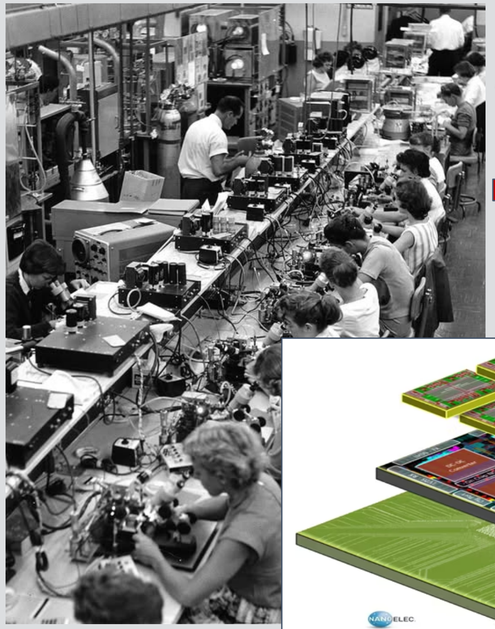
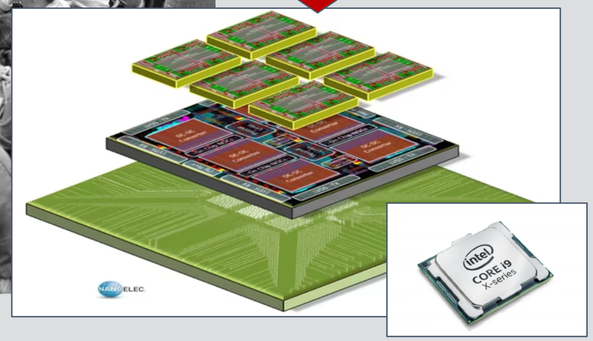
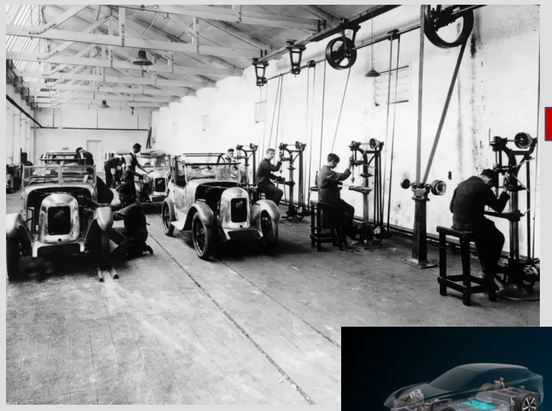


Production line at Fairchild Semiconductor in San Rafael, 1960





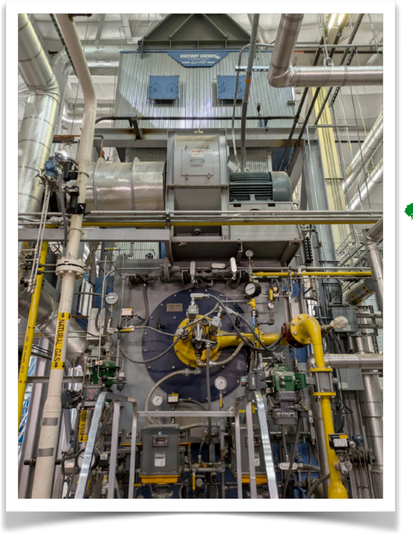
The assembly line at Ford in Detroit, early 1900



Customized EV modular platform, Williams Advanced Engineering (WAE)

Platform-Based Design for energy system retrofits

Michael Wetter and Matthias Sulzer
Lawrence Berkeley National Laboratory
October 14, 2026



?

Energy systems are still designed using pre-industrial, craft-based modes of engineering

BERKELEY LAB

Overview

The problem

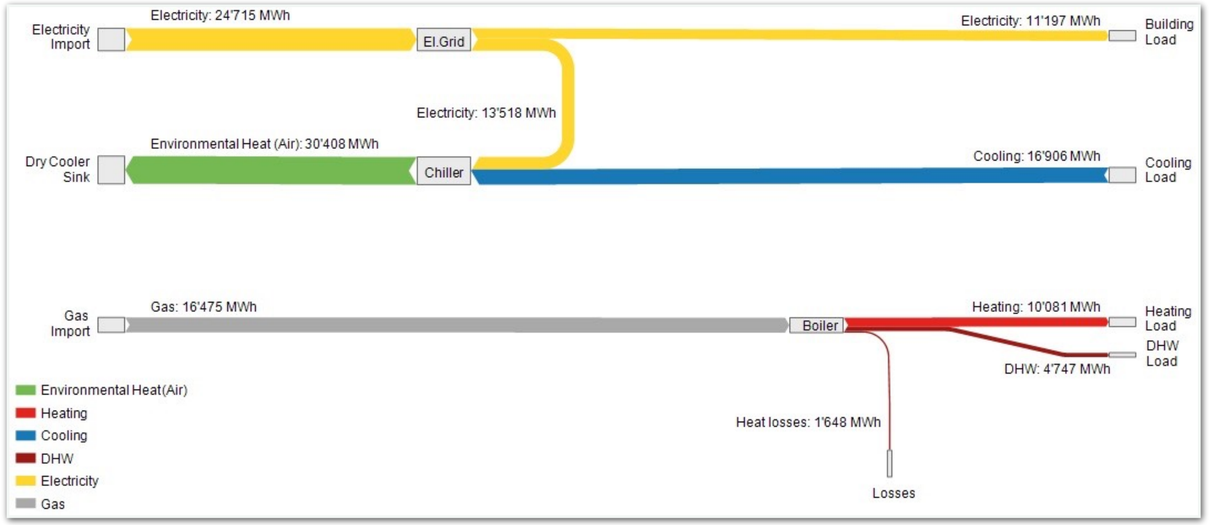
Platform-Based Design

Application at Joint Base Andrews

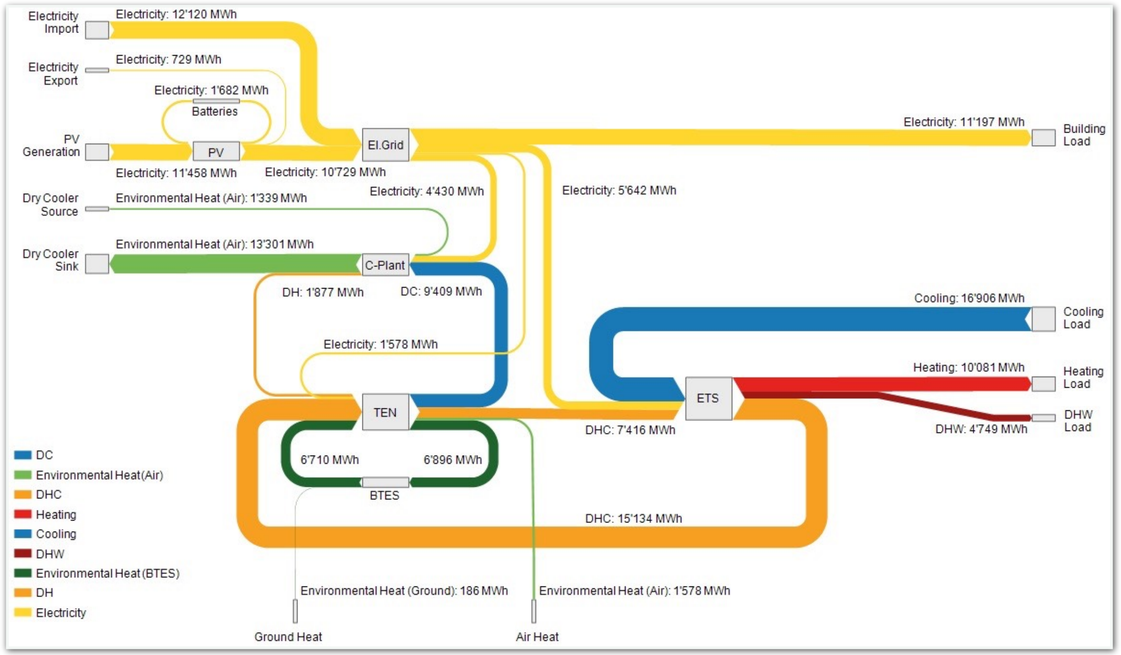
The role of Modelica

Problem

How do you discover energy systems that reduce energy use by 4x, peak demand by 2x, and are financially viable?
… and how do you de-risk them and reliability install and operate them?



Gas heating and air-source chiller**:**
2 coupled systems.



Geothermal Energy Network with PV and batteries.
25 coupled systems.

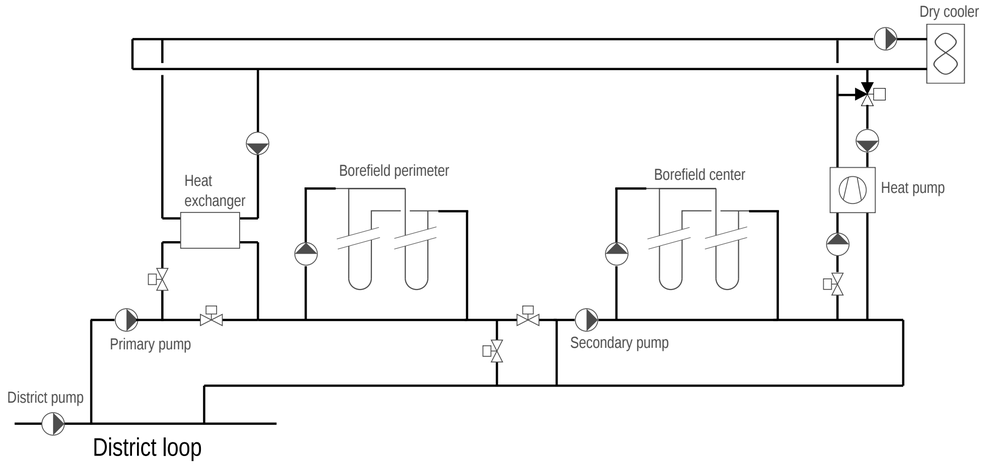
Michael Wetter, Matthias Sulzer, Eric Nyenhuis, Jianjun Hu, Hongxiang Fu, Remi Patureau, Virak Dee, Andrew Tech.
Design, Verify, Deploy: The New Platform-Based Design Paradigm for Large-Scale Energy System Retrofits.
https://dx.doi.org/10.2139/ssrn.6557422

75% energy reduction.
45% electricity peak reduction.
100% gas reduction.

6% increase in life cycle costs.

Additional financial benefits of PBD:
- >$2 million in first cost reduction
- >$300,000 in annual life cycle cost reduction
- catching design flaws prior to construction

Geothermal coupled thermal energy networks require a fully coupled subsurface, energy and control simulation



These are not wrong, but they depend on the energy & control system context!

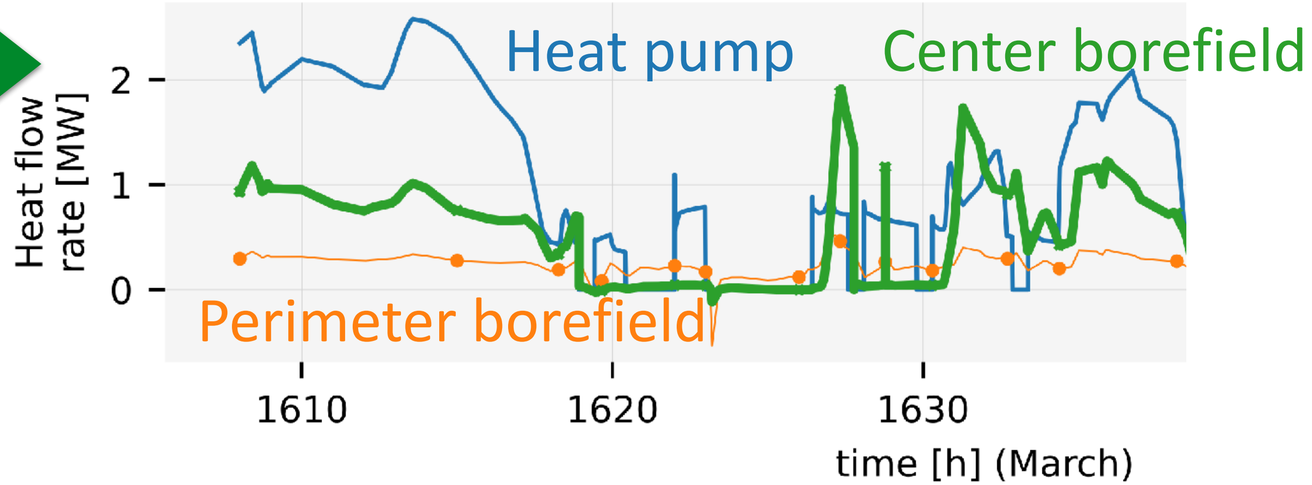
18 Thermal use of shallow groundwater

Table 1.2 Specific heat extraction rates for single closed system BHEs (W m^{-1}) of 40–100 m length (only heating) for given total annual operation times

		VDI 4640 (VDI 2001a)	*VDI 4640 (VDI 2001a)*	*MCS (2011)*	*Numerical Simulation (Erol 2011)*
Rock and soil material		*1800 h/a*	*2400 h/a*	*2400 h/a*	*2400 h/a*
Unconsolidated soils (dry conditions)	Sand	<25	<20	n. a.	38–48
	Gravel	<25	<20	n. a.	34–43
Unconsolidated soils (saturated)	Clay	35–50	30–40	22–35	27–32
	Loam (silt)	35–50	30–40	22–35	32–39
	Sand	65–80	55–65	23–46	38–49

Stauffer et al, 2013. https://doi.org/10.1201/b16239

Dynamic coupling is critically important



A process problem is that industry crafts complex dynamic energy systems in discipline silos, defers testing past construction, and then patches the system until “it works”.

Business as usual:
American Institutes of Architects (AIA) stages



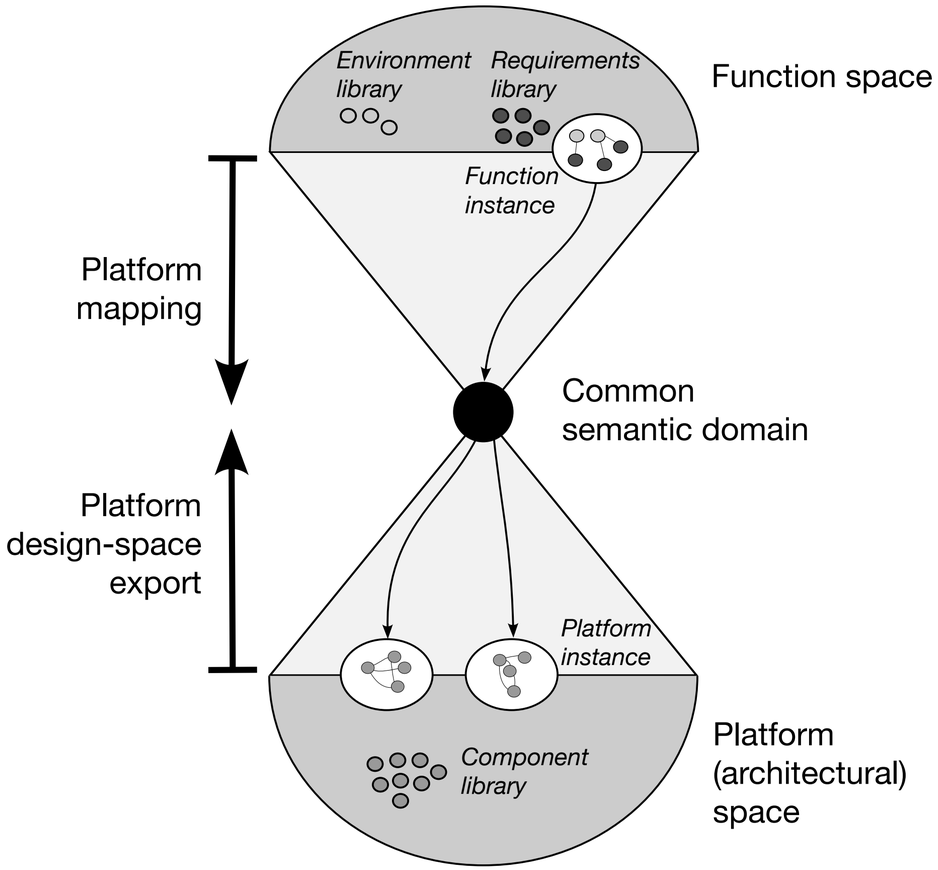
The first time that a system is being tested is during operation!

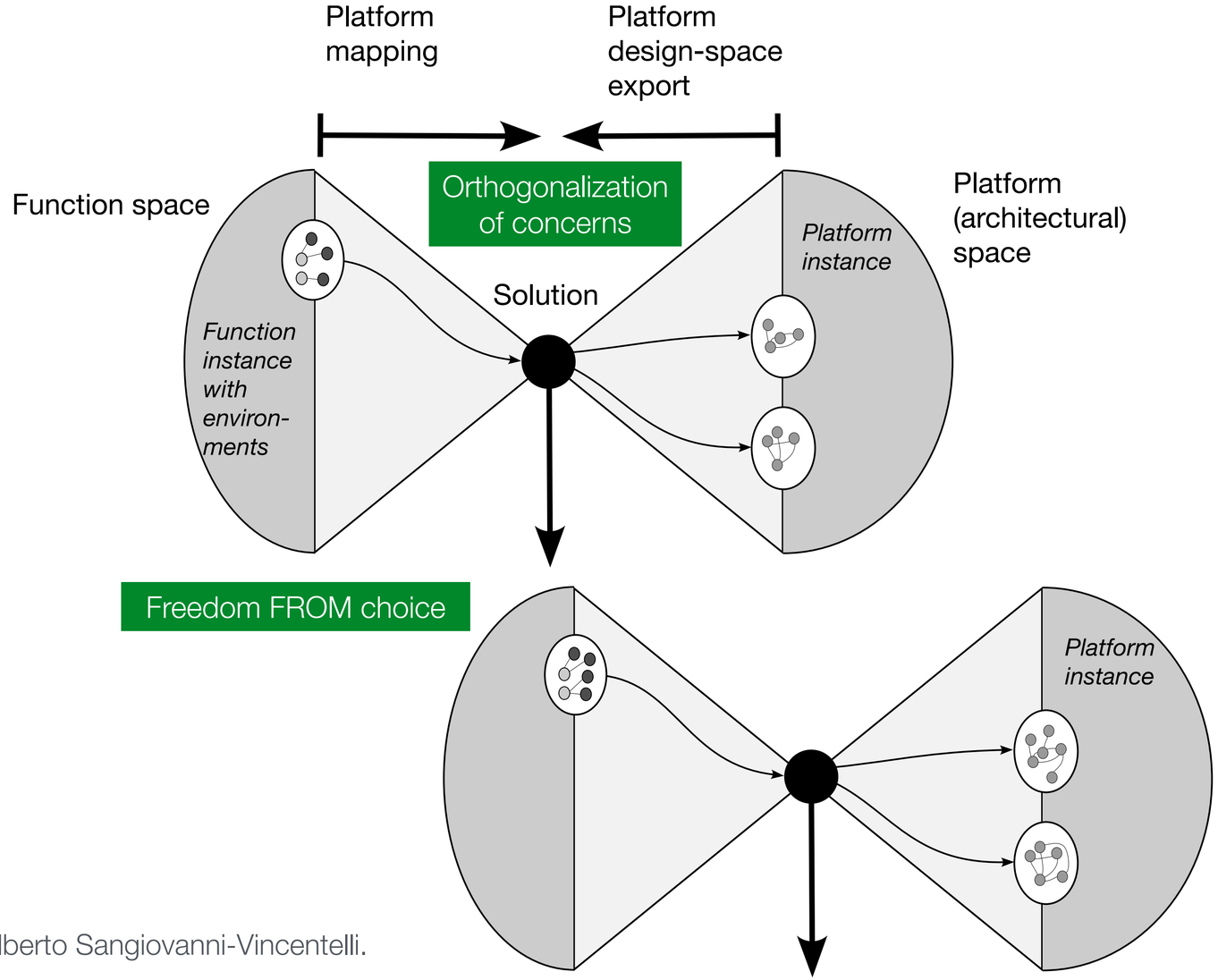
- You cannot improve system quality through trial and error during operation.
- Late-stage error recovery is very costly.

This is pre-industrial craft-based, biased engineering in which human interactions and negotiations patches a system!

A holistic approach for sequential decision making under uncertainty: Platform-Based Design

The core principle of Platform-Based Design is the clear separation of functional space and platform space, with successive refinement of design where the model becomes the specification



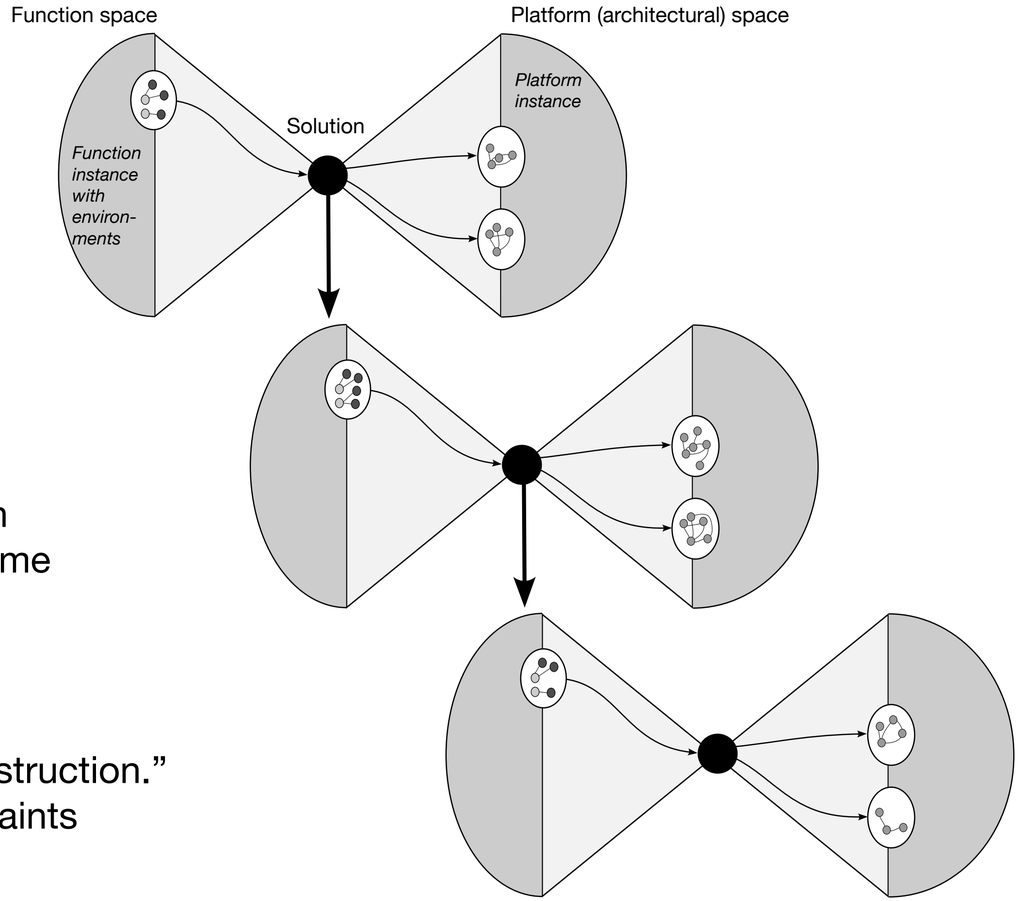


Matthias Sulzer, Michael Wetter, Robin Mutschler and Alberto Sangiovanni-Vincentelli.
Platform-based design for energy systems.
Applied Energy, 352, 2023.

Platform-Based Design manages complexity, enables holistic design space exploration and de-risks design



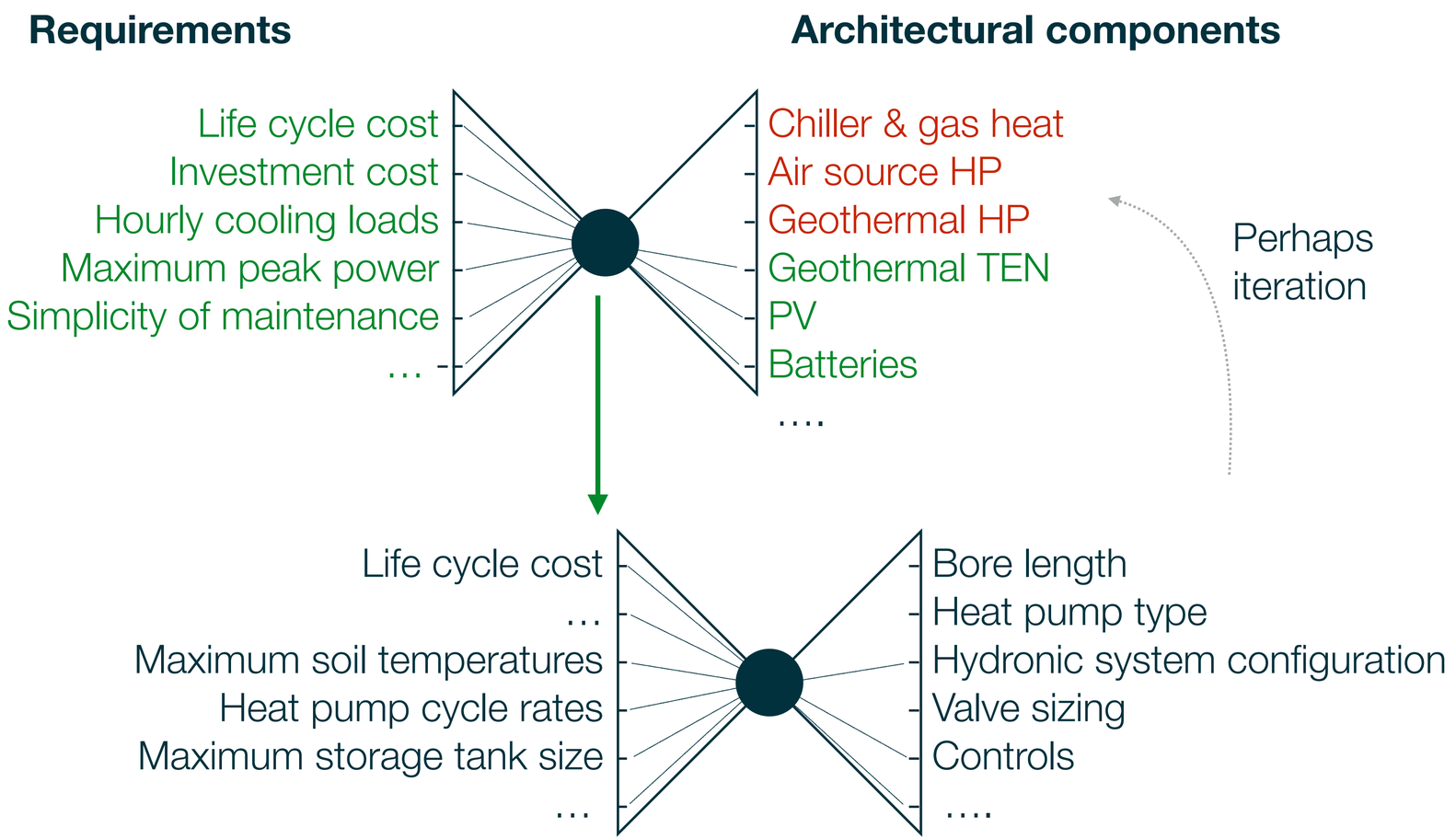
Objective	Requirements	Approach
Configure and size system	• Costs. • Meet loads. • …	Optimization, such as MILP or NLP
De-risk system integration and dynamic operation	Above, plus • control stability • setpoint tracking • failsafe operation • equipment run-time • …	Dynamic modeling of energy, controls using Modelica Buildings Library
Digitally manufacture & install	Above, plus • “Correct-by-construction.” • Real-time constraints • …	Deploy using ASHRAE Standards 231 and 223P



Application at Joint Base Andrews

Platform Based Design demonstration at Joint Base Andrews, Maryland





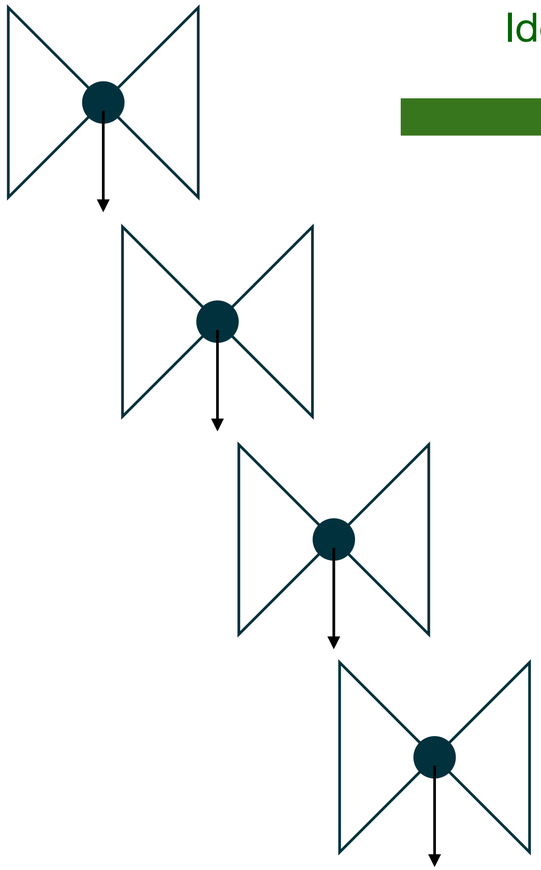
Platform Based Design - identifying set of permissible candidate solutions

DoD Policy & Guidelines

System Selection

Design & Verification

Manufacturing & Installation



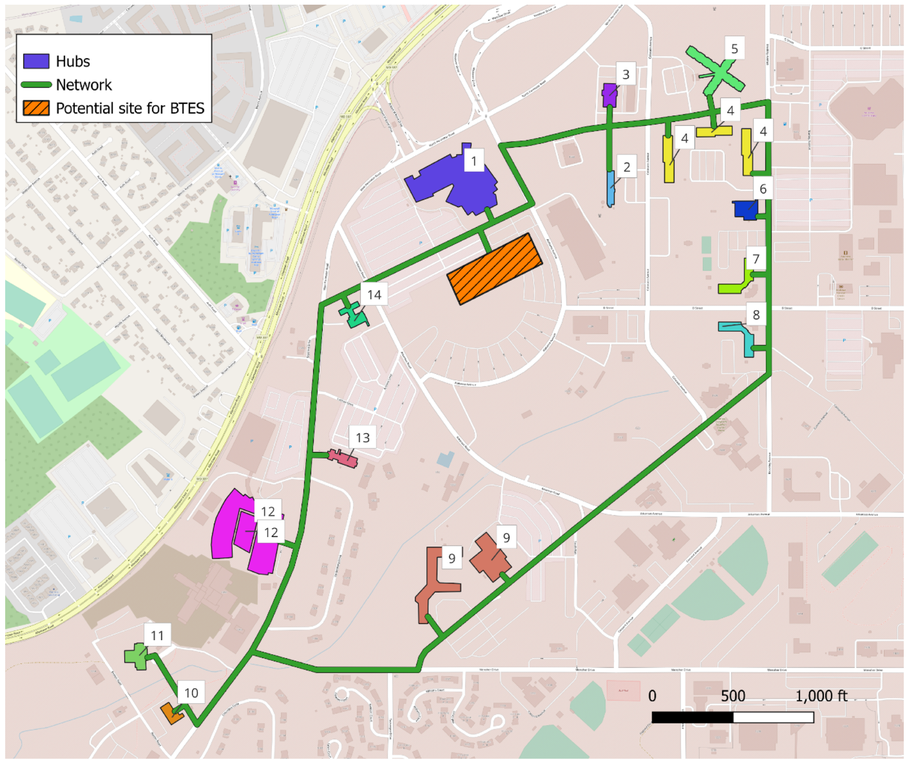
Identify candidate systems

Renew gas furnace and chillers

Air source heat pumps for heating and cooling

Geothermal heat pumps for heating and cooling

Thermal energy network with geothermal storage and heat recovery chillers



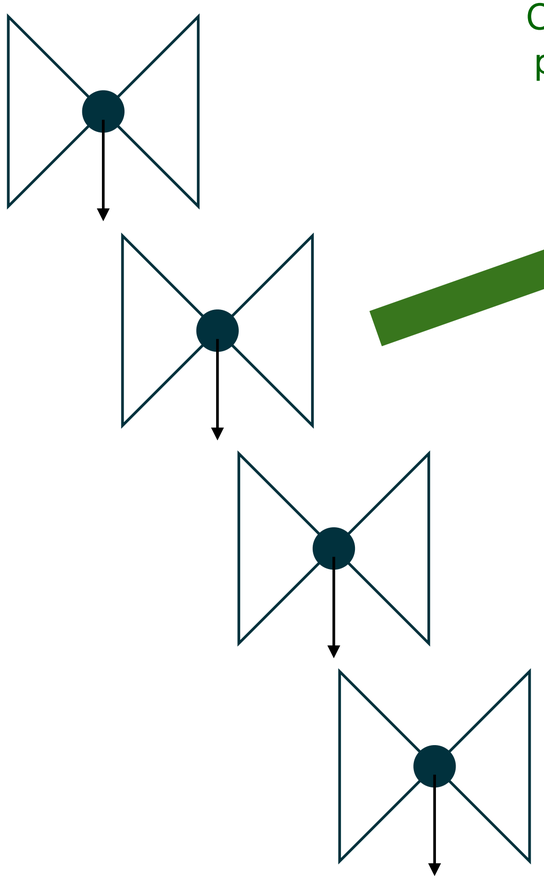
Platform Based Design - contrasting techno-economic performance of candidate solutions

DoD Policy & Guidelines

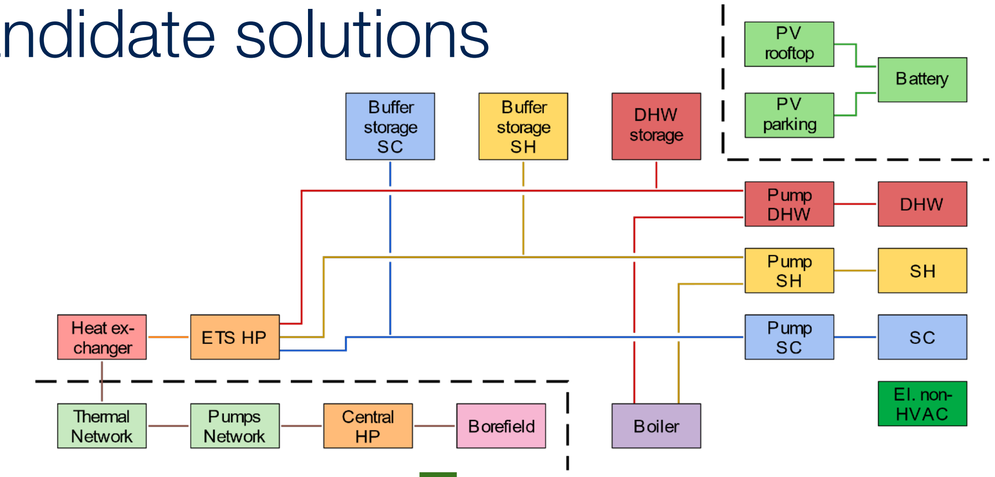
System Selection

Design & Verification

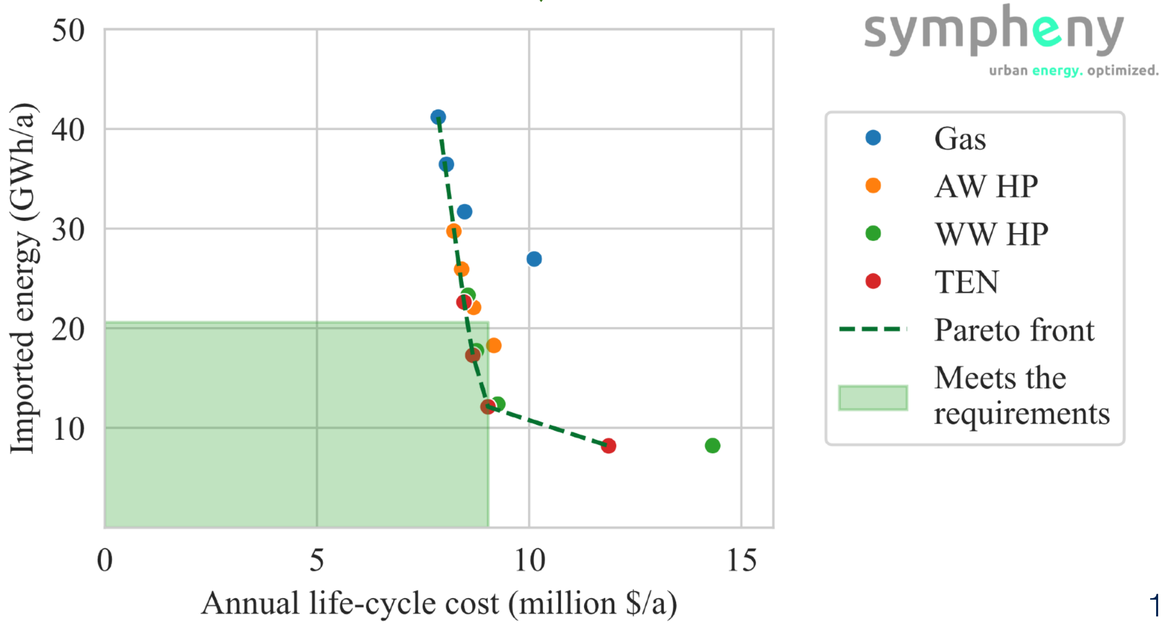
Manufacturing & Installation



Contrast techno-economic performance of candidate systems



System selection based on MILP using energy hub abstraction



M. Geidl, G. Koeppel, P. Favre-Perrod, B. Klockl, G. Andersson and K. Frohlich, "Energy hubs for the future," in IEEE Power and Energy Magazine, vol. 5, no. 1, pp. 24-30, Jan.-Feb. 2007. https://doi.org/10.1109/MPAE.2007.264850

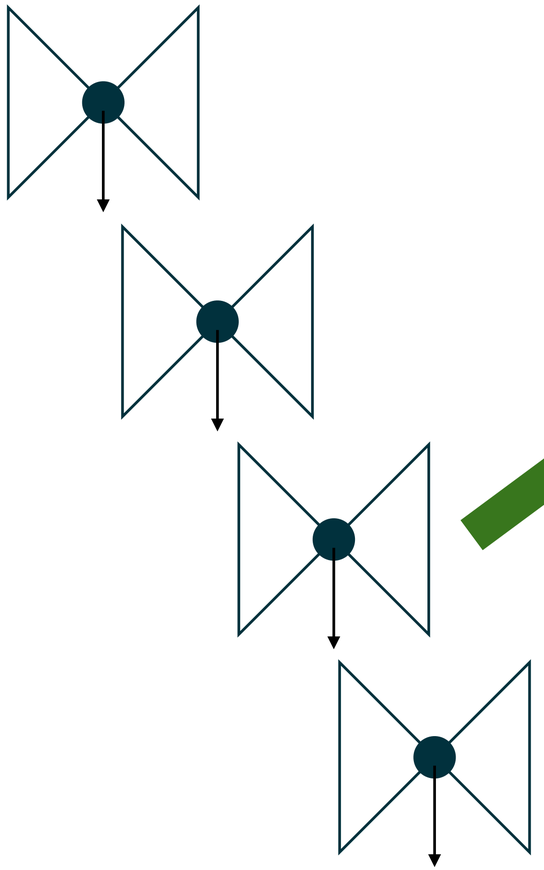
Platform Based Design -
de-risking design and quantifying techno-economic sensitivities

DoD Policy & Guidelines

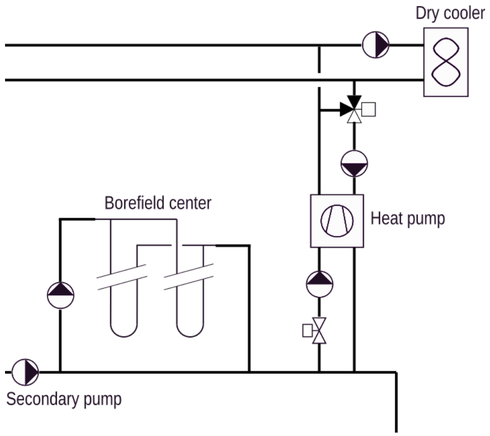
System Selection

Design & Verification

Manufacturing & Installation

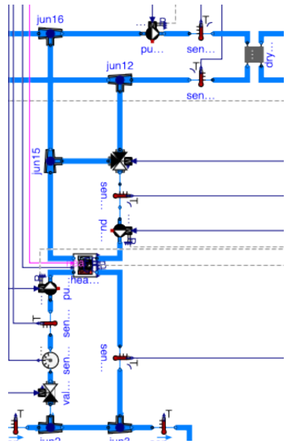


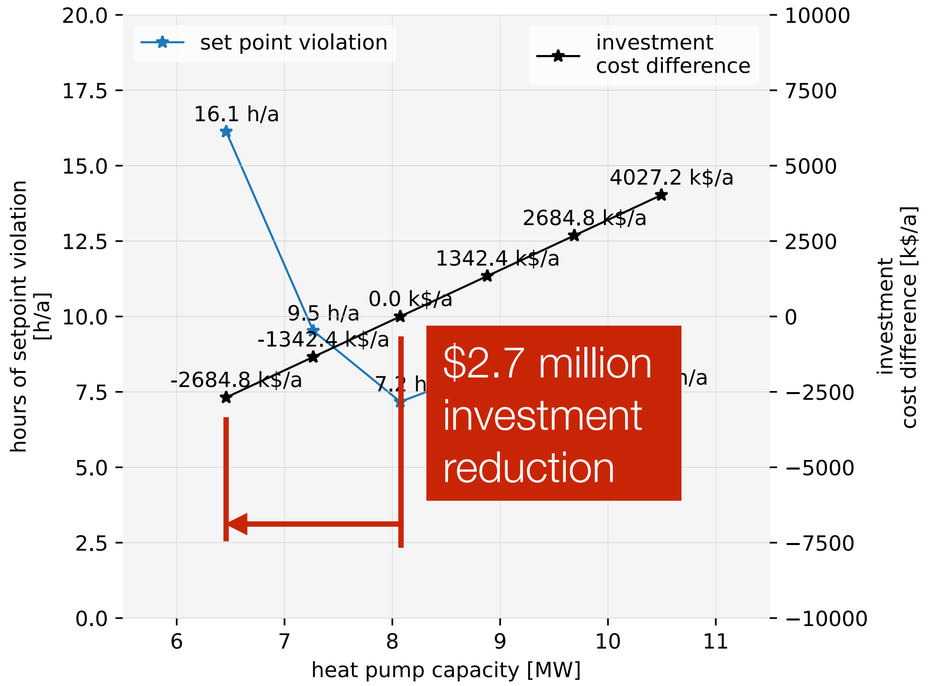
Refine design of candidate solution



Verification using **prescriptive** models that couple mechanical, geothermal and control design

Modelica Buildings Library





Data-driven techno-economic optimization

Michael Wetter, Wangda Zuo, Thierry S. Nouidui and Xiufeng Pang.
Modelica Buildings library.
Journal of Building Performance Simulation, 7(4):253-270, 2014.
doi:10.1080/19401493.2013.765506

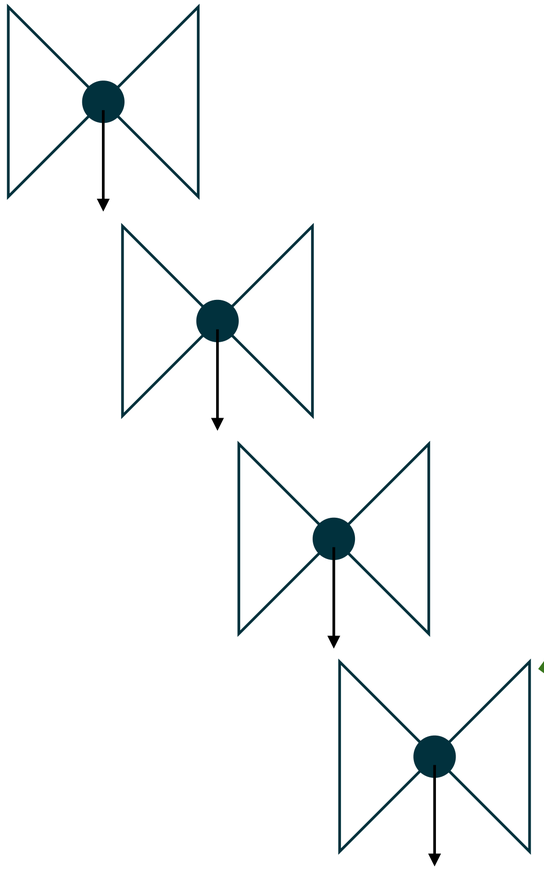
Platform Based Design -
digitalizing deployment based on digital twin technologies and open standards

DoD Policy & Guidelines

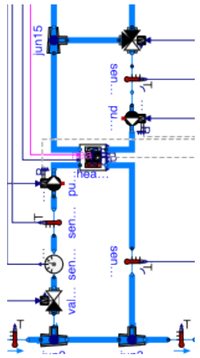
System Selection

Design & Verification

Manufacturing & Installation

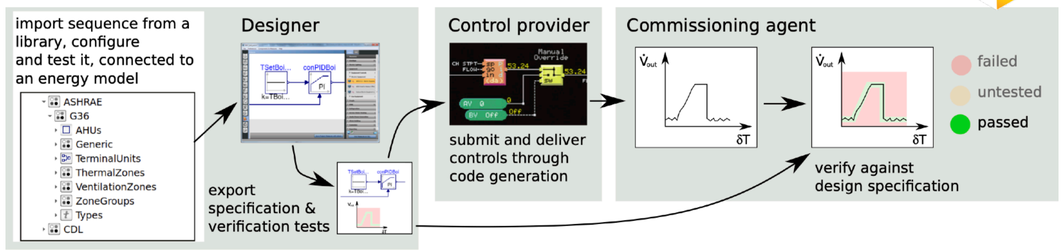


Digitalized construction workflow

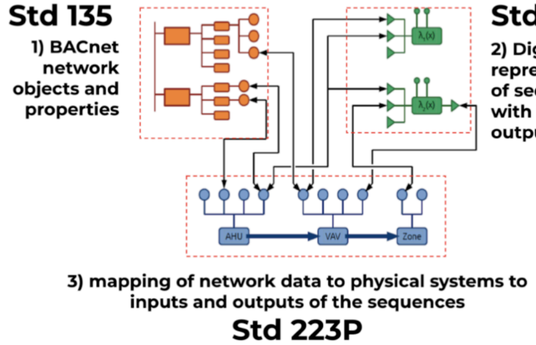


Export verified, digital control specification (Modelica/ASHRAE Std 231)

Open Building Control



Export standardized
- point list
- control logic
- semantic model



Digital twins for operation



M. Wetter, P. Ehrlich, A. Gautier, M. Grahovac, P. Haves, J. Hu, A. Prakash, D. Robin and K. Zhang. OpenBuildingControl: Digitizing the control delivery from building energy modeling to specification, implementation and formal verification. Energy, Volume 238, Part A, 2022.

Marco Pritoni, Michael Wetter, et al.
Digital and Interoperable: The future of building automation is on the horizon. What's in it for me?
ACEEE Summer Study on Energy Efficiency in Buildings Asilomar, CA, August 2024.

The role of Modelica

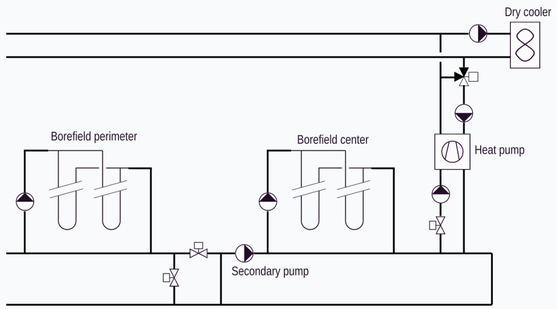
The role of Modelica for system integration derisking and for digitalized control workflows

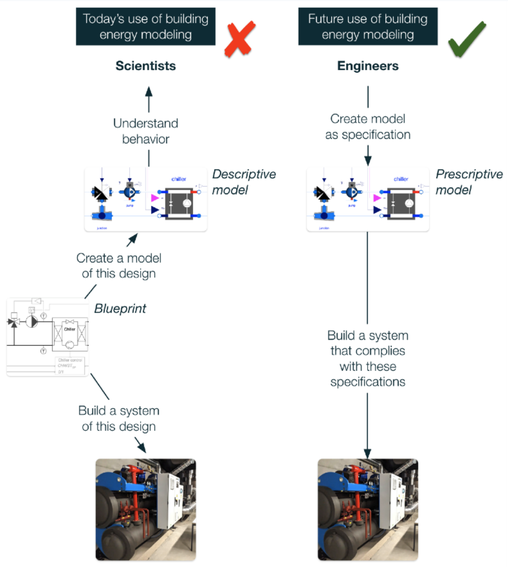
1 → 2 → 3

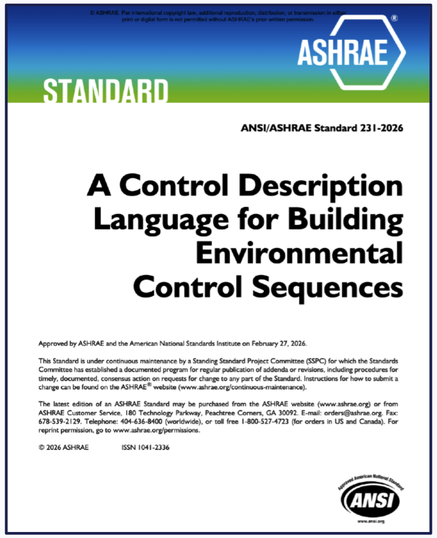
Integration of energy system, geothermal and controls

Specification and testing through prescriptive models

Digital deployment through ANSI/ASHRAE Std 231



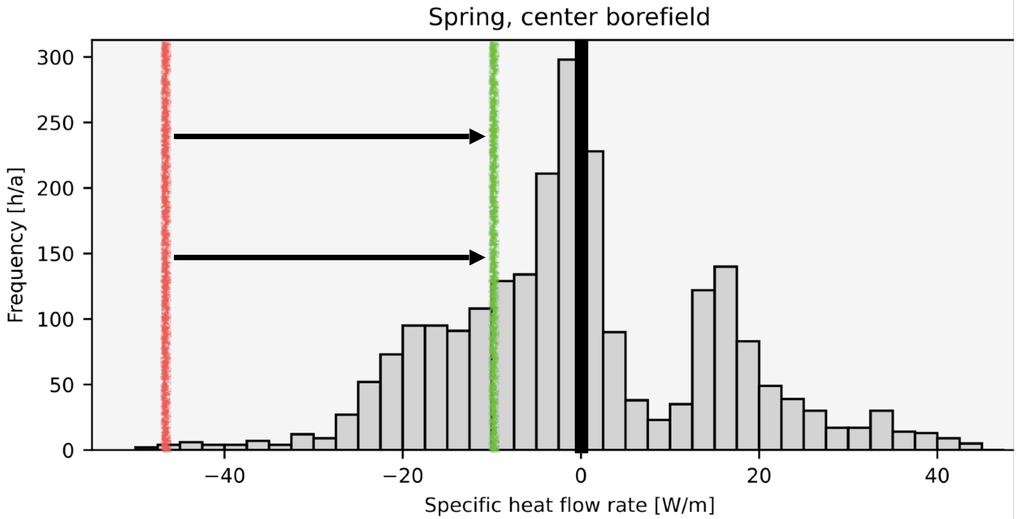




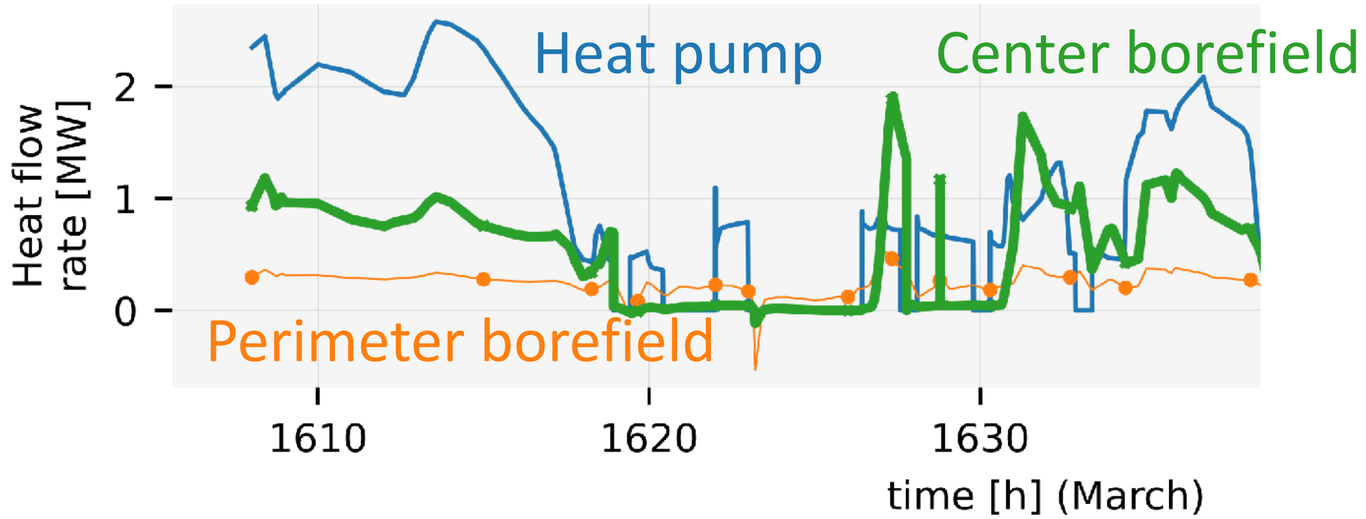
A point in case: Stove-piped geothermal design, energy system design and control design leads to wrong design

Initial MILP input

Revised MILP input, based on Modelica



Modelica Buildings Library



System design **requires a fully coupled** simulation with realistic control.

Coupled geothermal, mechanical and control simulation avoided a grossly undersized central plant.

BERKELEY LAB

Lesson learned: Rushing deployment of established equipment in new, unproven designs risks **unmet performance goals, expensive retrofits, and stranded assets**

Simulation-Enabled De-Risking

Coupled geothermal, energy system, and control simulation enabled systematic de-risking of system integration.

Key Takeaway

All corrections are made on models during the **design stage**, avoiding typical costly, late-stage changes during the commissioning phase.

Learnings are implemented in updated architectural component library, enabling continuous improvement across project portfolios.

1. Heat Pump & Borefield

Heat pump undersized due to MILP performance overestimation.
Corrected via detailed Modelica simulation.

2. Borefield Piping

First integration lacked performance.
Corrected through complete re-design of central plant hydronics.

3. Central Plant & Loop Control

Tested 3 sequences to meet energy performance, maintain district loop temperatures, and avoid heat pump cycling.
Corrected using integrated control simulation.

4. Transfer Station Control

Unstable resets & mistaken tank flushes.
Corrected through hydronics and control changes.

5. Central Plant Economizer

Investment Avoided

Coupled simulations successfully showed this equipment was not worth the financial investment.

Thank you

Michael Wetter
MWetter@lbl.gov

Michael Wetter, Matthias Sulzer, Eric Nyenhuis, Jianjun Hu, Hongxiang Fu, Remi Patureau, Virak Dee, Andrew Tech.
Design, Verify, Deploy: The New Platform-Based Design Paradigm for Large-Scale Energy System Retrofits.
Pre-print: https://dx.doi.org/10.2139/ssrn.6557422

Matthias Sulzer, Michael Wetter, Robin Mutschler and Alberto Sangiovanni-Vincentelli.
Platform-based design for energy systems.
Applied Energy, 352, 2023.
doi:10.1016/j.apenergy.2023.121955

Michael Wetter and Matthias Sulzer.
A call to action for building energy system modelling in the age of decarbonization.
Journal of Building Performance Simulation. P. 1-11. 2023.
doi:10.1080/19401493.2023.2285824

Michael Wetter, Wangda Zuo, Thierry S. Nouidui and Xiufeng Pang.
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Journal of Building Performance Simulation, 7(4):253-270, 2014.
doi:10.1080/19401493.2013.765506

Acknowledgments

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Program (ESTCP) of the U.S. Department of Defense (DoD), under Contract No. EW25-9639.