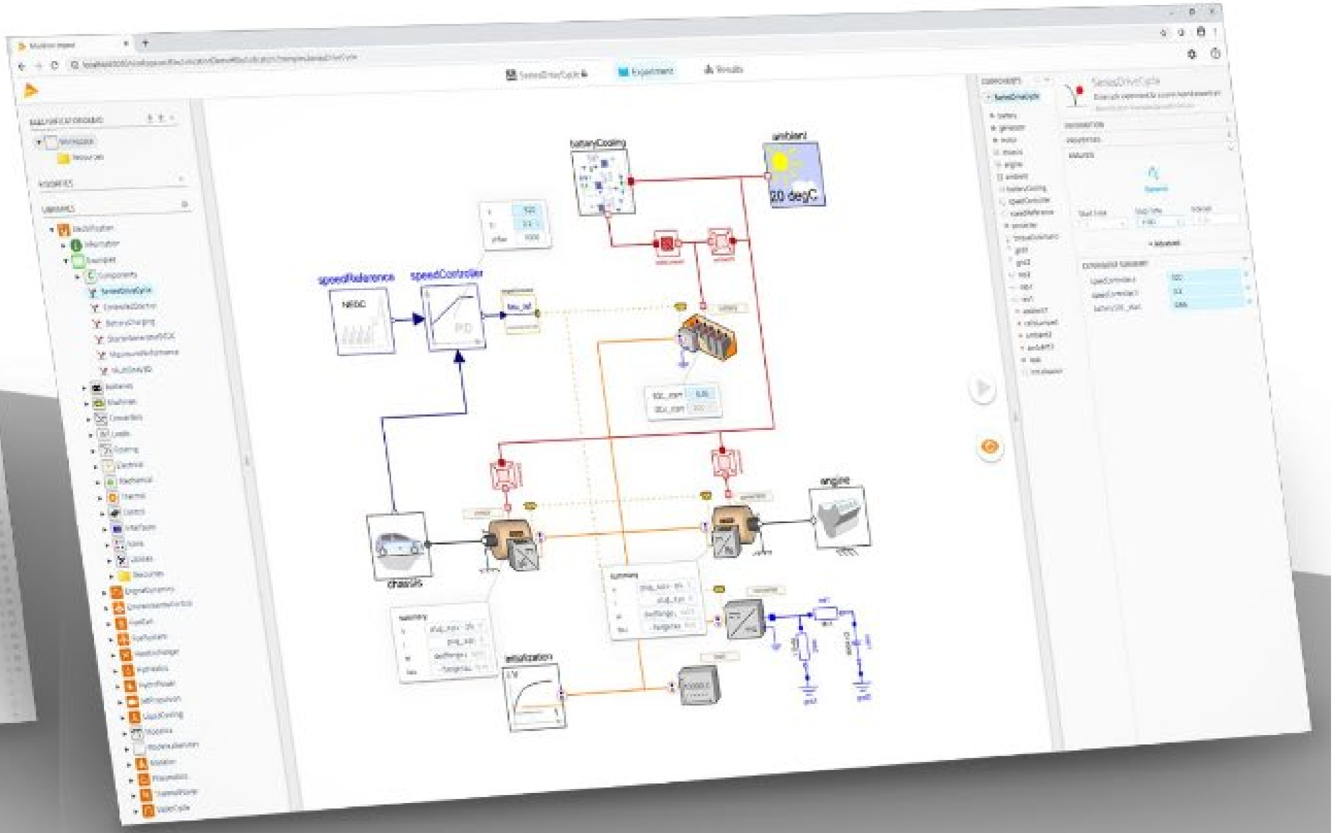
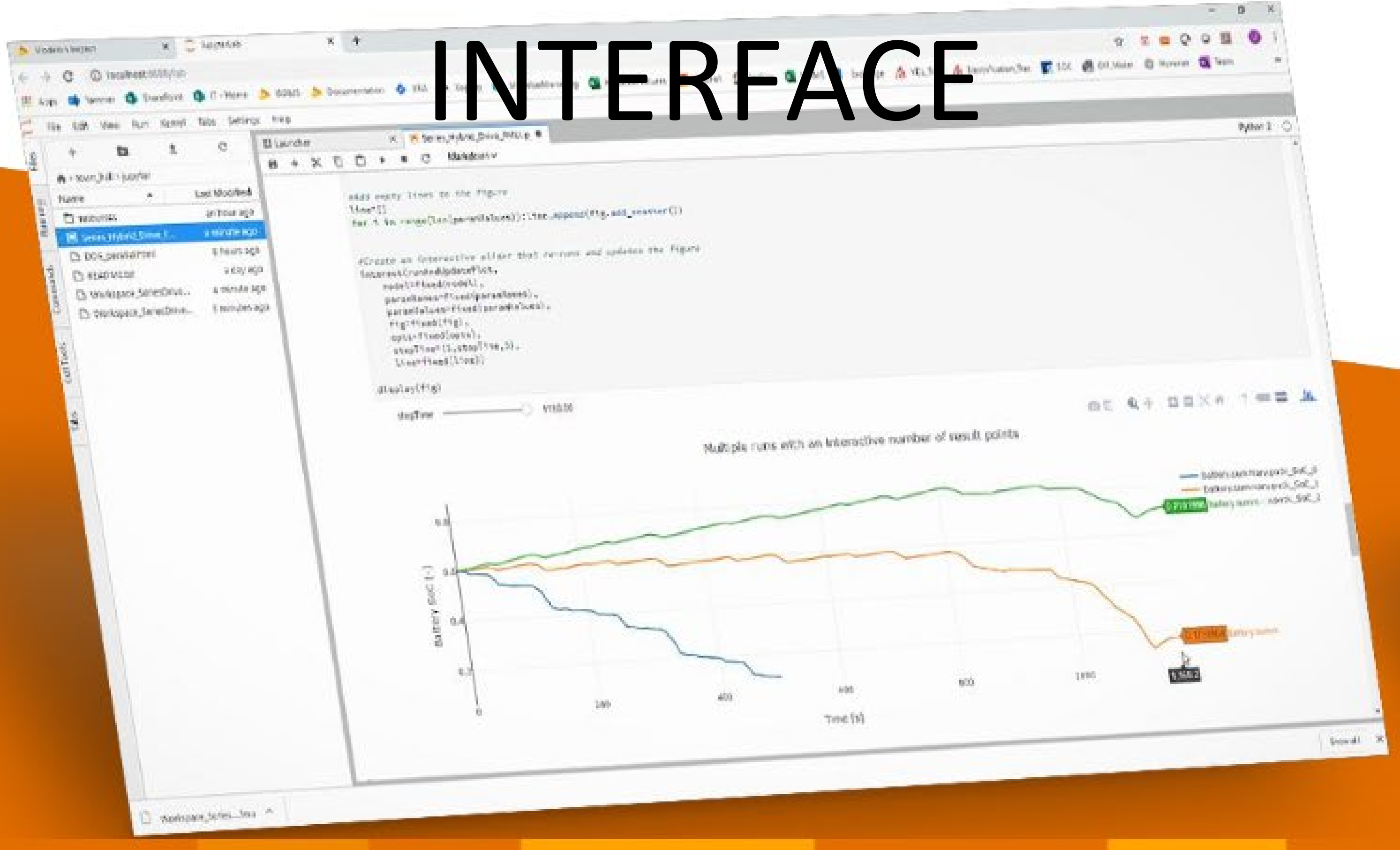
MODELING INTERFACE





MODELON IMPACT

MODELING + CODING INTERFACE



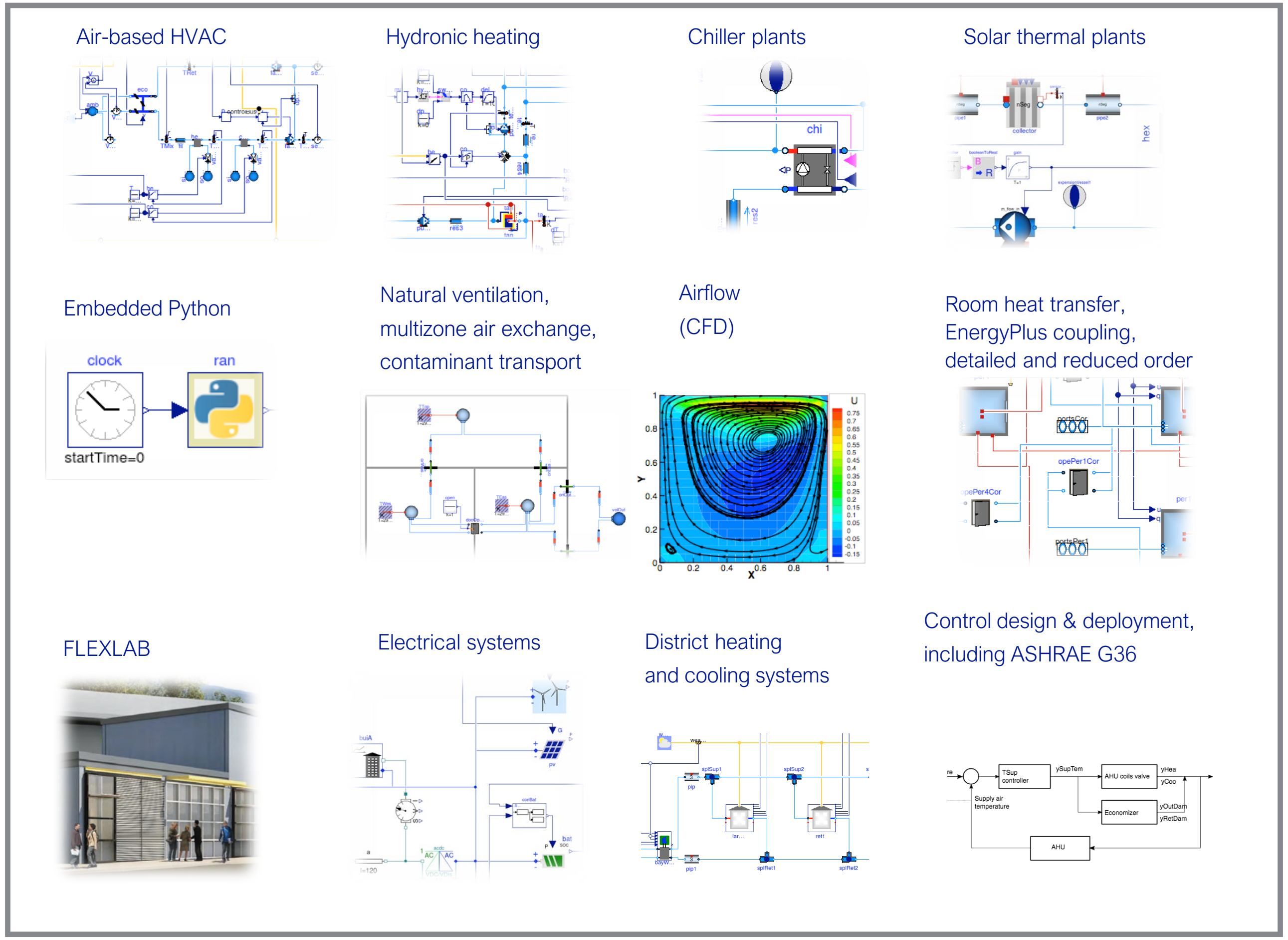
MODELICA LIBRARIES: BUILDINGS LIBRARY

CO-DEVELOPED WITH IBPSA MODELICA LIBRARY, INCLUDING DISTRICT HEATING AND COOLING SYSTEMS

BERKELEY LAB

Modelica Buildings Library

+2000 VALIDATED OPEN-SOURCE MODELS



https://simulationresearch.lbl.gov/modelica/

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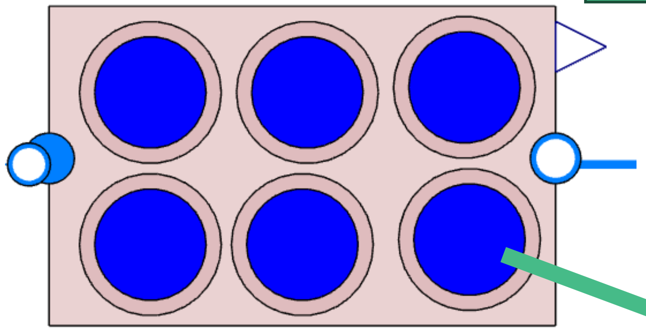
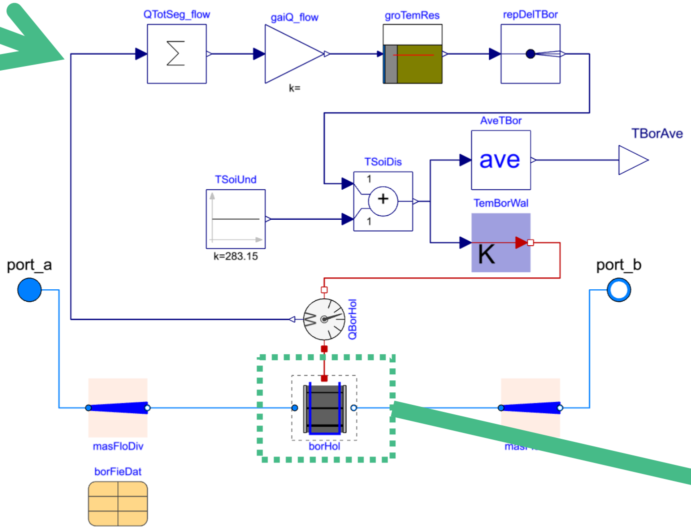
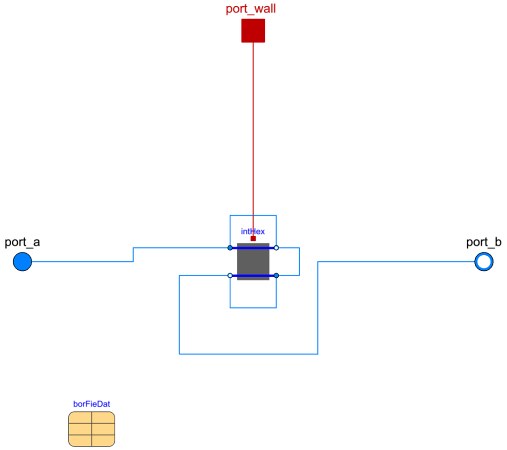
BUILDINGS LIBRARY: BOREFIELD MODEL

BOREFIELD

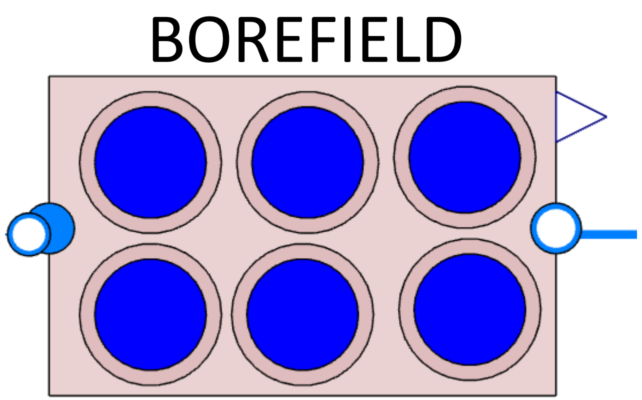
ONE BORE (U-TUBE)







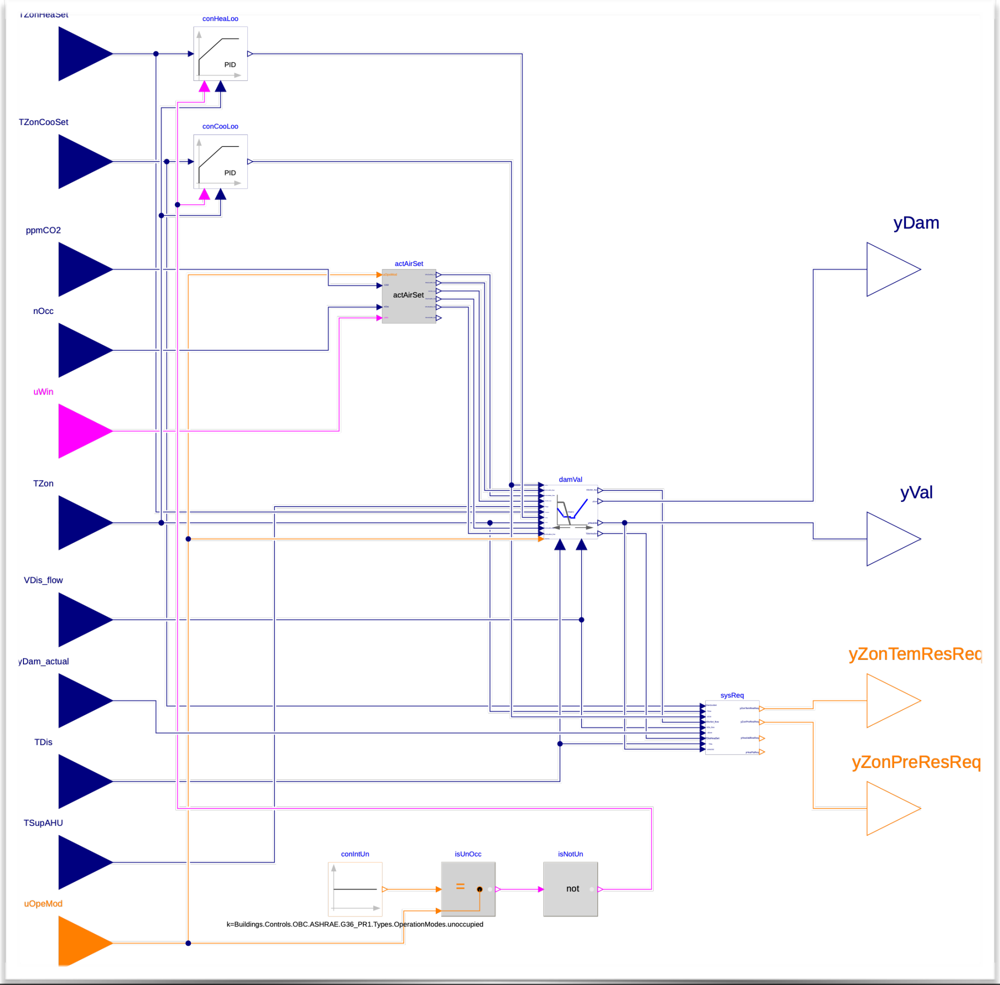
BUILDINGS LIBRARY: BOREFIELD MODEL



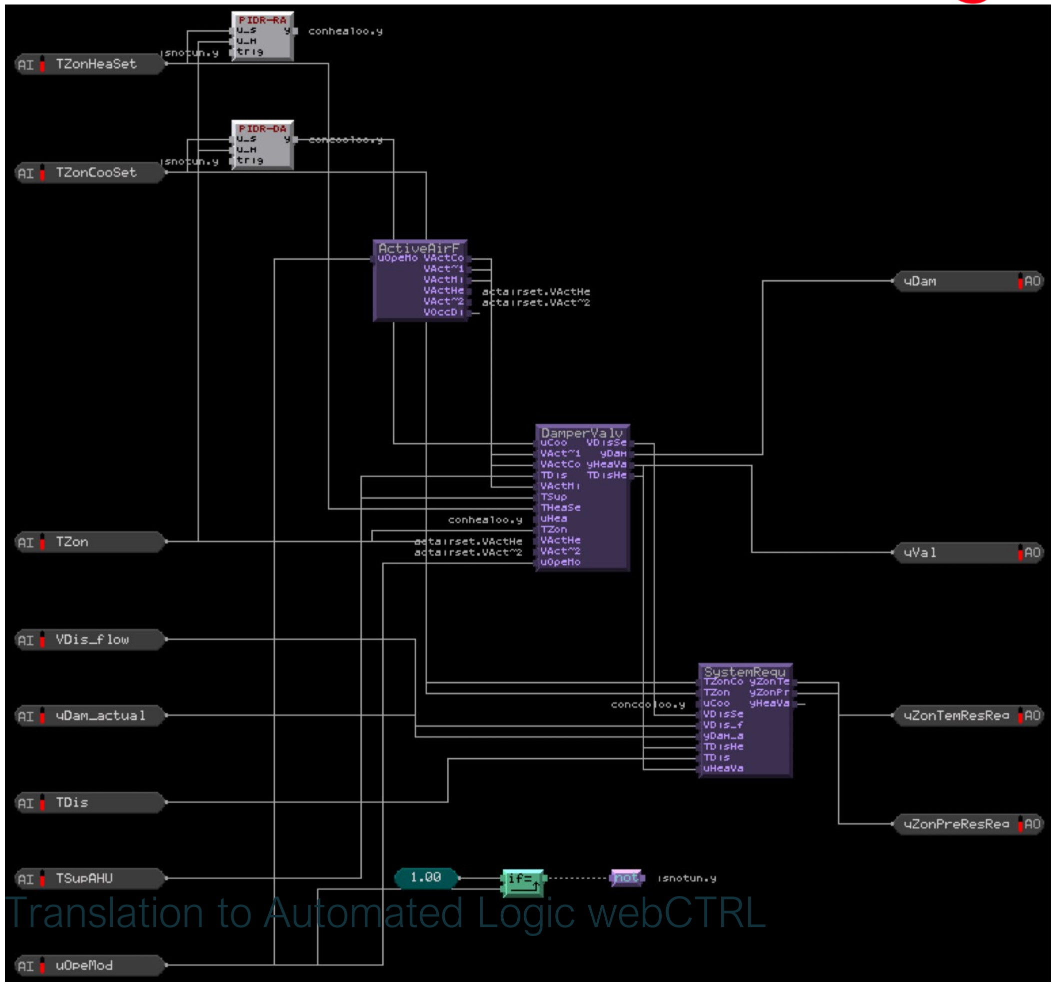
- **Short Term Response** > Manage electrical demand charges and peak building load
- **Long Term Response** > Inform seasonal load imbalance
- **Real controls with dynamic flow rates** > Trust the results

BUILDINGS LIBRARY: CONTROL DESCRIPTION LANGUAGE (CDL)

DIGITAL MODEL



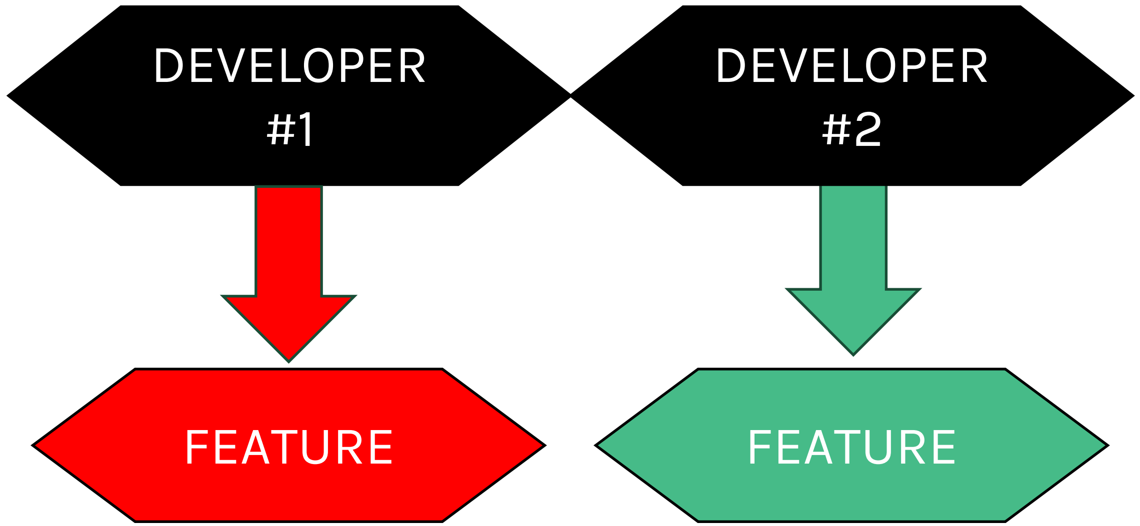
BUILDING CONTROLS



MODELICA LIBRARIES: CONSTANT DEVELOPMENT

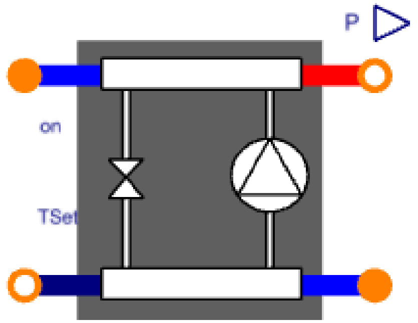
- **Worldwide development**
  - Modelica Buildings Library (Lawrence Berkely National Lab)
  - **Modelica International Building Performance Simulation Association (IBPSA) Library**
  - Modelica Standard Library
  - Modelon: ~17 Libraries

DEVELOPMENT WORKFLOW



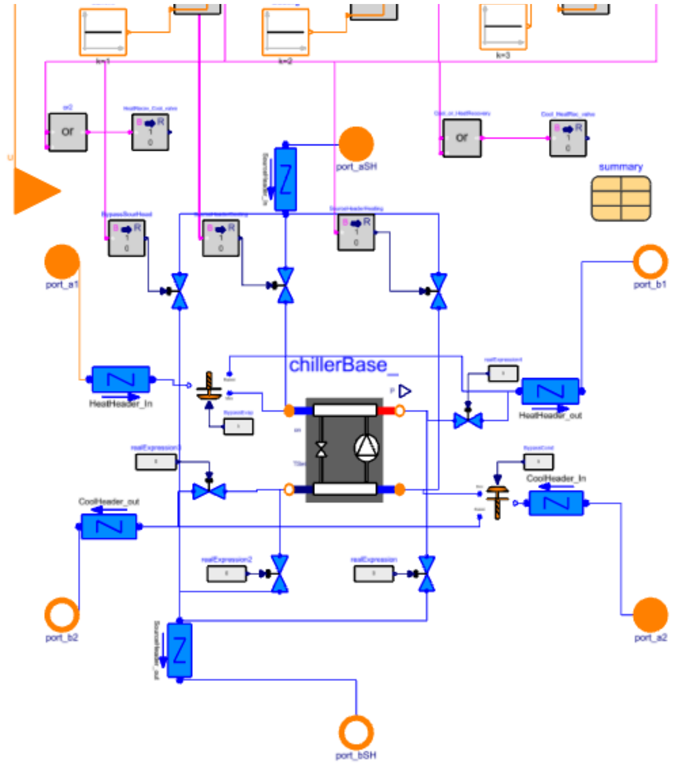
RAPID MODEL DEVELOPMENT

BASE
4 PIPE HEAT PUMP

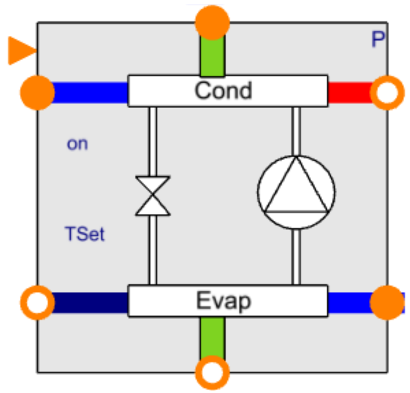


HEATING
OR
COOLING

COMPONENT DEVELOPMENT

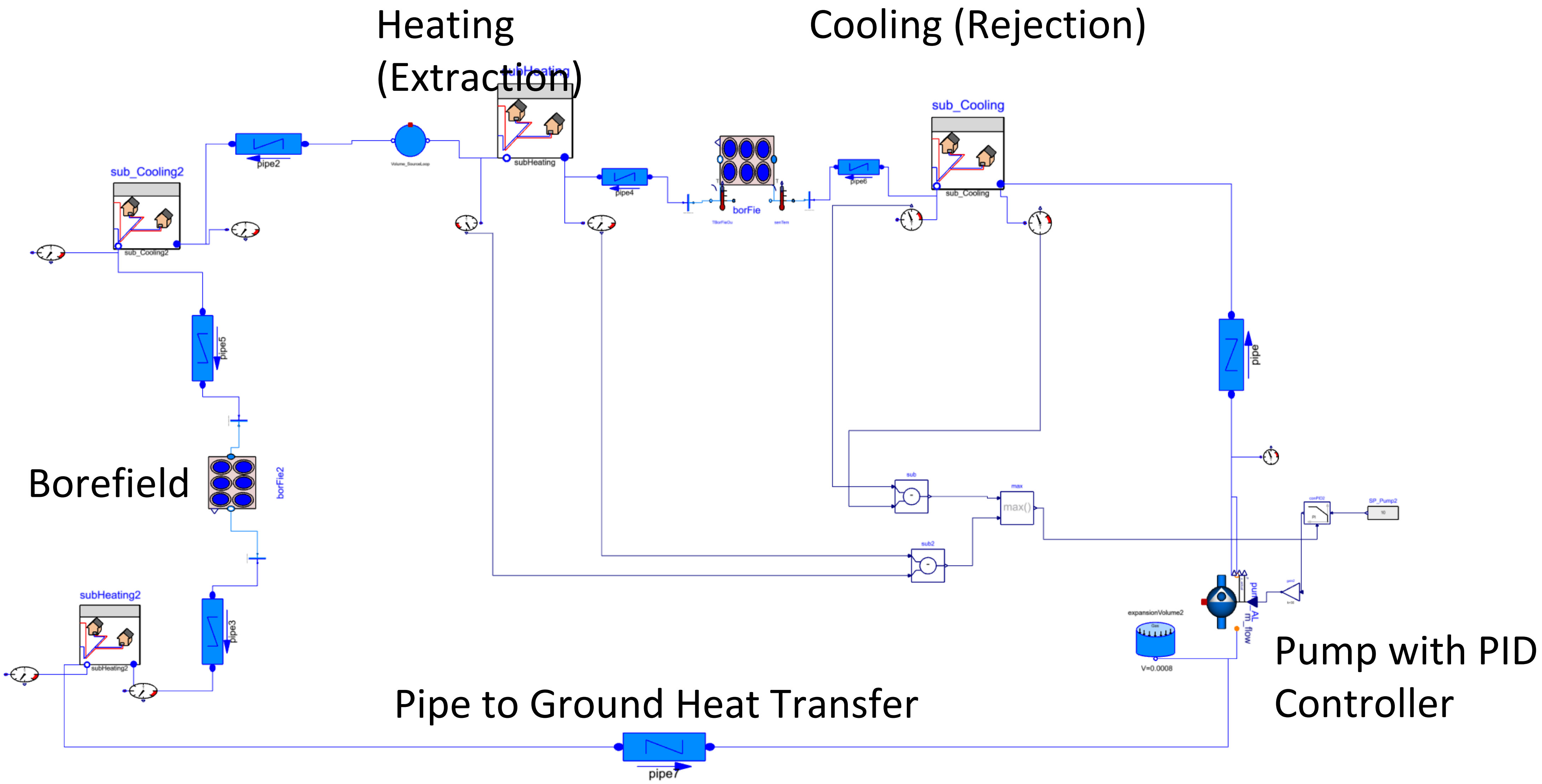


NEW
6 PIPE HEAT PUMP



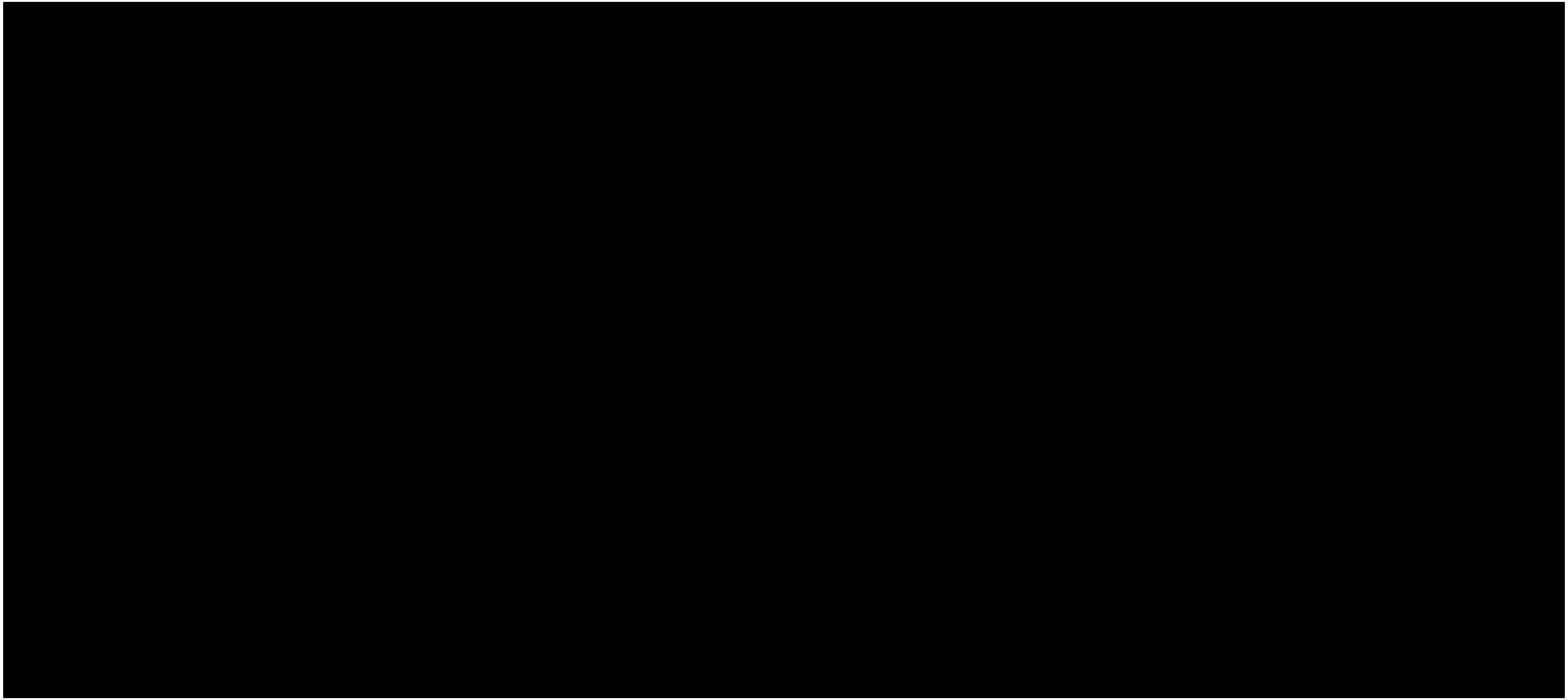
HEATING
OR
COOLING
OR
SIMULTANEOUS

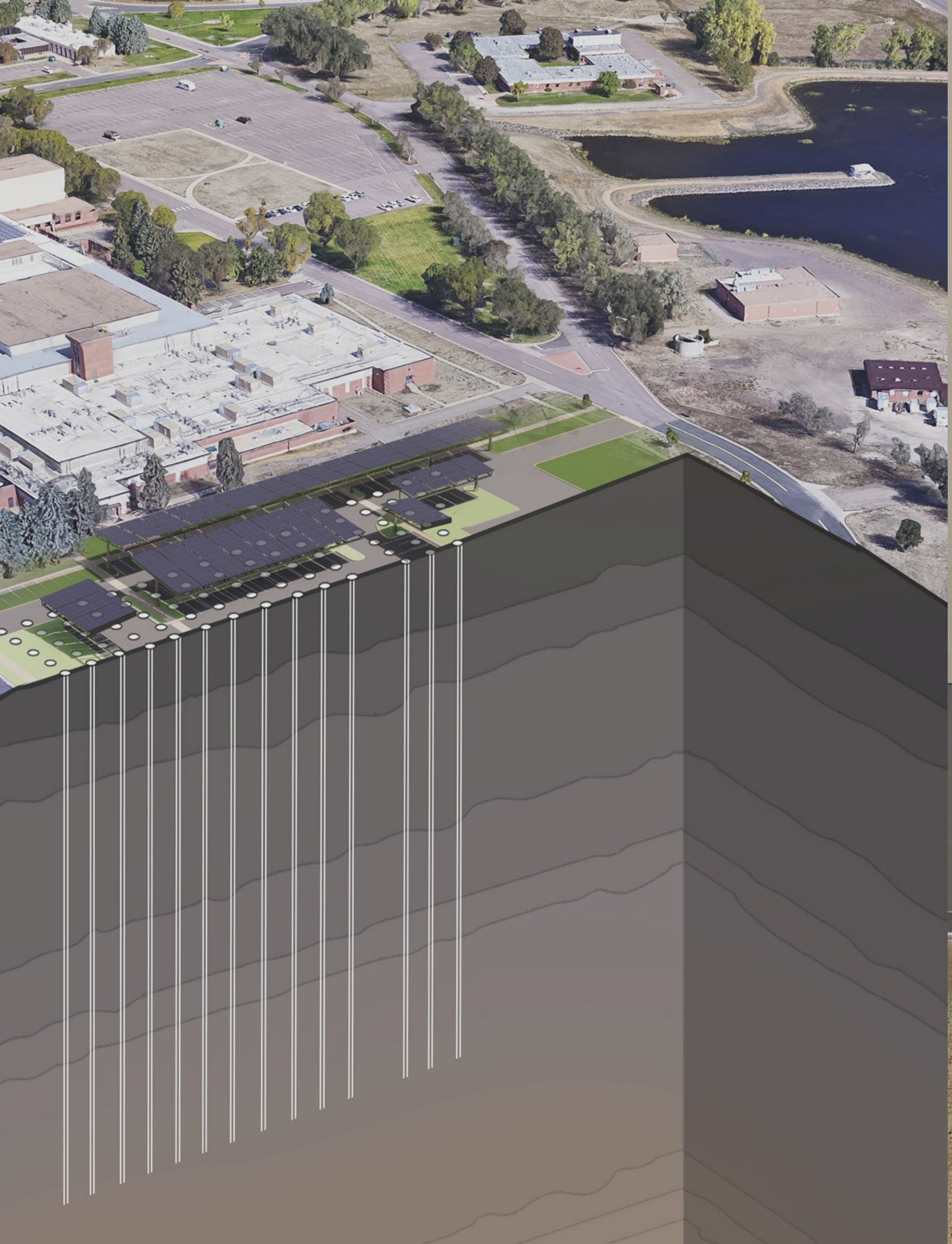
THERMAL ENERGY NETWORK – AMBIENT LOOP



SMITHGROUP

THERMAL ENERGY NETWORK – AMBIENT LOOP



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UNIVERSITY OF THE PACIFIC
ARTHUR A. DUGONI SCHOOL OF DENTISTRY
GEO
ROCKS

Salas O'Brien™

Network Geothermal Modeling Tools

Presented by:
Brian Urlaub, Senior VP
Director of Geothermal Operations
E. brian.Urlaub@salasobrien.com

TRNSYS (Transient) Modeling

- Extremely Powerful & Flexible Modeling Tool
- Long History of Successful Projects
- Equation Solver Based on Black Box Component Concept
- Components = Pumps, Chillers, Pipes, Geo, Controllers etc.
- Parameters + Inputs → Outputs
- Output to Input Connections
- Very Easy to Add Content (New Models)
- Easily Coupled with Other Tools (Optimization, Loads, Output Processing, etc.)

TRNSYS Synopsis

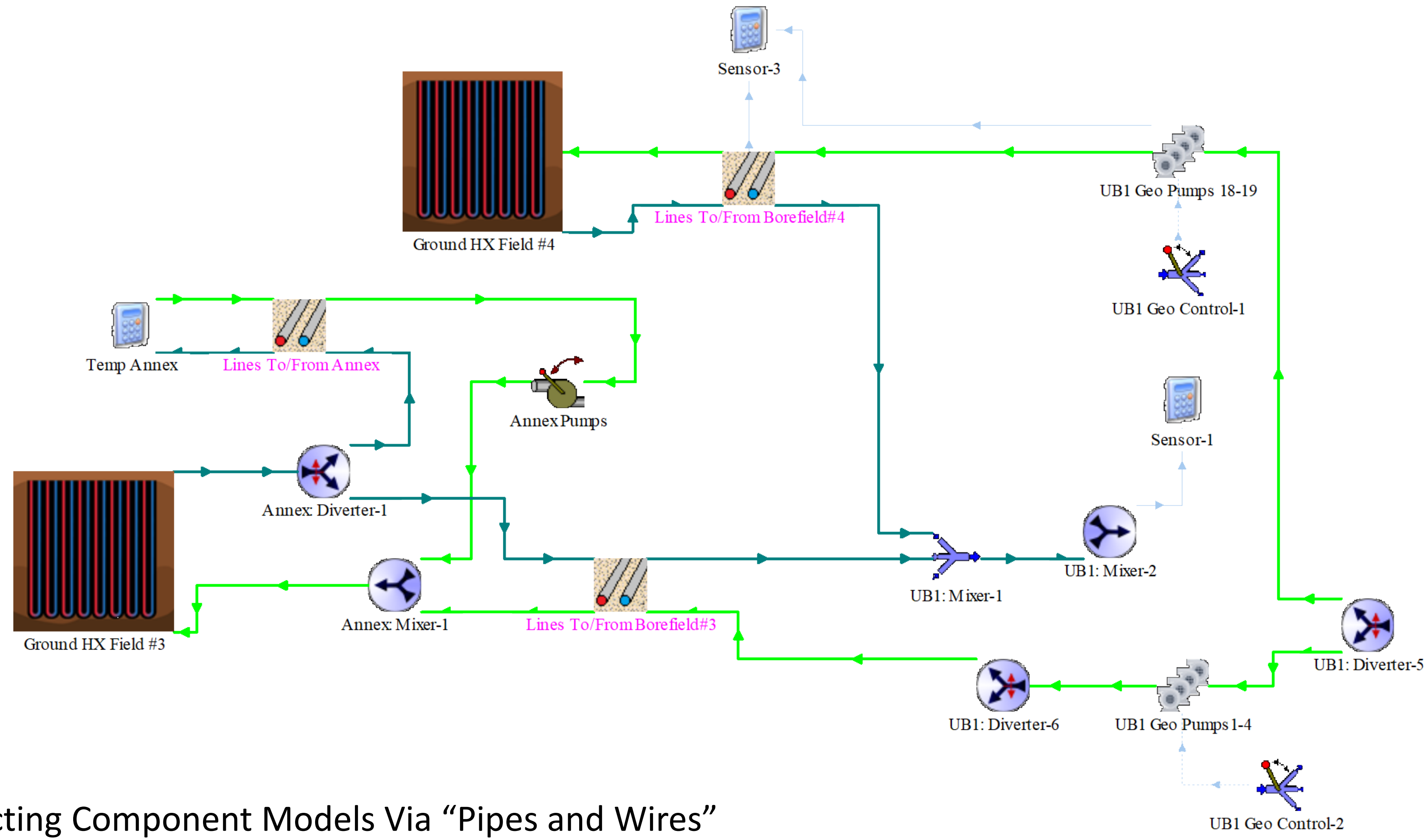
- Dynamic solution technique **reveals interconnected nature of complex system** and its components

- Utilizes an **extensive library of first principles-based component models which can be customized for each specific project**: i.e., boilers, combustion turbines, heat exchangers, pumps, pipes, storage tanks, chillers, heat pumps, cooling towers, energy recovery, ground heat exchangers, and renewable energy systems

- Custom projects are developed for **site-specific controls that can integrate multiple plants, energy sources, loads, or other system stresses**

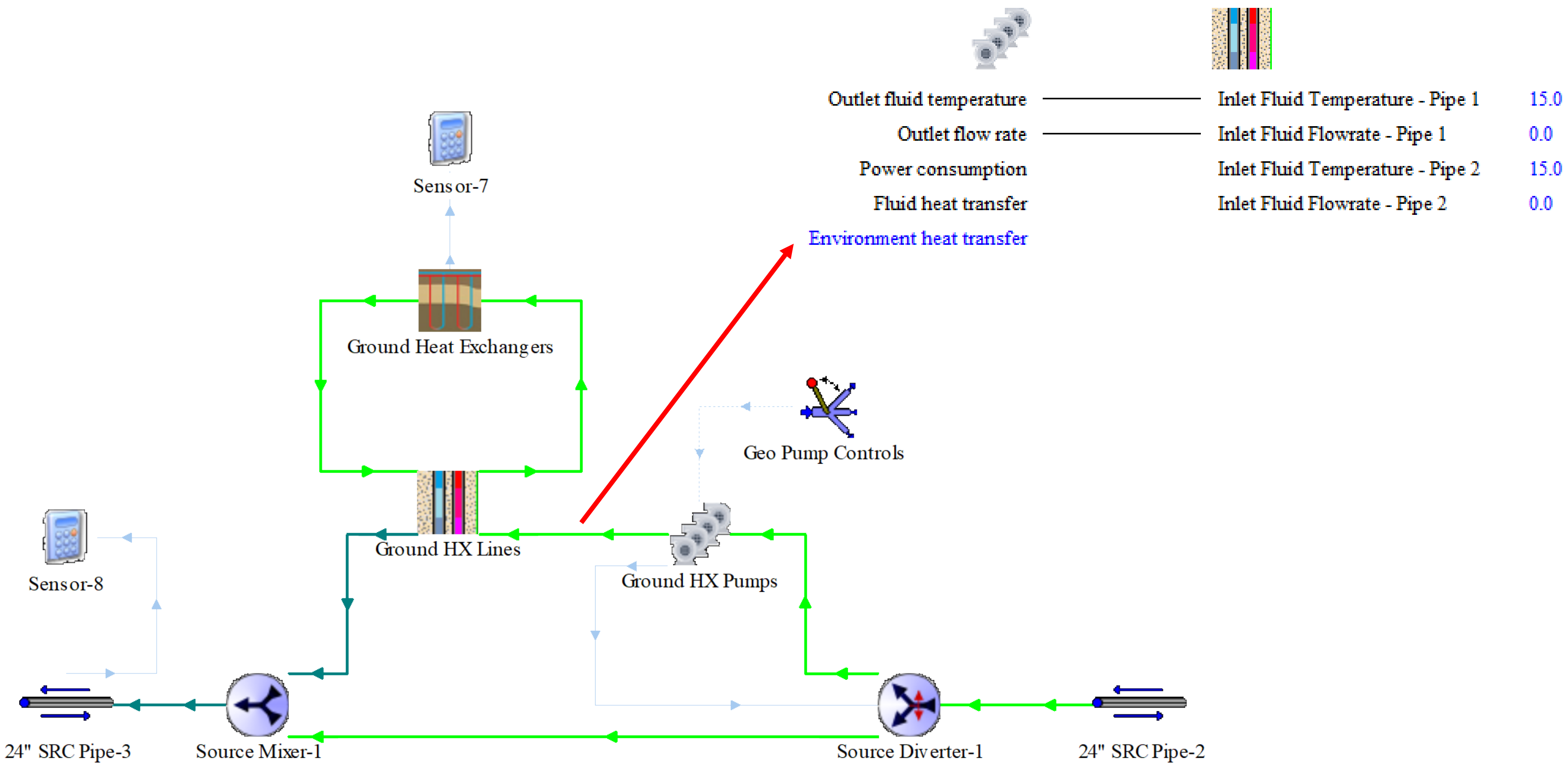
- <u>Planning / Design team can "watch" the modeled system run for greater insight related to asset dispatch, plant performance, and load optimization.</u>

Building the TRNSYS Model



Connecting Component Models Via “Pipes and Wires”

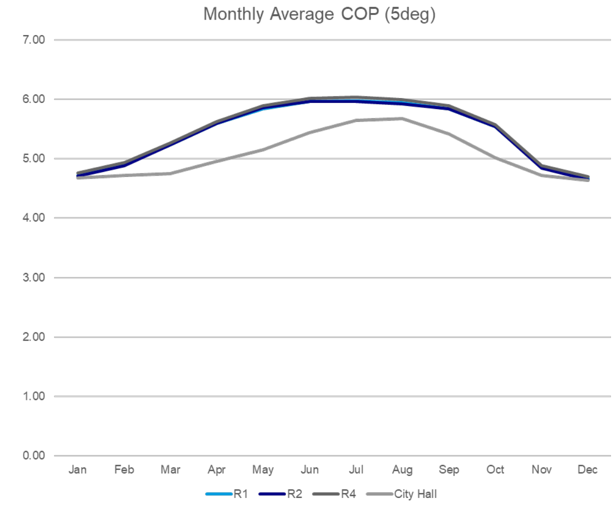
Building the TRNSYS Model

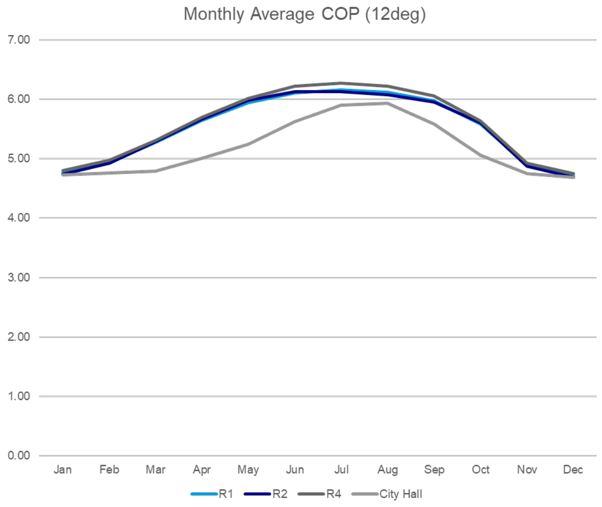


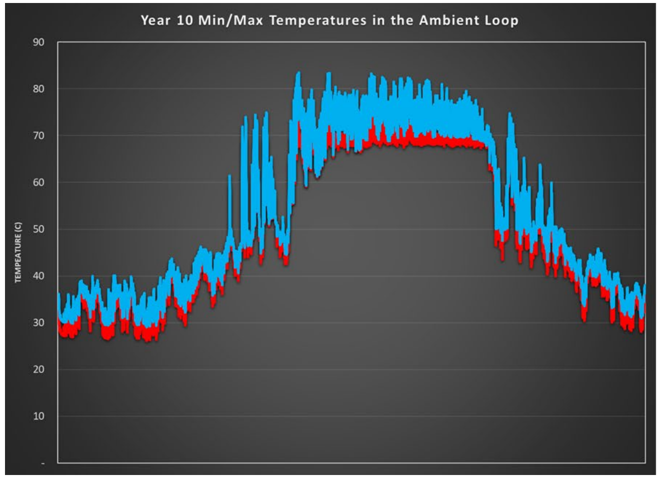
Connecting Component Models Via “Pipes and Wires”

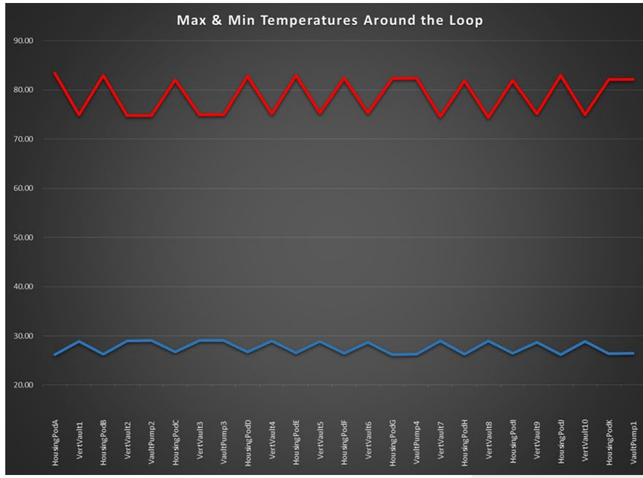
TRNSYS Outputs

- Every Temperature, Flow Rate, Power Consumption, Heat Transfer, Control Signal, etc. Can Be Output at Every 1-Minute Timestep - or Integrated and Reported Hourly, Daily, Monthly, and Annually
- Outputs Can be Displayed as the Simulations Run to Study System Behavior, Control Decision Impacts, etc.









Questions?

Thank You!

Thermal Energy Network Modeling Tools

Moderator: Aeowyn Kendall / *Aztech Geothermal, LLC*

Panel: Brendan Hall / *CHA Solutions*

Jason Willeford / *Jacobs*

Victor Braciszewski / *SmithGroup*

Brian Urlaub / *Salas O'Brien*