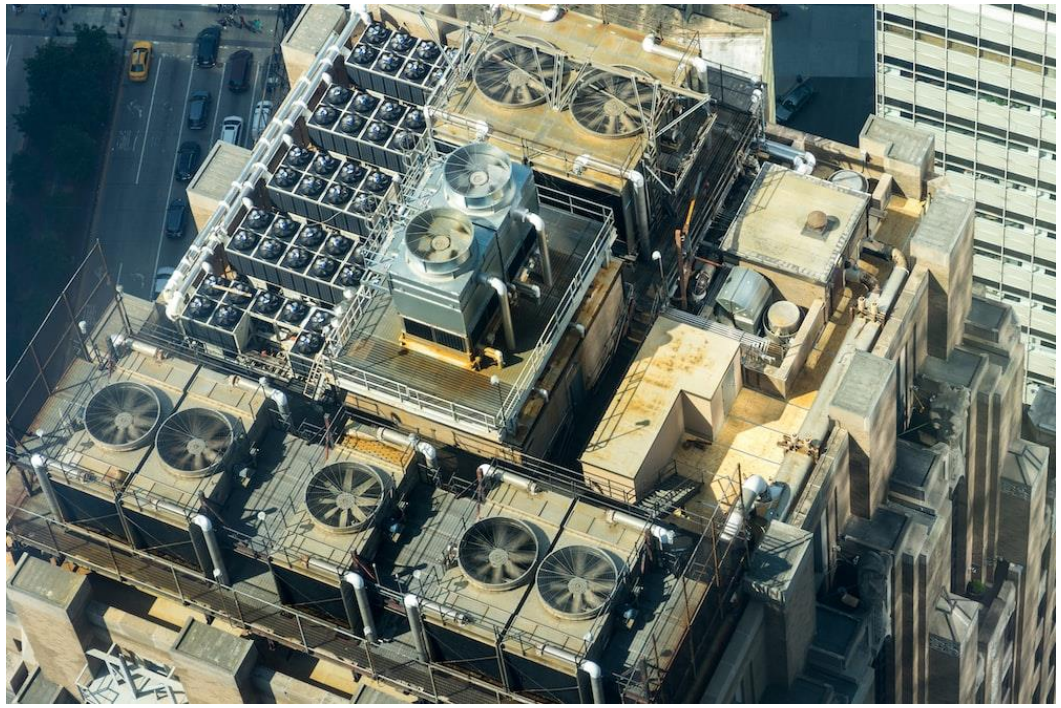
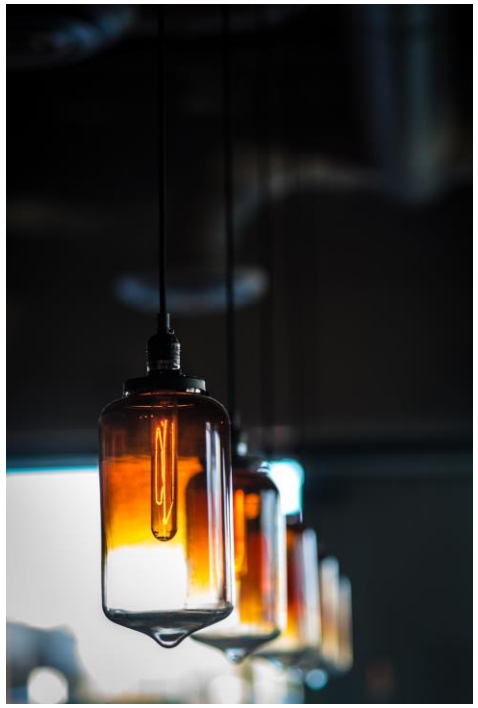
Protocols for Evaluating Ruleset Application in Building Performance Models


Pacific Northwest National Laboratory
Supriya Goel, Senior Research Engineer
(503) 417-7554, supriya.goel@pnnl.gov
WBS # 3.5.5.54

Project Summary

Objective and outcome

- Streamline and automate performance-based compliance submittal reviews
- Develop an automated project testing framework that can verify implementation of rulesets (such as 90.1 App G) in energy models
- Develop **ASHRAE Standard 229P** which defines the protocols for project testing and provides a methodology that can be adopted and used for other rulesets (like T-24 ACM, RESNET)

ASHRAE Standard 229P Committee Members

Team and Partners

- **PNNL:** Leading the development of the ASHRAE Standard and the RCT
- **GARD Analytics:** Leading the development of the Schema, supporting the development of the RCT
- **Karpman Consulting:** Leading the development of tests for verifying schema export by software tools and supporting the development of the RCT

Stats

Performance Period: October 2019- September 2024

DOE budget: $2.3 M, Cost Share: $0

Milestone 1: Approval of ASHRAE Project Committee; November 2019

Milestone 2: Committee approval of the RMD Schema; December 2022

Milestone 3: Public Review Draft of Standard 229P; Targeting January 2024

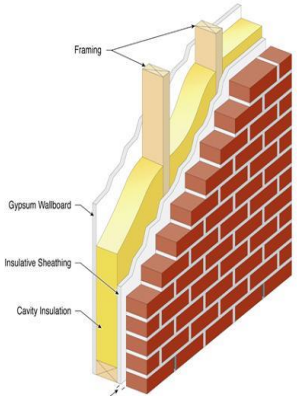
Introduction: Code Compliance Pathways

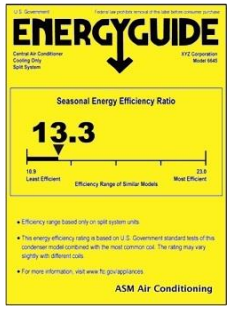
Prescriptive Path

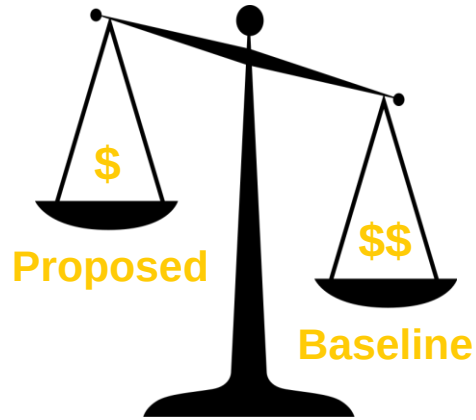
- Specifies minimum requirements for individual building components
- Easy to understand and widely used for code compliance

Whole Building Performance Path

- Uses whole building modeling (BEM) to demonstrate performance meeting or exceeding that of a “baseline” building built to minimum prescriptive requirements
- Procedure for deriving baseline building model from proposed called a “ruleset”
- Rulesets: ASHRAE 90.1 Performance Rating Method (PRM) aka “Appendix G”, CA Title24 ACM, RESNET ERI



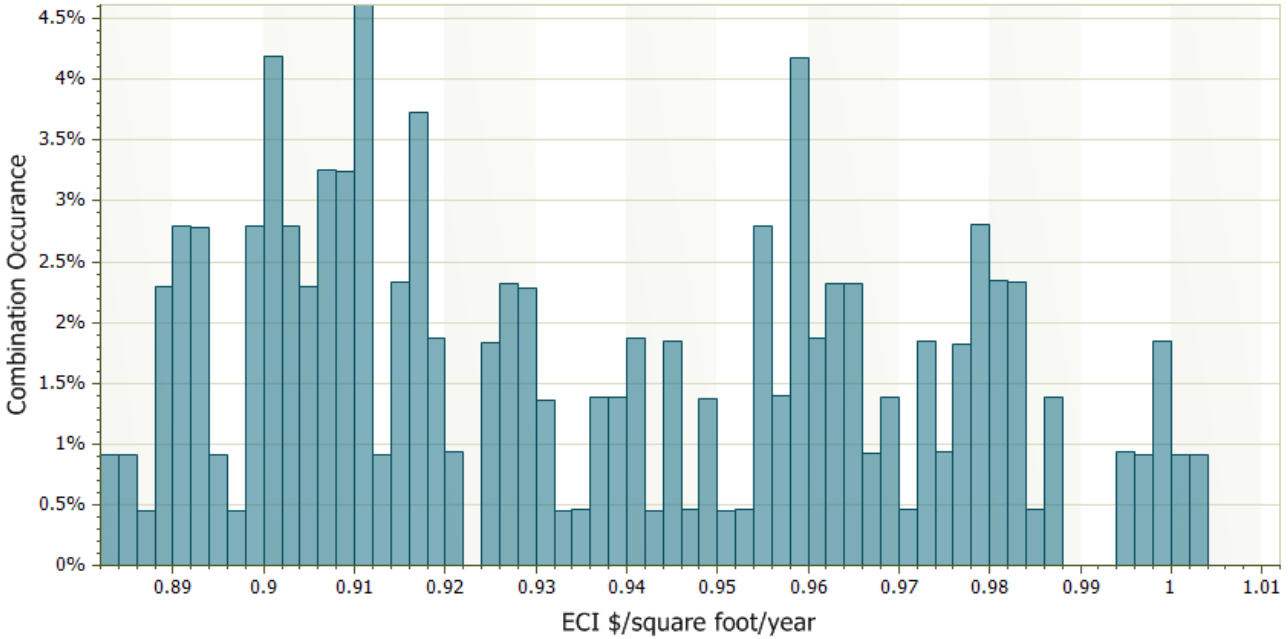




Introduction: Prescriptive Path Challenges

- Does not prescribe energy use or recognize good design choices
- Can result in a wide variation of energy outcomes based on design choices
- Does not provide a cost-effective way to transition to net zero

Varying just six parameters for Medium Office Building
Climate Zone 5A
14% variation in annual energy cost

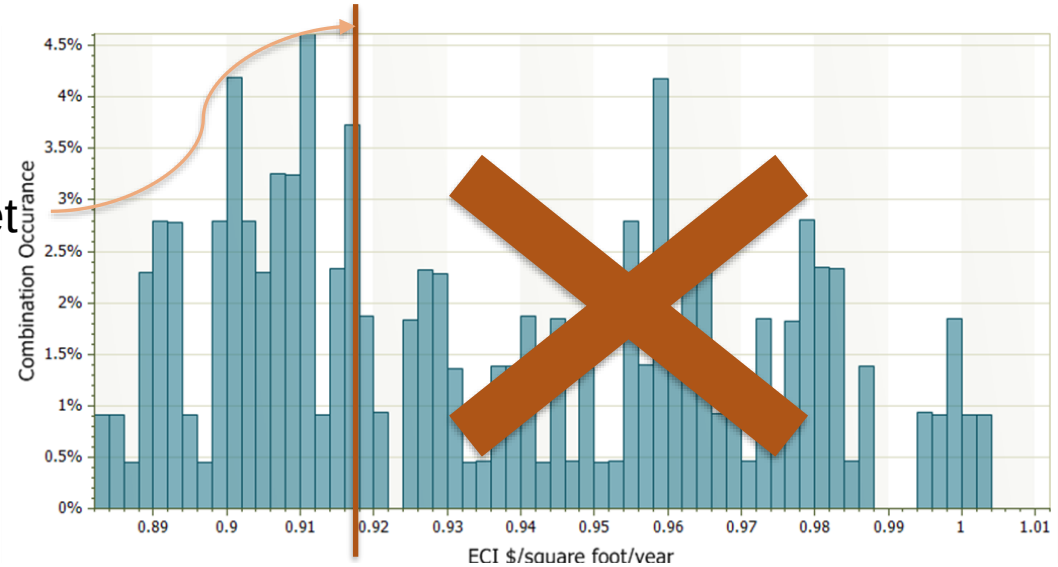


- Window-wall ratio (WWR):
  25%→40%
- Window frame:
  metal→ non-metal
- HVAC size:
  small → large
- Roof insulation:
  above deck → below deck
- Wall type:
  steel frame → mass wall
- Heat source:
  electric →natural gas

Introduction: Performance Path Opportunities and Challenges

- **Provides design flexibility, achieves deeper savings[1]**
  - Rulesets are automated in a lot of BEM software
- **Used in <5% of projects in >50% of jurisdictions surveyed[2]**
  - Time and cost associated with modeling, i.e., generating proposed model
  - Opportunities for both honest errors and "gaming" in creating baseline model
  - Lack of resources & gaps in knowledge required for model review and compliance verification

Performance Target



[1] Rosenberg M.I., R. Hart, J. Zhang, and R.A. Athalye. 2015. Roadmap for the Future of Commercial Energy Codes. PNNL-24009. Richland, WA: Pacific Northwest National Laboratory. https://www.pnnl.gov/main/publications/external/technical_reports/PNNL-24009.pdf

[2] Karpman M, M Rosenberg 2021. Performance-Based Code [1] Compliance: A Roadmap to Establishing Quality Control and Quality Assurance Infrastructure https://www.energycodes.gov/sites/default/files/2021-07/Performance-Based_Code_Compliance_Roadmap_Final.pdf

Unlocking deeper savings from codes requires performance-based compliance to be used more often (e.g., CA T24)

Approach

Solution: Streamline and Automate the Compliance Review Process

Approach 1: Software Testing

Certify individual ruleset automation implementations by testing a large number of representative cases

Benefits: Removes maximum burden from reviewers. Used by CA, FL, RESNET

Challenges: Requires a large test suite which can be challenging to define and which the current state of interoperability does not support. Doesn't address manually generated baseline models. Doesn't address exceptional cases.

Approach 2: Project Testing

Test ruleset application on a per-project basis

Benefits: Doesn't require large test suite, or interoperability, a standard reporting format is enough. Can handle manually generated baselines and saves reviewing time even in exceptional cases.

Challenges: Unfamiliarity with this concept, requires some manual review.

Chosen Approach: Project Testing

Develop a Ruleset Checking Tool (RCT) to automatically verify ruleset application by comparing proposed and baseline models

- **Reviewers** run RCT to verify ruleset application + identify areas that need manual review
- **Modelers** run RCT before submission to identify and fix problem spots in advance
- Faster, more rigorous, more consistent, and more transparent project review
- More projects using performance path

Challenges:

- Project testing approach hasn't been attempted before
- Requires a coordinated effort from all affected stakeholders: jurisdictions, software vendors, modelers to agree on a consensus standard

ASHRAE Standard 229P: Protocols for Evaluating Ruleset Application in Building Performance Models

Alignment and Impact

- **Faster, more rigorous, more consistent, and more transparent project review**
- **More projects using performance path**

Increase Building Energy Efficiency

BEM and performance-based codes are critical to meet ambitious energy and carbon reduction goals[1,2]. Standard 229P will support the transition to performance-based codes, resulting in higher-performing buildings and increased energy efficiency. Increasing use of the performance path will also spur more use of BEM in design, further improving performance.

Accelerate Building Electrification

Performance-based codes can be tailored to meet different policy objectives, such as electrification. 229P will allow more jurisdictions to adopt performance-based codes and hence facilitate electrification and decarbonization.

[1]Rosenberg M., S Goel, M Tillou. Paving the Way for Net Zero Energy Codes through Performance Based Approaches. In proceedings, 2020 ACEEE Summer Study on Energy Efficiency in Buildings. Asilomar, CA
[2]Roth, Amir, and Reyna, Janet. *Innovations in Building Energy Modeling: Research and Development Opportunities for Emerging Technologies*. United States: N. p., 2020. Web. doi:10.2172/1710155. https://www.nrel.gov/docs/fy21osti/77835.pdf

Approach: ASHRAE Standard 229P

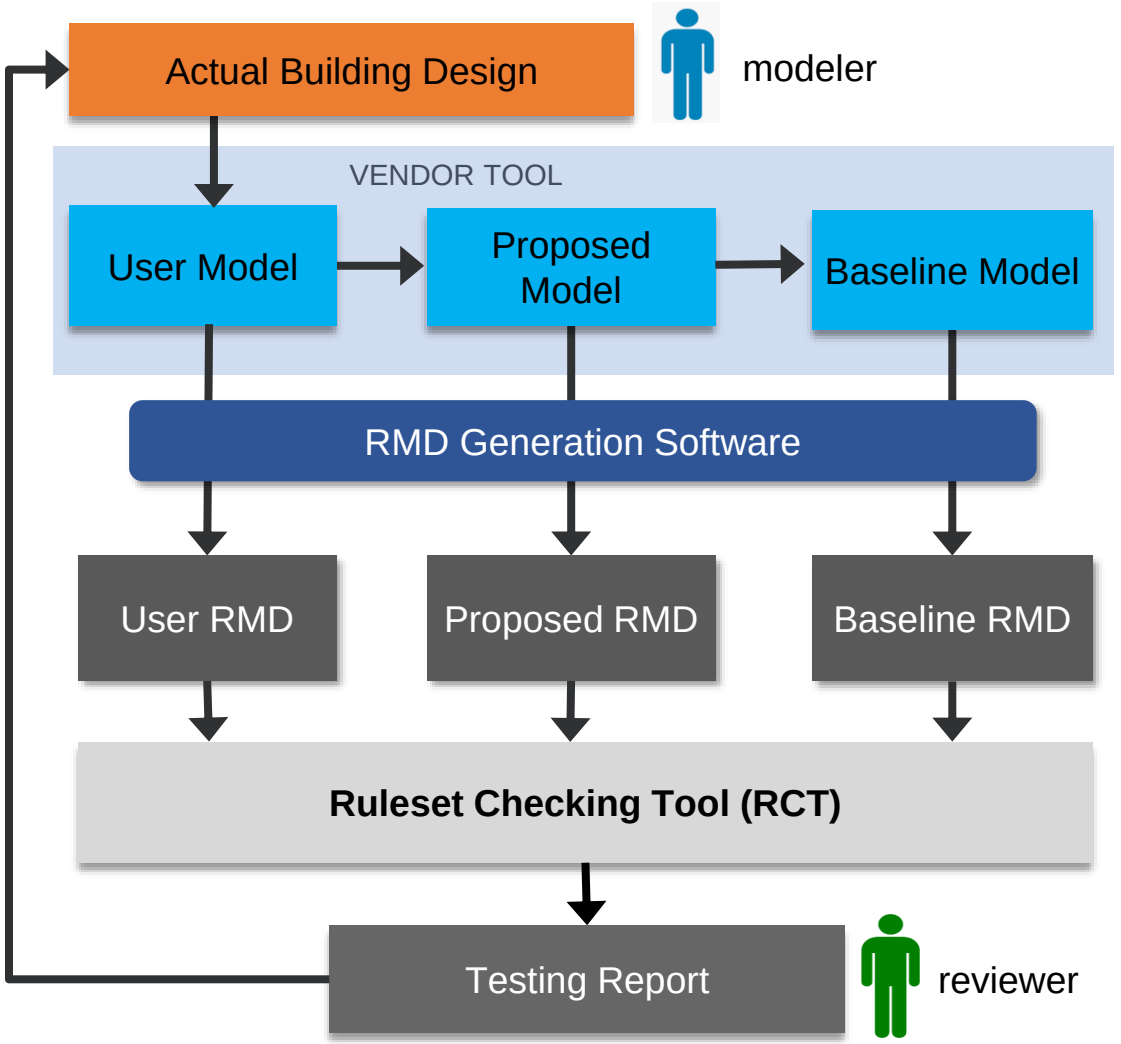
Title, Purpose, Scope

- **Title: Protocols for Evaluating Ruleset Application in Building Performance Models**
- **Purpose: This standard establishes tests and acceptance criteria for application of rulesets and related reporting for building performance models**
- **Scope: This standard applies to evaluation of the implementation of rulesets associated with new or existing buildings, their systems, controls, sites, and other aspects described by the ruleset. It establishes requirements for:**
  - building performance modeling software
  - software that evaluates building performance models and associated information to check the application of a ruleset (i.e RCT)

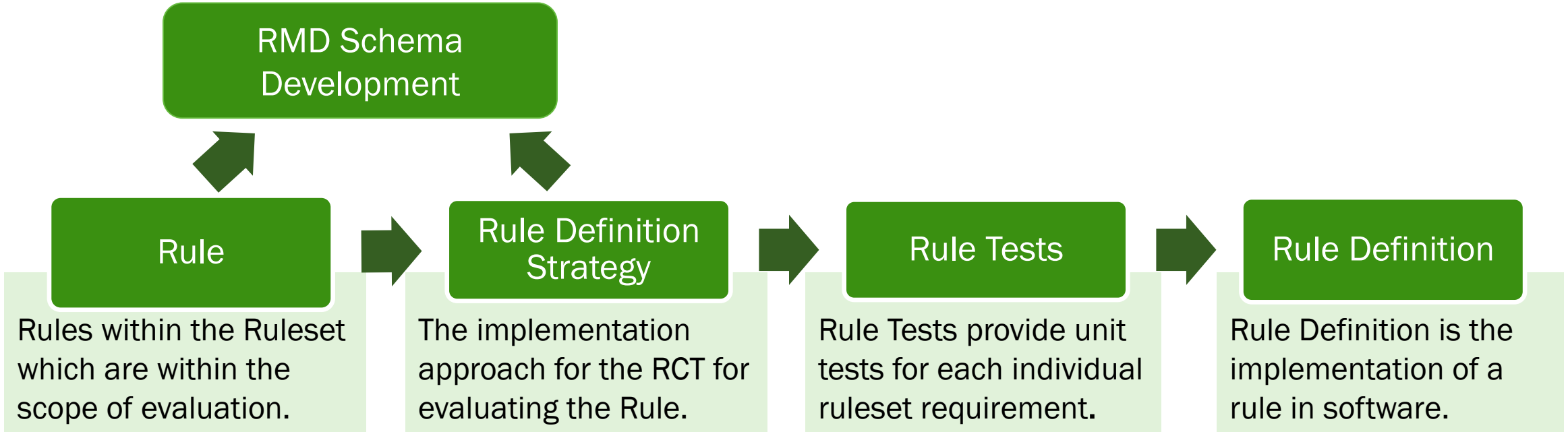
- **Standard committee includes a diverse group of stakeholders**
  - key to success of the standard being implemented & adopted
- **Phase I targets Standard 90.1 Appendix G**
  - Could be developed further to apply to T-24 NACM, RESNET, and others in the future

Approach: Project Testing Framework

- **Two new software components**
- **Ruleset Model Description (RMD) schema**
  - Ruleset level of detail
  - Not a detailed BEM-to-BEM schema
  - Not ruleset specific
  - Exported by BEM vendors
- **Ruleset Checking Tool (RCT)**
  - Checks implementation of ruleset logic on RMD submittals
  - Produces standard output report
  - Open-source



Approach: RCT + RMD Development



For ruleset being evaluated, developing the Ruleset Checking Specification entails

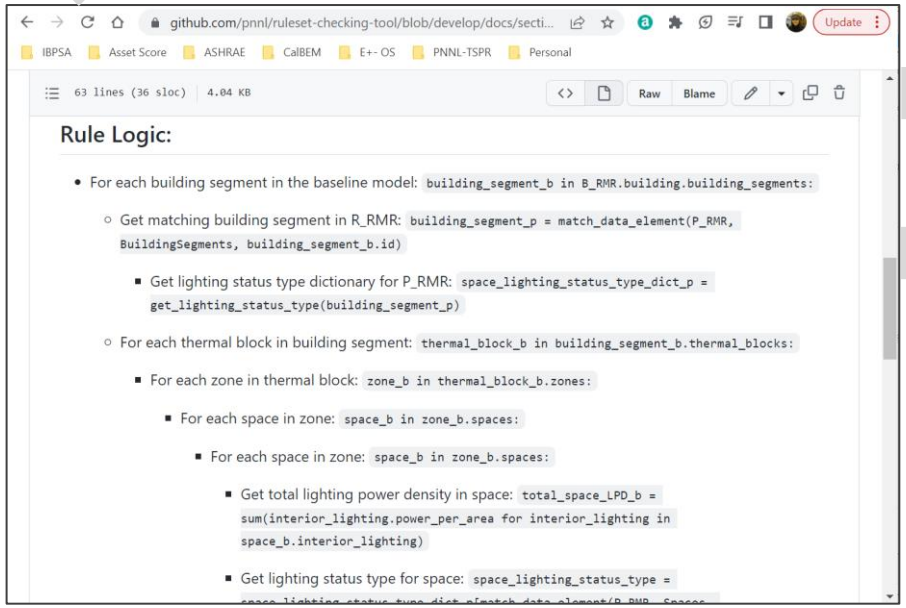
- Identifying rules within scope of the evaluation
- Developing the implementation approach for evaluating each rule (Rule Definition Strategy)

Approach: Example Analysis Workflow

Rule

Standard 90.1 Rule: Interior lighting power in the *baseline building design* shall be determined using the values in Table G3.7.

Rule Definition Strategy



Rule Definition: Rule Engine (RCT) Implementation

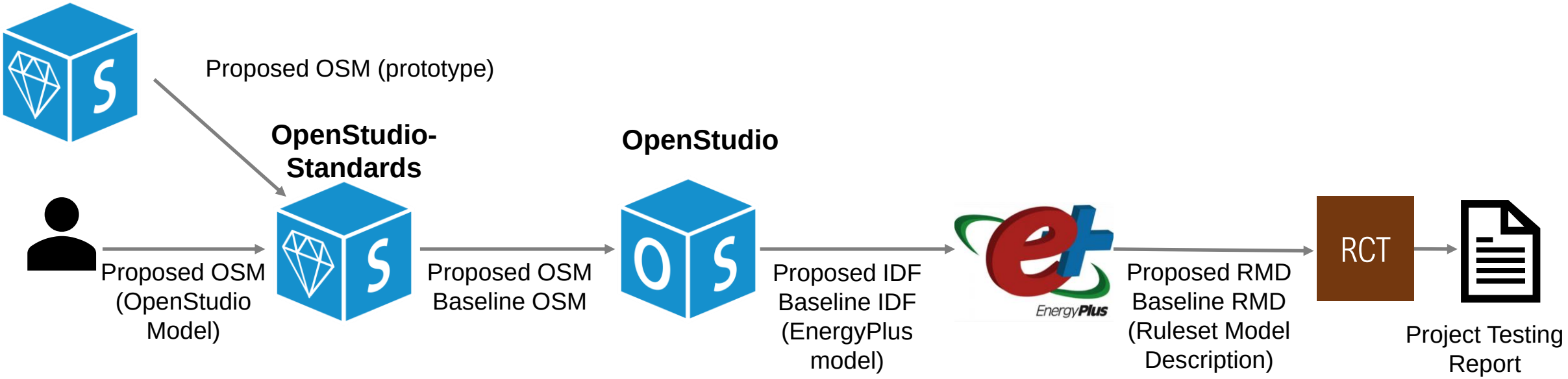
```python
def get_calc_vals(self, context, data=None)
    space_lighting_power_per_area = sum(
        find_all("interior_lighting[*].power_per_area", context.baseline)
    )
    lighting_space_type = context.user["lighting_space_type"]
    interior_lighting_power_allowance = table_G3_7(space_type=lighting_space_type)
    return {
        "space_lighting_power_per_area": space_lighting_power_per_area,
        "interior_lighting_power_allowance": interior_lighting_power_allowance,
    }
def rule_check(self, context, calc_vals, data=None):
            return (
        calc_vals["space_lighting_power_per_area"]
        == calc_vals["interior_lighting_power_allowance"]
    )
```

Rule Test RMD Snippet

```
"id": 0,
"name": "zone_name",
"spaces": [
    {
        "id": 1,
        "name": "Space 1",
        "lighting_space_type": "OFFICE_ENCLOSED",
        "floor_area": 1000,
        "status_type": "NEW",
        "interior_lighting": [
            {
                "id": 1,
                "name": "Office Lighting",
                "power_per_area": 1.1
            }
```

Approach: RCT Development and Testing

- **In addition to unit tests, project team is developing whole building integrated tests using OpenStudio Standards, data + OpenStudio Measures that allow a user to**
  - Create a detailed model from a high-level specification
  - Create a code baseline model from a proposed model



- RCT can be tested using prototype models as well as actual building designs

Approach: Adoption and Compliance with Standard 229P

Authority Having Jurisdiction (AHJ)

- AHJ adopts Standard 229
  - Approves use of BEM tools that have a supporting RMD generation capability, in order to enable use of RCT for project review
  - Uses the RCT to verify ruleset implementation in projects

Modeler

- Standard 229P does not impose project or performance requirements beyond those of the ruleset being tested, e.g., ASHRAE 90.1 Appendix G
- Modeler may run RCT before submittal as a pre-check to identify and fix issues

Software Vendor

- ASHRAE 229P compliance applies to software tools used for RMD export
  - *RMD Generation Software*: would need to comply with the standard
  - 229P includes **RMD tests** to evaluate and verify this capability
  - Note: Software tools do not need to implement ruleset automation

Approach: Stakeholder Engagement

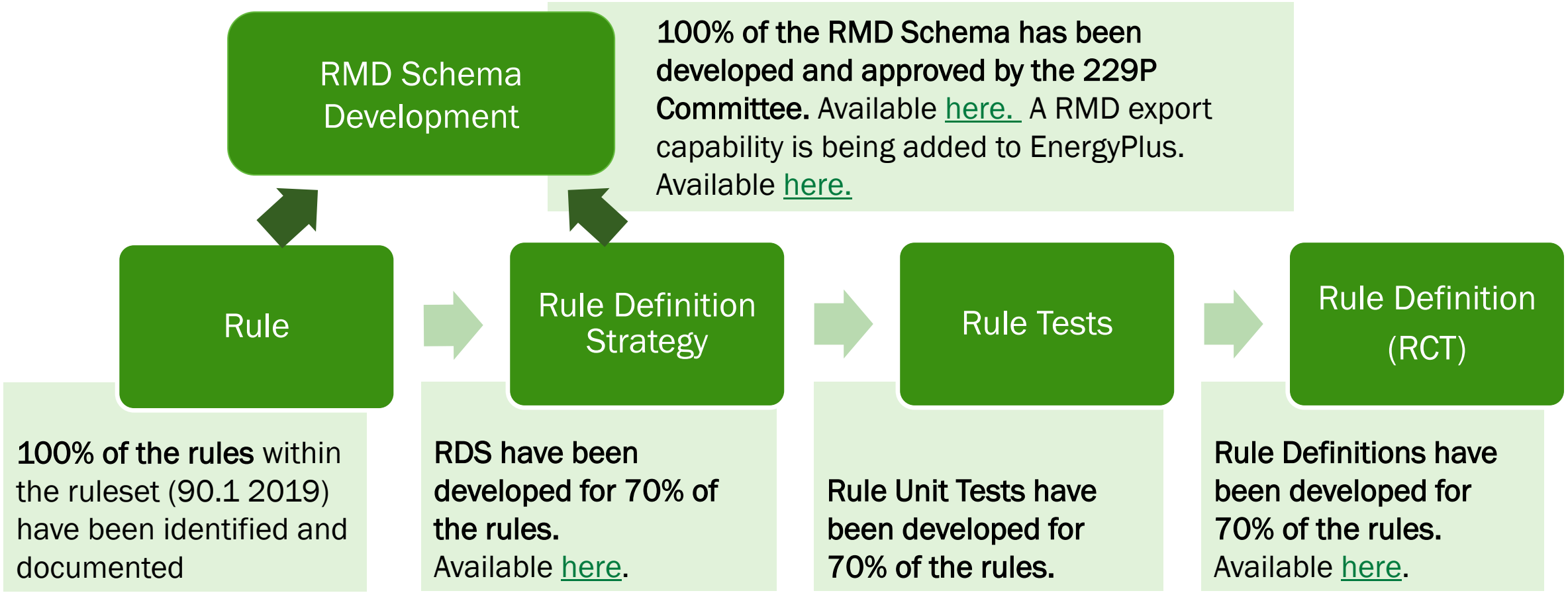
- **In addition to committee members, a large number of software vendors are regularly engaged to review the RMD**

- **Success of the Standard depends on:**
  - **ASHRAE consensus process**
  - **BPM vendors** implementing **RMD export**
  - **Jurisdictions adopting Standard 229P** and requiring use for all buildings complying via Standard 90.1-2019 PRM

Progress: 229P Standard

FY19 (pre-project approval)	FY20 – Year 1	FY21 - Year 2	FY22 - Year 3	FY23 - Year 4	FY24 - Year 5
Project scope and vision discussion with key stakeholders	• ASHRAE Committee formed • **Standard Title, purpose and scope approved** • Committee buy-in on the project testing approach	• **Schema WG is formed** and RMD schema definition begins • **RCT framework** is developed and refined • **Rule Test framework** for RCT testing + compliance is developed	• **RMD schema is completed and approved by the committee**	• Standard language developed and will be brought for committee vote in summer/fall • RCT development completed and tool will be made open-source	• **First public review draft of the Standard** • Support for software vendors to export RMD files

Progress: Software Development



RCT for key 90.1 baseline requirements (envelope, lighting, HVAC systems) is targeted for completion in July 2023

Future Work

FY24

- **Market Adoption**
  - Work with AHJs to support project testing using the RCT
  - Work with software vendors to support RMD export
- **RCT Testing**
  - Verify RCT capabilities on actual building projects using RMDs generated by other software tools
- **Documentation**
  - Identify and provide required documentation and support materials required for AHJs to use the RCT and for vendors to generate the RMD

FY25 and Beyond

- **Identify additional rulesets that could be tested via 229P framework**
- **Expand Standard 229P (if necessary) to support the additional ruleset(s)**
- **Develop RCTs for these rulesets (or assist others in doing so)**

Thank You

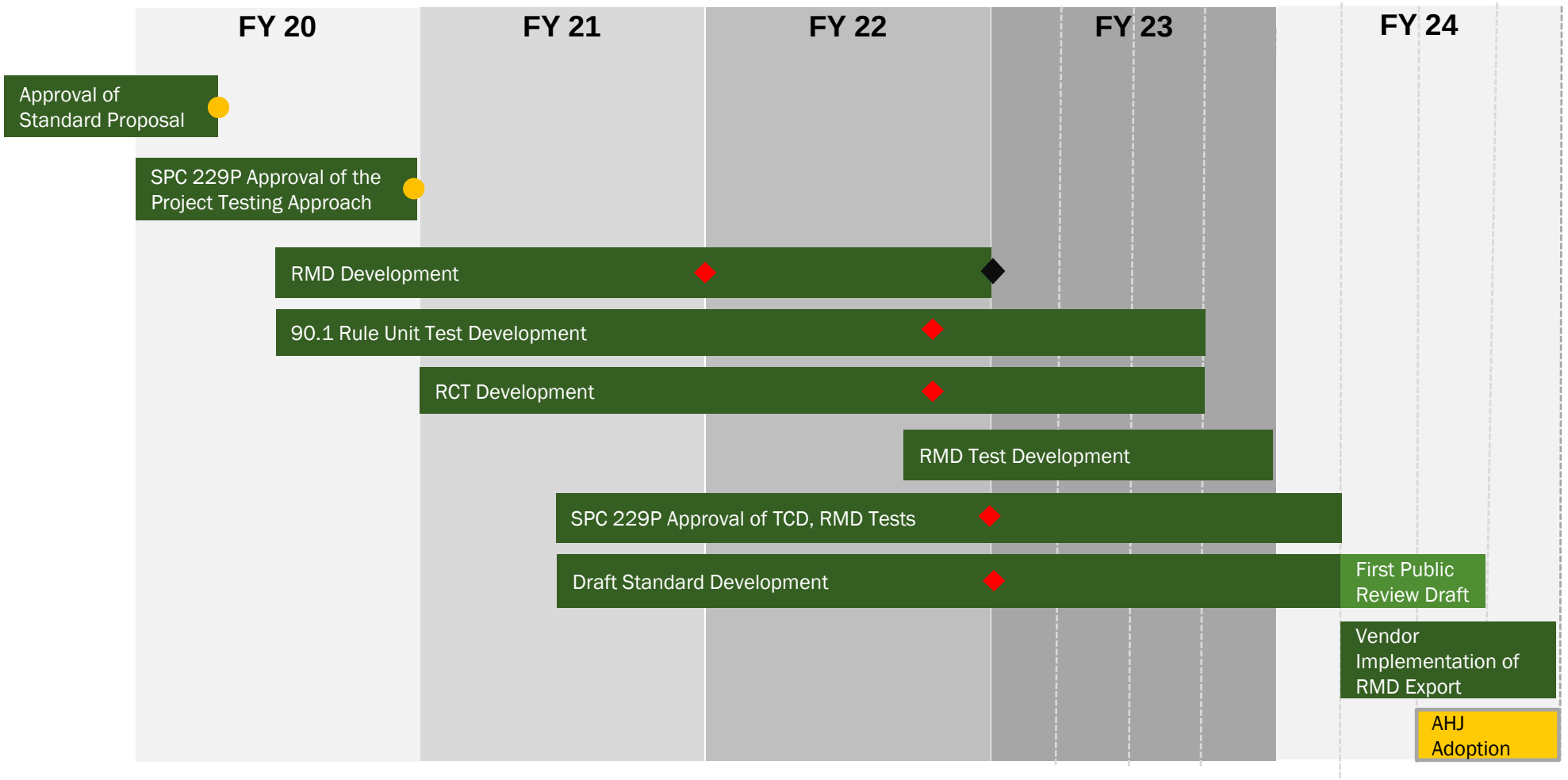
Pacific Northwest National Laboratory
Supriya Goel, Senior Research Engineer
supriya.goel@pnnl.gov
WBS # 3.5.5.54

REFERENCE SLIDES

Project Execution

Project Start Date: 10.01.2019
Project End Date : 09.30.2024

Planned	$ 700,000	Planned	$ 1,210,508	Planned	$ 1,106,766	Planned	$ 894,890
Spent	$ 388,320	Spent	$ 803,732	Spent	$ 911,886	Spent	$ 396,289



Team

Supriya Goel

Michael Rosenberg

Weili Xu

Project team includes experts in **performance-based ruleset development**

Team has **expertise in software development, schema development**

Juan Gonzalez

Charlie Holly

Yun Joon Jung

Jason Glazer, GARD Analytics
Subcontractor

Maria Karpman, Karpman Consulting
Subcontractor