

EnergyPlus

2014 Building Technologies Office Peer Review



Building Energy Modeling Engine



www.energyplus.gov

U.S. DEPARTMENT OF
ENERGY

Energy Efficiency &
Renewable Energy

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Project Summary

Timeline:

Start date: 1997

- 1980s if counting predecessors, e.g., DOE2

Planned end date: N/A

Key Milestones:

1. V8.1 (FORTRAN)—Nov. 15, 2013
2. C++ transition—Mar. 31, 2014

Budget:

Total DOE \$ to date: \$65,000k+

- 2X if counting predecessors, e.g., DOE2

Total DOE \$ future: \$2,500k+/yr

Target Market/Audience:

Building energy modeling for building design, codes and standards development, controls, continuous commissioning, product design and master planning.

Key Partners:

FSEC	GARD Analytics
Trane	Autodesk

Project Goal:

Maintain and advance EnergyPlus as BTO's best-in-class product for whole-building energy performance modeling, by incrementally improving its capabilities and accuracy, and by supporting users and application developers.

Purpose and Objectives

Problem Statement: “Develop, maintain, and support a software tool for fair and accurate assessment of different energy efficiency measures for all types of buildings projects.”

Target Market and Audience: Architects, mechanical engineers, energy consultants, standards bodies, standard-compliance officials, ratings organizations, energy-efficiency program managers, product developers, researchers, educators, software vendors.

Impact: via multiple use-cases

- Entrenched—development of standards & beyond standard design guides
- Elevating—integrative design
 - Can save 8-16 quads annually in 2050 [RMI “Reinventing Fire”]
 - 600 TBTU annually in commercial buildings by 2030 [BTO P-Tool]
 - Will track this via AIA+2030 Commitment Reporting
- Emerging—“integrative operations”
 - Continuous commissioning & fault-detection/diagnosis, control & demand response

Industry Context

EnergyPlus sets the pace for other energy simulation engines

- Others: DOE2.1E, DOE2.2, TRNSYS, IES Apache, Trane TRACE, Carrier HAP, ESP-r, TAS
- Only EnergyPlus combines state-of-the-art features & open-source licensing
- Allows EnergyPlus to serve as basis for codes & standards, e.g., ASHRAE 90.1 ...
- ... and for programs that build on them, e.g., IRS 179D, code-compliance, LEED, etc.
- Other engines gain legitimacy by comparison with EnergyPlus via ASHRAE 140 standard

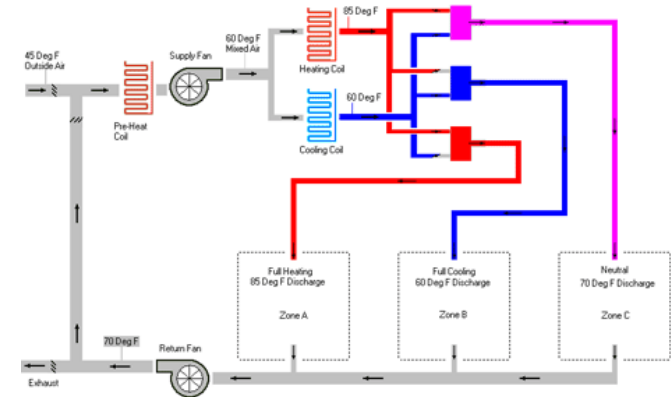
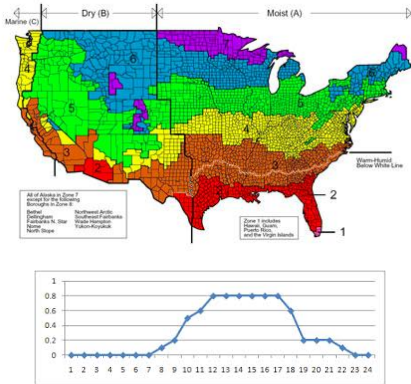
EnergyPlus slowly displacing other energy simulation engines

- New tools & end-user applications primarily targeting EnergyPlus
 - OpenStudio helping here
- State & utility programs requiring EnergyPlus
- Commercial vendors dropping proprietary engines rather than investing in “catch-up”
 - Open-source makes partnering with EnergyPlus easy
- International support for and use of EnergyPlus is growing, e.g., Canada, Brazil

Energy simulation application universe is growing rapidly

- EnergyPlus & OpenStudio playing a big role

Problem Statement Unpacked



“Develop, maintain, and support a software tool for fair and accurate assessment of different energy efficiency measures for all types of buildings projects.” —**simple to say, but a considerable undertaking**

- Big building multi-physics & HVAC system integration engine, how big?
 - 700,000+ lines of code, 4,500+ pages of docs & 700+ of validation reports!
- Must keep up with an advancing technology landscape
 - Materials & assemblies, HVAC components & configurations, controls
- Also needs to be accurate, fast, transparent, supported, easy-to-use, etc.

Requires significant & sustained investment: currently \$2,500k/yr

- DOE is the only viable source for this funding given transparency & neutrality needs

Approach, Issues & Characteristics

Approach:

- Large team (includes industry) with broad expertise & significant experience
- Draws heavily on ASHRAE-developed methods & research results
- Requirements process incorporates BTO, end-users & software vendors
- Rigorously tested according to ASHRAE 140

Key Issues:

- Characterization of accuracy ... and improvement where necessary
- Catching up to, then keeping up with HVAC&R & controls technology
- Execution speed
- Better integration with design tools ecosystem
- Support for operations use cases
- More readily-available training & support

Distinctive Characteristics:

- DOE-branded production software that supports standards & commercial tools
- Successful, multi-lab/contractor/university/industry collaboration

Approach—Team

Team: large & fairly stable with broad-base expertise & experience

- Labs, competitively solicited contractors & in-kind commercial partners
- Total ~7.0 FTE, Edwin Lee is only 1.0 FTE, others are 0.1-0.5 FTE



Brent Griffith
Linda Lawrie



Kyle Benne
Eric Bonnema
Edwin Lee
Luigi Polese
Pablo Tabares



Fred Buhl
Philip Haves
Tianzhen Hong
Thierry Noiudui
Geof Sawaya
Simon Vidanovic
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Pacific Northwest
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Krishnan Gowri
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Xiaobing Liu
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Jibo Sanyal
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Larry Scheier
Jim Spielbauer



Stuart Mentzer



David Bosworth
Shannon Mackey



Peter Ellis
Neal Kruis



Vince Abeyta
John Kennedy
Barry Tsai



Amir Roth

Approach—Project Management & Processes

Requirements: integrate BTO, vendors & end-users (helpdesk & surveys)

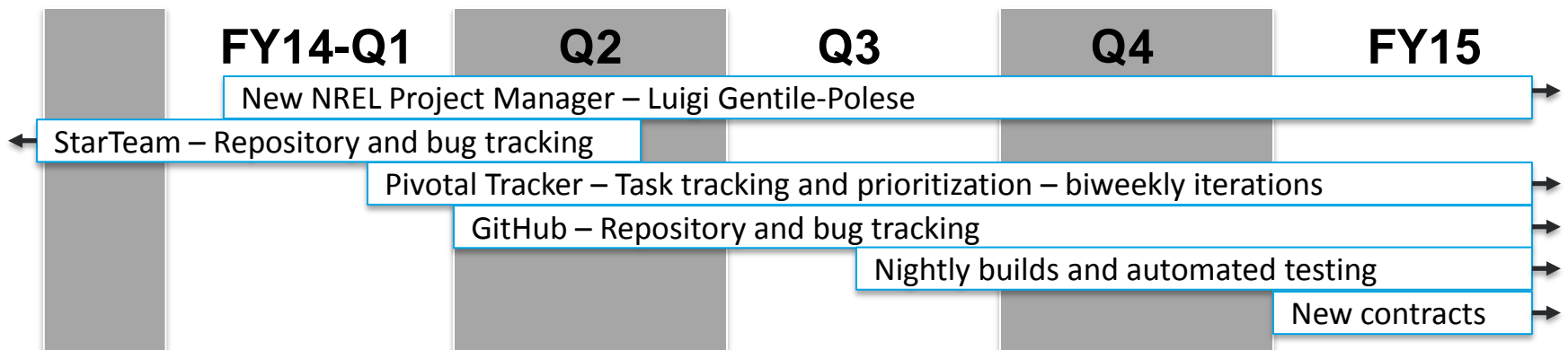
- Annual in-person team meeting for task planning & budgeting

Development: “agile” tools & processes for development, testing & release

- Bi-weekly all-team web-meetings & more frequent “scrums” in smaller teams
- Feature process: proposal → design → review → code → test → review → check-in
- GitHub code repository, PivotalTracker for bugs & features, nightly builds & tests
- Two annual releases with full documentation & validation reports

Support: handle ~100 request / mo via energyplus.helpserve.com

- Training at major conferences
- Goal is to bootstrap a self-sustaining training & support ecosystem



FY14 Activities—New Features

V8.1 release: Nov 15, 2013

- Improved cross- and natural- ventilation models
- Comprehensive models for unitary HVAC systems
- Many new HVAC templates including VRF, dual-duct, heat/cool VAV
- HVAC “optimal start” control
- Model for Daikin high-performance “Rebel” RTU
- Component model sizing diagnostics
- Some models for equipment & operation faults including airside economizer
- Full list available from energyplus.gov website

V9.0 release: planned for Nov 15, 2014

- Unified, updated routines for equipment sizing
- Unified model for room air and multi-zone air-flow network
- Better support for complex zone geometry & interior windows (via Radiance)
- Models for servers & some datacenter HVAC equipment
- Additional models for equipment & operation faults
- XML schema for input & output
- New command-line interface for easier scripted analysis

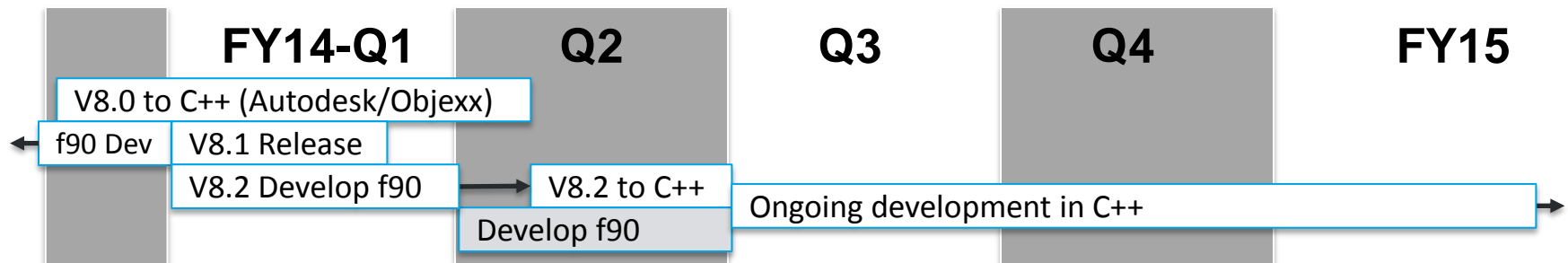
FY14 Activities—FORTRAN to C++ transition

Background & context

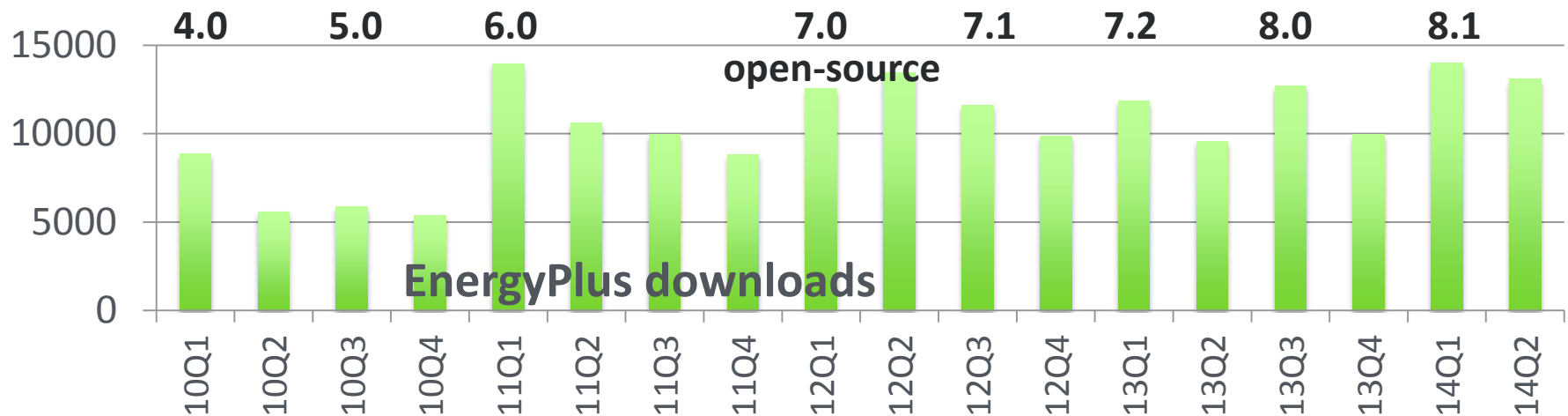
- EnergyPlus originally in FORTRAN due to origins in BLAST program
- FORTRAN has limited access to modern hardware, software libraries & programmers
- DOE considered internal C++ transition several times, but difficult to pull off
 - Can't "stop the world" & little internal expertise

Autodesk stepped up to fund & lead translation

- To facilitate uptake of EnergyPlus into their products
- Objexx performed 2-step translation: i) V8.0, ii) V8.2 "catch-up"
 - "Stopped the world" for 3 months rather than 9
- Currently removing C++ performance overhead (30% remaining)
- Will add object-orientation incrementally, automated translation gave FORTRAN-ic code
- <http://energy.gov/eere/articles/energyplus-boosts-building-efficiency-help-autodesk>



Progress & Accomplishments



Downloads: ~20,000 downloads per version

Market Impact: new tools in past year (that we know of & can talk about)

- Interfaces: GreenSpaceLive gEnergy, ExpertApp N++, Sefaira Concept, ArchSim, Bentley AECOSim EnergySimulator V8i, DesignBuilder 3.4, LBNL/Digital Alchemy Simergy, OpenStudio application & Parametric tool*
- Others: Xcel EDAPT*, CEC CBECC-Com*, BTO Asset Score*, Concept3D Simuwatt*
- * based on OpenStudio SDK—most new development will use this path

Awards/Recognition: 2003 R&D 100 award



Project Integration & Collaboration

Top-down integration: goal is to support 50 vendors, not 50,000 end-users. EnergyPlus uses OpenStudio to accelerate vendor uptake. It's working!

Bottom-up integration: team active on ASHRAE standards and technical committees and in IBPSA. Algorithms & data sets based on latest peer-reviewed & ASHRAE accepted results.

- Collaboration with ASHRAE MTG EAS on airflow modeling
- Collaboration with ASHRAE TC 9.9 on datacenter modeling



Research: combination of advanced capabilities & open-source licensing gives EnergyPlus a significant research presence. Most energy simulation research publications (ASHRAE, IBPSA) use EnergyPlus.

Communications: multiple channels

- energyplus.gov website (most hits in BTO, 3rd most in EERE)
- EERE progress alerts & GovDelivery on new releases
- EERE “success stories” & blog posts
- Seminars on new features & training sessions at major conferences (ASHRAE & IBPSA)



Future—Inaccuracy/Validation & Uncertainty/Calibration

Target problem: perceived & real “inaccuracy” of energy simulation

- Some is “inherent” to physical approximation, most is “propagated” from uncertain inputs
- Limits use cases to comparative (“A is X% better than B”), not predictive (“A EUI is X”)
 - Although you can actually do a lot this way
- Reduces confidence in all use cases, even comparative ones ☹️

Approach I: inaccuracy & algorithm validation

- Characterize & attribute (in)accuracy
- Use small well-characterized setups to remove input uncertainty
 - FLEXLAB, Annex 58 participants, maybe MAXLAB FRP too
 - Currently working out initial set of experiments
- Formalize & publish test cases & results via ASHRAE standard 140
- Use 140 comparative testing to identify additional physical experiments



Approach II: uncertainty & input calibration

- Outside of EnergyPlus, but complements end-uses
- Implementing two mechanisms in OpenStudio
 - Bayesian: fast & easy, includes uncertainty
 - Evolutionary (Autotune): takes longer but gets you closer



Future—Spawn-of-EnergyPlus

Target problem: monolithic structure with built-in imperative solvers

- Inhibits parallelization and co-simulation
- Barrier to prototyping of models for new technologies
- Poorly suited to operations-based use cases



Long term vision: use Modelica for EnergyPlus HVAC&R/controls

- Modelica is a declarative modeling language
 - Decouples governing equations of the system from solver
 - Simplifies prototyping & sharing of models (no need to merge solvers)
 - Supports verification, optimization & direct implementation of control algorithms
- Developed & supported by international community (mostly EU)
- Born in automotive & aerospace world, but making headway in buildings

Approach: Spawn-of-EnergyPlus

- Develop Modelica library for components & systems (LBNL & IEA Annex 60)—started FY13
- Develop & pilot prototype simulation master (LBNL, ORNL)—FY14
- Couple C++ EnergyPlus to solver (use RFP)—FY15-16
 - Will look like conventional EnergyPlus interface to existing users
- Incrementally replace existing C++ components with Modelica components over time

REFERENCE SLIDES

Project Budget

Project Budget: funded since 1997 at \$2,100—5,000k per year

FY14 Spend to Date: \$925k

Additional funding: in-kind labor from Trane & Autodesk

Additional funding: supported by other BTO-funded projects

- ASHRAE 140 for testing
- FLEXLAB for validation
- Modelica Buildings Library & Annex 60 for Spawn-of-EnergyPlus
- Radiance for some geometry algorithms
- WINDOW for fenestration algorithms
- OpenStudio SDK and other CBI projects for deployment

Budget History

1997 – FY2013 (past)		FY2014 (current)		FY2015 – (planned)	
DOE	Cost-share	DOE	Cost-share	DOE	Cost-share
~\$65,000k	?	\$2,500k	\$400k	\$2,500k/yr	?

Project Plan & Schedule

Six month release cycles: Oct. & Apr.

- Months 1- 4: new features and planned enhancements
- Month 5: bug fixes, clean up, robustness testing
- Month 6: critical bug fixes, packaging, distribution testing
- Month 7: post release validation testing and reports

Project Schedule												
Project Start: 1997	Completed Work											
Projected End: N/A	Active Task (in progress work)											
	Milestone/Deliverable (Originally Planned)											
	Milestone/Deliverable (Actual)											
	FY2013				FY2014				FY2015			
Task	Q1 (Oct-Dec)	Q2 (Jan-Mar)	Q3 (Apr-Jun)	Q4 (Jul-Sep)	Q1 (Oct-Dec)	Q2 (Jan-Mar)	Q3 (Apr-Jun)	Q4 (Jul-Sep)	Q1 (Oct-Dec)	Q2 (Jan-Mar)	Q3 (Apr-Jun)	Q4 (Jul-Sep)
Past Work												
V7.2 release		◆										
V8.0 release			◆									
V8.1 release				◆								
Transition to C++ & Agile					◆							
Current/Future Work												
V9.0 release										◆		