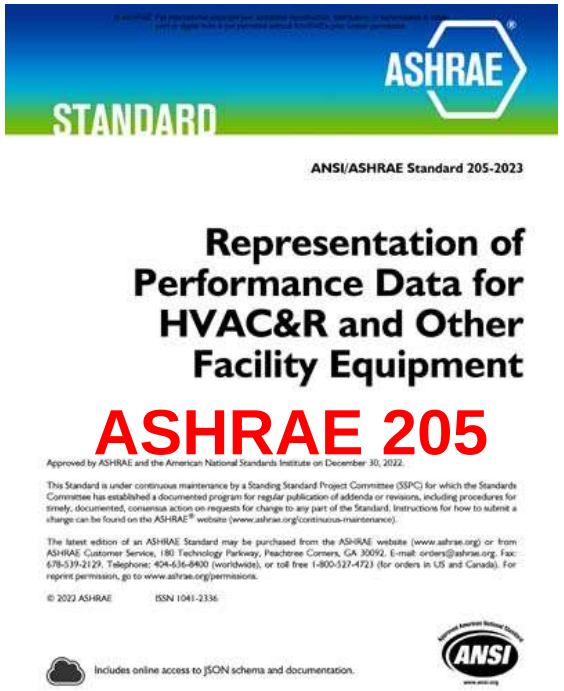
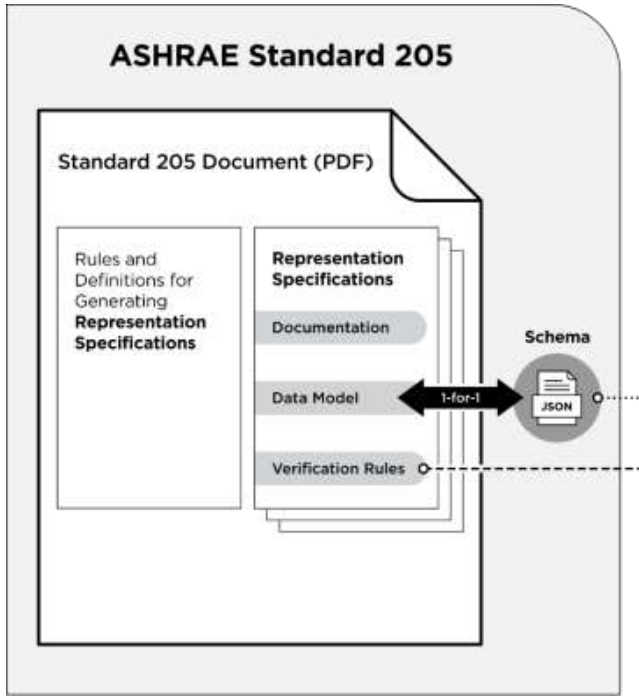
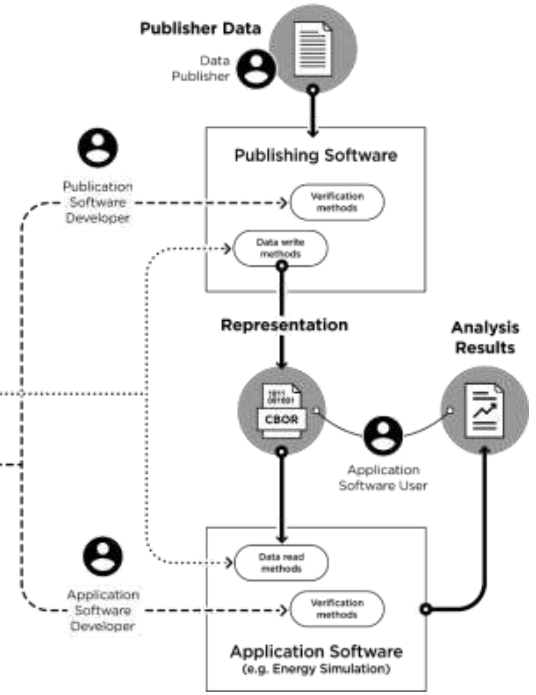
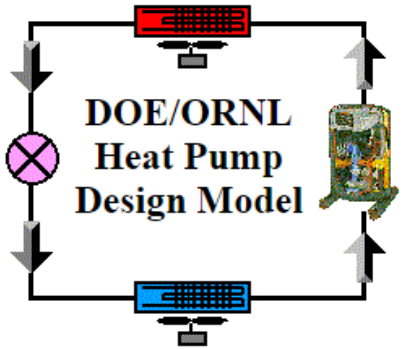
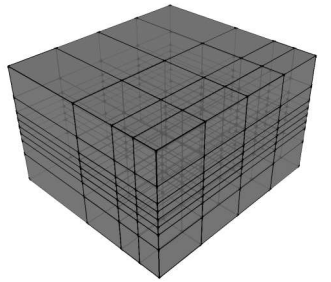
ASHRAE 205 Development and Maintenance









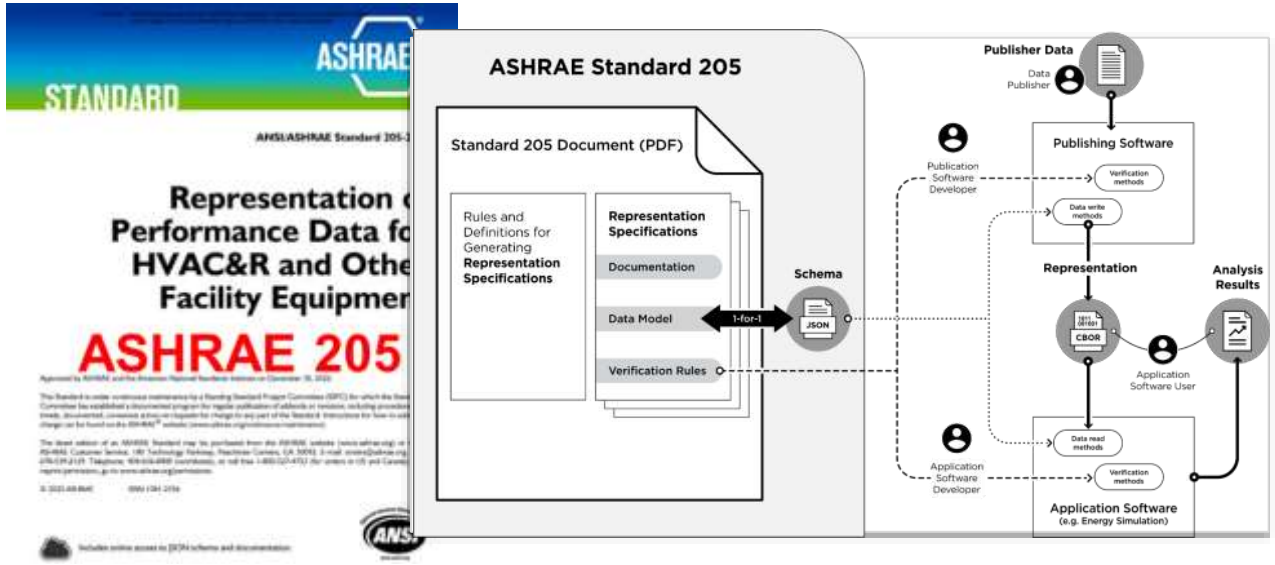


Argonne and Oak Ridge National Laboratories
PI: Dr. Ralph T. Muehleisen
rmuehleisen@anl.gov
WBS 3.5.5.51

Project Summary

Objective and outcome

ASHRAE Standard 205 “Performance Data for HVAC&R Equipment” improves the accuracy of HVAC performance data used in BEM, allowing HVAC equipment to be properly evaluated and sized. This is especially important for newer equipment that has multiple operating modes and complex performance characteristics.



Team and Partners

- **Argonne National Laboratory**
  - Big Ladder Software, Thermal Energy System Specialists
- **Oak Ridge National Laboratory**

Stats

Performance Period: 10/2022 – 9/2025

DOE budget: $850k, Cost Share: $0k

Milestone 1: First Stakeholder Meeting

Milestone 2: Publication of 205-2023

Milestone 3: Publication of First 205 Addenda

Problem: Rating Standards are NOT sufficient for Modeling

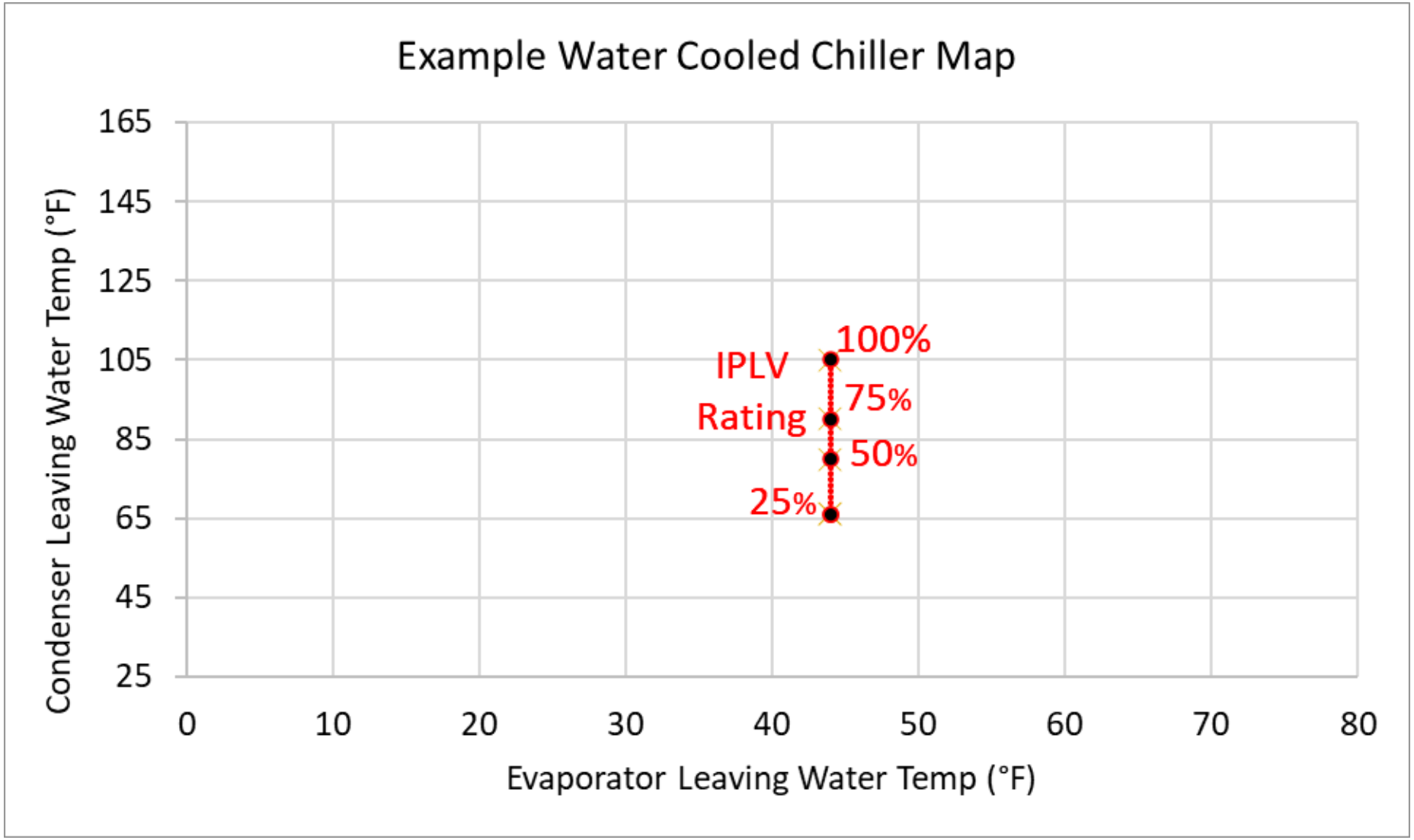
Standard Ratings are Insufficient for Detailed Models

- Standard equipment ratings (SEER, IPLV, etc.) do not provide enough information to model equipment over its full operating range
- Even some Standardized Maps (e. g. AHRI Certified) do not cover full operating range

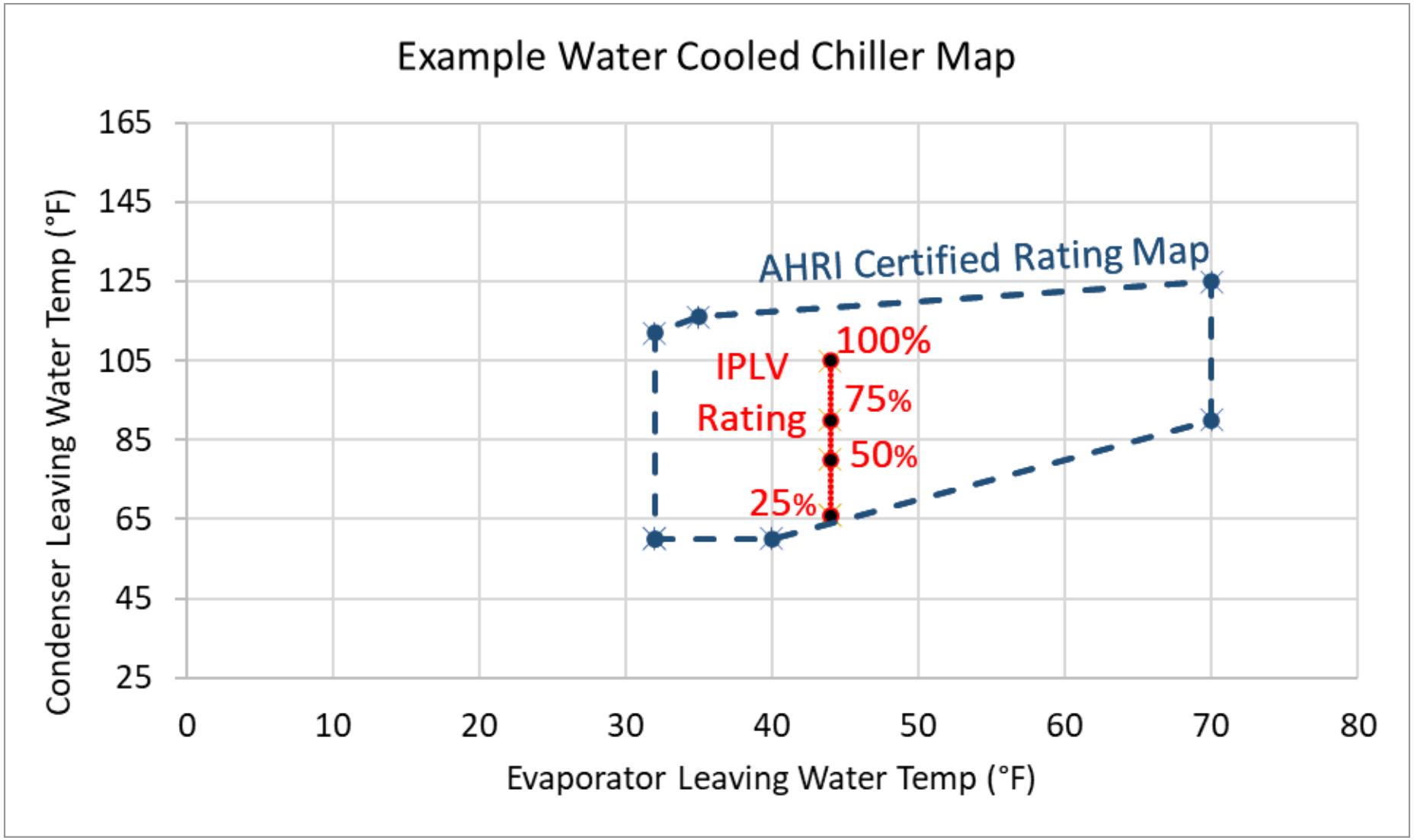
Lack of Model Consistency Between Software

- Performance curves are not standardized, so different software use different curves and predict performance differently
- Software developers and modelers need to "guess" on operating range of equipment
- Performance curves poorly model advanced multicomponent systems

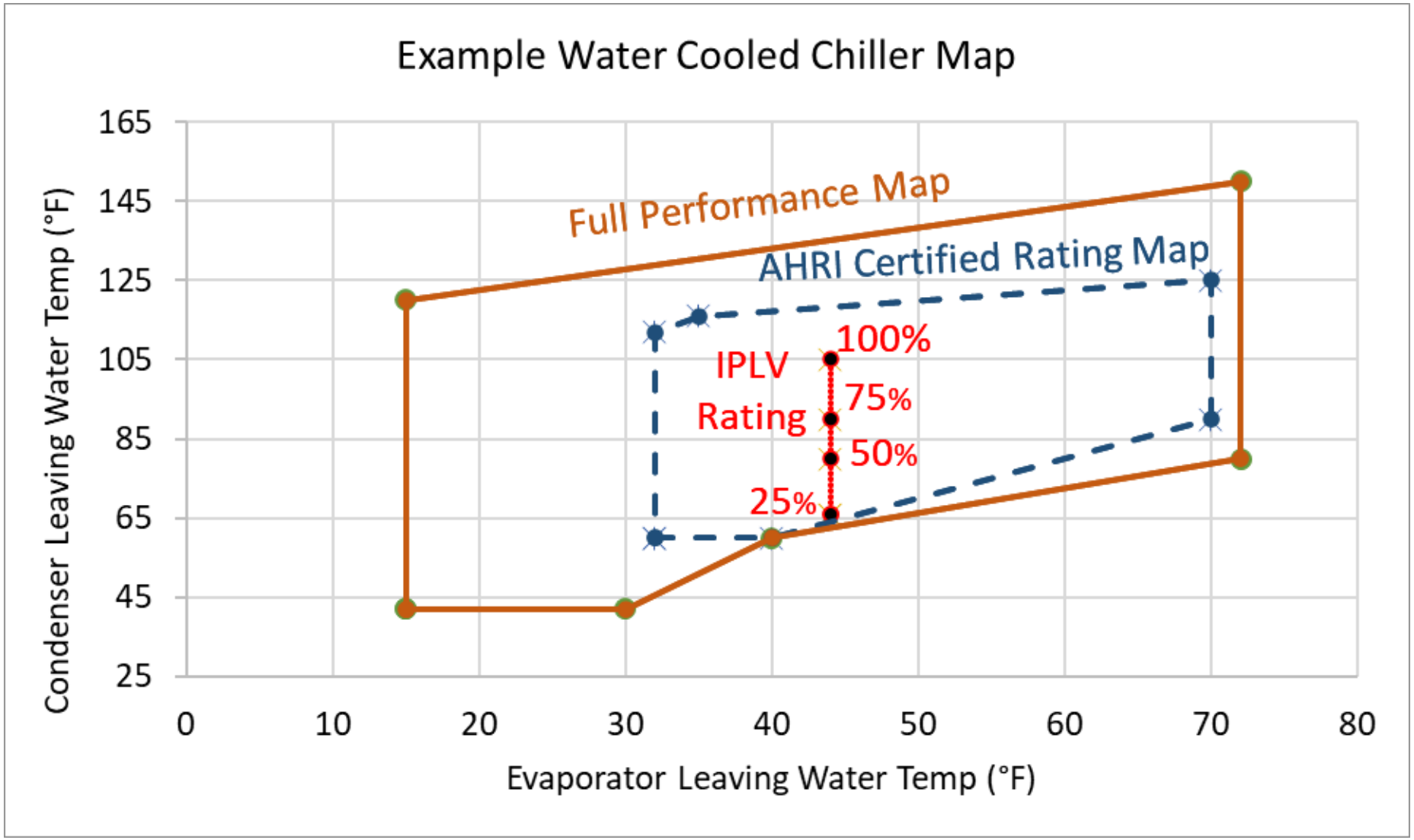
Problem: Rating Standards are NOT sufficient for Modeling



Problem: Rating Standards are NOT sufficient for Modeling



Problem: Rating Standards are NOT sufficient for Modeling



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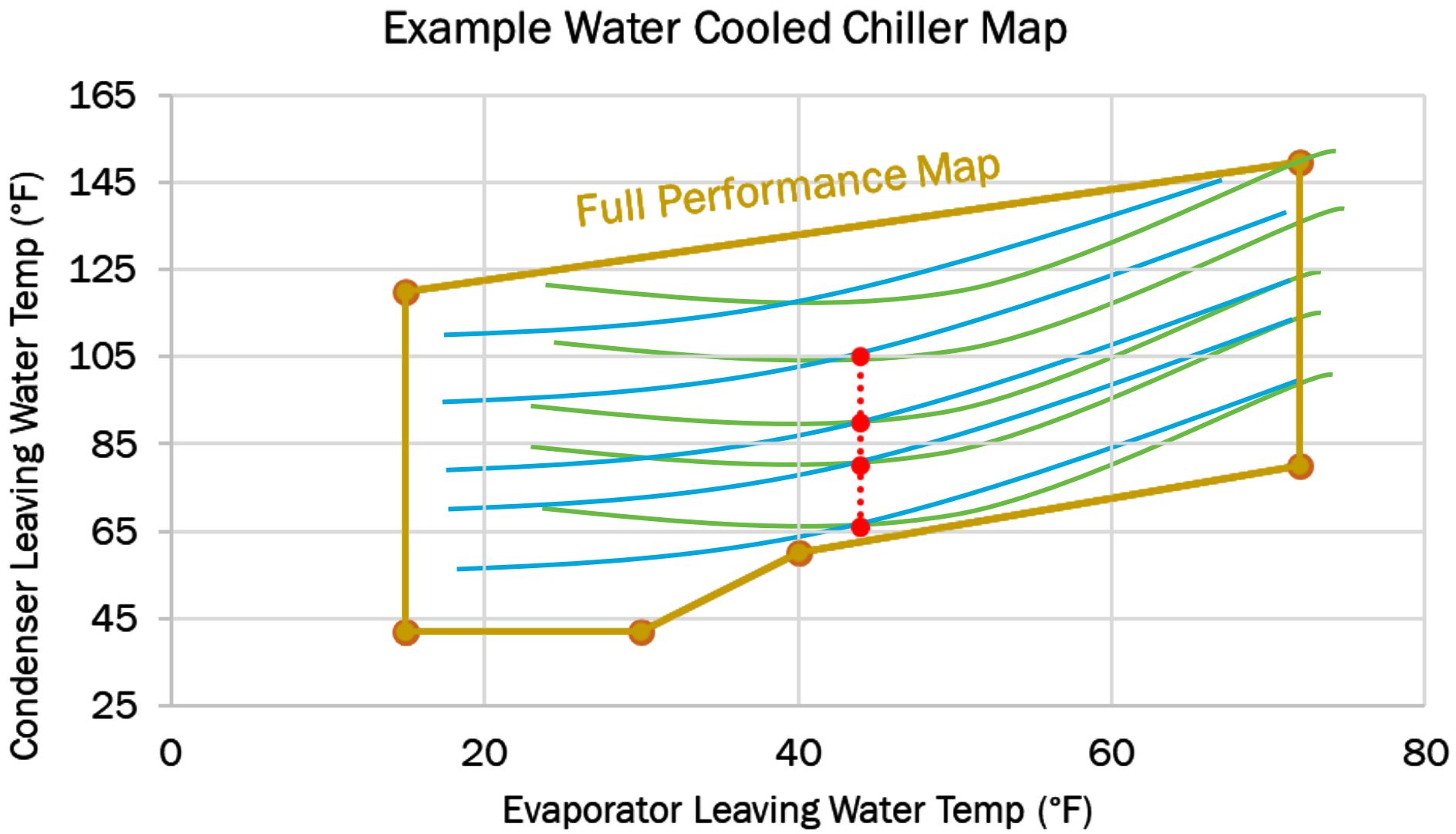
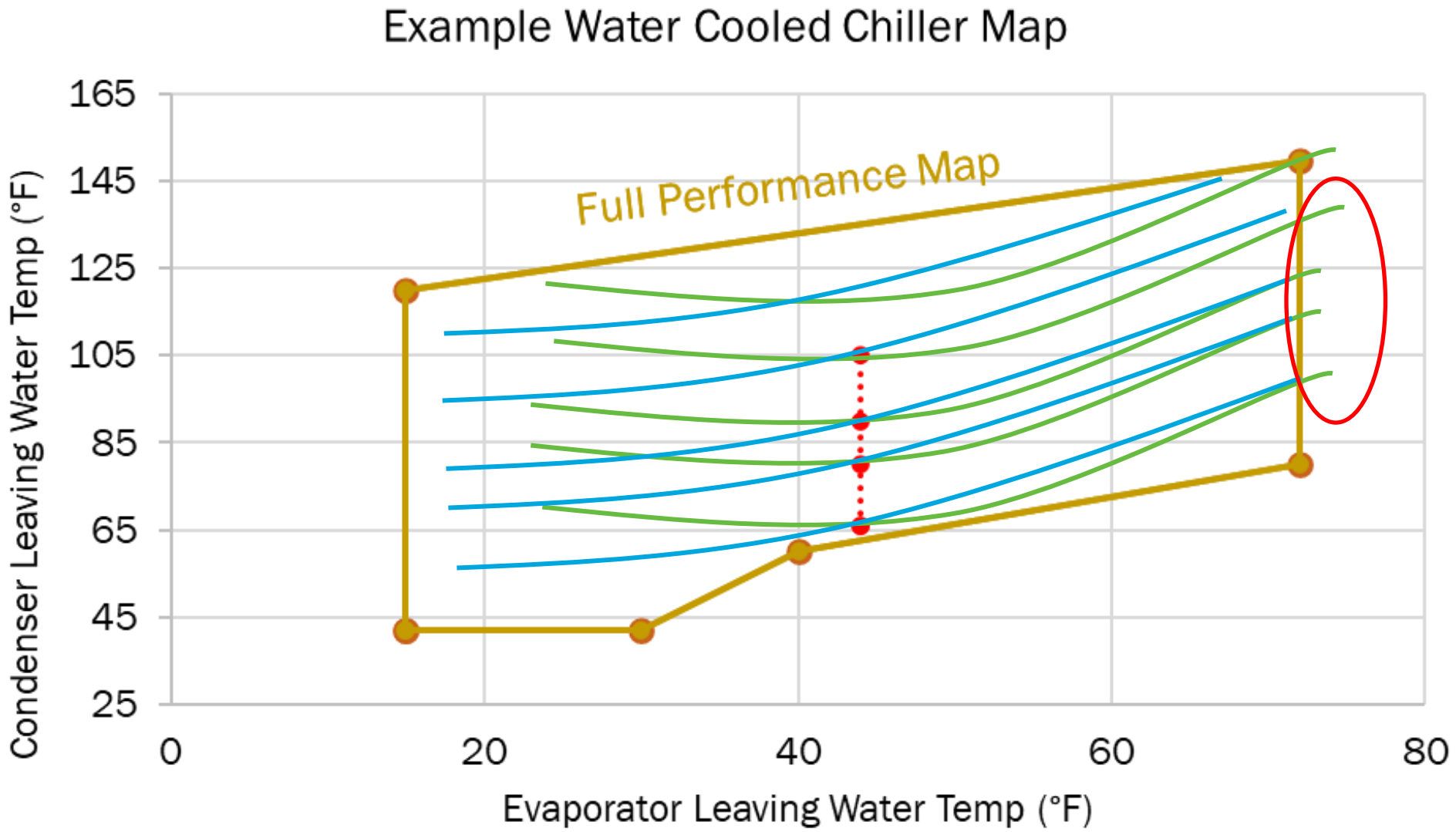
Problem: Performance Curves are not Standardized

- Different Software = different performance curves = different predictions of energy use
- Systems of multiple components are not always accurately modeled using multiple curves



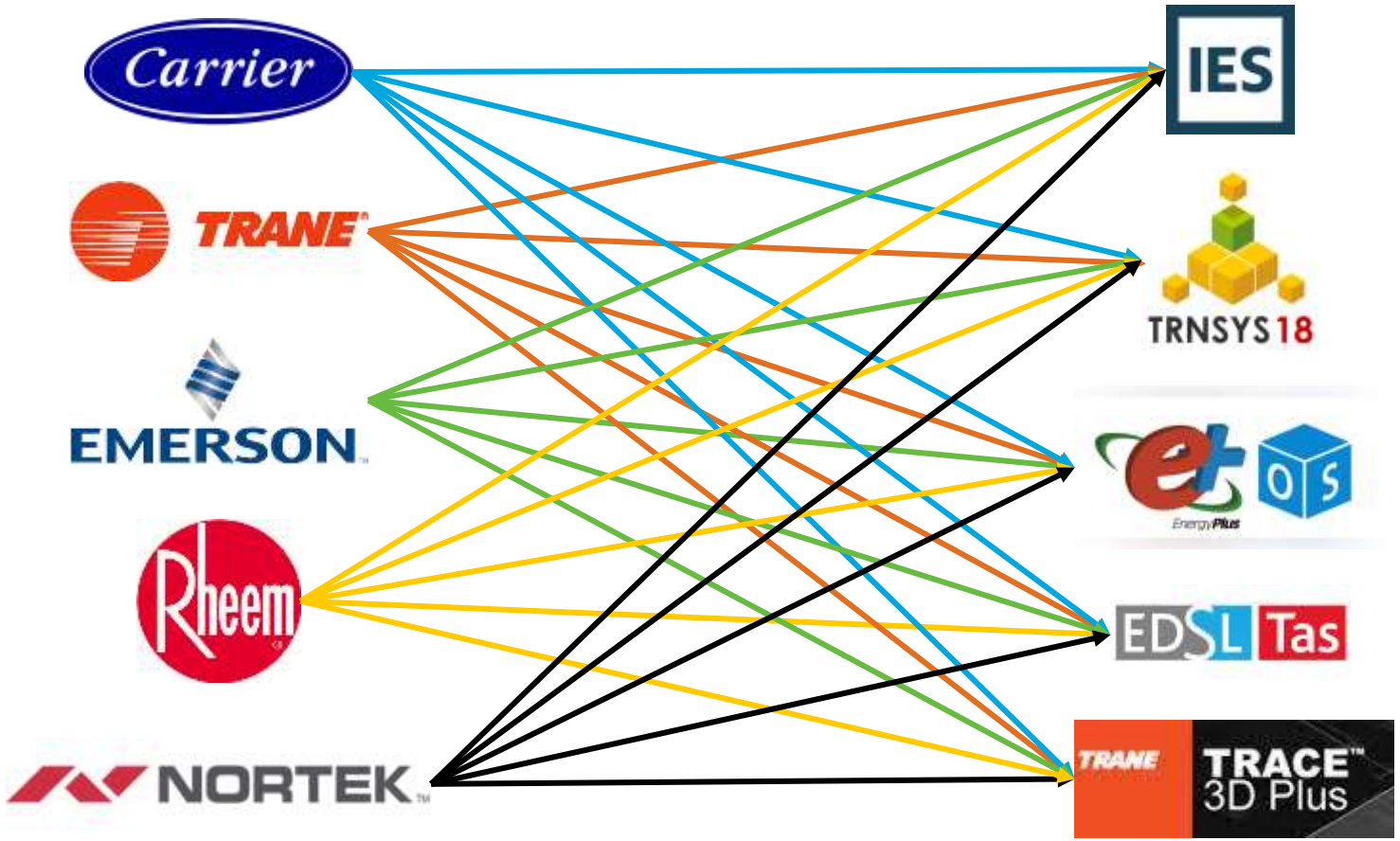
Problem: Performance Curves are not Standardized

- Performance curves missing info about when equipment shuts down
- No standard way for manufacturer to inform simulation about safe operating region



Problem: No Standard Way to Communicate Performance Data

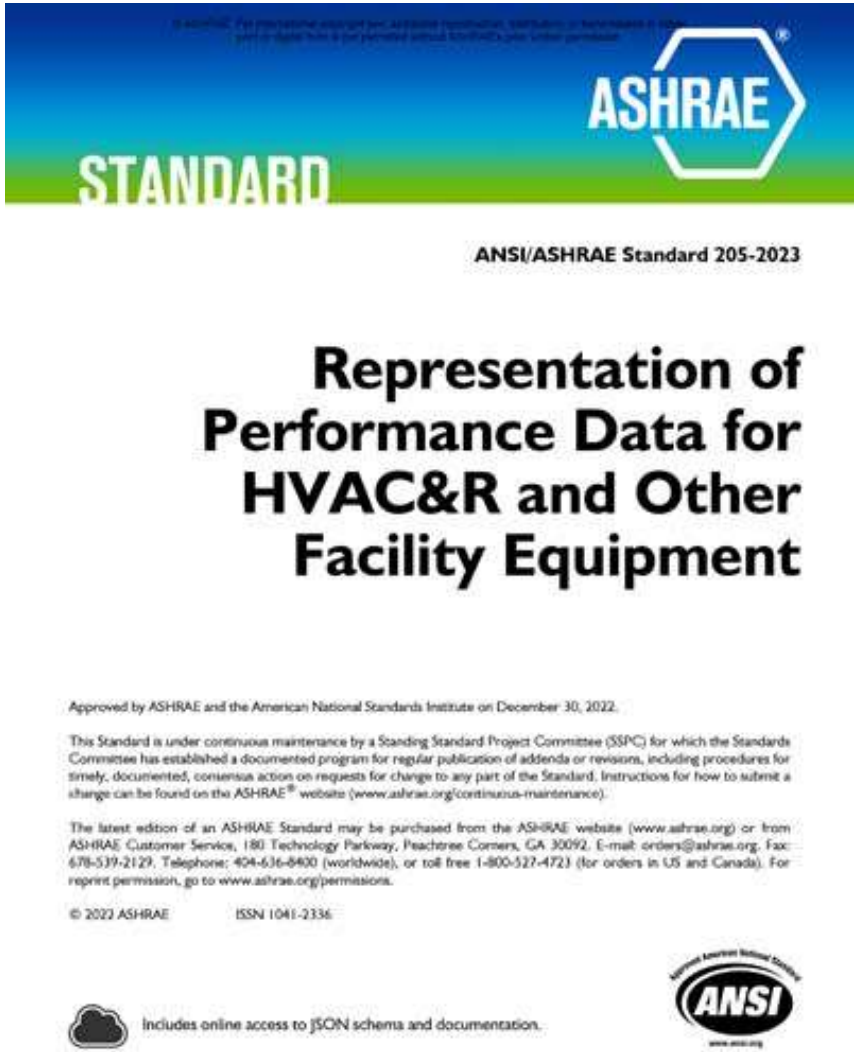
- Multiple Vendors & Software all with Different Data Formats = LOTS of Data Translation with Reduced Productivity and more Potential for Modeling Errors



Solution: ASHRAE 205

The Solution is **ASHRAE Standard 205 Representation of Performance Data for HVAC&R and Other Facility Equipment**

- Standard file format for storing and exchanging performance data
- Defines the equipment specific data, both required and optional, to be included in the file
- 205 is **NOT** a new rating or method of test.



Solution: ASHRAE 205

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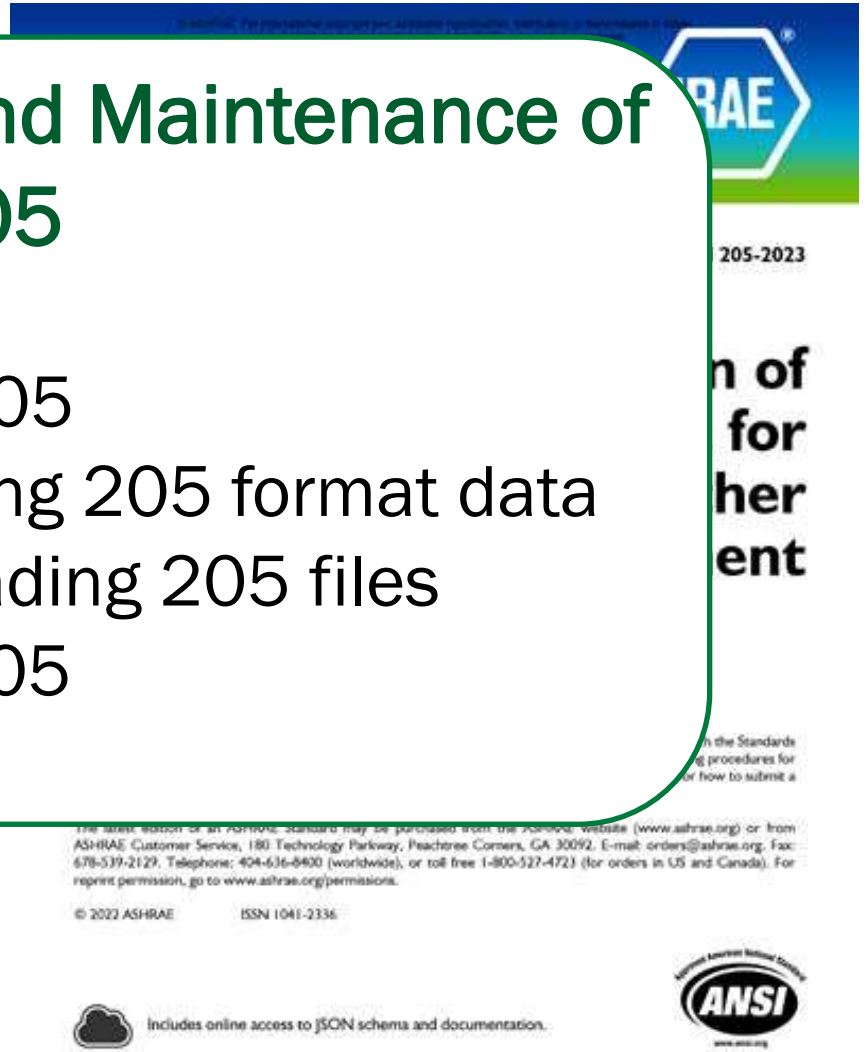
  required and optional, to be included in the file
- 205 is **NOT** a new rating or method of test.

Project goal: Support Development and Maintenance of ASHRAE Standard 205

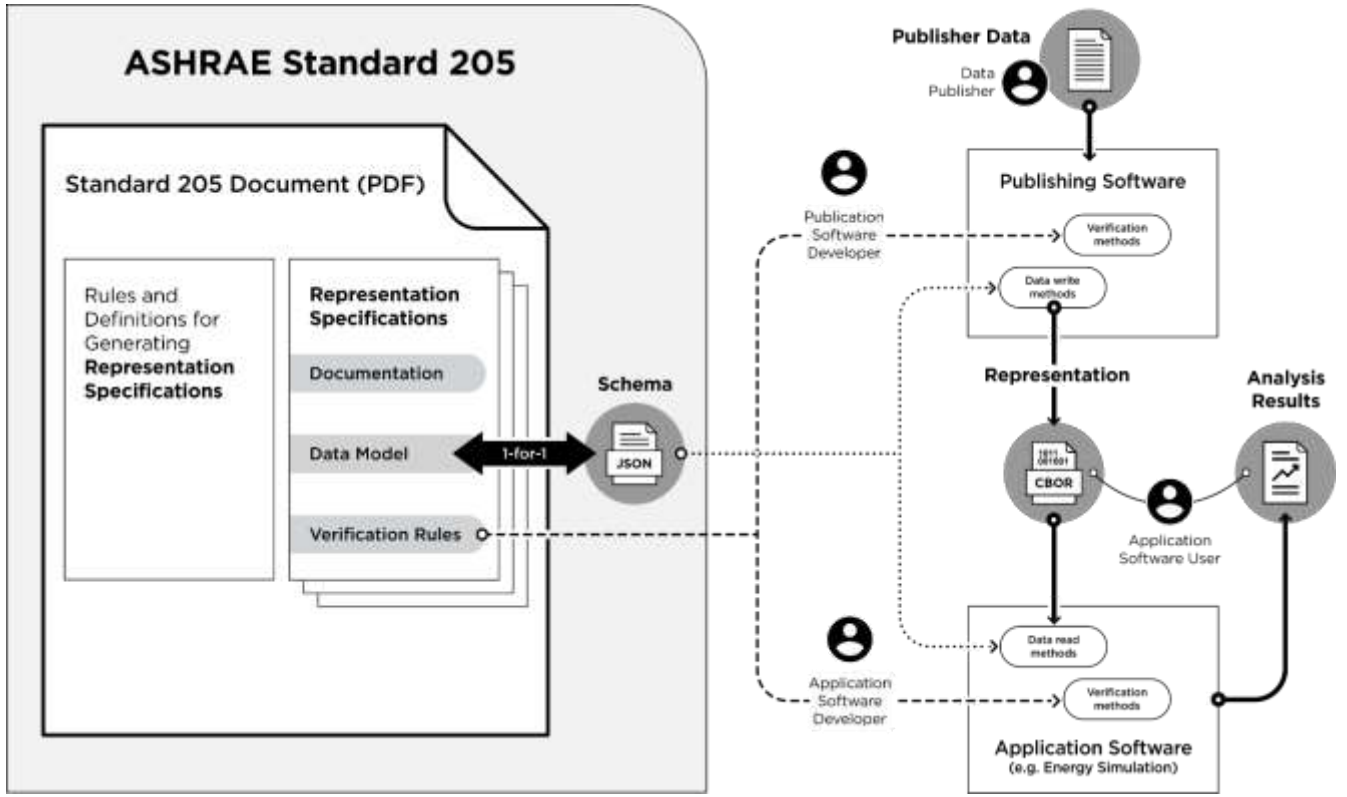
- Grow range of equipment covered by 205
- Grow number of manufacturers providing 205 format data
- Grow number of software programs reading 205 files
- Get codes and standards to use/cite 205



Solution: ASHRAE 205

- ASHRAE 205 allows a manufacturer to tell a modeler/user how their equipment **really** operates over its full operating range

- ASHRAE 205 allows a manufacturer to tell a modeler how a built-up system of components operates as a whole (including component interactions and internal controls)



ASHRAE 205 Representation Specification (RS)

- **205 is a data file (called a representation) that includes descriptive information and one or more "performance maps"**
  - The detailed set of data for a specific piece of equipment is called a ***Representation Specification*** (RS)
- **Base data file format is CBOR, a binary version of JSON**
  - CBOR is smaller, faster to read/write than JSON, and has encryption capabilities as part of the standard format
  - CBOR can be translated to/from JSON, YAML, and even XLSX as needed
- **Three main parts in a RS**
  - Metadata: This identifies the RS, versioning, and how the 205 file was generated
  - Description: Manufacturer Description (model numbers etc.)
  - Performance Map(s)

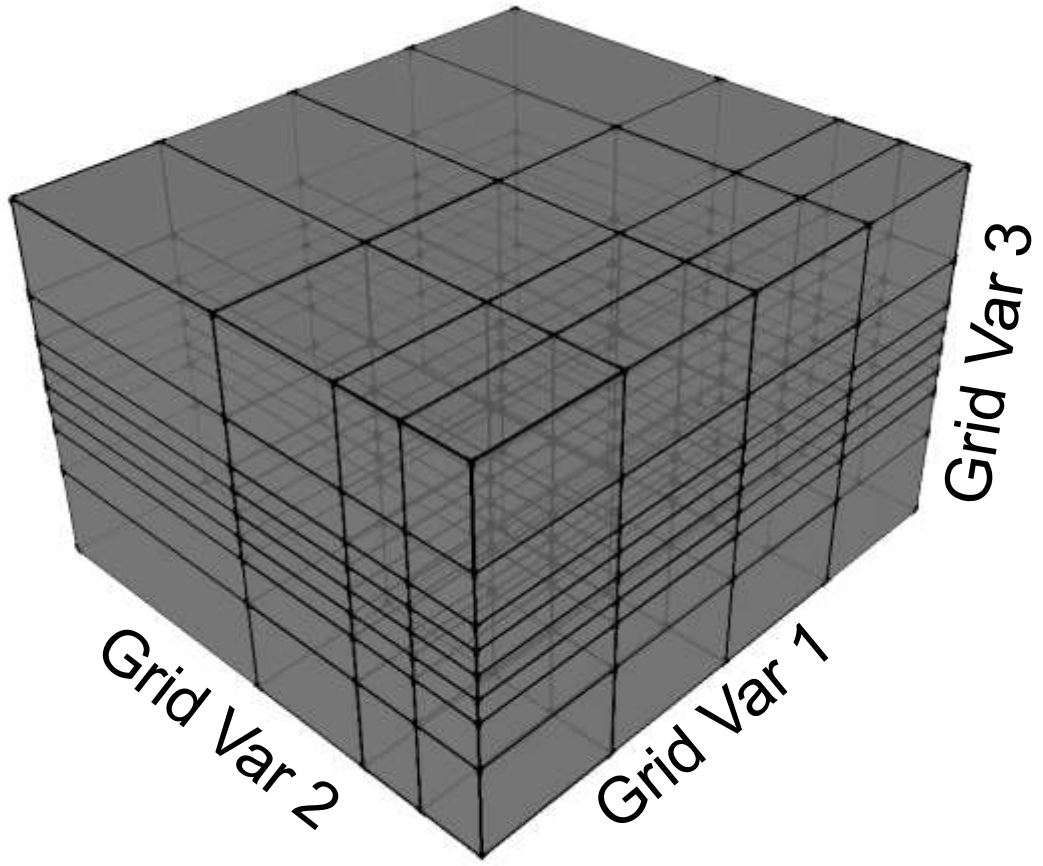
ASHRAE 205 Performance Map

The Performance Map is the Key Element of ASHRAE 205. It maps inputs of the system to outputs at various input states and can disaggregate power outputs

- Grid Variables : System Inputs
- Lookup Variables: System Outputs

This is essentially an *N*-dimensional lookup table

- NOTE: By using performance maps, simulation can be orders of magnitude faster than full detailed component simulation (e.g. HPDM or VapCyc) for advanced multicomponent systems



Example 205 Data File for a simple DX system


```
"metadata": {
        "schema_version": "0.2.0",
        "data_model": "ASHRAE_205",
        "schema": "RS0004",
        "description": "DX System with Constant Efficiency",
        "id": "123e4567-e89b-12d3-a456-426614174000",
        "data_timestamp": "2020-05-07T00:00Z",
        …
    },
    "description": {
        "product_information": {
            "outdoor_unit_manufacturer": "ABC HVAC",
            "outdoor_unit_model_number": "DX AB12",
            "indoor_unit_manufacturer": "ABC HVAC",
            "indoor_unit_model_number": "DX AB12",
            "refrigerant": "R-410A",
        …
```

Example 205 Data File for a simple DX system


```
"performance": {
    "compressor_speed_control_type": "DISCRETE",
    "cycling_degradation_coefficient": 0.25,
    "performance_map_cooling": {
        "grid_variables": {
            "outdoor_coil_entering_dry_bulb_temperature": [283.15, 323.15],
            "indoor_coil_entering_relative_humidity": [0, 1 ],
            "indoor_coil_entering_dry_bulb_temperature": [283.15, 313.15],
            "indoor_coil_air_mass_flow_rate": [5.4,26.8],
            "compressor_sequence_number": [1, 2],
            "ambient_absolute_air_pressure": [81.273, 101.325]},
        "lookup_variables": {
            "gross_total_capacity": [42191.636, 42191.636, 56877.119999999995, … ]
            "gross_sensible_capacity": [25314.9816, 25314.9816, 34126.272, … ]
            "gross_power": [13610.20516,13610.20516, 18347.458064516126, … ]
    "performance_map_standby": {
        "grid_variables": {
            "outdoor_coil_environment_dry_bulb_temperature": [283.15, 323.15],
            …
```

Example Performance Map in a Table

performance.performance_map_cooling

grid_variables						lookup_variables		
outdoor_coil_entering_dry_bulb_temperature	indoor_coil_entering_relative_humidity	indoor_coil_entering_dry_bulb_temperature	indoor_coil_air_mass_flow_rate	compressor_sequence_number	ambient_absolute_air_pressure	gross_total_capacity	gross_sensible_capacity	gross_power
K	-	K	kg/s	-	Pa	W	W	W
283.15	0	283.15	5.4	1	81.273	42191.636	25314.9816	13610.20516
283.15	0	283.15	5.4	1	101.325	42191.636	25314.9816	13610.20516
283.15	0	283.15	5.4	2	81.273	56877.12	34126.272	18347.45806
283.15	0	283.15	5.4	2	101.325	56877.12	34126.272	18347.45806
283.15	0	283.15	26.8	1	81.273	62919.299	37751.5794	20296.54806

Impact

ASHRAE 205 can transform how the HVAC&R manufacturers provide equipment data to the rest of the HVAC industry:

Standardized performance map data reduces variations in modeling system performance between software

Standardized and complete performance maps ensure that equipment performance is accurately modeled by BEM software

Standardized data format allows designers to compare more equipment, in more tools, with less effort, and less chance for data entry errors

Consensus standard format ensures that smaller manufacturers have influence and larger industry players are not able to force their data format on others because of their sheer size

Alignment

More accurate HVAC modeling

- More properly selected and sized HVAC equipment
- Better HVAC control strategies
- Greater adoption of high-performance equipment
- Expanded utility programs
- Stricter Energy/Carbon Codes

- Decreased Bldg Energy and Carbon Footprint
- Reduced HVAC costs (especially important for DACs)
- Improved occupant comfort

Risks and Mitigation Strategy

Risk	Mitigation Strategy
Generation of performance maps too burdensome for some manufacturers	• Develop toolsets to streamline generation including automation scripting and Heat Pump Design Model (HPDM) prototypes
Manufacturers concerned about data privacy issues and performance map data leaking to competitors	• CBOR file format has a standard method of encryption. 205 files could be encrypted by manufacturers who then control decryption authority
Software vendors slow to update software to read 205 files	• Develop example code in Python and C, (and develop Fortran linking headers) • Generate 205 files for 90.1 reference equipment and work with 90.1 and other codes to encourage use of 205 files

Approach

Lead Development of New Specs

- Lead the development of core new equipment Representation Specifications to expand ASHRAE 205 Coverage
- Develop “how-to” guides to help industry lead their own RS development
- Coordinate and assist industry led working groups to create reference specifications for new equipment

Develop Software Tools for Industry

- Update ORNL Heat Pump Design Model (HPDM) to let OEMs who use HPDM directly generate 205 format files
- Develop tools for equipment manufacturers to generate and validate 205 equipment files
- Develop tools and example implementation code for modeling software to read and use 205 data files in BEM and load calc software

Approach

ASHRAE 205 Stakeholder Meetings

- Host open meetings with manufacturers to understand their tool needs and help guide development of representations for new equipment categories
- Host open meetings with software developers to understand their tool needs and guide development of example code for simulation engines

Support SSPC ASHRAE 205

- Continue to provide guidance and organization for SSPC ASHRAE 205 activities
- Develop roadmap for guiding and prioritizing future standard and reference specification development
- Work with codes and standards to reference 205

Approach: Commercialization and Market Transformation

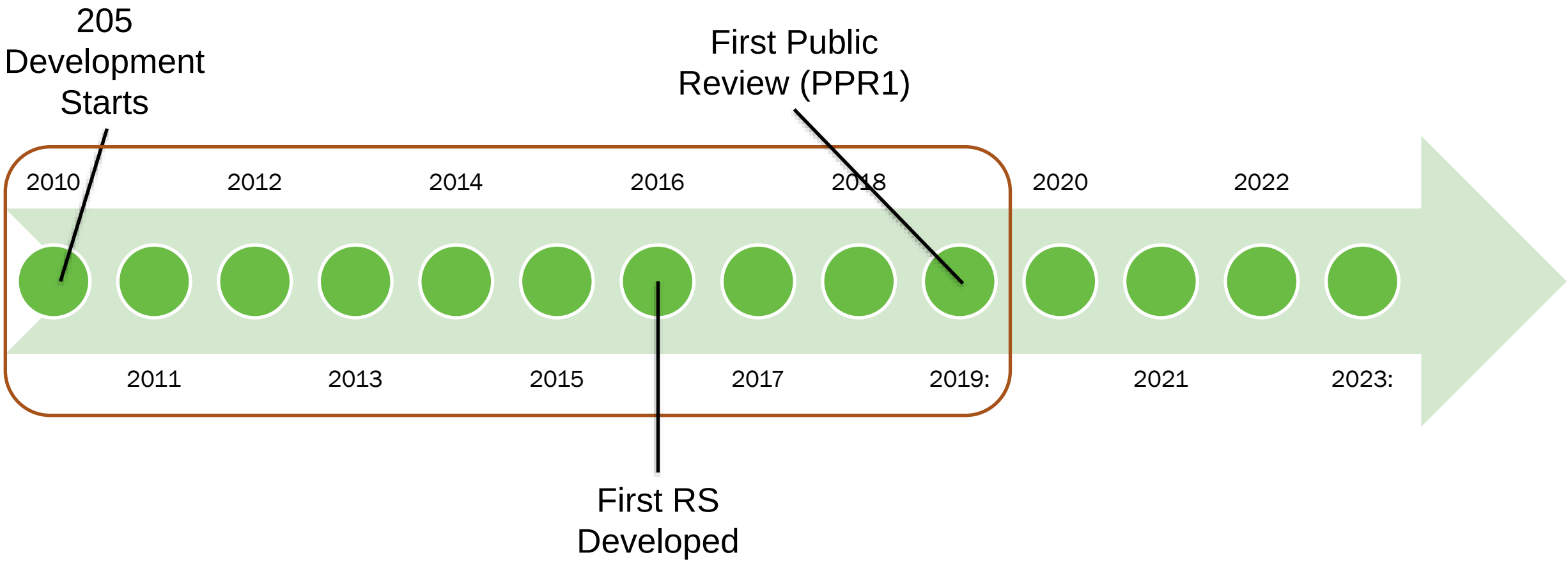
Software Toolkit Released as OSS with Berkeley 3 license

- Industry is free to use code in their own commercial tools/software to speed development of reading and using 205 files
- Already being integrated into EnergyPlus, TRNSYS, and CSE

Team Working with Small and Large OEMs to Help Them Develop Workflows for Creating 205 files

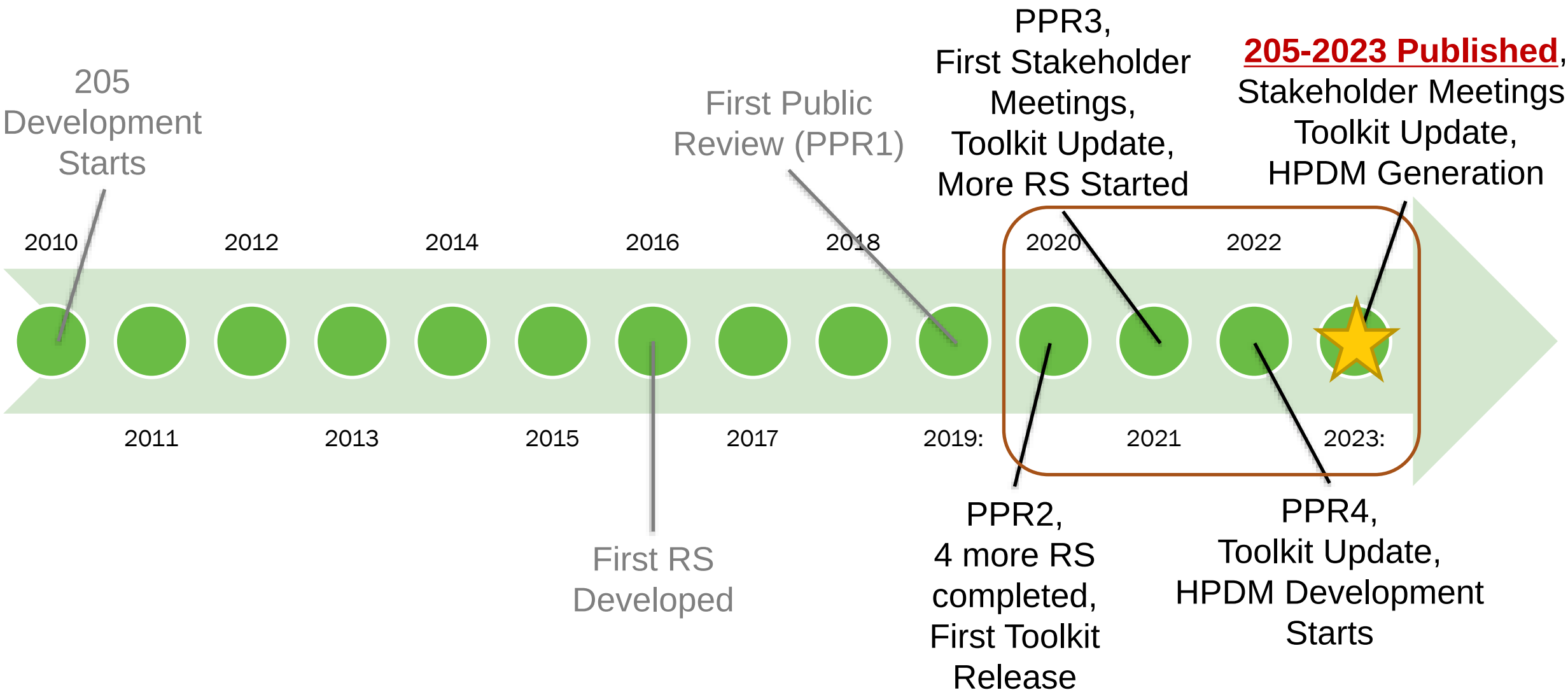
- Streamlining the process of generating 205 format files to speed adoption of 205 as a common way of providing data to designers and engineers
- ORNL adapting HPDM to output 205 files directly

Progress: Without DOE Support 205 Development was SLOW!!



After 9 years SPC205 had only advanced to one public review of 205

Progress: ASHRAE 205 Published in 2023



With DOE support, development progress is now more than 5x faster

Progress: Software Development

- **Developed an open-source software toolkit including file generation, validation, and visualization tools**
  - Tools for converting between spreadsheets, JSON, YAML, and CBOR to accommodate conversion of existing equipment performance maps in many formats to 205 files and helping automated generation of performance maps
  - Tools for validating 205 files as being schema compliant
  - Tools for visualizing 205 files that can directly integrated into web servers

- **Developed example code for reading 205 files into BEM software**
    - Code already being integrated into EnergyPlus, CSE, and TRNSYS to read and utilize 205 files for modeling

Progress: Representation Specification (RS) Development

Already In 205

- Liquid Cooled Chillers
- Unitary AC
- Fan Assembly
- Air-to-Air DX Coils
- Motors
- Electronic Motor Drive
- Mechanical Drive

Under Development

- Air-to-Air Heat Pumps
- Air Cooled Chillers
- Fan Coil Units
- Water Pumps
- ERV
- Fan Coils
- Fenestration

On the Horizon

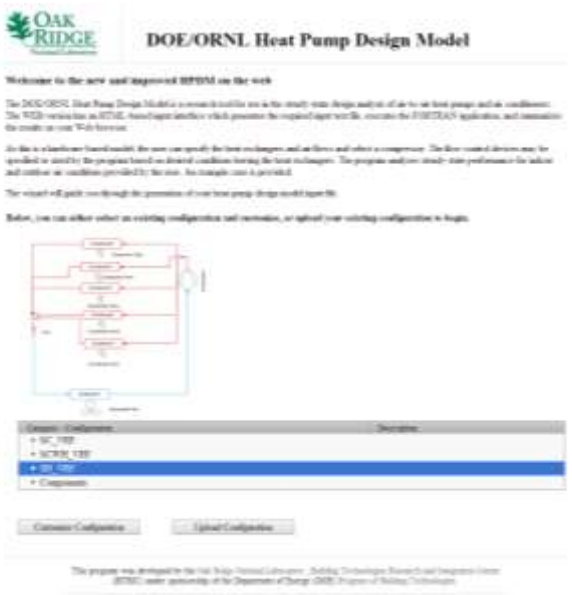
- VRF
- Cooling Towers
- Boilers
- Furnaces
- Water Heaters

ORNL HPDM Progress

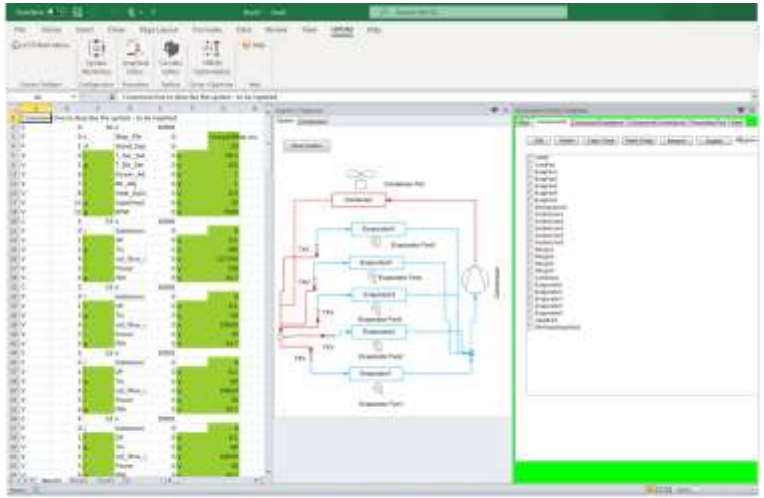
HPDM: A Public Domain System Design Tool

- The web-based tools have been used more than **360,000 times.**
- Important analytical tool for CFC to HFC and ongoing lower GWP refrigerant transitions.
- Adopted by multiple U.S. OEMs including Emerson, Nortek, and Rheem.
- Performance simulation engine behind Emerson's System Design Simulator (compressor selection tool), distributed to more than> 80 OEMs.

✓ **Web Interface**



✓ **Desktop Excel Add-In to Exploit All Capabilities**



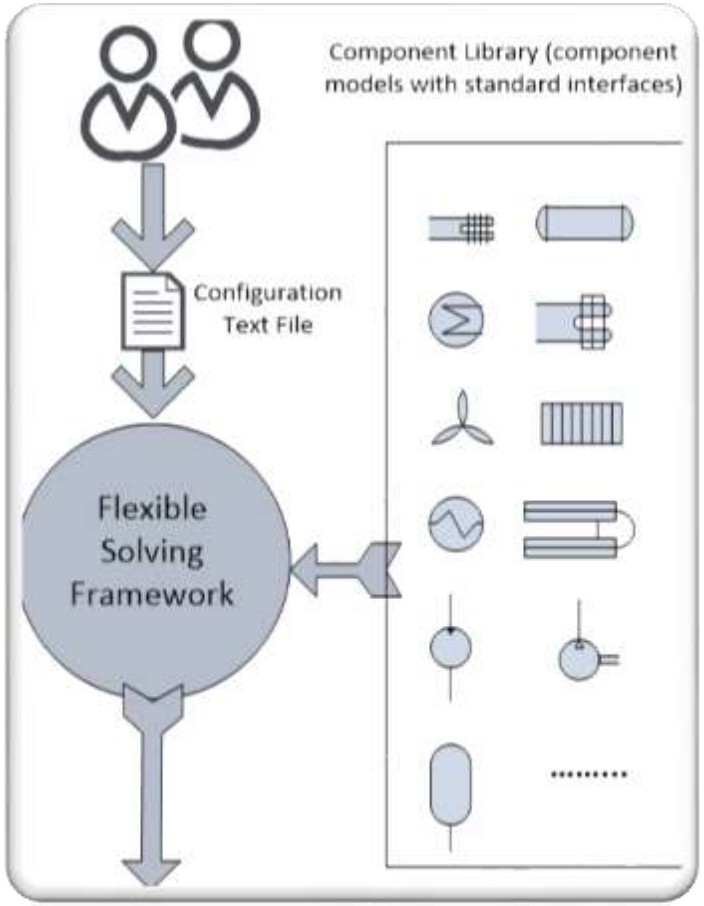
Excel Add-in Interface enables parametric study, constructing the system, GenOpt optimization, SEER/HSPF calculations, etc.

NORTEK

EMERSON

Rheem

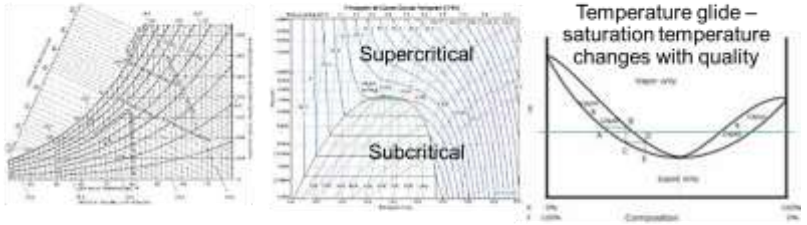
HPDM: a component-based flexible modeling platform



- ❑ Plug-&-Play
- ❑ Standard interface
- ❑ Automatically connect

Hundreds of working substances in HVAC&R industry: air, water, glycol, CO2, HFC, HCFC, CFC, HFO, natural substances

Air psychometric chart | Refrigerant property | Refrigerant mixture

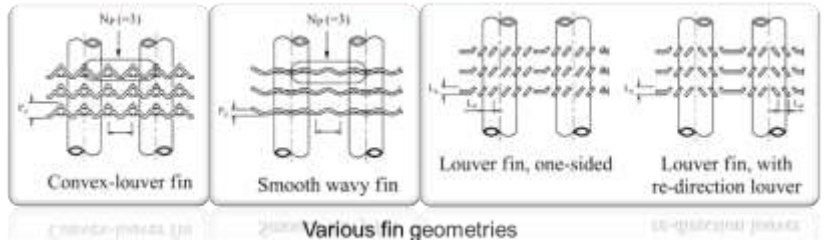


Next Generation Refrigerants (low global warming - GWP, zero ozone depletion) – detailed system modeling with new refrigerant property, to assess long-term impact using life cycle analysis, provide design guidance based on fundamental study.

- ❑ Universal working fluid property management

- ❑ Numerous components

- ❑ Extensive applications and system configurations



- ❑ Plenty of tube and fin types

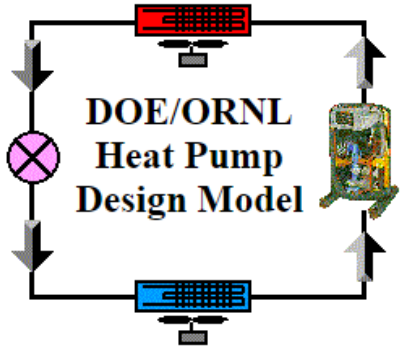
How HPDM Supports 205 and Market Transformation

- **ASHRAE 205 is the new common data language!!!!**
- **HPDM industry-standard, comprehensive design software is being used to validate STD205 and processes**
  - Using HPDM to generate example performance maps for testing 205 tools and give industry examples for various equipment
- **Next step: Develop wrapper and configuration tools for middle/small HVAC OEMs to use HPDM as one option to generate their 205 compliant performance tables.**

Detailed system structures

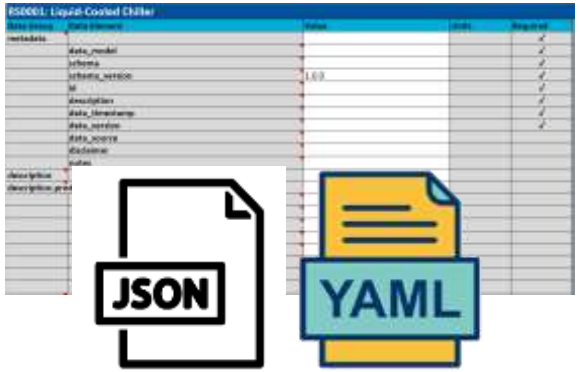
ASHRAE STANDARD

Parametric operating conditions



Performance Table (Simulation results under different conditions)

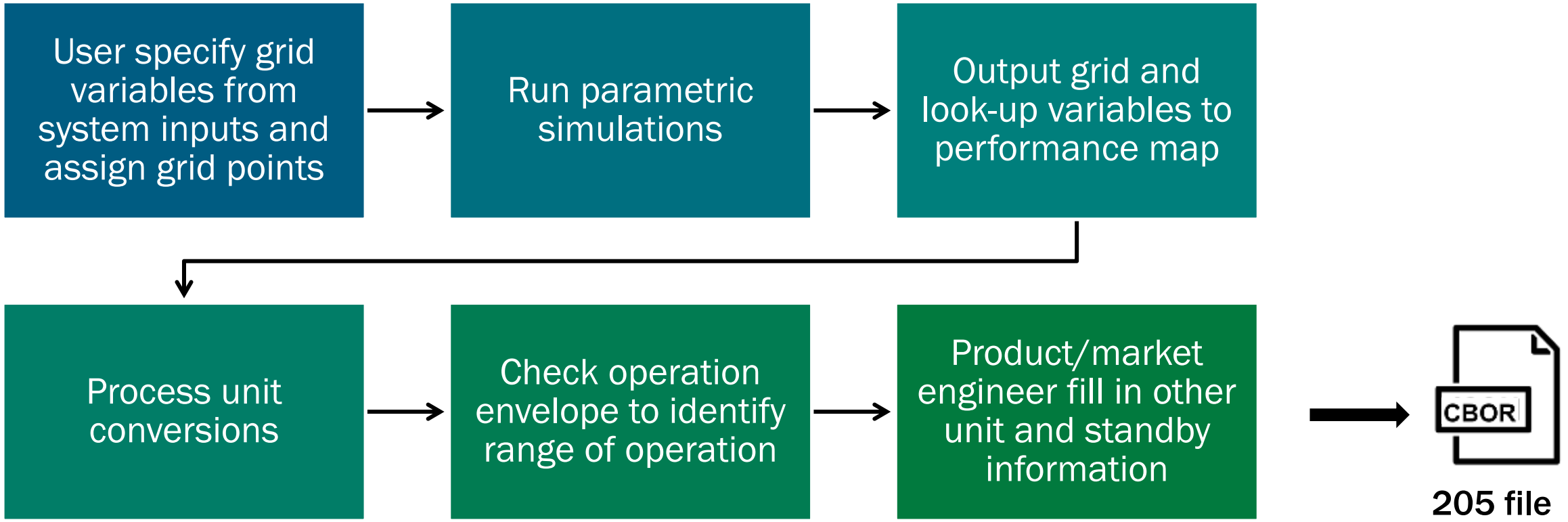
205 Data Files



CBOR

HPDM-STD205 Support

Developing Python Tools to Automate 205 Performance Map Production Process

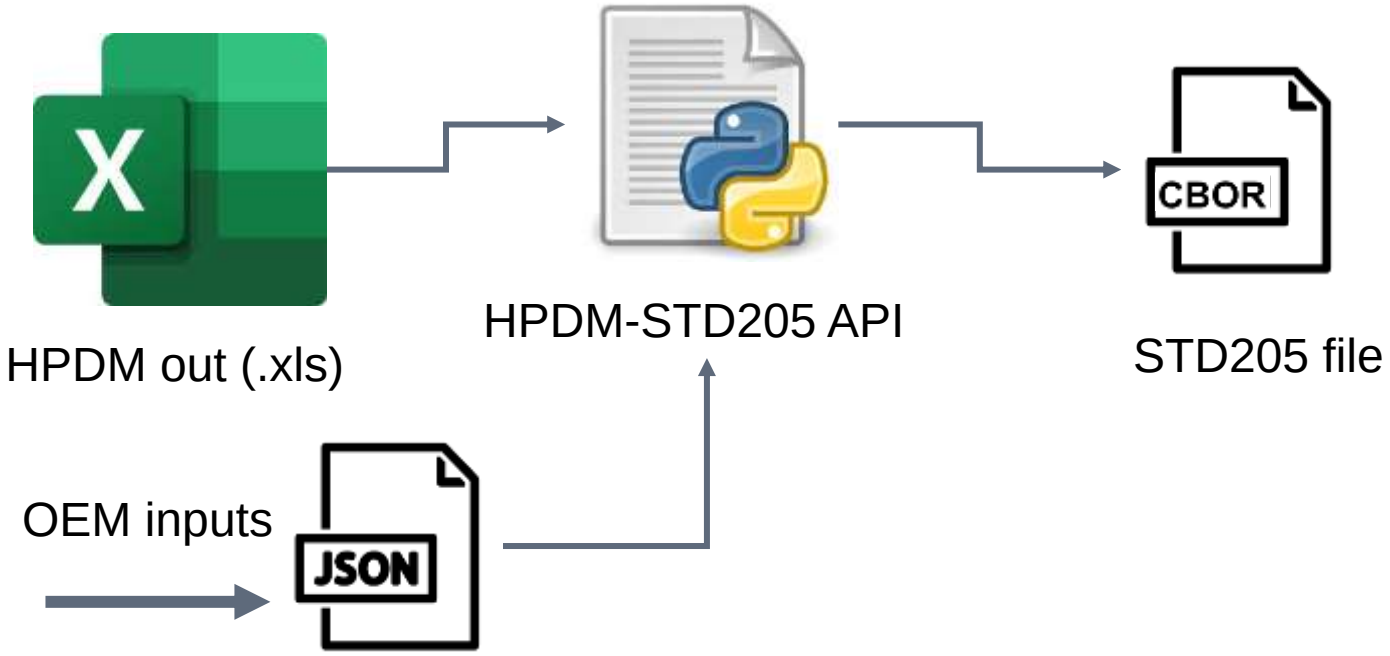


HPDM 205 Python API

An OSS Python Library Package with :

- A “Dictionary” Translating HPDM Data to STD205 Data
- Unit Conversion to SI Units
- Examples for all “RS”

- Will be released on ORNL GitHub page (https://github.com/ORNL/HPDM-STD205)



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RS0001: LIQUID-COOLED CHILLER
RS0002: UNITARY COOLING AIR-CONDITIONING EQUIPMENT
RS0003: FAN ASSEMBLY
RS0004: AIR-TO-AIR DIRECT EXPANSION REFRIGERANT SYSTEM
RS0005: MOTOR
RS0006: ELECTRONIC MOTOR DRIVE
RS0007: MECHANICAL DRIVE

ASHRAE 205: Eye Toward the Future

- **Continue Development of New Specifications and Software Toolkit**
- **Get Other Standards Citing 205 and using 205 files**
  - ASHRAE 90.1 Reference Equipment, CA Title 24
- **More Stakeholder Meetings**
  - Manufacturers (especially OEM who use HPDM)
  - BEM and Loads Software Developers
- **Continued HPDM Tool Integration Development**
  - Make Process Even More Automated and Include More Realistic Equipment in 205 Example Files
  - Work with OEMs to Help Them Integrate 205 into Their Custom Tools

Thank You

Argonne, ORNL, PNNL
PI: Dr. Ralph T. Muehleisen, Chief Building Scientist, Argonne
rmuehleisen@anl.gov
WBS 3.5.5.51

REFERENCE SLIDES

Project Execution

	FY2022				FY2023				FY2024			
Planned budget												
Spent budget												
	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
Past Work												
Q1 Milestone: All PPR3 Public Comments Resolved	◆											
Q2 Milestone: Stakeholders Meeting		◆										
Q3 Milestone: Publish PPR4			◆									
Q4 Milestone: All PPR 4 Public Comments Resolved				◆								
Q1 Milestone: ASHRAE 205-2023 Published					◆							
Current/Future Work												
Q3 Milestone: Release Updated Software Toolkit							◆					
Q4 Milestone: Stakeholder Meeting								◆				
Q4 Milestone: Release HPDM Generation Library								◆				

Team

ANL, PI
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Jeannie Kim

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Neal Kruis

BLS
Chip Barnaby

BLS
Tanaya Mankad

TESS
Tim McDowell

ORNL
Piljae Im

ORNL
Bo Shen

ORNL
Hanlong Wen

EERE/BTO goals

(Not a template slide – for informational purposes only)

The nation's ambitious climate mitigation goals

Greenhouse gas emissions reductions

50-52% reduction by 2030 vs. 2005 levels

Net-zero emissions economy by 2050

Power system decarbonization

100% carbon pollution-free electricity by 2035

Energy justice

40% of benefits from federal climate and clean energy investments flow to disadvantaged communities

EERE/BTO's vision for a net-zero U.S. building sector by 2050

Support rapid decarbonization of the U.S. building stock in line with economywide net-zero emissions by 2050 while centering equity and benefits to communities

Increase building energy efficiency

Reduce onsite energy use intensity in buildings 30% by 2035 and 45% by 2050, compared to 2005

Accelerate building electrification

Reduce onsite fossil -based CO_2 emissions in buildings 25% by 2035 and 75% by 2050, compared to 2005

Transform the grid edge at buildings

Increase building demand flexibility potential 3X by 2050, compared to 2020, to enable a net-zero grid, reduce grid edge infrastructure costs, and improve resilience.

Prioritize equity, affordability, and resilience

Ensure that 40% of the benefits of federal building decarbonization investments flow to disadvantaged communities

Reduce the cost of decarbonizing key building segments 50% by 2035 while also reducing consumer energy burdens

Increase the ability of communities to withstand stress from climate change, extreme weather, and grid disruptions