THE CLEAN ENERGY ECONOMICS CALCULATOR

Contents

Introduction

...designed to help consumers evaluate the cost effectiveness of clean energy systems...

Individuals and companies are increasingly turning to photovoltaics (PV) and other clean energy systems as an alternative to conventional utility electric supply. Motivated by a desire to reduce utility bills and help the environment, they want to know if these alternatives are good investments.

The cost-effectiveness of a clean energy system is determined by the technology purchased, system cost, economic incentives, utility bill savings, the financing method, and tax effects. These economic components are affected by a variety of factors. For example, utility bill savings are determined by the electricity produced by the system, the electric rate structure, current electricity consumption, and how system output is metered.

Due to the large number of influential factors, evaluating cost-effectiveness for a clean energy system is a complex task. While each consumer could hire a qualified consultant to evaluate their situation, a more practical alternative is to use a consumer-oriented computer program to assist in the evaluation.

The Estimator is a suite of Internet-based applications designed to help consumers evaluate the cost-effectiveness of clean energy systems. It provides a personalized estimate of the costs and benefits of a system for a specific residential or commercial customer.

As shown in Figure 1, the Estimator's three critical components are data, analysis, and applications.

- The databases include electric rate tariffs, incentive programs, solar resource, load profiles, emissions factors, and tax information
- The analysis engine contains the algorithms necessary to calculate cost-effectiveness; they are based on many years of research
- The applications include Web Client, Web Service, Quote Generator and Market Analysis programs

The applications can be used to support the objectives of equipment manufacturers, resellers and dealers, utilities and state agencies, and the federal government.

- Manufacturers use the Estimator to expand their web presence, generate quality sales leads, assess new markets, and offer targeted incentives
- Resellers and dealers use the Estimator to screen potential customers, produce professional sales quotations on-site, and assess site feasibility
- State agencies and utilities use the Estimator to educate consumers, support incentive programs, assist in rebate processing, and evaluate system performance
- The federal government uses the Estimator to promote clean energy technologies, evaluate new incentives, and answer complex research questions

The Estimator was first commercially introduced to evaluate PV for a few cities in California in 1998. Since that time, the program has been expanded to evaluate PV in 5 countries, evaluate 7 types of clean energy technologies, and include more than 1,500 electric rate tariffs. It has been used by individuals more than a quarter of a million times. At the current rate of usage, that number will double in the next 6 months.

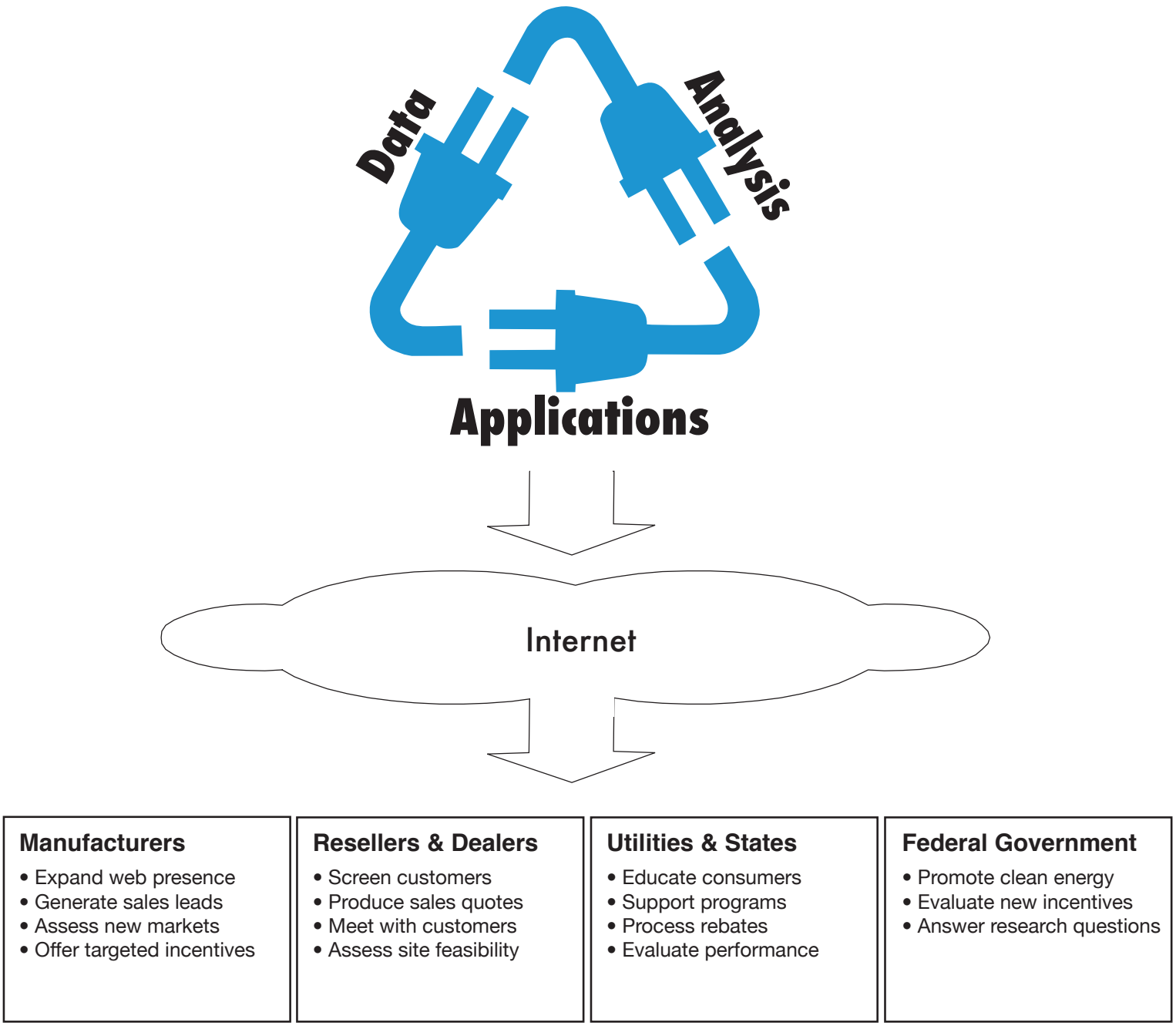

Figure 1 - Estimator Overview

The Estimator consists of four major components: the Estimator Databases, the Data Retrieval Component, the Analysis Engine, and the Application. Figure 2 shows the relationship between these components and illustrates how users access them via the Internet. In the following sections, the various uses for the Estimator will be discussed and each of the components will be described in more detail.

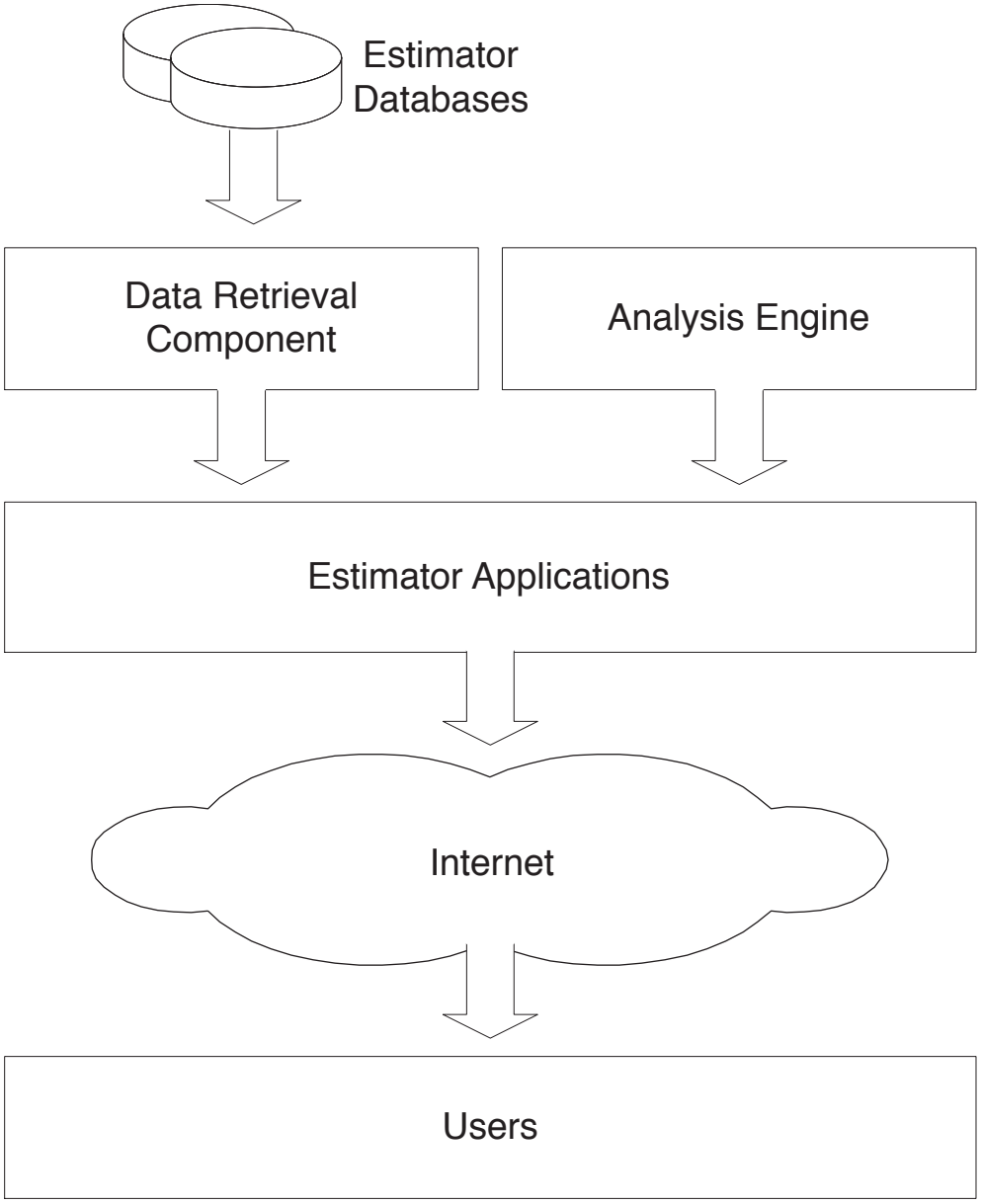

Figure 2 - Estimator Components

Uses

The Estimator has numerous uses, some of which have only begun to be explored. This section describes different ways in which the Estimator can be used. The uses are grouped by equipment manufacturers, resellers and dealers, state agencies and utilities, and the federal government.

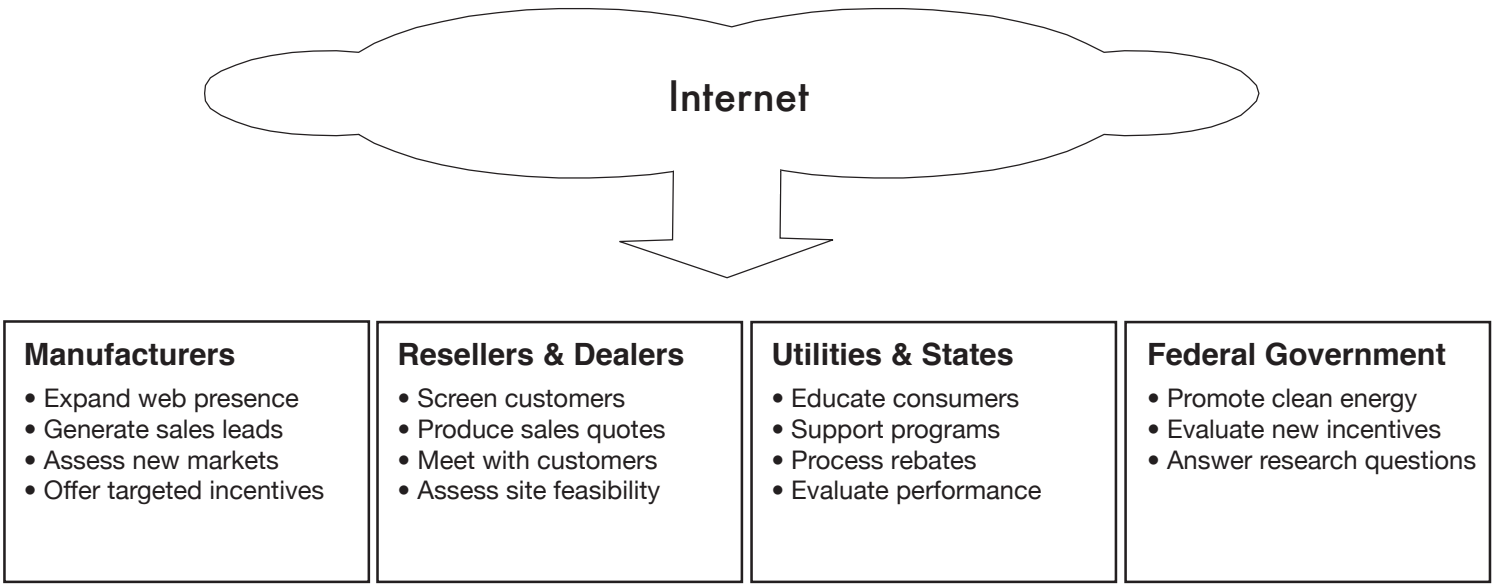

Figure 3 - Estimator Uses

Equipment Manufacturers

Expand Web Presence

Manufacturers can integrate the Estimator into a broader website effort. They can develop Internet content and integrate the Estimator into the website.

Generate Quality Sales Leads

Some manufacturers use the Estimator as part of their customer screening process in order to generate high quality leads for their dealers.

Assess New Markets

Information is recorded about the location of program uses (but not the identity of any particular user). In addition, one of the Estimator applications is the Market Analysis Program (MAP). When combined together, this allows marketers to identify locations where the economics are favorable and locations where consumer interest is high.

Offer Targeted Incentives

Manufacturer-specific targeted incentives can be offered using the Estimator. These incentives are in addition to state buy down programs, utility rebates, and tax credits and are only available if the customer purchases products through a particular website. This enables resellers and manufacturers to include rebates in the analysis that are available only through their site.

Resellers and Dealers

Screen Potential Customers

Resellers, dealers, and manufacturers use the Estimator to inform potential customers about the economics of clean energy systems prior to investing time with them. This enables them to focus their marketing and sales efforts on the customers most likely to make a purchase, resulting in a cost savings by moving the process of educating consumers from a person-to-person process to an Internet-based process, and allowing consumers to screen themselves prior to talking with a salesperson.

Produce Professional Sales Quotations

Some companies have used the Estimator to prepare bids they present to customers. The Estimator is particularly useful when the analysis involves multiple technologies such as PV and efficiency. The analysis can be transferred to a spreadsheet, such as Microsoft Excel, and then combined with other information.

A recent addition to the Estimator suite of applications is the Quote Generator. Using this tool, dealers can generate professional quality quotations in Adobe Acrobat PDF format in minutes. These quotations are customizable and can contain a large amount of detail (or be very simple). Furthermore, they can even be produced on-site while meeting with customers, thus saving the expense (and possibly lost sale) of returning to the office.

Assess Site Feasibility

The Estimator contains a state-of-the-art ground obstruction analysis routine. The enables dealers and resellers to evaluate system performance while meeting on-site with customers.

State Agencies and Utilities

Educate Consumers

State agencies and electric utilities use the Estimator to inform consumers about the costs and benefits of clean energy technologies. These agencies either have an economic incentive program or part of their mission is to educate the public on the benefits of renewable energy.

Support Incentive Programs

A growing number of electric utilities with incentive programs are making the Estimator available on

their websites to support contractors. Only utility-approved equipment is included in the program. This provides contractors with a marketing and sales tool for use with the utility's customers.

Assist in Rebate Processing and Evaluate System Performance

The Estimator can be used to support rebate processing. Critical information necessary to calculate rebates and determine program effects for specific equipment is calculated by the Estimator. Rebate processing personnel run the program to obtain this information.

Some rebate programs require that the system output satisfy minimum performance standards. The Estimator automatically performs these calculations and notifies the user if the standards are not satisfied.

Federal Government

Promote Clean Energy Technologies

The federal government can promote the use of clean energy technologies using the Estimator.

Evaluate Potential New Incentives

The National Renewable Energy Laboratory has expanded the Estimator to allow users to modify, add, or delete any incentive available in the United States. This enables incentive program managers to evaluate their programs from the consumer's perspective prior to implementation.

Answer Complex Research Questions

The Estimator has been used to perform marketing and research studies and address complex research questions. This is a list of known papers written using the Estimator:

- C. Herig, et.al., PV in Commercial Buildings – Mapping the Breakeven Turnkey Value of Commercial PV Systems in the U.S., American Solar Energy Society's 2003 Annual Conference (June 2003)
- R. Perez, et.al., Quantifying Residential PV Economics – Payback vs. Cash Flow, American Solar Energy Society's 2003 Annual Conference (June 2003)
- R. Perez, et.al., Validation of a Simplified PV Simulation Engine, American Solar Energy Society's 2003 Annual Conference (June 2003)
- T. Jimenez, et.al., A Tool To Market Customer-Sited Small Wind Systems, American Wind Energy Associations's 2002 Annual Conference (June 2002)
- T. E. Hoff and C Herig, Electricity Rate Structures Can Be Used to Promote Customer-Sited PV: A Lesson From California, American Solar Energy Society's 2002 Annual Conference (June 2002)
- R. Perez, T. E. Hoff, and G. Ball, Using Product Portfolios to Increase the Value of Customer-Sited PV, UPEx 2001 (October 2001)
- T. E. Hoff, Using the Internet to Promote PV and Other Clean Technologies, American Solar Energy Society's 2001 Annual Conference (June 2001)
- T. E. Hoff and C. Herig. The Market for Photovoltaics in New Homes Using Micro-Grids. Proceedings of the 2000 ASES Annual Conference (June 2000)

Applications

There are currently four Estimator applications that can be licensed. Although all of them make use of the core data retrieval and analysis engine components, each application provides a different set of services and serves a different class of users. Figure 4 shows how each of the Estimator applications fits into the overall Estimator architecture. This section briefly describes each of those applications and provides additional details on the operation of the most commonly used application - the Web Client.

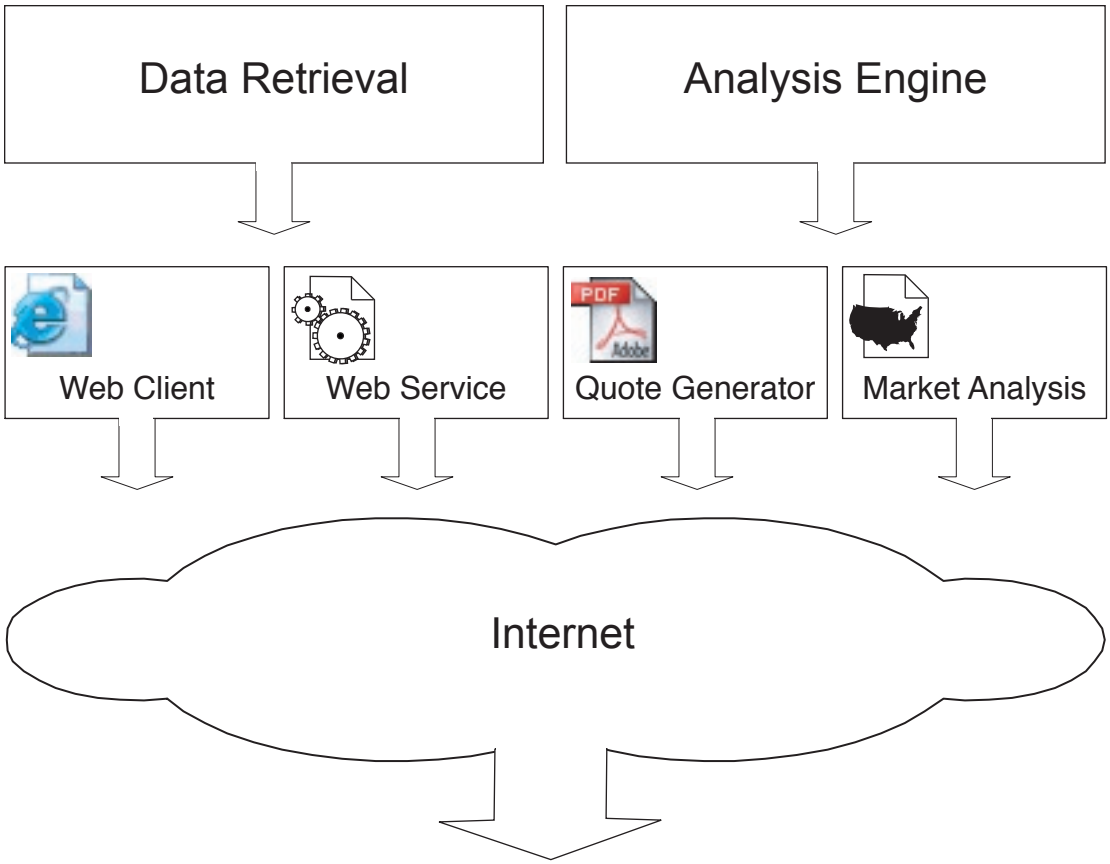

Figure 4 - Estimator Applications

Web Client

The Web Client application provides a simple way for potential customers to evaluate a variety of scenarios for the purchase of clean energy systems. With this application, the web browser submits location data to the server-side component through an intermediate web server. The server-side

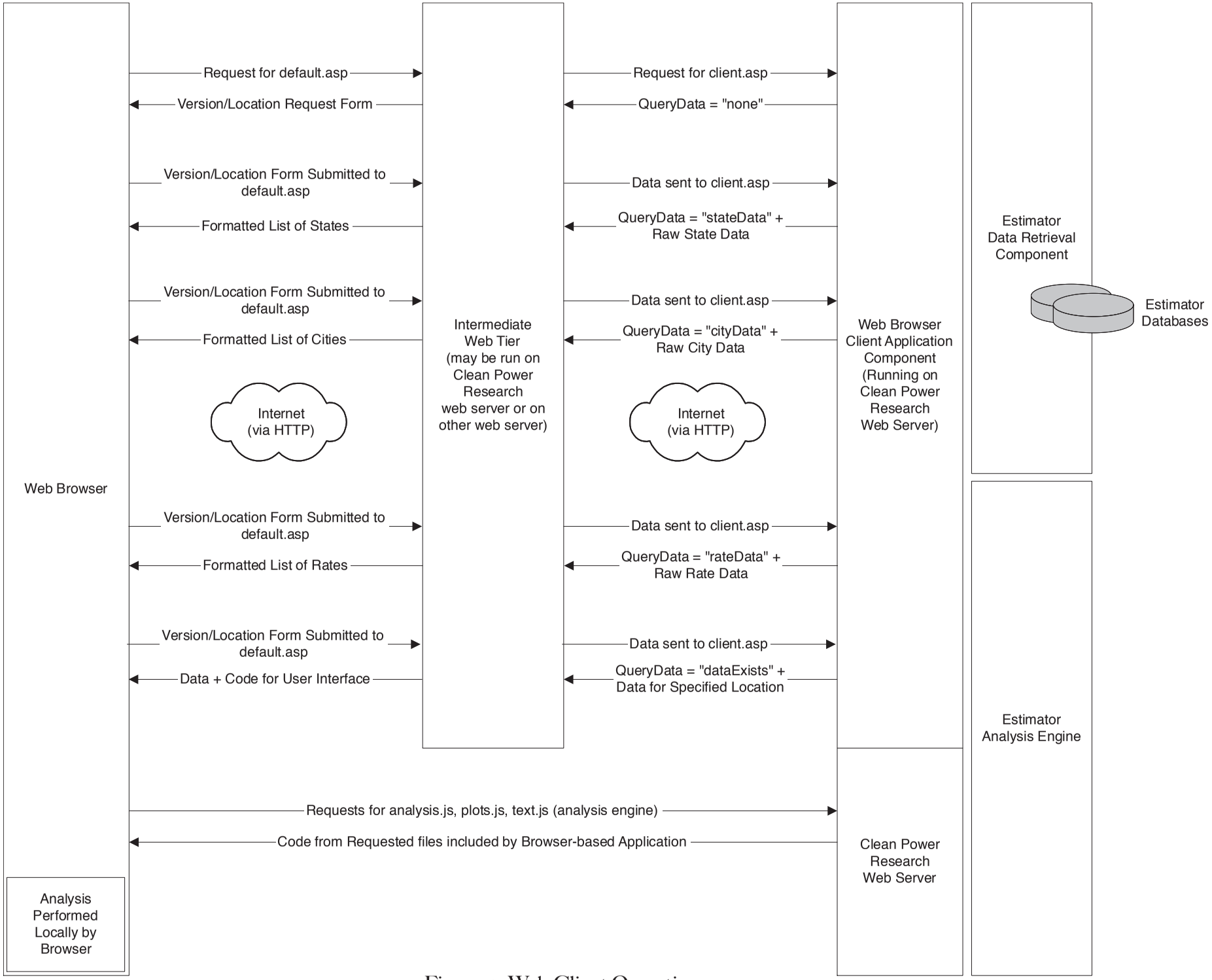

Figure 5 - Web Client Operation

application component then either returns data for the requested location or requests more specific location or rate data by subsequently providing lists of states, cities, or rates. This list is formatted by code by the intermediate web server tier, and then returned to the browser as an HTML form. Figure 5 illustrates this process. Each arrow on the diagram indicates a transaction from one tier to another. The transactions at the top of the drawing would normally occur first. Transactions that are lower on the page occur later in time. Note that the intermediate web server tier can be run on Clean Power Research web servers or on some other web server[1]. In either case, Clean Power Research provides the files necessary to get customized versions of the web browser-based client application up and running.

Setup and Configuration

Due to the numerous analysis results available as charts, tables and graphs, and the large variety of possible inputs for photovoltaic, wind, solar thermal and other clean energy investments, it is often advisable to simplify the Estimator Web Client by providing multiple versions of the program, each of which can be focused on a specific market segment or customer profile. The Estimator setup program provides Clean Power Research customers with a web-based interface for creating or modifying these versions and allows them to preview the configured versions of the program.

Web Service

The Estimator is also exposed as a web service so that web-enabled programs can access specific analytical results that can be calculated by the analysis engine. These web-enabled programs include web pages, Excel spreadsheets, Adobe Acrobat documents, and so on. The web service is capable of calculating results for multiple scenarios in a single call, eliminating the need for multiple HTTP connections from the calling script. The web service currently supports two formats for data interchange: WDDX and JavaScript/JScript code.[2] WDDX is an XML-compliant format developed by Allaire (now Macromedia) – makers of a J2EE-based application server called Cold Fusion. If you are using Cold Fusion to develop your web application, support for WDDX is already built into its scripting language (CFML). If you are using Microsoft's ASP technology, use of WDDX is possible, but JScript code exchange is preferred. To make use of the web service, script writers must create a data structure that contains information about each of the scenarios for which results are to be calculated. The structure must also contain a list of locations that each scenario will be calculated for and a list of variables identifying the specific analytical results data to be returned. Upon completion of the calculations, the web service will return either a WDDX record set packet, which can be parsed by Cold Fusion and treated just as the results of a database query would, or JavaScript code which can be evaluated to create an in-memory data structure with the resulting data.

Quote Generation

When it comes to providing an accurate estimate of the costs and benefits of a clean energy system, the sheer complexity prevents most companies from providing customers with a quote while they're still on site with the customer. Being forced to return to the office to work out the details of a quote can mean

delays that result in lost sales. The Estimator Quote Generation application allows system integrators to prepare and prepare print customized bids using information from the Quote Generator. The Quote Generator can even create the appropriate pre-filled-in rebate forms. Although this application can be used from a desktop computer, the use of laptop, handheld computer, or personal organizer, along with a portable printer and digital cellular telephone will allow on-site preparation and printing of a complete and accurate proposal for your customers.

Market Analysis Program (MAP)

The Market Analysis Program, or MAP, provides a useful tool for analyzing specific data or calculation results from diverse geographical areas. The resulting data from the Market Analysis Program can be used to generate maps that can help you readily identify potential markets for your clean energy products. The MAP is capable of returning any of the results that the Estimator can calculate for geographic areas that match any of a variety of specified criteria.

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[1] Support for ASP and server-side JScript are required. Microsoft Internet Information Server 5 or later is strongly recommended.
[2] Support for SOAP and/or XML RPC is under consideration.

Databases

One of the key components of the Estimator is its data. In order to accurately evaluate the economic feasibility of PV systems the Estimator must have the correct utility rate, incentive data applicable to the specific customer, and solar resource data. The Estimator contains a comprehensive set of databases for this purpose. These databases have been developed over a four-year period and are regularly maintained and updated to ensure that all Estimator licensees are using data that is accurate and up-to-date. Figure 6 shows the major databases used by the Estimator and their relationship to the data retrieval component, which provides methods that make accessing the data more convenient.

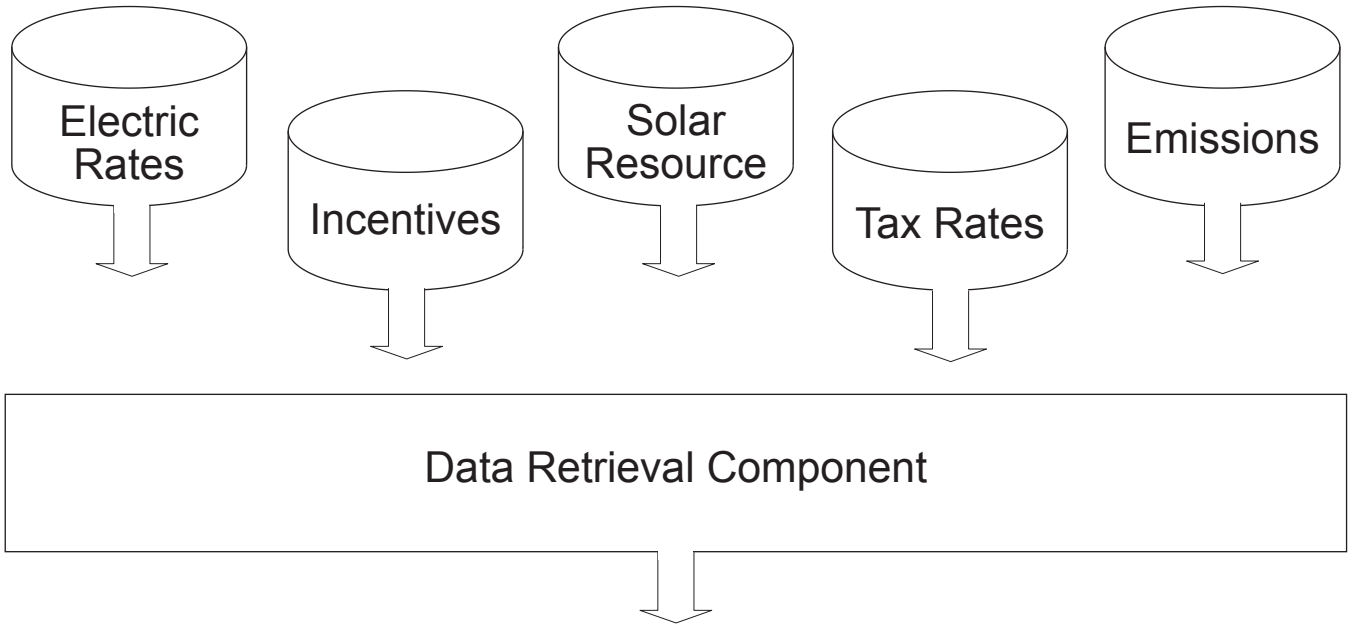

Figure 6 - Estimator Databases

Table 1 provides a more detailed description of the databases. Note that some of the "databases" listed in this table are actually combined into a single database that contains different types of related data.

Database	Description
Electricity Rates	Rates (tariffs) for residential and commercial customers, including net metering tariffs. This database provides great flexibility in capturing the range of tariff structures, including seasonal variations, time of day variations, metering charges, energy pricing, demand pricing, energy and demand tiers, sell-back pricing, fuel cost adjustments, public programs, and other special charges. The Estimator contains over 1,500 tariffs. The tariffs are updated using the Estimator's semi-automated monitoring tools.
Utility Incentives	The "buy-down" and incentives provided by utilities. These incentives can include a variety of cost, size, and tax treatment constraints.
State Incentives	Incentives provided by state governments or other jurisdictions below the federal level.
Federal Incentives	Incentives provided at the federal level.
Solar Resource[1]	Hourly "typical" solar irradiance (insolation) by month (12 x 24 values). The US database is derived from the TMY-2 data and includes 237 locations.
Electricity Load Profiles	These hourly profiles are based upon independent utility research showing consumption patterns for various locations and customer types, such as all-electric heating, gas water heating, etc.
State Tax Rate Schedules	The tax rate schedules reflect tax filing status, such as personal income for married couples filing jointly, individuals, corporations, etc., for all states.
Federal Tax Rate Schedules	Similar information as above, except for federal taxes.
Depreciation Schedules	Depreciation schedules such as the Modified Accelerated Cost Recovery System (MACRS) of the US tax code used by businesses to depreciate their PV capital investment.
Environmental Emissions Factors	Air emissions (CO_2, SO_2, and NO_x) offset rates by state based upon the regional mix of power plant sources, such as coal, gas, diesel, hydro, and nuclear.

[1] A separate database contains wind resource data for wind energy applications of the Estimator.

When it was first introduced, in late 1998, the Clean Power Estimator provided information for only a few cities in California. Since that time, the tool has grown substantially. It now includes more than 1,500 rate structures and has been extended to work for residential and commercial consumers in 16,000 cities throughout the United States as well as cities in 4 other countries.

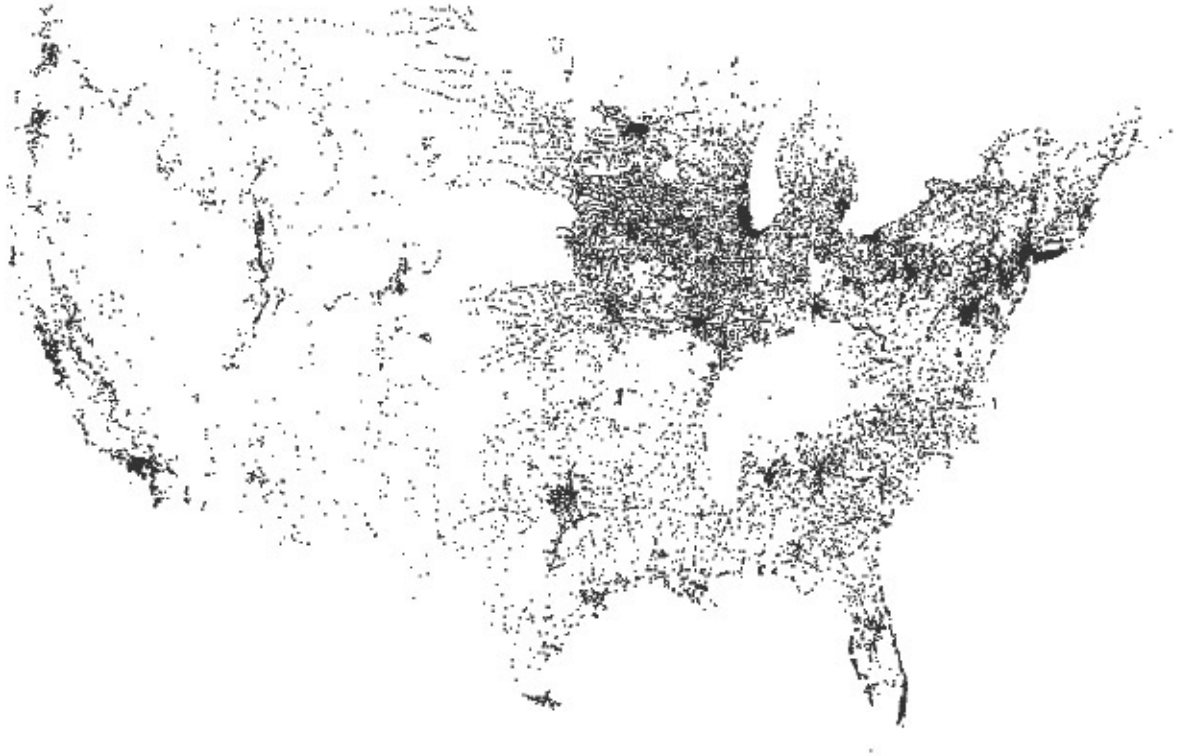

Figure 7 - U.S. Locations where the Estimator Applies

Analysis Engine

This section describes the methods provided by the Analysis Engine. The analysis is performed by calculating:

1. Current load
2. Proposed load for each year
3. Emissions savings
4. Marginal tax rates
5. Current and proposed utility bills by year
6. O&M cost by year
7. Other value by year
8. Economic incentives
9. Loan costs
10. Tax effects
11. Cash flows and other financial statistics

The flowchart in Figure 8 shows the flow of control from one process to another during analysis. Analysis generally ends when the calculated results are returned to one of the Estimator applications.

Current Load

The customer's current electrical load can either be directly specified or calculated from a set of input assumptions. The typical method used is to calculate it.

The calculation is based on the customer's annual utility bill, the customer's current electric rate structure, and the sample load profile associated with this rate structure.

Proposed Load

The proposed electrical load is calculated based on the current load, the technology selected, and the technology's life. The proposed load can vary by year if there are multiple technologies in the system and the technologies have different equipment lives. For example, a system composed of a PV system with a 30-year life and an efficiency investment with a 5-year life will have one load for the first 5 years and then another load for the remaining 25 years.

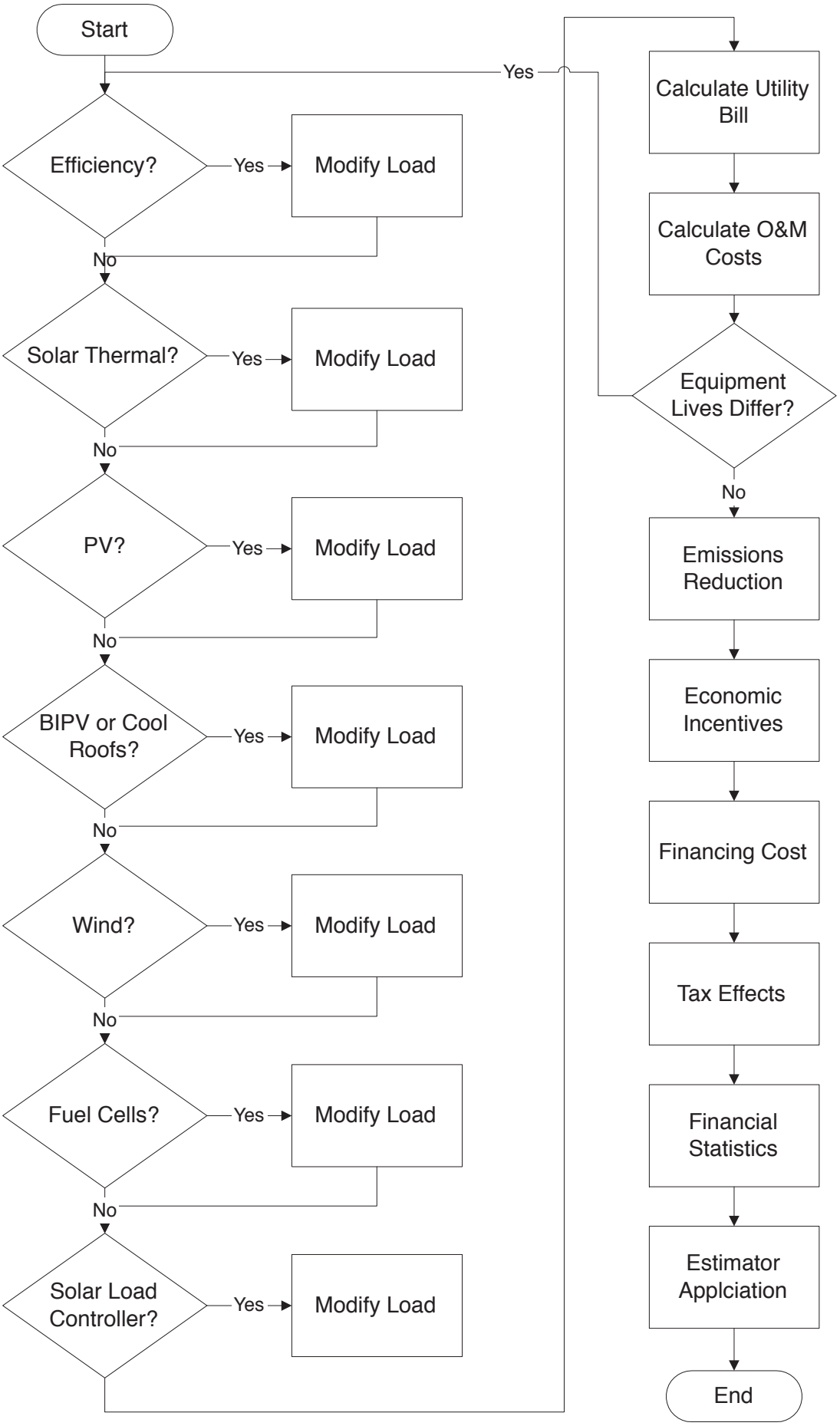

Figure 8 - Estimator Analysis Process Flow

Calculating the proposed load requires estimating the output (or savings) from each technology. The technologies are evaluated in the following order:

- Efficiency
- Solar thermal
- PV
- Thermal benefits from BIPV, cool roofs, or radiant barriers
- Wind
- Fuel cells (or other natural gas based generation)
- Solar load controller

Efficiency

At a minimum, the user specifies the annual electrical efficiency savings. In addition, they can specify the shape of the efficiency savings (peak load or base load) and the months during which the savings are applicable. This allows users to model a diverse range of efficiency investments.

Solar Thermal

The model currently contains a generic solar thermal estimation option.

PV

PV output is calculated based on location-specific weather data, system size, and orientation. A set of pre-calculated tables have been developed based on NREL's weather database for the U.S. The accuracy of this method has been documented by Perez, et.al. in "Validation of a Simplified PV Simulation Engine" (ASES 2003).

In addition, as a result of a contract with NYSERDA, users can enter key information about system shading and perform a shading evaluation associated with ground obstructions.

Thermal Benefits from BIPV, Cool Roofs, or Radiant Barriers

Roof-integrated PV systems (or cool roofs and radiant barriers) can provide added thermal savings benefits to a building. As a result of a contract with the California Energy Commission, these benefits can be calculated.

Wind

The output of a wind system is calculated by creating a power curve for all units selects, adjusting the output for inverter efficiency, and then calculating the monthly wind output using location-specific wind speed data.

Fuel Cells

The output of a fuel cell is calculated based on the size of the fuel cell and the mode of fuel cell operation. The corresponding natural gas consumption is based on fuel cell efficiency, existing building equipment, and use of waste heat.

Solar Load Controller

The solar load controller allows buildings to shave their peaks (and thus reduce demand charges) by allowing customers to have a slight level of inconvenience during times at which the demand is high but the PV is unavailable.

Emissions Savings

Emissions savings are calculated based on emissions factors published by the EPA and the amount of electricity produced. They are based on state-wide average values.

Marginal Tax Rates

Actual tax rate structures for all states and the federal rates when combined with reported taxable income specify the user's marginal tax rates (and thus the amount of money saved in taxes associated with tax-deductible expenses).

Current and Proposed Utility Bills

Current and proposed utility bills are calculated based on current and proposed loads combined with the customer's electric rate structure (and natural gas price when working with fuel cells). The load is fed through the rate structure to calculate the utility bill. The difference between the current bill and the proposed bill is the utility bill savings.

The program currently has more than 1,500 electric rate structures. The rate structures can include: energy costs by season, period (time-of-day), and tier (amount of energy consumed), demand charges by season, period, and tier, demand charges that are relative to consumption, fixed costs, minimum, bills, bill discounts, billing method (standard and net metered), and various types of net metering.

O&M Cost

The O&M costs, when specified, are calculated for each technology.

Other Value

Consumers may specify other values not included in the analysis. These values are included in this section.

Economic Incentives

The Estimator calculates economic incentives. These incentives can occur at the federal, state, utility, city or manufacturer targeted level. They can also be interacting incentives. For example, in California for small PV systems for commercial customers, one first calculates the California Energy Commission, then the federal incentive on the reduced amount, and finally the state incentive after adjusting the cost for both the CEC and federal incentives.

Loan Costs

Customers can purchase PV systems by paying cash or financing them with loans. The loan calculations are based on net system cost, financing method, and loan parameters. Loan types include non-tax deductible loans, tax deductible loans, home mortgages, home refinances, loans with interest buydowns or grace periods, loans with points, etc.

Tax Effects

Purchasing a clean energy system has tax consequences. These include potential tax benefits (tax based incentives, depreciation, loan interest tax savings, and O&M cost tax savings) and tax liabilities (taxes on tax credits and increased income taxes due to decreased utility bills). The Estimator calculates theses benefits and liabilities.

Cash Flows and Other Financial Statistics

The final step in the analysis is to calculate financial statistics and tests. These include cash flows (with discounting) and other financial statistics (NPV, simple payback, etc.)

Inputs

Simple versions of the Estimator can be run with only four inputs with default values used for everything else. More sophisticated versions of the program can request a broad range of inputs. This section describes the input parameters that can be specified.

PV System

- System type
  - Generic PV (in DC or AC kW)
  - Systems packaged by manufacturers
  - Customizable list of manufacturer-specific modules (and quantity) and inverters
- Cost (cost in DC or AC kW or cost for each component)
- Slope and azimuth orientation (there can be multiple orientations)
- System shading
- Life (years)
- O&M cost
- PV output adjustment (to match internal company models)

Wind system

- Type (customized manufacturer-specific wind systems)
- Cost ($ per DC or AC kW)
- O&M cost
- Life (years)
- Wind speed range (low, average, high)
- Tower height and/or wind speed

Efficiency

- Annual savings (kWh)
- Cost (total or per kWh saved)
- Effect on load
  - Months where applicable
  - Load factor
  - Base load or peak load investment
- Life (years)

Fuel Cell

- Size (DC or AC kW)
- Cost ($ per DC or AC kW)
- Annual capacity factor
- Efficiency
  - Electrical
  - Thermal
  - Total
  - Efficiency units (LHV or HHV)
- O&M cost
- Life (years)
- Mode of operation (peak load, base load)
- Use of waste heat (electrical or thermal loads)

Generic solar thermal

Generic solar load controller

Financing Information

- Method (cash, loan, secured loan, home loan, refinance)
- Basic loan information
  - Rate
  - Life
  - Points
- Refinance information
  - Current home loan amount
  - Current loan rate
- Loan buydown programs
  - Loan buydown amount
  - Buydown period
  - Grace period
- Years of loan reserves (for bonds)

Utility Bill

- Current annual electric bill
- Current annual natural gas bill
- Annual escalation
- One-time rate adjustment
- Natural gas price (select from previous years)

Other information

- Taxable income
- Tax filing status
- Other value (initial cost savings and/or annual savings)
- Number of buildings
- Type of house (standard or energy star)

Building information

- Building Height, roof area, and fraction windows
- Current R-Values (walls, windows, and roof)
- Current and proposed roof type
- Increase in roof R-value
- Fraction of roof covered by new technology
- Cost of new roof technology ($/s.f.)
- Radiant barrier emissivity
- Life (years)
- Temperature at which AC turns on
- Allowable user inconvenience (for SLC)
- Build response to temperature
- Current and proposed COP for AC system
- Current thermal efficiency of heating system
- Percent of fuel switchable consumption
- Cooling load adjustment

Outputs

The Estimator can produce thousands of outputs. These results can be broadly categorized as Economic and Technical Results. These results can be viewed in the Web Client, used in Quote Generation, or obtained from the Web Service or MAP.

Economic Results

- Yearly Cash Flow
  - Net cash flow
  - Discounted cash flow
  - Cumulative cash flow
  - Cumulative discounted cash flow
  - Detailed cash flow components (utility bill savings, loan payment, tax effects, etc.)
- Savings and costs by year
  - Monthly savings and costs
  - Annual savings and costs
- Other
  - Net cost after incentives
  - Monthly electric bill savings
  - Net present value (NPV)
  - Simple payback
  - Cost per kWh
  - Bond breakdown
  - Community results
  - Marginal tax rates
  - Depreciation schedules
- Monthly electric bill details
  - Energy charges
  - Monthly demand charges
  - Period demand charges
  - Excess production credit
  - Fixed costs
  - Minimum bill
  - Bill discount
  - Period Definition

Technical Results

- Current average daily load
- Proposed average daily load
- Monthly consumption
- Daily air conditioning load
- Daily natural gas load
- Hourly, daily, monthly, and annual technology output for
  - PV
  - Wind
  - Efficiency
  - Fuel cell
- Environmental savings

Architecture

The Estimator can be accessed through a variety of applications, each of which provides a unique set of features related to analyzing clean energy systems data and presenting the results of the analysis. All of the applications make use of two core components – the Analysis Engine and the Data Retrieval component – and all are accessed via the Internet either programmatically, or directly by the user through a web browser. Figure 9 shows the relationships between these applications and the core components.

Estimator Analysis Engine

As its name implies, the analysis engine is where the calculation of a wide variety of financial results, technology energy production, net consumption and demand, emissions reductions, and a host of other results are performed. These analyses may be executed by the Clean Power Research server or downloaded and run on a customer's computer, depending on the application. The raw data used by the analysis engine is passed in by the application, which uses the data retrieval component.

Data Retrieval Component

The data retrieval component provides a programmatic interface for other components that need to obtain data from the Estimator databases and create the data structures required by the analysis engine.

First-Tier Server-side Application Components

Estimator applications are generally multi-tiered. They consist of a first-tier server-side component, which is written and maintained by Clean Power Research, runs on a Clean Power server, and one or more server or client tiers that invoke the first-tier server-side application component via HTTP. First-tier server-side application components make direct use of the analysis engine and data retrieval component, whereas other application components utilize these components indirectly through the first-tier server-side component. The Applications section describes in more detail the type of data that is sent to first-tier server-side application components and the responses that are returned to the caller.

Second-Tier Server-side Application Components

Second-Tier Server-side components are built to run either on one of Clean Power's servers or on a web server belonging to a Clean Power Research licensee. Their primary function is to communicate with first-tier components via HTTP, then either directly make use of the returned data or pass it along to a client (usually a web browser) running on the consumer's computer.

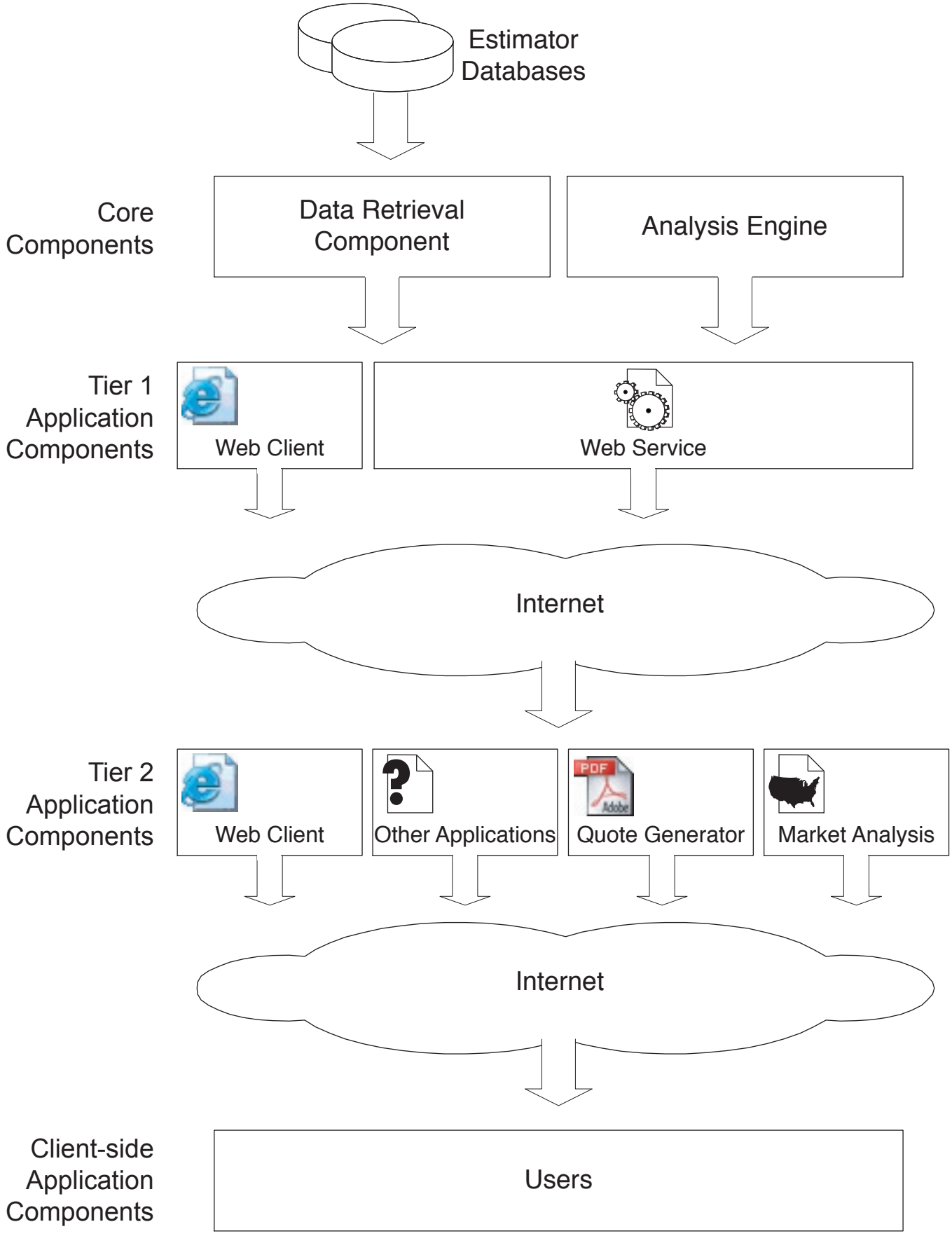

Figure 9 - Estimator Architecture

Client-side Application Components

Client-side components are generally written in JavaScript and built to run within the consumer's web browser. The Estimator analysis engine itself can run either as a first-tier server-side component or as a client-side component. Another example of a client-side component is the data graphing component which communicates with the Macromedia Flash player to draw the graphical charts that are available in the Estimator Web Client application.