

Re-implementing DEER using EnergyPlus and OpenStudio

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Status quo. DEER (Database for Energy-Efficiency Resources) is an important multi-purpose tool in California's building energy-efficiency enterprise. At its core, DEER uses DOE-2.2 energy simulation to calculate energy savings for different energy-conservation measures (ECMs) on models of typical CA residential and commercial buildings. These typical energy savings calculations are combined with information about typical ECM costs and lifetimes to characterize ECM energy-efficiency and cost-effectiveness. DEER is used in several ways, but the most frequent and impactful of these is *ex ante* underwriting for energy-efficiency incentives for both new construction (e.g., Savings by Design) and existing building upgrades (e.g., Energy Upgrade California).

As with a twenty-year old building, DEER is due for a deep retrofit. The DEER component in most urgent need of replacement is the oldest one, the DOE-2.2 simulation engine. Whereas DOE-2.2 enabled the construction of DEER and kept it at the forefront of technology for over a decade, it has become dated and its use is now weighing down DEER and the analyses and enterprises that use it. Two aspects of DOE-2.2 are problematic:

- **Limited simulation capabilities, especially for low-energy designs and systems.** DOE-2.2 uses algorithms from the 1970's and 80's that exploit simplified "compact" calculations—specifically, i) use of one temperature/humidity/heat node per zone, and ii) simulation of HVAC at the system rather than component level—that sacrifice simulation capability in the interest of computational efficiency. This trade-off was appropriate given the available energy-efficiency technologies and computing power of the time, but it no longer is. Computing power has grown by three orders of magnitude while energy efficiency technologies that require more detailed calculations—for instance, i) heating and sensible cooling using radiant surfaces, and ii) HVAC configurations that move heat between zones or end uses like variable-refrigerant-flow air conditioners and integrated air-conditioning/water-heating heat-pumps—have become more prevalent. DOE-2.2's inability to model these technologies forces projects that use them into the longer and more expensive "custom" review pipeline.
- **Lack of transparency and access.** Despite the presence of DOE in its name, DOE-2.2 is not DOE-funded (open-source) software—it is proprietary. Packaged within the popular eQuest interface, DOE-2.2 *is* free to end-users, but this "public good" is subsidized by up-front funding DOE-2.2 and eQuest development, maintenance, and support. This setup funnels all DEER maintenance activity to and through the purveyors of DOE-2.2, limiting competition but also analysis and project bandwidth. And while the results of the analysis are public and subject to scrutiny, the calculations that produce them—along with the many default values that are embedded within DOE-2.2—are not. Lack of access to DOE-2.2 source and development resources also restricts the ecosystem of tools that

In a larger context, DEER's reliance on DOE-2.2 presents a challenge because California's energy-efficiency standard, Title-24, now uses analysis and compliance tools based on the EnergyPlus engine. California now has standards based on one set of calculations and tools and workflows and above-code programs based on a separate set of calculations and a separate, essentially non-interoperable set of tools (although the CBECC compliance engine is designed to interface with other tools, eQuest and PowerDOE have not been linked to it yet). This means additional process work—and reduced productivity—for energy-efficiency professionals.

Alternate future. Re-basing DEER on DOE's EnergyPlus simulation engine will eliminate the above drawbacks and unify California's code and above-code analyses and workflows.

- **Advanced simulation capabilities.** EnergyPlus simulates the relevant physical building phenomena in detail, simulates HVAC at the component level, and has a runtime language that allows for modeling of arbitrary and user-defined control-sequences and strategies. EnergyPlus is fully supported by DOE, religiously maintained and regularly updated—major updates are released twice a year and bug-fixes and new features are available on a continuous basis. EnergyPlus cannot only simulate today's energy-efficiency technologies, but it is set up from both a software architecture and a funding standpoint to keep up as these technologies evolve. A DEER based on EnergyPlus could accommodate additional ECMs and reduce expensive "custom project" traffic.

- **Transparency.** EnergyPlus does not use internal defaults. All values, even seemingly trivial ones like physical characteristics of air and water, are explicit in the input which fully documents the simulation. EnergyPlus is also open-source software. Not only can all of its inputs be audited by anyone, so can its calculations and assumptions. Calculations can also be fixed—and new features added—by anyone, although contributing code to EnergyPlus is a detailed process that properly requires extensive documentation, testing, and documentation, and review. Although engaging EnergyPlus at this level is not easy, but many more people have access to EnergyPlus than do to DOE-2.2.

Simply upgrading the DEER engine from DOE-2.2 to EnergyPlus will address some pressing DEER performance issues but retain the mechanics of its processes and its “driving experience”. A better, and counter-intuitively more cost-effective approach would be to re-build the entire DEER chassis using OpenStudio—DOE’s open-source SDK (software development kit) for energy modeling that dramatically improves the productivity of both modeling itself *and* of the process of developing applications that use modeling. From the point of view of DEER, the most compelling feature of OpenStudio is the concept of “measures”. OpenStudio exposes the building model—and the results of the simulation—to scripting languages like Ruby and Python. An OpenStudio measure is a small program that transforms a building model—i.e., applies an ECM to it, hence the name measure—or queries a model or its simulation results for reporting or quality assurance. Measures help extend and automate energy modeling workflows. “Help someone model VRF you’ve helped them model one building. Write a VRF measure, you’ve helped many modelers model a lifetime worth of buildings”. Or something like that. There are over 170 measures already available on the Building Components Library (<https://bcl.nrel.gov/nrel/types/measure>) online database for many types of asset and operational ECMs. And measures are parameterized so a single lighting upgrade measure can, given different arguments, model many different lighting upgrades.

The concepts and mechanics of OpenStudio measures align with those of DEER maintenance and can be used to streamline them. Measure implementations fully document the ECM in a compact way. For each DEER ECM, the OpenStudio measure can be programmed once—most of them don’t need to be programmed because they already exist—and then automatically applied to all typical building models to analyze performance under a variety of contexts and conditions. Multiple measures can also be evaluated in combination with no additional effort. Consultants can write their own measures—measure-writing is simpler than hacking the innards of EnergyPlus and OpenStudio, and a number of consultants are already facile with it—for non-DEER ECMs and submit them for review and inclusion in DEER updates. Measures not only streamline DEER updates, they allow them to be partially crowd-sourced. The ability to quickly stamp out large scale analysis is the reason why re-building DEER using OpenStudio will be faster and more cost-effective than surgically cutting out DOE-2.2 and replacing it with EnergyPlus while retaining the existing (human) infrastructure.

Measures also can transform the way in which DEER is used on in projects. Obviously, DEER ECMs can be actively used by consultants in modeling projects. Less obviously, reporting and quality-checking measures—for instance, “ensure occupancy schedules in baseline and proposed building are identical”—can be written to streamline review of “custom” projects, and these can be made program specific. An open-source project management workflow called EDAPT (Energy Design Assistance Program Tracker) (<http://eda-pt.org/>) uses OpenStudio reporting and quality-checking measures in this exact way and can be adapted for DEER-based project review.

Summary. The future for DEER is bright, and it is close—like stars, closer futures appear brighter. Many of the components are already in place, and this includes a number of the California specific components which LBNL created in the service of the CEC-funded CBES (Commercial Building Energy Saver) project (<http://cbes.lbl.gov/>). There is obviously work to be done in extending typical building model and measure coverage to match DEER, and in cross-walking DOE-2.2 based calculations and analyses with those based on EnergyPlus. Some of those cross-walks and analyses may already have been done by CEC for the Title24 EnergyPlus transition. Those that haven’t will pay for themselves quickly.

DOE was ecstatic when California adopted its advanced, open-source simulation tools and platforms for Title24, and it is eager to see DEER undergo the same transition. DOE is putting together a DEER-style analytical framework for its own internal strategic investment, goal-setting, and evaluation processes—this is the (in)famous prioritization tool or p-tool—and is happy to share in the development effort where there is overlap.