Arnold Schwarzenegger
Governor

DEVELOPMENT OF AN ENERGY MODULE FOR I-PLACE^{3}S

PIER FINAL PROJECT REPORT

Prepared For:
California Energy Commission
Public Interest Energy Research Program

Prepared By:
Marek Czachorski
Julia Silvis
Gina Barkalow
Linda Spiegel
Matt Coldwell

September 2008
CEC-500-2008-024

Prepared By:
Marek Czachorski,
Gas Technology Institute
Commission Contract No. 500-04-026

Julia Silvis, Gina Barkalow, and Linda Spiegel
California Energy Commission
Matt Coldwell
California Institute for Energy and Environment

Prepared For:
Public Interest Energy Research (PIER) Program
California Energy Commission

Gina Barkalow
Contract Manager

Linda Spiegel
Program Area Lead
Energy-Related Environmental Research

Mike Gravely
Office Manager
Energy Systems Research

Martha Krebs, Ph.D.
PIER Director

Thom Kelly, Ph.D.
Deputy Director
ENERGY RESEARCH & DEVELOPMENT DIVISION

Melissa Jones
Executive Director

Preface

The California Energy Commission's Public Interest Energy Research (PIER) Program supports public interest energy research and development that helps improve the quality of life in California by bringing environmentally safe, affordable, and reliable energy services and products to the marketplace.

The PIER Program conducts public interest research, development, and demonstration (RD&D) projects to benefit California.

The PIER Program strives to conduct the most promising public interest energy research by partnering with RD&D entities, including individuals, businesses, utilities, and public or private research institutions.

PIER funding efforts are focused on the following RD&D program areas:

- Buildings End-Use Energy Efficiency
- Energy Innovations Small Grants
- Energy-Related Environmental Research
- Energy Systems Integration
- Environmentally Preferred Advanced Generation
- Industrial/Agricultural/Water End-Use Energy Efficiency
- Renewable Energy Technologies
- Transportation

Development of an Energy Module for I-PLACE^{3}S is the final report for the I-PLACE3S Energy Module project (contract 500-04-26) conducted by the Gas Technology Institute. The information from this project contributes to PIER's Energy-Related Environmental Research Program.

For more information about the PIER Program, please visit the Energy Commission's website at www.energy.ca.gov/pier or contact the Energy Commission at (916) 654-4878.

Please cite this report as follows:

Czachorski, M., et al. 2008. *Development of an Energy Module for I-PLACE^{3}S.* California Energy Commission, PIER Energy-Related Environmental Research Program. CEC-500-2008-024.

Table of Contents

Abstract

This project improves the California Energy Commission's Internet-based land use modeling tool, Planning for Community Energy, Economic, and Environmental Sustainability (I-PLACE^{3}S), by adding the capability to calculate the energy use of different development scenarios. The new energy module estimates the overall energy consumption of various building types and land uses, allows analysis of distributed generation technologies and selected building energy efficiency measures, and allows planners to compare the relative energy use and related emissions of different development scenarios. Future enhancements may add an economics component and expand the energy module's analytical capabilities, particularly in the energy efficiency and distributed generation areas.

Designed for use by local and regional government planners, the energy module aims to promote land use decisions that decrease energy consumption and carbon dioxide emissions. The tool helps clarify which development choices will allow the state to better meet the greenhouse gas emission targets set out in Assembly Bill 32.

Keywords: I-PLACE3S, PLACE3S, energy end use, land use planning, energy end-use modeling, building energy efficiency

Executive Summary

Introduction

In the 1990s, the California Energy Commission developed a desktop computer–based geographic information system software application for land use planning called Planning for Community Energy, Economic, and Environmental Sustainability (PLACE^{3}S). Designed to facilitate "smart growth" decisions throughout California, the program allows planners to compare the impacts (vehicle miles traveled, housing, employment, amount of urbanized land, preservation of agricultural land, and others) of different land use and development scenarios. PLACE^{3}S became a standard planning tool. In 2001, the Energy Commission worked with the U.S. Department of Energy to add an energy component to the desktop version. The desktop PLACE^{3}S energy module included algorithms to calculate energy demand and weigh options for distributed energy generation for any given geographic area in California, but was incapable of handling the data volume, speeds, and complexity necessary for sophisticated assessments and real-time response. In 2002, the Energy Commission contracted with EcoInteractive Inc. to convert PLACE^{3}S from a desktop personal computer program to an Internet-version—called I-PLACE^{3}S—which dramatically improved processing times and accessibility. However, this initial Internet version did not include any of the more complex desktop energy module calculations of the energy impacts of buildings or distributed generation. Consequently, the Energy Commission again contracted with EcoInteractive Inc. to create an Internet-based energy module that equips planners to consider how their decisions will influence a building's future energy use.

Purpose

This project developed an energy module to be compatible with the Internet-based I-PLACE^{3}S planning tool. The new energy module was developed to equip regional and local governments with a user-friendly tool to compare energy supply and efficiency options during land use decision-making processes.

Project Objectives

The energy module project set out to accomplish the following:

- Provide local and regional governments with the ability to analyze community building energy demand and consumption (both gas and electric) and emissions, based on different growth and land use options.
- Help governments evaluate the benefits of applying distributed energy generation technologies in residential, commercial, and selected industrial applications and better understand the economics associated with these options when they are developing growth and land use plans.
- Provide data, such as the energy demands of various development scenarios, that will assist the development of a region-wide energy strategy and an energy element in general plans for cities and counties.

- Test and validate the developed energy module by key stakeholders.
- Define user needs and create a robust I-PLACE^{3}S energy module featuring:
  - User-friendly "point and click" interfaces.
  - Robust performance for energy efficiency and distributed generation technology options that can be calculated in minutes (or seconds).
  - The ability to calculate energy demand and consumption at a single application/building level and at a whole-project/community level.
  - The ability to determine the optimal application of distributed energy generation options, including combined heat and power, wind, and photovoltaics.
- Validate the energy calculations in the new I-PLACE^{3}S version of the energy module.

Project Outcomes

The Internet-based energy module allows users to compare energy demands associated with different building types based on an extensive library of prototypical buildings. This capability provides planners comparative energy use profiles and associated emissions when considering various growth plans; for instance, more single-family homes (business as usual) will show a higher per capita energy profile than a smart growth plan that emphasizes mixed-use, multi-family buildings. The module evaluates the effectiveness of various distributed generation options, and, because California policy prioritizes energy efficiency as a first step in reducing energy use, the module can also evaluate a selected package of building energy efficiency measures when comparing different energy-saving strategies.

While the desktop version provided a valuable starting point, several modifications were necessary. Using new programming logic, the following modifications were incorporated in the Internet-based module:

- The module's buildings and land use types were matched more closely to those used by planners (for example, type and size of building).
- A new residential database (seven building types) was developed and calibrated. Validation of the desktop version revealed serious flaws with the energy use profiles associated with the modeled baseline residential buildings. Using metered data from the Sacramento Municipal Utility District, the residential buildings database was calibrated to more closely match observed field data.
- Homes built in 2005 and after were added to the residential database.
- The commercial buildings database was replaced with a new data source—the Database for Energy Efficiency Resources, which features 23 building types including 2005+ vintage.[1]

---

1. Sponsored by the California Energy Commission and California Public Utilities Commission (CPUC, the DEER database (http://www.energy.ca.gov/deer/) is designed to provide well-documented estimates of energy and peak demand savings values, measure costs, and effective useful life (EUL) all with one data source. The users of the data are intended to be program planners, regulatory reviewers and

- Carbon dioxide, nitrogen oxide, and sulfur dioxide emissions were calculated related to building energy use and on-site power generation.
- Marginal emission rates were incorporated for calculating impacts of carbon dioxide emissions reduction.
- Analysis of the impact of energy efficiency measures on commercial buildings' energy use and emissions was added (selected package including glazing, heating, ventilation, and air conditioning (HVAC), and lighting).
- A new energy indicators scenario comparison module was developed.
- Distributive energy generation technology choices were refined to meet user needs (including several technologies that are part of the Self-Generation Incentive Program—reciprocating, microturbines, gas turbines, fuel cells and solar photovoltaics). Renewable DG options were simplified to include only solar PV.
- New user interface and output reporting options were added.

The validity of the energy calculations implemented in the first beta version of I-PLACE^{3}S energy module was extensively tested by the Gas Technology Institute. All of Gas Technology Institute's "essential" and most of their "recommended" fixes were incorporated, except for three related to economics calculation and reporting. The revised beta version was tested and validated in the hypothetical, and the Gas Technology Institute and Alternative Energy Systems Consultants, Inc. also added a small-scale quality control test.

This second round of beta testing concluded that the revised energy module provides technically acceptable energy and emissions calculations. However, the energy efficiency and distributive energy generation components, although functional, still require further work before the Energy Module can be considered a fully featured modeling tool. The module is missing calculations from the economic impacts of various distributive energy generation and energy efficiency scenarios to steer planners toward the most cost-effective options.

Conclusions

This project successfully developed a new Energy Module for the Internet version of PLACE^{3}S, but the module has some important limitations. It is a modeling tool that should be used to compare building energy use and related emissions in a *scenario* format.

The model provides results for a user-specified area and selected mix of prototypical buildings (for example, a "generic" house, hotel, office building, or hospital); its results should only be interpreted as relative between scenarios rather than as absolute energy usage predictions. The modeling should not be used to calculate actual emission profiles for a planned community or to obtain carbon dioxide reduction credits. The results, however, are very useful for assessing how different land use options will affect electricity use/demand, natural gas use/demand, and

---

planners, utility and regulatory forecasters, and consultants supporting utility and regulatory research and evaluation efforts. Database for Energy Efficiency Resources has been has been designated by the California Public Utilities Commission as its source for deemed and impact costs for program planning.

carbon dioxide emission profiles, so that relative scenarios can be compared to improve understanding of the energy implications for various growth patterns.

While the current version of the I-PLACE^{3}S energy module appears to be a good tool for evaluating differences in buildings' energy consumption under different development scenarios, as well as the effects of implementing distributive energy generation and selected energy efficiency measures, more testing and validation with real building energy demand data in different climate zones is necessary. Addition of an economics component is needed to prevent users from selecting energy efficiency and distributive energy generation options that may not be practical. With further refinement, the energy module should help support development of a region-wide energy strategy and an energy element in general plans for cities and counties.

Recommendations

It is recommended that selected features of the energy module found in the desktop computer version but not transferred to the Internet version, be transferred, specifically:

- Calculation of gas and electric costs to customer.
- Economic ramifications of implementing distributive energy generation and photovoltaic technologies:
    - Return on investment.
    - Simple payback.
    - Installation costs and operating and maintenance costs.
- Expanded renewable technologies option (wind).
- Extension of distributive energy generation heat recovery to building cooling (absorption chillers).

The following new features are also recommended for inclusion in I-PLACE^{3}S:

- Energy efficiency–compatible residential database.
- Selected energy efficiency measures for homes and multifamily dwellings.
- Economics of implementing energy efficiency measures in commercial and residential buildings.
- Expanded library of fuel cell technologies (molten carbonate and PEM).
- Solar thermal technology in residential buildings.
- Selected recommended upgrades by the Project Advisory Committee (see Section 5.2 of report).

Furthermore, the module with these additional features should be validated through a series of real-life test cases involving larger numbers of buildings, various weather zones, and various land use planning scenarios.

Benefits to California

Local and regional governmental land use planners and regional transportation agencies (such as Metropolitan Planning Organizations/Councils of Governments) that allocate transportation funds are core users of the I-PLACE^{3}S. These entities are often involved in regional planning issues beyond transportation, such as housing, the economy, and the environment. Recently, users of I-PLACE^{3}S have expressed interest in using the software for comprehensive regional energy planning. The I-PLACE^{3}S Energy Module, even at its current stage of development, provides a tool for governmental planners (as well as utility planners, government officials, and citizens) to coordinate planning across a region and evaluate specific growth scenarios by energy use, related emissions, and implementation of distributive energy and selected energy efficiency measures. Furthermore, the Energy Module may provide information helpful to local governments for developing an energy element in their general plans. The I-PLACE^{3}S energy module forms part of a growing suite of tools California can use in evaluating ways to meet its ambitious greenhouse gas reduction agenda.

Note that energy module users must have an agreement with EcoInteractive Inc., and the software requires uploading extensive regional data. Current users of I-PLACE^{3}S may use the energy module as part of their existing agreement, but should confer with EcoInteractive regarding the sort of energy planning they wish to do and if any changes to their existing agreement are necessary to cover additional analyses.

1.0 Introduction

Land use planning leads to decisions that determine the fabric of our communities for decades, and one of the difficulties in land use planning is envisioning how a development decision made today will play out over future generations. Computer modeling has allowed us to glimpse multiple versions of the future in many other applications, and land use decision making is a natural fit for modeling programs. Such models are complicated and costly to develop, however, and generally beyond the ability of any single local government to create.

In response to the need for computer tools to assist local land use decisions and facilitate "smart growth" throughout California, the California Energy Commission (Energy Commission) supported development of a desktop personal computer (PC) version of geographic information system (GIS) software application for land use planning called Planning for Community Energy, Economic, and Environmental Sustainability (PLACE^{3}S). The PC version of PLACE^{3}S application was released in the late 1990s, and was used in large-scale and long-range planning projects in San Diego, Sacramento, Atlanta, and in the San Francisco Bay Area. In general, planners welcomed the new insight PLACE^{3}S gave them into the ramifications of their decisions; however, they desired a program that could handle more data and offer more sophisticated capabilities. In 2001, the Energy Commission, working with a U.S. Department of Energy (U.S. DOE) grant, began development of a prototype PLACE^{3}S energy module, which forecasts the energy demand implications of various development decisions.[2] The GIS-based PLACE^{3}S energy module ran on desktop PCs and included algorithms to calculate energy demand and weigh options for distributed energy generation (DG) for any given geographic area in California, but was incapable of handling the data volume, speeds, and complexity necessary for sophisticated assessments and real-time response.

In 2002, the Energy Commission contracted with EcoInteractive Inc. to develop an improved Internet-based version of the original desktop PLACE^{3}S. The improved version is known as Internet – Planning for Community Energy, Economic, and Environmental Sustainability (I-PLACE^{3}S). EcoInteractive reprogrammed the PLACE^{3}S land-use model using leading-edge technologies (server farm, enterprise database, and new GIS technologies), which dramatically increased accuracy and data volume capabilities, reduced calculation times, and provided new functionality. The Internet-based I-PLACE^{3}S community planning software has been used in several metropolitan regions, including Sacramento's six-county region, San Diego County, and San Luis Obispo County.

The next logical step in the tool's evolution was to add the energy calculations capability to this new Internet version of the program. Hence, in 2005, the Energy Commission again contracted with EcoInteractive Inc. to incorporate an energy module into I-PLACE^{3}S.

---

2. The desktop PLACE^{3}S energy module was developed in 2002 by Parsons Brinckerhoff Quade & Douglas, Space Imaging, Eley Associates, and Alternative Energy Systems Consulting.

The primary purpose of this project was to develop a comprehensive and user-friendly energy module for I-PLACE^{3}S that would allow local governments and interested stakeholders to understand and weigh energy planning scenarios in broader local/regional governmental planning efforts.

2.0 Overview of Approach

EcoInteractive Inc. analyzed the desktop version of the PLACE³S energy module to gain a thorough understanding of what changes were needed to convert it to an Internet-based version (such as the database used, data attributes, assumptions and programming logic), to evaluate the technical accuracy of outputs, and to document any enhancements or changes required to rewrite the program code using the Internet-based I-PLACE³S system architecture.

To evaluate the needed changes in the desktop version of the energy module, this project engaged critical stakeholders to participate as policy and technical advisors. The Project Advisory Committee (PAC) was composed of regional planners, utility planners, energy experts, city energy officials, researchers, and nonprofit organizations. The PAC provided advisory guidance to the Energy Commission at key points in the project. The core Technical Advisory Committee (TAC) was composed of representatives from the Gas Technology Institute (GTI) and the California Institute for Energy and Environment (CIEE), with occasional participation from Sacramento Municipal Utility District.

In addition, the PIER management team solicited the services of GTI, Architectural Engineering Corporation, and Alternative Energy Systems Consulting, Inc., (AESC) to act as technical advisors to staff to ensure technical quality control of the project.

During the review and modification of the Energy Module, it became apparent that "user needs" might be different than "analysis requirements. The current users of I-PLACE³S are government agencies (specifically, councils of governments) that use the software for transportation and regional planning, and their planning horizon is typically 20–30 years. These entities use I-PLACE³S for guidance on future planning decisions as defined in the general plan; for example, for consideration of land use parcel zoning. Therefore, the tool is most typically used on a large scale (geographically and temporally) with a large focus (multiple activities).

At the same time, to properly model energy usage profiles, very specific and detailed energy data calculations are required—down to every hour in the day, for multiple different end-uses such as lighting, appliances, heating and cooling—in stark contrast to the level of detail that regional planners typically use. For example, current I-PLACE³S users do not specify the size of buildings when using the tool, let alone even consider what energy end-uses might apply. Yet, to use the tool to calculate energy consumption and to consider distributed generation (DG) and energy efficiency (EE) options, it is necessary to specify the size of the building.[3] However, data for this type of fine detail at the parcel and building level are not typically available to or provided by users who prepare and analyze long-term and region-wide scenarios. Thus, Energy Commission staff, technical consultants, and EcoInteractive looked for ways to obtain this

3. Building size is a key piece of information because it determines energy density (energy use per square foot per dwelling unit), and energy density is an important metric to gauge the appropriateness of a particular DG technology, which are best suited to serving areas with high/low energy density.

information and build it into the program so that users would not need to provide it in order to run the program.

The desktop PC version of the energy module already had a database of energy use profiles for residential and selected commercial buildings. However, a validation of that existing database showed serious flaws with the energy use profiles associated with the modeled baseline residential buildings. Using SMUD metered data, the residential buildings database was calibrated to more closely match observed field data. Because SMUD did not have statistically significant data to validate the commercial buildings database, the PAC, TAC, and Energy Commission determined that the Database for Energy Efficiency Resources (DEER) would provide the best available data for determining baseline commercial buildings data.[4] Consequently, EcoInteractive Inc. set out to incorporate this database into the energy module.

Another significant factor guiding the module development was incorporation of the loading order, the Energy Commission and California Public Utilities Commission's (CPUC) order of priority to reduce energy demand.[5]

EcoInteractive Inc. developed the I-PLACE^{3}S energy module after thorough review of the aforementioned considerations. However, an examination of the first beta version of the Energy Module by the Gas Technology Institute revealed several significant problems and resulted in recommendation for major changes before the tool could be considered acceptable for public release. The review also identified a series of other enhancements needed for the tool to be more user-friendly and to have a more thorough DG and building EE evaluation capability.[6]

EcoInteractive agreed to fix problems identified in GTI's report as essential, but felt that some considered less important were beyond the funding level of the project. Therefore, the readers should be aware that additional work would be required to have a more thorough DG and building energy efficiency component of the energy module as it currently exists.

---

4. Sponsored by the California Energy Commission and California Public Utilities Commission (CPUC, the DEER database is designed to provide well-documented estimates of energy and peak demand savings values, measure costs, and effective useful life (EUL) all with one data source. The users of the data are intended to be program planners, regulatory reviewers and planners, utility and regulatory forecasters, and consultants supporting utility and regulatory research and evaluation efforts. DEER has been has been designated by the CPUC as its source for deemed and impact costs for program planning. DEER is located at www.energy.ca.gov/deer and maintained by J. Hirsch & Associates.

5.The loading order was established in the Energy Action Plan (available at www.cpuc.ca.gov/word_pdf/REPORT/28715.pdf) drafted in the wake of the 2001 electricity crisis. It prioritizes the following strategies for meeting California's energy needs: (1) increased efficiency and conservation; (2) increased energy generation from renewable sources; (3) increased energy generation from clean fossil-fuels; (4) improved transmission and distribution infrastructure.

6. M. Czachorski, Gas Technology Institute, "Evaluation of Beta Version of I-PLACE^{3}S Energy Module," April 16, 2007.

A second technical review conducted by the Gas Technology Institute and Alternative Energy Systems Consultants, Inc., found that EcoInteractive completed all essential and most of the recommended fixes except for those related to implementing economics calculations and reporting. Additional quality control testing, using small-scale test setup with three buildings, was conducted by both GTI and AESC, who concluded that the revised energy module is capable of providing technically acceptable results related to the energy and emissions calculations, although it is still missing the economics component, which is needed to help users select practical EE and DG options.

In addition to developing I-PLACE^{3}S energy module, EcoInteractive developed an online tutorial with detailed user instructions, available as Attachment C to this report.[7]

7. The online tutorial is available at http://places.energy.ca.gov/places/energy_tutorial/. Interested parties may also contact EcoInteractive Inc. at info@ecointeractive.com.

3.0 Review of PLACE³S Desktop Energy Module

As a first step, EcoInteractive performed a detailed review of the desktop PLACE³S energy module, including review of:

- The logic and methods used to calculate energy consumption and peak demand as well as DG options.
- The 2002 building energy database.
- The screens layout, interfaces, and data entry requirements for the users.
- Interviews with members of the PAC.

EcoInteractive also reviewed the 2002 PLACE³S Energy Module Project Summary Report (Parsons Brinkerhoff Quade & Douglas et al. 2002), and a presentation by Nancy Hanson of the Energy Commission at the Fourth Annual International Symposium on Distributed Energy Resources (Hanson et al. 2002). The following are important findings.

3.1. Overview of Desktop Energy Module Functionality

The 2002 desktop PLACE³S energy module was designed to forecast land-use-plan energy consumption (the "2002 PLACE³S Energy Calculator"), and to analyze DG options for a given area (the "2002 DG Analysis"). It was designed to calculate the energy indicators shown below in Table 1.

Table 1. Indicators in the PLACE³S desktop Energy Module

Calculated Indicators for the Desktop PLACE³S Energy Module	Description (Unit of Analysis)
Annual grid electric energy	Kilowatt-hours (kWh) per dwelling and/or employee
Peak annual grid electric energy	Kilowatt (kW) demand per dwelling and/or employee; the highest rate of energy consumption throughout the year
Annual natural gas consumption	One thousand British thermal units (kBtu) per dwelling and/or employee
Total installed capacity of each DG technology	Capacity per installed unit (kW)
Total area used, by area type, for each DG technology	Roof, ground, underground parking square footage
Economic indicators	Changes in expenditure (in dollars) associated with changes in electricity and fuel usage
Return on investment	Calculated as first-year savings divided by capital investment
Simple payback period	Capital investment divided by first-year savings
Total installed costs	Cost per installed unit
Operation and maintenance (O&M) costs	Cost per year and/or cost per kWh
Environmental impacts	Air emissions

Source: Parsons, Brinkerhoff, Quade & Douglas, Eley Associates, Alternative Energy Systems Consulting, and Space imaging 2002

Using both parcel-specific data and project-level data (global assumptions), the 2002 PLACE³S energy module determined energy demand data for each parcel by matching user inputs with a building energy consumption database developed using U.S. Department of Energy's U.S. DOE-2 computer model.[8] The energy demand data was then aggregated for each energy zone or sub-area defined by the user.

Calculating the total energy use of a scenario required two separate levels of information. The first set of data was at the parcel level. These data included specific information about the development on an individual parcel, such as the building type, average building size, and number of stories.

The second dataset required significant user input and knowledge and applied to the geographic area of the project instead of individual parcels; these are called *global assumptions* since they are applied "globally" to a particular project, such as climate zone and location.

Specifically, the user entered a climate zone for each project (that is, each group of parcels that defines a planning area). The user then assigned the percent of building types within the project area, as well as the percent of heating type used for each development type in the project.

This calculation produced estimates of both total energy use and peak demand, the latter being an important consideration in electric system planning. The energy demand outputs were based on "typical" energy usage associated with particular types of buildings over the course of the day; the numbers were aggregate energy representations of particular residential and commercial buildings. The total energy use of one scenario was then subtracted from the total energy use of another scenario to return a difference in energy use between one development scenario and another. The method worked with both residential and commercial building types. This approach allowed planners to compare one scenario to another, and it also assumed that the *relative* differences among electric demand (particularly peak demand)—as opposed to *absolute* energy use—are most important in assessing the energy impact of alternative development scenarios.

EcoInteractive reviewed the screening logic and data elements used by the 2002 PLACE³S energy module to calculate the total energy use of each scenario. Some elements were reviewed in more depth than others, as discussed below.

---

8. DOE-2 is a widely used and accepted freeware building energy analysis program that can predict the energy use and cost for all types of buildings. DOE-2 uses a description of the building layout, construction, operating schedule, conditioning systems (lighting, HVAC, etc.) and utility rates provided by the user, along with weather data, to perform an hourly simulation of building energy demand and to estimate utility bills. For more information on the data and modeling capabilities of this freeware, go to www.doe2.com.

3.2. Distributed Generation Screening Logic and Data Elements

3.2.1. Desktop DG Component

One of the key tasks of this project was to review the algorithms and logic used in the desktop version of the PLACE^{3}S energy module to determine the best DG options for a given area[9] and identify any need for enhancements. DG was a key feature of the PLACE3S energy module, because at the time the Energy Module was being developed, California had not made official its loading order, which prioritizes energy efficiency over DG in terms of supply reduction options. Further, DG typically uses natural gas with heat recovery potential and was a cheaper alternative to grid-supplied electricity. DG is still considered important in California's energy mix, and in concert with improved building energy efficiency, can help cities manage energy demand as they grow.

DG screening requires three types of data: location-specific data, building characteristics, and DG technology specifications. Each dataset contains data sub-elements (attributes) that can be used to define a specific location of a DG application. These datasets are overlaid to determine "feasible" DG applications, which is the first step in determining DG impacts. A database of general DG technology characteristics—similar to the California Alliance for Distributed Energy Resources (CADER) technology matrix—was developed for the desktop PLACE^{3}S energy module. This database included a range of DG characteristics:

- Technology type
- Fuel
- Full-load capacity (kW)
- Heat rate, both full- and part-load rates (Btu/kWh higher heating value [HHV])
- Air emissions (lb/kWh)
- Minimum load, as a percent of full load (kW)
- Deployment method (e.g., on-peak, load-following, baseload)
- Footprint (square foot per kW installed)
- Capital cost ($/kW)
- Installation cost ($/kW)
- Maintenance costs ($/kWh)

The following DG technologies were included in the desktop version:

- Reciprocating internal combustion engines, in both simple-cycle and cogeneration configurations (natural gas only, 50–6000 kW)
- Microturbines, in both simple-cycle and cogeneration configurations (50–50 kW)

9. A given area will typically encompass multiple types of development, such as various types of residential, commercial, industrial, or public buildings.

- Small gas turbines, in both simple-cycle and cogeneration configurations (500–10,000 kW)
- Solar photovoltaics
- Wind turbines
- Fuel cells (phosphoric acid type only, ~200 kW)

3.2.2. Calculation of Distributed Generation Options—Simplifying the Interface

The desktop PLACE³S software required large number of user inputs. This level of control introduces significant complexity, which may confuse some users, and imposes a heavy data-inputting burden. Stakeholders agreed that the complexity of the user interface in the desktop PLACE³S software may potentially reduce the module's use. It was felt that software users should be able to accomplish the following tasks with relative ease:

- Evaluate the feasibility of meeting a renewable energy goal.
- Compare different distributed energy options.
- Incorporate predetermined permit constraints and technology choices in analyses.

In response to this feedback, EcoInteractive worked with AESC to simplify the user inputs required and gear the process to better fit user needs. In the original program, the user was required to enter very detailed information for each development type in order to analyze DG deployment. EcoInteractive simplified this interface. (Example screen shots are available in the online tutorial at http://places.energy.ca.gov/places/energy_tutorial/.)

For instance, many cities would like to evaluate the benefits of applying optimized deployment of DG. Therefore the new DG interface was modified to allow users to evaluate DG options by selecting from the following deployment goals:

- Maximize reduction of grid electric purchases
- Minimize the cost of electricity
- Maximize electric service reliability

Users can investigate the potential to achieve any of these deployment goals with either fossil-based DG, renewable energy/based photovoltaic systems, or mix of both.

In addition, users can now select from the following preset preferences to determine DG deployment rankings:

- Environmentally friendly
- Most economical (lowest generation cost)
- Minimum space use (smallest footprint per kW)

Discussions with AESC suggested that in California the only DG options being implemented on a widespread basis are single-family homes with photovoltaics (PV) and solar thermal (hot water heating). At the request of PAC members, the DG choices were made to include those that are part of the Self-Generation Incentive Program (SGIP). These technologies all have cost data available that may assist in economic analyses. Sufficient cost information is not available on solar thermal and for that reason; it is currently not a technology choice in the energy module. Thus, in this version of the energy module, DG options for single-family residential homes are limited to PV.

The energy module has been designed so that users can request to have new technologies added as they become available. If users want to add solar thermal, they will need to provide funding for this option. The advantage of this arrangement is that if one user makes the change, all users benefit, but it may be difficult to find users willing to spend money to improve the program.

3.3. Buildings Energy Demand: Data Gaps and Need for Validation

The land use inventories and development types used by the Council of Governments did not match well with building types defined in the PLACE^{3}S energy module energy database, and some development types were not listed. In response to this concern, EcoInteractive worked with the Sacramento Area Council of Governments (SACOG), the city of Sacramento, and the city of Rancho Cordova to review development types and to determine what changes needed to be made to the residential energy database, so that module developers could incorporate similar building categories in the energy database.

In addition, the energy demand calculations needed to be compared to “real world” energy data to test and validate the technical approach. To address this issue, EcoInteractive programmed the energy demand calculations and logic from the desktop prototype into the Internet version of I-PLACE^{3}S, which would enable users to calculate annual electric demand (in kW) and annual energy consumption (in kWh) for a given area. These numbers could be then compared with available data from actual electric bills.

3.4. Summary of Major Findings

The following are the major findings and recommended changes stemming from review of the 2002 PLACE^{3}S energy module, as well as a brief description of how they were addressed in the new version of the energy module:

- **The energy database building types do not always match the land use types used by planners.** Planners may use types of “mixed use, urban living” and “medium density mixed use” which may include both commercial and residential uses. It was an open question how the energy database building types, which are strictly divided into residential and commercial buildings, should be aligned with the parcel descriptions. This problem was addressed in I-PLACE^{3}S by allowing the users to specify a mixed percentage of any parcel place type (for example, 80% high-rise residential and 20% retail commercial).

- **The energy calculator requires extensive data entry for a variety of fields.** The large data entry need is burdensome for users and may reduce the use of the Energy Module. This problem was addressed by using standardized building prototypes and, in the case of commercial buildings, by incorporating the DEER data (23 prototype commercial buildings).
- **Some data elements are not widely available on a systematic basis.** Accurate and reliable data for year built (or building era), water heating fuel type, and occupancy are not readily available for all parcels. This problem was addressed by incorporating the data that were available and identifying data sources. For example, year built is sometimes available for residential detached homes from assessors' files, and the Census Bureau tracks home water heating type by census block. Consequently, the user can define the building vintage or ask the program to use average census data for the analyzed location. For new developments the data issues are not as problematic, but for redevelopment projects it can be more difficult to obtain the important information.

4.0 Validation of Building Energy Databases

Both PAC and TAG members stressed the need for validation of the module's energy calculations. As part of this task, EcoInteractive conducted a thorough review of the building energy databases in the desktop version of the energy module.

4.1. Validation of Residential Buildings Database

The desktop PLACE³S software was tested by the Architectural Engineering Corporation for the ability to produce reasonable energy results that correlate with SMUD data. Initial testing showed that the PLACE³S database over-predicted energy usage for residential homes in the Sacramento area.

EcoInteractive Inc. focused on validating and calibrating load profiles of the residential buildings (detached, townhouse, and high-rise) in the energy database, which was originally developed by Eley Associates (now ArchEnergy) using U.S. DOE-2 modeling of various buildings for each of the 16 California weather zones. To assure program accuracy, EcoInteractive used a detailed dataset of energy consumption from over 400,000 Sacramento Municipal Utility District (SMUD) meters in the Sacramento area to directly calibrate the residential buildings so that the database end-use load profiles would reflect field data of annual energy use (both consumption and electric demand). The main focus was on the detached single family homes, multiple-family residential buildings such as townhouses, and low-rise and high-rise apartment/condo buildings.

There was a need to differentiate between buildings three-stories and lower from buildings higher than three stories because the distributed generation options could vary greatly depending on the size of the building. EcoInteractive relied on energy expertise from the Gas Technology Institute, ArchEnergy, and the California Institute for Energy and the Environment in the calibration effort. There was a fair amount of technical work required to determine appropriate adjustments to the model in order to obtain outputs that better reflect real-world data.

A good example is the case of 2000+ era buildings. Since metered energy data on these newer buildings was not yet available in a statistically significant sample, the TAC relied on the actual Title 24 2001 prescriptive approach to verify U.S. DOE-2 modeling. Additional guidance to determine what changes should be made to account for improved building efficiencies was provided by the National Renewable Energy Laboratory (NREL 2004).

Testing of the residential buildings energy database versus SMUD data also indicated that the energy database should separately model rural homes, mobile homes, and group homes. After investigation of the SMUD data, the following categories were added to the energy database:[10]

---

10. The energy usage of each building category is estimated by multiplying the energy usage (in kWh) of a detached single-family home by a constant, which has been calculated using SMUD electric metering

- Group Home = 1.82 x Detached Single-Family House Energy Usage
- Mobile Home = 1.23 x Detached Single-Family House Energy Usage
- Rural Residential = 1.49 x Detached Single-Family House Energy Usage

Additionally, another building vintage, 2005+, was added to the database. This vintage reflects the Title 24 2005 standard and differs from the 2000+ era buildings that were based on Title 24 2001 regulations. Information from the Title 24 2005 standard and a report by Eley Associates (California Energy Commission 2005) was used to modify U.S. DOE-2 modeling for 2005+ vintage buildings. Because no actual empirical studies have been conducted yet, the TAC believed this to be the best information available for updating the model with this vintage category.

4.2. Validation of Commercial Buildings Database

Because SMUD did not have statistically significant data to validate the commercial buildings and because so much time was required to update the baseline residential buildings, the TAC concluded that it was important to find a new data source for the commercial buildings. Additionally, because the loading order prioritizes energy efficiency, the TAC recommended that the new energy module should be able to analyze the energy efficiency of commercial buildings.

The TAC originally intended to use the latest version of the Commercial End-Use Survey (CEUS) database completed by the Energy Commission. The CEUS database is based on extensive onsite surveys of 2,800 commercial premises and provides energy consumption profiles by market segments, as defined by building categories and climate zones. The TAC believed this was the best data source available to validate and calibrate the model because the information reflects real-world energy use for California commercial buildings. When the CEUS data were made available, however, technical issues became apparent. It was determined that the CEUS data would require very significant effort (estimates of over 500 hours by the CEUS contractor) to be processed for use in I-PLACE^{3}S.

As a result, EcoInteractive pursued the possibility of obtaining building data from the Database for Energy Efficient Resources (DEER).[11] Sponsored by the California Energy Commission and California Public Utilities Commission, the DEER database is designed to provide well-documented estimates of the costs of different EE measures, their energy and peak demand savings values, and their effective useful life—all with one data source. Information is available for 16 different California climate zones, 36 different building types, and five building vintages. Using the DEER database allows the possibility of conducting energy efficiency analyses that would not be possible using only CEUS data.

---

data. In this simplified approach, the derived constant also serves as a "universal multiplier" for all forms of energy use, e.g., lighting, cooling, space heating, and water heating (whether gas or electric).

11. Database for Energy Efficient Resources, www.energy.ca.gov/deer.

To obtain the DEER information in a useful format, EcoInteractive worked with James J. Hirsch & Associates (the company responsible for U.S. DOE-2 modeling for the DEER database.) Although there were delays, the necessary DEER data were eventually obtained and EcoInteractive was able to add the ability to calculate alternative load profiles reflecting the impacts of selected energy efficiency measures applied to commercial buildings.

5.0 I-PLACE³S Energy Module (Internet Version)

This section of the report summarizes the modifications to the desktop version necessary to develop an Internet version of the energy module, as well as the PAC-recommended enhancements and their implementation status.

5.1. Implementation Overview

While the desktop version provided a starting point and much of the original programming logic was retained, several (major and minor) modifications were deemed necessary to create an Internet version of the energy module, including the following:

- energy module buildings and land use types were matched more closely to those used by planners (for example, by types of building, size of building).
- A new residential applications database was developed and calibrated (seven building types).
- 2005+ vintage residential buildings were added to the residential database.
- The commercial buildings database was replaced with the DEER commercial buildings database (23 building types, includes 2005+ vintage).
- Capability was added to calculate CO_2, NOx, SOx emissions related to building energy use and on-site power generation
- Calculation and reporting of marginal CO_2 emissions savings was implemented.
- For commercial buildings, analysis of the energy and emissions impacts of selected EE measures (including glazing, HVAC, and lighting) was added.
- A new energy indicators scenario comparison module was developed.
- Technology choices for DG were refined to better meet user needs.
- The calculation of renewable DG options was simplified to include only solar PV.
- A new user interface and output reporting options were added.

In addition, EcoInteractive Inc. accomplished the following technical objectives:

- Established the technical environment by setting up servers and infrastructure for the development environment.
- Developed modified data entry screens.
- Had key PAC/TAC members review prototype screens.
- Integrated algorithms, database, and logic to support energy demand calculations.
- Integrated algorithms, database, and logic for analyzing DG, CHP, and solar PV options.
- Integrated the energy module with the GIS interface queries.

- Integrated the energy module with the GIS interface reports and maps.
- Developed energy module query tools.
- Had key PAC/test users review prototype data entry screens, GIS interface, and reports.
- Developed user tutorial (http://places.energy.ca.gov/places/energy_tutorial).

5.2. Implementation of Features Recommended by PAC

Interviews and meetings with PAC members to identify the features they would like to see implemented in the energy module to address energy needs in community planning decisions revealed a number of specific recommendations. The following is a detailed list of PAC-suggested energy module enhancements and the status of their implementation:

General

- Validate the energy module energy calculations with small scale (three buildings) testing of the second beta version—completed.
- Pilot-test energy module using a single planning agency's data; obtain user feedback from planners and energy experts during the pilot test—initiated by EcoInteractive Inc. but not completed.
- Streamline user interfaces—implemented.
- Develop a format for uploading localized solar insulation and wind speed data—not implemented, considered as potential future energy module enhancement.

Buildings Database

- Update commercial buildings energy database with DEER commercial buildings—completed.
- Validate building energy databases—completed validation of residential buildings using SMUD metered data; validation of DEER commercial building data not necessary.
- Update energy database to include energy consumption data for Title 242005-compliant commercial and residential buildings—completed.
- Update the energy database to include energy consumption data for commercial and residential buildings that exceed the 2005 Title 24 standards—not implemented, considered technically too complicated for implementation in the current version of the energy module (see discussion in Section 5.3 of this report).

Technologies and Other Modeling Features

- Add molten carbonate fuel cell type (~200 kW) —not implemented, considered as potential future addition to the energy module DG equipment database.

- Add PEM fuel cell type (1–50 kW)—not implemented, considered as potential future addition to the energy module DG equipment database.
- Add solar thermal—not implemented, considered as potential future addition to the energy module DG equipment database.
- Provide calculation of CO_2 emissions associated with building energy use—implemented.
- Include calculation of energy-related greenhouse gas emissions—EcoInteractive Inc. elected to calculate and report the CO_2 emissions related to electric generation (based on California Climate Action Registry data) and the CO_2 emissions associated with buildings' natural gas consumption, including that of fossil fuel–based DG technologies. In addition, a marginal CO_2 emission factor[12] was used to estimate the emission impacts of lower electric consumption associated with implementing building energy efficiency measures.
- Add a District Heating and Cooling (DHC) Module for the ability to evaluate systems in a community setting (for example, a DHC system to serve multiple buildings on a university campus)—not implemented, considered as being outside of the workscope; however, cooling and heating load profiles can be generated by EcoInteractive Inc. for use in external district heating and cooling modeling software.[13] Evaluation would need an economic analysis to be valuable.

---

12. The program's default value of the electric generation-related marginal CO_2 emission factor related to reduction in electric energy consumption is 855 lbs / 1 MWh. This value represents the avoided power plant emissions in terms of dispatch order of existing plants and not the avoided future power plant construction. If needed, the user can modify the electric generation-related CO_2 marginal factor.

The default value of the electric generation–related marginal CO_2 emission factor is based on the assumption that the marginal power plant is a gas-fired unit generating 815 lbs of CO_2 per each 1 MWh of electricity produced (48.8% efficient combined-cycle plant). Assuming that 85% of the time the electricity will be from an in-state plant where the line losses will be about 4.5% and 15% of the time from an out-of-state plant where the line losses will be about 7.5%, the adjusted factor will be 815 + (815 x 0.045 x 0.75) + (815 x 0.075 x 0.15) = ~ 855 lbs / 1 MWh.

The program's default value of the marginal CO_2 emission factor related to reduction in natural gas consumption is 116.4 lbs / 1 MMBtu. This value represents the avoided CO_2 emissions based on a natural gas carbon content of 31.9 lbs / MMBtu and oxidization fraction of 0.995. The user cannot modify this gas consumption-related CO_2 reduction marginal factor.

13. In general, installing DHC requires aggregating loads for a group of parcels so that a larger generator, boiler, and chiller could serve multiple local loads. Although DHC is not a technology choice in the new energy module, the ability to aggregate loads for a designated area encompassing thousands of parcels (and more) is useful to utilities in determining the feasibility of a DHC system versus power from the grid, and there may be interest in using the tool for this purpose. An economic analysis would be important to assess the practicality of different options.

- Allow comprehensive energy assessment, including factors such as subdivision design and proper placement of shade trees—not implemented, considered outside of the workscope (see Section 5.3).
- Allow modeling scenarios when a specific renewable energy percentage goal is met such as 20% PV on residential homes—implemented, user can select buildings and percentage of roof area where PV applies.
- Allow users to evaluate DG options by selecting a goal such as:
  - Minimize grid electric purchases—implemented.
  - Maximize deployment of renewable technologies—implemented.
  - Minimize the cost of electricity—not implemented, economics are not calculated.
  - Maximize electric service reliability—implemented using simplified approach of eliminating renewable and internal combustion engine technologies from available DG technology options.
- Incorporate a module for public infrastructure (for example, street lighting, water pumping and treatment, wastewater treatment, transmission and distribution lines, pavement width)—not implemented, considered as being outside of the workscope.
- Add ability to measure how new or modified homes compare against a community's adopted "sustainability" standard by assessing landscape, stormwater, water, thermal comfort, and energy usage—not implemented, considered as being outside of the workscope (see discussion in Section 5.3 of this report).
- Allow I-PLACE^{3}S energy module data to work in other platform interfaces to be able to see the results in the visual context of other community planning programs; include ability to produce standard output and input files that users could download and use in other community planning tools and the ability to pre-populate fields with other program data from these tools (for example, Index and Community Viz)—not implemented, considered as being outside of the work scope.

Economics

- Tie energy savings to incentives offered by the utilities (or other agencies) to calculate return on investment for these energy savings—not implemented, economics are not calculated.
- Update the distributed energy calculations to include 2005 utility rate data—not implemented, economics are not calculated.
- Include net energy metering (NEM) for PV—not implemented, economics are not calculated.
- Add the ability to input utility rate data—not implemented, considered outside the workscope. This will need to be done on a project-by-project basis because rates change and vary by service territory. Local governments using the energy module should

include their local utility representatives to facilitate the input of rate information. This information is key in being able to calculate the economic impacts of different scenarios. Alternatively, because of the complicated nature of the utility rate structure, calculating a general rate for the different building types would also be useful and practical for estimating the price implications associated with energy savings.

- Add the ability to analyze additional cost to developers associated with implementation of EE packages, so that associated incentives or disincentives can be clearly demonstrated—not implemented, considered as being outside of the workscope.
- Add the ability to look at a time series of CO_2 emission profiles and account for impacts of technology advances (for example, CHP might look good now, but over its lifetime may not look so good)—not implemented, considered outside of workscope and technically complicated.
- Consider the impact of transportation modeling, moving from parcel-based models to activity-based models—not implemented.

Output Data Processing / Formatting

- Evaluate CO_2 and particulate matter (PM) emissions for different scenarios and allow side-by-side comparisons—implemented for CO_2; not implemented for PM.
- Develop indicators such as energy use by building type, costs, CO_2 emissions, and so forth to allow comparisons of base case and alternative scenarios—partially implemented; cost-related indicators were not developed.
- Allow aggregation of energy profiles for selected areas—implemented, profiles can be generated by EcoInteractive Inc. on client request.
- Allow evaluation of energy savings under a range of conditions and time frames—energy module could be potentially used to conduct such study; however, the user would need to define time-related impacts on energy use (for example, future power generation efficiency and associated emissions as well as energy efficiency of future buildings).
- Evaluate whether the building meets LEED[14] certification—not implemented, considered technically too complicated for implementation. LEED is a point-based rating system where energy efficiency measures for the building envelope, lighting, and the HVAC systems are one of many items within the LEED checklist; other areas include

14. LEED is the nationally accepted benchmark for the design, construction, and operation of high-performance green buildings. LEED gives building owners and operators the tools they need to have an immediate and measurable impact on their buildings' performance. LEED promotes a whole-building approach to sustainability by recognizing performance in five key areas of human and environmental health: sustainable site development, water savings, energy efficiency, materials selection, and indoor environmental quality. See www.usgbc.org/DisplayPage.aspx?CMSPageID=222.

human and environmental health, sustainable site development, water savings and materials selection and indoor environmental quality. LEED analysis extends far beyond the capabilities of the energy module.

- Allow users to evaluate the percentage exceedance of Title 24 and mix and match efficiency options for groups of buildings, to determine level of compliance—not implemented, considered technically too complicated for implementation in the current version of the energy module.
- Evaluate energy savings under the following conditions:
    - If planners need to estimate energy usage for scenarios for 25+ years in the future—not implemented, the user must define time-related impacts on energy use, and the tool is not programmed for this sort of analysis.
    - If a portion or all of the relevant new development in a particular area uses specific types of cool roofs—not implemented, roof type cannot be changed with current version of building energy database.
    - If a portion or all of the relevant new development in a particular area uses specific types of cool paving materials—not implemented, paving impacts on energy are not considered in the energy module.
    - If a portion or all of the relevant new development in a particular area uses specific types of trees in specific shade configurations—not implemented, tree planting and of its impact is not considered in the energy module (see discussion in Section 5.3 of this report).
-

5.3. Selected Features Not Implemented in Energy Module

Two new functionalities of the energy module were often suggested by the PAC members but were not implemented in the current version of the program: the first was to allow users to compare new or modified homes against a community's adopted "sustainability" standard by assessing landscape, stormwater, water, thermal comfort, and energy usage; and the second was to allow for a neighborhood-scale energy assessment, including factors such as subdivision design and proper placement of shade trees.

A functionality to quantify the energy impacts of homes that are more energy efficient, comfortable, and less expensive to maintain than most existing homes was considered by the development team, and was determined to be beyond the scope of this current project. A subgroup of the PAC met to discuss the importance and possibilities for including infrastructure and water analytical capabilities. It was determined that such activities were beyond the scope of this particular project; however, the importance of such features was noted. SACOG is particularly interested in adding a water module; however, the amount of data required for such analyses is difficult to obtain. The PIER program is currently funding the Water Energy Sustainability Tool (WEST) designed to be used by water utilities. When the project is complete, it may be worth investigating the potential to incorporate a similar methodology and inviting water planners to the larger planning discussions.

Another subgroup of the PAC met to discuss the importance of including a shading reduction factor for PV. This appeared feasible, but the data were not available in time for it to be incorporated into the energy module, and there may be additional technical issues with such an addition. If this concern remains, users may request I-PLACE^{3}S to incorporate a reduction factor for the PV electrical output to account for any shading of the PV installation.[15] In the future, if the average shading effects of policies such as "smart shading" were known, factors could be calculated to account for the loss of PV output as well as any savings in air conditioning energy use. If utilities are interested in using the energy module for their own planning purposes, the ability to factor in shading reductions even in terms of gross percentages could be helpful.

15. The Energy Commission is funding the National Energy Renewable Laboratory (NREL) to develop a Subdivision Energy Analyzer Tool (SEAT). Energy Commission staff discussed this proposal with EcoInteractive and concluded that the scale of the SEAT tool is different than that of I-PLACE3S. In I-PLACE3S, the actual design of a building is not known, just a representative aggregate building type for various residential and commercial buildings. The I-PLACE^{3}S Energy Module is expected to be used primarily in developing long-range growth scenarios (in conjunction with transportation planning activities), whereas SEAT is geared to the design of a few buildings (and which can be extended to view them in a subdivision), including a few specified building types and their energy profiles which change based on orientation. The SEAT tool is tied in part to the New Solar Home Initiative. Although the residential buildings in I-PLACE^{3}S will be capable of being modeled with PV and it is possible that utilities may be interested in using I-PLACE^{3}S for some PV-related planning activities, the conclusion was that SEAT would be better able to model building orientation and shading than would I-PLACE^{3}S.

6.0

Energy Module Beta Validation Testing

Due to time constraints, EcoInteractive Inc. did not perform thorough beta testing of the energy module in-house. The TAC had several discussions with staff from SMUD about using the I-PLACE^{3}S energy module to analyze energy supply options for the Sacramento Railyards Redevelopment Project.[16] This would have been an opportunity to test the capabilities of the I-PLACE^{3}S energy module and confirm that this new feature of the software can provide important input into actual land use decision making. However, at the time, the DG and EE features were not incorporated into the energy module, so the energy module did not undergo complete field-testing by utility personnel as originally intended. However, small-scale testing of two beta versions of the software was conducted as described below.

6.1. Testing First Beta Version of Energy Module

The first beta version was evaluated in March 2007 by the Gas Technology Institute, which conducted independent, detailed, micro-level testing and analysis of the energy module. Input from key PAC members reinforced that this was an appropriate approach. Being able to verify energy outputs at an individual building level and then at a sub-section of a city was more manageable and reliable than verifying aggregate numbers for entire cities—although with further use of this tool, validation of a large-scale modeling effort would be appropriate.

This initial beta testing concluded that the new I-PLACE^{3}S energy module was a well-designed program that was still in its alpha/beta phase of development, and in need of additional work and enhancement before it could be released for public use. More work was needed to achieve properly functioning DG and EE features and fully functional output reporting. Detailed findings and recommendations from GTI's initial evaluation are provided in Appendix A to this report.

6.2. Testing Second Beta Version of Energy Module

EcoInteractive Inc. agreed to make most of the necessary fixes recommended by GTI after the first beta testing. EcoInteractive Inc. worked with GTI, AESC, CIEE consultants, and Energy Commission staff to better define the necessary calculations, algorithms, and reporting corrections required to produce an acceptably functioning module. These fixes were completed in November 2007, and GTI and AESC completed a second round of beta testing in December 2007. Detailed findings and recommendations from this second beta evaluation are provided in Appendix B.

---

16. See project website at www.sacramentorailyards.com/home/home.htm.

7.0 Conclusions and Recommendations

This project was successful in developing a new energy module for the Internet version of PLACE^{3}S, but the module has certain important limitations. Because the model is based on generic building types rather than exact building specifications, the model should be used to compare building energy use and related emissions in a scenario format. Results should be interpreted as *relative* between scenarios, rather than as absolute energy use projections.

Energy usage predictions are calculated for a user-specified area and selected mix of prototypical buildings. The energy module's database contains a number of typical residential and commercial building prototypes, each a generic representative of a specific type of building (hotel, office building, hospital). For obvious reasons, the module's buildings library does not include all possible building types and configurations, and users must therefore select the prototypes closest to those of planned development.

Consequently, it is not recommended that the model be used to calculate actual emission profiles for a planned community or to obtain CO_2 reduction credits. The results are, however, very useful in helping to better understand how different land use options affect electric, natural gas, and associated CO_2 emission profiles so that relative scenario comparison can be performed, at the highest levels, to improve understanding of the energy implications for various growth patterns.

While the current version of the energy module appears to be a good tool for evaluating relative differences in building energy consumption under different development scenarios—as well as the impacts of deploying DG and selected EE measures—more testing and validation with real building energy profiles in different climate zones is warranted. An economics component is needed to prevent users from selecting EE and DG options that may not be financially practical. With further refinement, the energy module should be helpful in supporting analysis needed to develop a region wide energy strategy and an energy element in general plans for cities and counties.

It is recommended that EcoInteractive Inc. implement selected features of the energy module that were present in the desktop PC version but not transferred to the Internet version, specifically:

- Calculation of energy costs to customer (electric and natural utility)
- Economics of implementing DG and PV technologies
    - Return on investment
    - Simple payback
    - Installed cost and O&M cost
- Expanded renewable technologies option (wind)
- DG heat recovery to building cooling (absorption chillers)

The following new features are also recommended:

- EE-compatible residential database.
- EE measures for residential buildings.
- Economics of implementing EE measures in commercial and residential buildings.
- Expanded library of fuel cells technology (molten carbonate and PEM).
- Solar thermal technology in residential buildings.
- Selected upgrades recommended by the Project Advisory Committee (see Section 5.2).

Furthermore, the module should be validated through a series of test cases involving a larger number of buildings, various weather zones, and various land use planning scenarios.

Benefits to California

Local and regional governmental planners that hold land use authority and regional transportation agencies (for example, Metropolitan Planning Organizations/Council of Governments) that allocate transportation funds are core users of the I-PLACE^{3}S. These entities are often involved in a variety of regional planning issues beyond transportation (housing, economy, environment, and so forth). In the recent past, users of I-PLACE^{3}S have expressed interest in using the I-PLACE^{3}S tool to do comprehensive regional energy planning. The I-PLACE^{3}S energy module, even at its current stage of development, will provide a tool for governmental planners (as well as utility planners, government officials and citizens) to coordinate planning across a region and evaluate specific growth scenarios in terms of energy use, related emissions, and implementation of DG and selected EE measures. Furthermore, the energy module may provide information helpful to local governments in developing an energy element in their general plans. The I-PLACE^{3}S energy module forms part of a growing suite of tools California could use in evaluating ways to meet its ambitious greenhouse gas reduction agenda.

Note that energy module users must have an agreement with EcoInteractive Inc., and the software requires uploading extensive regional data. Current users of I-PLACE^{3}S may use the energy module as part of their existing agreement, but should confer with EcoInteractive regarding the sort of energy planning they would like to do and if any changes to their existing agreement would be necessary to cover additional analyses.

8.0 References

Eley Associates. California Energy Commission Report, *Impact Analysis 2005: Update to the California Energy Efficiency Standards for Residential and Nonresidential Buildings,* June 20, 2003 P400-03-014; Contract 400-00-061 & 400-01-023. http://www.energy.ca.gov/title24/2005standards/archive/rulemaking/documents/2003-07-11_400-03-014.PDF.

Hanson, Nancy, Mike McKeever, Sarah Stein, Arron Herriford, and Ronald Ishii. 2002. *DER Deployment Analysis in Regional Planning.* 4th Annual International Symposium on Distributed Energy Resources, San Diego, Calif., November 10–12, 2002.

National Renewable Energy Laboratory. 2004. *Development of an Energy Savings Benchmark for All Residential End-Uses.* Conference Paper NREL/CP-550-35917. Contract No. DE-AC36-99-GO10337. http://www.nrel.gov/docs/fy04osti/35917.pdf.

Parsons, Brinkerhoff, Quade & Douglas, Eley Associates, Alternative Energy Systems Consulting, and Space Imaging. 2002. *PLACE*^{3}*S Energy Option Matching Module Project Summary Report.* July 31.

State of California Energy Action Plan. 2003. www.cpuc.ca.gov/word_pdf/REPORT/28715.pdf.

U.S. Census Bureau. American Housing Survey (AHS). www.census.gov/hhes/www/housing/ahs/metropolitandata.html.

U.S. Green Building Council. "What is LEED?" www.usgbc.org/DisplayPage.aspx?CMSPageID=222.

9.0 Glossary

AESC	Alternative Energy Consulting Systems
BL	Baseload generator control strategy
CADER	California Alliance for Distributed Energy Resources
CEUS	Commercial End-Use Survey, a database compiled by the Energy Commission
CIEE	California Institute for Energy and Environment
CO	Carbon monoxide
CO_2	Carbon dioxide
CPUC	California Public Utility Commission
DE	Distributed energy
DEER	Database for Energy Efficient Resources
DG	Distributed generation—the use of small-scale power generation technologies located close to the load being served
DHC	District heating and cooling
DOE	U.S. Department of Energy
EE	Energy efficiency
ELF	Electric-load-following generator control strategy
EUL	Effective useful life
FL	Full load
GIS	Geographic information system
HHV	Higher heating value
ICE	Internal combustion engine
kBtu	One thousand British thermal units
kW	Kilowatt
kWh	Kilowatt-hours
LEED	Leadership in Energy and Environmental Design
MMBtu	One million British thermal units

MW	Megawatt
NEM	Net energy metering
NO_X	Nitrogen oxides
OCC	Occupancy
O&M	Operations and maintenance
PAC	Project Advisory Committee
PC	Personal computer
PEM	Polymer Electrolyte Membrane, or Proton Exchange Membrane, fuel cells
PIER	Public Interest Energy Research
PK	On-Peak operation generator control strategy
Place Type	A place type is used to define a building and can be made up of multiple sector types. For example, a Retail Mixed Use place type could be composed of the sector types "Retail" and "Townhouse."
PV	photovoltaic
RMI	Rocky Mountain Institute
ROI	Return on investment
SACOG	Sacramento Area Council of Governments
SANDAG	San Diego Association of Governments
Sector Type	Defines a specific type of use, such as Retail, Townhouse, or others
SMUD	Sacramento Municipal Utility District
SO_X	Sulfur oxides
TAC	Technical Advisory Committee
TLF	Thermal-load-following generator control strategy
VOC	Volatile organic compounds
Year Built	The estimated year the building on a given parcel was built

Appendix A

First Beta Version Validation Testing and Recommendations

Appendix A:
First Beta Version Validation Testing and Recommendations

The March 2007 beta testing conducted by GTI concluded that the new I-PLACE3S Energy Module was a well-designed program that is still in its alpha/beta phase of development and needs additional work and enhancement before it can be released for public use. More work is needed for the tool to have properly functioning DG and building energy efficiency features and fully functional output reporting.

The detailed findings were as follows:

- The accuracy of the buildings' baseline electric and gas consumptions reports generated by the I-PLACE3S energy module for all three tested buildings (Hospital, Grocery Store, and Residential Building) from the program building loads database was found to be satisfactory.
- I-PLACE3S energy module only calculates emissions associated with the production of electric energy buildings receive from the grid. However, it neglects to calculate the following important energy production and consumption related air emissions:
    - Buildings' air emissions associated with consumption of natural gas.
    - Emissions from natural gas fired on-site power generation systems.
    - Reduction in local air emissions associated with the heat recovery from on-site power generation systems and EE measures.

  This is a significant shortcoming of the examined version of I-PLACE3S energy module as it provides an incomplete picture of the environmental impacts of implementing DG and energy efficiency technologies. I-PLACE3S energy module air emission calculations must include DG and energy efficiency technologies for the emission reporting to be meaningful.
- Calculation of the reduction in electric energy consumption (kWh) stemming from energy efficiency measures in commercial buildings (tested with Grocery Store) showed much lower reductions than that derived directly from the DEER database. The results demonstrate a need for a review and correction of I-PLACE3S energy module energy efficiency programming algorithms and/or their implementation.
- Testing showed that PV capacity sizing algorithms were properly implemented in single-story buildings (Grocery Store and Residential). However, in a multi-story Hospital building, a problem was found with the calculation of roof space available for PV. The program coding needs to be checked to identify the source of the problem. Further validation should be conducted to see if this problem exists for the other multi-story buildings in the I-PLACE3S energy module. Calculations of PV power generation effectiveness such as a function of cell tilt angle and the annual number of generated kWh were found to be correct.

- Capacity sizing algorithms for internal combustion-based power generation technologies were properly executed by the program.
- Power generation algorithms for internal combustion (IC) engine-based power generation technologies were tested using single generator operating in load following mode (LFM) mode and found to be executed properly.
- Although the I-PLACE3S energy module database contains models of DG technologies with and without heat recovery option (co-generation and simple cycle) the program does not calculate building energy efficiency, utility costs savings and environmental benefits associated with the heat recovery from co-generation DG. This is a significant problem as DG without heat recovery is rarely used for economic reasons (The California Self-Generation Incentive Program requires heat recovery). Modeling co-generation systems option should be activated in I-PLACE3S energy module.
- DG equipment operating strategies evaluated by analyzing results of deploying IC engine generators at two commercial buildings showed that ELF strategy operated properly. However the remaining three; Thermal Load Following (TLF), Base Loading (BL), and On Peak (PK) did not operate properly. Activation of all operating strategies is recommended, especially PK which is most often used in commercial buildings.
- The Reduction of Grid Electric Purchases power generation deployment strategy tested with IC engine based systems was found to be functioning properly. However, this strategy is not realistically expected to be employed given the cost of the DG technologies, the economics of DG operation and the fact that limiting grid consumption is rarely the goal of a typical DG deployment. Users might be interested in exploring scenarios with this strategy, but a warning must be made that without a cost analysis that is missing in current version of the program, this strategy can not be fully evaluated.
- The Minimizing Cost of Electricity power generation deployment strategy tested with IC engine based systems did not function properly. To properly execute such a deployment objective, the I-PLACE3S energy module would need to compare the cost of the grid-provided electricity with the cost of electricity that can be generated on-site by various DG technologies. Although the I-PLACE3S energy module database includes information necessary to calculate the cost of generated electricity (first/installed costs of various DG equipment types and their specific natural gas consumption), the I-PLACE3S energy module user interface does not allow the user to enter natural gas and electric utility cost information that is necessary to conduct a comparative calculation. Thus, the current implementation of the Minimizing Cost of Electricity deployment strategy could be considered misleading to I-PLACE3S Energy Module users, and this strategy should be deactivated or fixed before made available for public use.
- The Maximizing Electric Service Reliability deployment strategy eliminates PV from the mix of available DG technologies. That DG deployment objective function was found to be operating properly. However, it is recommended that the user manual clearly explain what selecting Maximizing Electric Service Reliability strategy in I-PLACE3S energy

module means as this term may lead users to expect a more sophisticated approach to the complicated problem of electric service reliability.

- All three DG deployment ranking options available in I-PLACE3S energy module were found to be operating properly in the evaluated "PIER" test setup case.
- The I-PLACE3S energy module outputs are limited mostly to reporting buildings' grid provided electric energy (kWh). The report of building loads also shows table of baseline annual consumption of natural gas. However, the natural gas use associated with DG operation is not reported. This is a major shortcoming as it does not provide an accurate picture of the community energy usage and efficiency impacts of implementing DG technologies.
- The installed and operating costs of DG technologies reducing buildings grid electricity use are not calculated. Consequently, I-PLACE3S energy module users cannot assess the economic aspect of deploying various DG options. The economic aspect of DG deployment was an important part of the previous desktop version of desktop version of PLACE3S energy module. The availability of DG-related economic indicators was accepted as an important feature of the new and enhanced version of I-PLACE3S energy module during the review of the desktop version. The program database contains data related to the installed and operating costs of various DG technologies; however, these are not being currently utilized by the program. In order to have a fully functional DG feature, the installed and operating costs of DG technologies associated with the reduced cost of grid provided electricity should to be calculated.
- Several important reports need to be added to the program to allow users to assess the energy-related implications of implementing DG and energy efficiency technologies. These reports include:
    - Annual and monthly electric peak demands (kW).
    - DG, heat recovery, and EE technologies impacts on peak electric demands (kW).
    - DG, heat recovery, and EE technologies impacts on natural gas consumption (MMBtu).
    - Emissions associated with the natural gas consumption by DG systems (CO_2, NOx, CO, other).
    - Emissions reductions associated with the heat recovery from DG cogeneration operation (CO_2, NOx, CO, other).
    - Economic indicators of implementing and operating DG (utility cost savings, paybacks on investment).
    - Economic indicators of implementing EE measures (utility cost savings, paybacks on investment).

- The Comparing Scenarios feature of I-PLACE3S currently does not include any energy module related indicators such as electric and gas energy consumptions, electric peak demands, air emissions, economic indicators, others. That makes the direct comparison of various energy related options very difficult. The energy module related indicators should be added to I-PLACE3S Comparing Scenarios user interface.
- A number of problems with the I-PLACE3S energy module user interface described in the User Interface section of beta testing report should be corrected
- Definition and units for all input data types available in the I-PLACE3S energy module user interface should be provided in the user manual.

Conclusions and Recommendations

From this first beta-testing it was concluded that the I-PLACE3S energy module as is could only be used for establishing baseline energy profiles for different scenarios of land use and evaluation of how they change based on the different types of buildings. This may be relevant in smart growth considerations because it could be important to know how housing designations or brownfield versus greenfield developments may impact per capita and total energy use for the region. This may be of particular interest to the utilities responsible for supplying power to the region.

However, the users of the program should not use the energy module DG or EE features – or air emissions feature until it has been updated to account for some of the shortcomings found during the March 2007 beta-testing of "PIER" test set up. The following fixes are necessary before a limited operation version is released for public use:

- Calculation and reporting of natural gas emissions from baseline scenarios.
- Correcting I-PLACE3S energy module energy efficiency programming algorithms to assure proper calculation of the energy efficiency measures related reductions in commercial buildings energy consumption.
- Correcting the problem of miscalculating roof area available for PV systems in multi-story buildings,
- Calculation and reporting of natural gas use by internal combustion DG systems.
- Calculation and reporting emissions from natural gas fired on-site power generation systems.
- Implementing DG operation in cogeneration configuration and reporting benefits of heat recovery.
- Adding a footnote in the output reports explaining that the Reduction of Grid Electric Purchases power generation deployment strategy does not include cost analysis of DG deployment.

- Deactivation of the current "Minimizing Cost of Electricity" deployment strategy to prevent misinterpretation of results by the user.
- Implementing an on-peak (PK) DG operating strategy option, as per algorithms provided by Ron Ishii.
- Reporting annual and monthly electric peak demands (kW) with and without DG.
- Adding to the I-PLACE3S Comparing Scenarios user interface energy module related indicators.
- Correct a number of problems with the I-PLACE3S Energy Module user interface described in the "User Interface" section of this report.
- Add a second set of emission parameters that allow for calculation of marginal CO_2 emissions, in addition to the average emissions as currently set up with utility reported emissions to the CA Climate Action Registry (CCAR).

To have a more user friendly and thorough DG and building energy efficiency component, the developer should implement/activate the following features in the energy module:

- Implement the "Minimizing Cost of Electricity" DG deployment strategy based on comparing the cost of the grid-provided electricity with the cost of electricity that can be generated on-site by various DG technologies.
- Implement Thermal Load Following (TLF) for all natural gas fired DG systems, as per algorithms provided by Ron Ishii.
- Activate calculation and reporting the reduction in local air emissions associated with the heat recovery from on-site power generation systems and energy efficiency measures (based on reduction in building natural gas and/or electric grid consumption).
- Report building air emissions associated with the consumption of natural gas (CO_2, NOx, CO, other).
- Report DG, heat recovery, and energy efficiency technologies impacts on peak electric demands (kW).
- Report DG, heat recovery, and energy efficiency technologies impacts on natural gas consumption (MMBtu).
- Report emissions associated with the natural gas consumption by DG systems (CO_2, NOx, CO, other).
- Report emissions reductions associated with the heat recovery from DG cogeneration operation (CO_2, NOx, and possibly other pollutants based on reduced building natural gas and/or electric consumption).

- Report economic indicators of implementing and operating DG (utility cost savings, paybacks on investment based on reduced building natural gas and/or electric consumption and costs of installing and operation of DG equipment).
- Report economic indicators of implementing energy efficiency measures (utility cost savings, paybacks on investment based on reduced building natural gas and/or electric consumption and costs of installing and operation of energy efficiency measures).
- Provide capability to calculate impacts of the energy efficiency measures on buildings electric peak demand (kW) and natural gas consumption kBtu.
- Provide definition and units for all input data types available in the I-PLACE3S energy module user interface in the user manual.

Appendix B

Second Beta Version Validation Testing and Recommendations

Appendix B:
Second Beta Version Validation Testing and Recommendations

The following are results of validation testing of the second beta version of Energy Module completed in November 2007 by GTI and AESC.

The most important findings are as follows;

- Emission factor for calculation of building natural gas related emissions was properly changed from 116.14 to 116.4 lbs of CO_2 per MMBtu of natural gas. The building natural gas related CO_2 emissions plus the electricity related CO_2 emissions are now displayed as TOTAL LBS CO_2 in the Annual Energy Usage by Place Type Report.
- Calculation for natural gas consumption changes associated with EE measures was adjusted to reflect fact that if
  - o High efficiency boiler measure is included in the package of measures, program should sum the gas penalties (negative savings) due to the non-boiler measures (if any), multiply this sum by [(1/.85)/(1/.80)]=0.94, [(1/improved boiler eff.)/(1/baseline boiler eff.)], then add the gas savings due to improved boiler efficiency.
  - o High efficiency furnace measure is included in the package of measures, program should sum the gas penalties (negative savings) due to the non- furnace measures (if any), multiply this sum by [(1/.94)/(1/.78)]=0.82, [(1/improved furnace eff.)/(1/baseline furnace eff.)], then add the gas savings due to improved furnace efficiency.
- Gas Usage Report is now generated when DG technologies are applied. This new report displays Gas Usage in a similar format to how Electric usage is reported. The building related natural gas plus the DG related gas usage is displayed as monthly and annual/total gas usage in the new report.
- CO_2 Emissions Report is now generated when DG and DG and EE technologies are applied. This new report displays total CO_2 emissions in a similar format that Monthly Electric usage is reported. The building related CO_2 emissions plus the DG related gas usage emissions are summed and displayed as monthly and annual/total CO_2 emissions in this new report.
- Gas Usage Report was modified to account for cogeneration heat recovery benefits. This new report displays Gas Usage in a similar format that Electric usage is reported. In this report, the building related natural gas plus the DG related gas usage is displayed as monthly and annual/total gas usage. When cogeneration DG systems are used, heat recovery benefits are factored into the monthly and annual/total gas usage results.
- A new interface was developed to allow users to enter Time of Use (TOU) electric rate schedule determining when rate peak hours occur. The TOU input is required for on-peak (PK) mode power generation algorithms.
- A new report was added that displays Electric Peak Demand Usage in a similar format that Electric Usage is reported. In this report, the Electric Peak demand will is displayed as monthly and annual highest coincident demand kW. The Electric Peak Demand for a given month is calculated as the highest electric demand (kW) for any given hour during the peak

hours defined by the TOU schedule. The annual Electric Peak Demand is calculated as the highest monthly Electric demand (kW). The Electric Peak Demand is reported separately as a highest coincident electric demand for all buildings by the Place Type and separately as a highest coincident demand for all buildings selected for analysis independent of the Place Type.

- AVG DU SIZE (SQFT) field on the ENERGY SECTOR PERCENTAGES screen was eliminated to prevent double entry. The average dwelling unit size is entered on the planning PLACE type screen.
- Users can now modify marginal emission factor (MEF) used to calculate marginal CO_2 emissions reduction due to application of DG and EE technologies.
- New Thermal Load Following (TLF) DG control strategy was implemented algorithm flowchart sent by Ron Ishii on 12/18/2007.
- A new functionality and interfaces was added to the Energy Module to enable users to compare various land use scenarios under differing energy options. The reporting options are detailed below.
    - Electric consumption (kWh)
    - Gas energy consumption (MMBtu)
    - Electric peak demand (kW)
    - CO_2 air emissions associated with consumed energy (lbs)
    - Marginal factor-based CO_2 emissions savings (lbs)
    - Installed fossil fuel on-site power generation (kW)
    - Installed PV on-site power generation (kW)
    - Electricity generated by fossil fuel on-site power generation (kWh)
    - Electricity generated by renewable on-site power generation (kWh)
    - Recoverable waste heat from fossil fuel on-site generation (MMBtu)
    - Recovered waste heat from fossil fuel on-site generation (MMBtu)
    - Building energy efficiency impacts on electric (kWh)
    - Building energy efficiency impacts on gas usage (MMBtu)

  Users should have an option to report the energy indicators listed above as:

    - Totals – Total annual value
    - Per SQFT – divide by total SQFT of building in project
    - Per dwelling unit - divide by total DU in project
    - Per employee – divide by total EMPLOYEES in project

Conclusions and Recommendations

Validation testing of the second beta version of energy module completed in November 2007 by GTI and AESC confirmed that EcoInteractive Inc. completed all necessary fixes to the Energy Module as defined in document "California Energy Commission Requirements - Fixing beta of IP3 Energy Module: version dated 12-19-2007." The revised Energy Module is capable of performing and providing technically acceptable results related to the energy and emissions calculations. It should be noted however, that the current version of the Energy Module is missing calculation of the economics which are necessary to guide users in proper evaluation and selection of feasible EE and DG options.

- It is recommended that the Energy module should be validated through a series of test cases involving larger number of buildings, various weather zones, and under various land use planning scenarios.

Attachment I

I-PLACE^{3}S Energy Module Tutorial

The tutorial is available at http://places.energy.ca.gov/places/energy_tutorial/.