Lawrence Berkeley National Laboratory
Lawrence Berkeley National Laboratory

Title

The Tariff Analysis Project: A database and analysis platform for electricity tariffs

Permalink

https://escholarship.org/uc/item/0bn0m503

Authors

Coughlin, K.
White, R.
Bolduc, C.
et al.

Publication Date

2006-05-12

The *Tariff Analysis Project*:
A database and analysis platform for electricity tariffs
LBNL-55680[1]

Katie Coughlin, Richard White, Chris Bolduc, Diane Fisher & Greg Rosenquist

Energy Analysis Department
Environmental Energy Technologies Division
Lawrence Bekreley National Laboratory
University of California
Berkeley, CA 94720

May 2006

Contents

List of Tables

List of Figures

1   Introduction

Much of the work done in energy research involves an analysis of the costs and benefits of energy-saving technologies and other measures from the perspective of the consumer. The economic value in particular depends on the price of energy (electricity, gas or other fuel), which varies significantly both for different types of consumers, and for different regions of the country. Ideally, to provide accurate information about the economic value of energy savings, prices should be computed directly from real tariffs as defined by utility companies. A large number of utility tariffs are now available freely over the web, but the complexity and diversity of tariff structures presents a considerable

barrier to using them in practice. The goal of the *Tariff Analysis Project* (TAP) is to collect and archive a statistically complete sample of real utility tariffs, and build a set of database and web tools that make this information relatively easy to use in cost-benefit analysis. This report presents a detailed picture of the current TAP database structure and web interface. While TAP has been designed to handle tariffs for any kind of utility service, the focus here is on electric utilities within the United States. Electricity tariffs can be very complicated, so the database structures that have been built to accommodate them are quite flexible and can be easily generalized to other commodities.

This report is organized as follows: In the rest of this section we discuss the project background, and provide an overview of how electricity tariffs function and what kinds of prices they define. In Section 2 we describe the TAP database in detail, including definitions of all the TAP tables and the fields they contain. Section 3 discusses how to input data to TAP, and presents a set of Perl scripts that can be used to do bill calculations from TAP data. In Section 4 we describe the web interface that has been built to view, enter and edit TAP data, and the *OnTAP* SOAP server. These applications are written in PHP [3]. In the Appendix we provide a set of tables detailing the database structure and summarizing the functionality and dependencies of the web scripts. For reference, figure 17 shows the entity-relationship diagram of the TAP database.

1.1   Background

TAP was originally developed as an analytic tool to be used in the economic benefits analysis for the U.S. Department of Energy (DOE) efficiency standards rulemakings, specifically for commercial air-conditioning [4] and distribution transformers [5]. Both these equipment types have peaky loads that are strongly correlated to the overall electric system peak. While it is obvious that the cost of serving peaky loads is higher than the average production cost per kilowatt-hour, just how much higher cannot be determined without considerable attention to detail. Moreover, the question of whether retail prices adequately capture these additional costs can be difficult to answer, especially for complicated tariff structures.

The most conceptually straightforward way to approach this question is to just calculate the actual bill a customer would see given a certain level of energy demand and consumption. If the changes to demand and consumption due to a standard can be estimated, then the bill can be recalculated, and the economic savings due to the standard follow directly. TAP was developed to implement this conceptually simple and accurate approach, by converting the information buried in detailed tariff documents to a rational database format. The complexity of the database reflects the fact that a tariff is not a list of prices *per se*, but rather an algorithm for computing customer bills. By surveying a large sample of utilities, the TAP analysis arrived at a standardized description of this algorithm that captures the most important determinants of the prices seen by utility customers. The features modeled in TAP include demand charges, seasonal rates, variable block rates, delivery voltage and time-of-use rates. TAP cannot and does not attempt to capture all the legal rules, requirements, exceptions and nuances that may be specified in a tariff.

The first version of the TAP database and the bill calculator were implemented as an Excel spreadsheet. Because tariffs change over time, more sophisticated database tools than those available through Excel were needed to update and maintain the tariff data. To address these issues, LBNL developed a mySQL database and a web interface **tariffs.lbl.gov** to view, enter and edit the data. TAP data can be viewed by the general public, and user accounts can be set up to allow access to the database for data entry and publication. The TAP website includes a simple bill calculator, which allows the user to input energy consumption and demand data, and view a calculated bill, including a breakdown by different types of charges. LBNL also maintains an archive of the utility documents which are the source of the tariff data.

For the DOE analyses LBNL developed a sample of about 300 tariffs from 90 electric utilities covering the continental United States [1]. This utility sample was designed to reflect the distribution of population across the country, and to capture the diversity of all of the industry characteristics that correlate with electricity rates, such as location, ownership type, and company size. Regional variation implicitly includes differences in climate, demographics, historical development, and market structures. Utilities included in the sample serve roughly half the commercial and residential customers in the U.S., which is sufficient to provide accurate estimates of electricity prices at the national and regional level (census divisions or larger areas). More detail on the application of TAP tariffs to the efficiency standards rulemakings is available through the DOE website [4, 5]. A thorough analysis of commercial average and marginal electricity prices based on TAP tariffs and related tools is also available as LBNL report number 55551 [1]. The database was updated in 2004-2005, and currently contains the default residential and non-residential secondary voltage tariffs, and primary voltage tariffs where they exist, for the original sample of 90 utilities. TAP has also been linked to the LBNL *Home Energy Saver* [1] website [2]. For this project, all residential tariffs for most of the electric utilities in California were collected.

1.2   Overview of how tariffs work

Electricity tariffs are typically classed as residential or non-residential. Non-residential may be further subdivided into general service, and special-use tariffs such as street-lighting, agricultural, *etc.* Occasionally utilities will define industry-specific tariffs, for example for food processing. Its important to note that although it is standard practice to report electricity data for the residential, commercial and industrial sectors, most utilities do not actually distinguish between commercial and industrial customers in their tariffs. Instead, they use more technical criteria, such as delivery voltage, transformer size or load factor, to define the tariff rules. Custom tariffs may be created for very large customers. Thus, in general, commercial and industrial customers with similar energy use profiles will be on the same tariff.

It is common practice to subdivide the general-service tariffs by customer sizes. Size is almost

---

[1]The HES website allows users to estimate the economic benefits of more efficient appliances and other improvements to household energy efficiency. Through the link to TAP, users can specify the utility and the tariff to use to calculate their electricity bills.

always defined by the value of the annual peak demand, although occasionally annual energy consumption may be used. Physically, the demand is defined as the rate of energy use per unit time, which can obviously not exceed the service capacity to the customer. In practice, demand is not measured instantaneously, but rather is averaged over a period of time defined by the tariff (and meter), usually fifteen or thirty minutes. The annual peak is the maximum demand over one calendar year. Each size class always includes a default tariff, and may have in addition several optional or experimental tariffs. Time-of-use (TOU) tariffs are available to both residential and non-residential customers, and are included in TAP if they are the default tariff. In the original TAP sample the default tariffs for residential and non-residential customers over all size classes were collected.

As noted above, a tariff essentially defines an algorithm for computing a customer[2] The primary inputs to the bill algorithm are the billing period, the energy consumption in kilowatt-hours (kwh) over the billing period, and the peak energy demand in kilowatts (kw) over the billing period. To simplify the discussion, we will assume that the billing period is always one calendar month. The annual peak demand, annual energy consumption and delivery voltage may be needed to define which tariff a customer will be on, but are not needed to compute the monthly bill. Conceptually, we can think of each tariff as a function which takes the input customer data and returns the bill:

$$B = F(m, E_m, D_m),\tag{1}$$

where m denotes the month, D_m is the current month demand, E_m is the current month consumption, and F is the function defined by the tariff. Because rates may vary by season, and the season definition varies by tariff, the bill depends explicitly on the calendar month m. Strictly speaking, for TOU tariffs the bill will be a function of energy use and demand in each of the TOU time periods, but we'll ignore this level of detail for the moment.

Given the bill and the customer inputs, a number of prices can be defined. For example, the average price in a given month is the bill divided by the energy consumption:

$$P_{avg} = B/E_m.\tag{2}$$

One of the key points to understand here is that the price is not determined solely by the tariff - it depends in a fundamental way on the input customer data as well. In other words, the price determined by a given tariff is a function of the customer variables E_m and D_m. This way of looking at prices turns out to be quite useful, as it allows us to forget the details of how a tariff is specified and just focus on how the *price function* behaves for different values of the independent variables.

In cost-benefit analysis, the quantity of interest is usually the *marginal price*, defined as the price that would be applied to the next increment of consumption or demand, relative to some baseline. Using TAP, it is easy to calculate marginal prices by comparing the baseline electricity

---

[2]The bill is really defined for energy use and demand measured at a meter. To keep the discussion clear, we'll assume here that a single customer corresponds to a single meter.

bill to the bill when energy and demand are perturbed. Defining the energy decrement ΔE and demand decrement ΔD, the change to the bill can be written

$$\Delta B = F(m, E_m, D_m) - F(m, E_m - \Delta E, D_m - \Delta D). \tag{3}$$

We define the *effective marginal price* P_{emp} [1] to be the ratio

$$P_{emp} = \Delta B / \Delta E. \tag{4}$$

This definition combines the effects of both energy and demand charges, TOU rate structures, and whatever else may be included in the tariff, and should not be confused with the marginal energy price which only looks at the changes in the bill that occur when the energy consumption is perturbed. The effective marginal price is by definition the economic value associated with the energy savings $(\Delta E, \Delta D)$. For small decrements, equations 3 and 4 can be combined to give

$$P_{emp} = \frac{\Delta B}{\Delta E}\big|_{\Delta D=0} + \frac{\Delta B}{\Delta D}\big|_{\Delta E=0}\frac{\Delta D}{\Delta E}. \tag{5}$$

Note that it is the ratio of ΔD and ΔE that enters this equation. This quantity is a variable that depends on the scenario under consideration, and is closely related to the load factor.

The load factor is defined as the ratio of the average energy consumption to the peak energy demand over some time period. For example, if the demand is defined as the average demand over one hour then the monthly load factor is

$$LF_m = \frac{E_m}{N_m D_m} \tag{6}$$

where N_m is the number of hours in month m. Because the load factor is a combination of the independent variables D_m and E_m, the average and marginal prices determined by a tariff could also be considered functions of either D_m and LF_m, or E_m and LF_m. In a detailed empirical study of prices for non-residential consumers [1], we have found that, for a given level of demand, the electricity price correlates more closely with load factor than with energy consumption. This is not surprising, as higher load factors (corresponding to flatter loads) are presumably more cost-effective to service.

In analogy with the load factor we define a *marginal load factor MLF*, again assuming demand is defined as average hourly demand:

$$MLF = \frac{\Delta E}{N_m \Delta D} \tag{7}$$

Equation 5 can then be written

$$P_{emp} = \frac{\Delta B}{\Delta E}\big|_{\Delta D=0} + \frac{\Delta B}{\Delta D}\big|_{\Delta E=0}\frac{N_m}{MLF}. \tag{8}$$
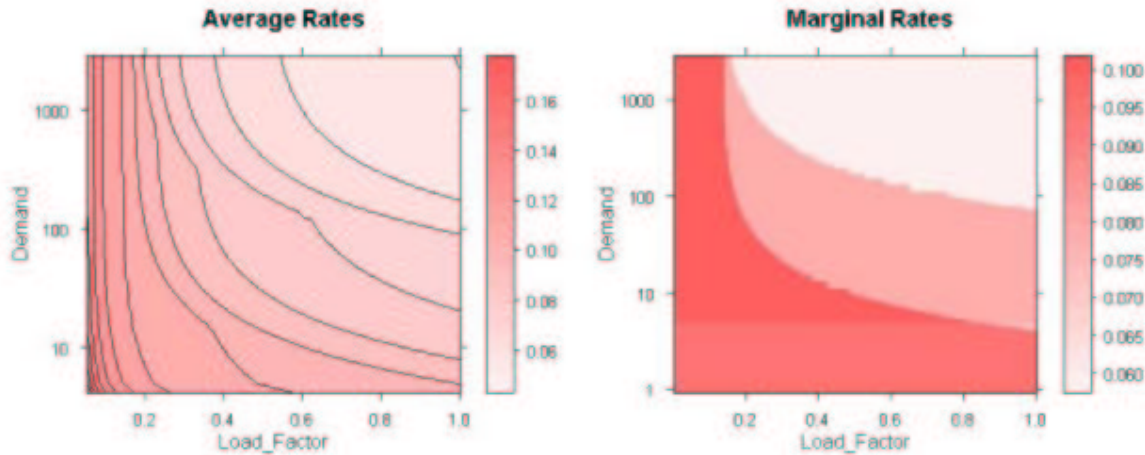
Figure 1: Example tariff maps. The average price (left) and effective marginal price (right) are shown as a function of demand and load factor. The demand axis is logarithmic.

The marginal load factor is a variable in the price equation, and is independent of the tariff. In applications, the actual value of the MLF will be set by the efficiency measure under consideration. One of the advantages of using TAP is that it allows each tariff, no matter how complicated, to be converted to the relatively simple formula in equation 8. Of the various determinants of price, those that depend on the tariff itself are clearly separated from those that depend on the customer characteristics.

As a final illustration of the price function concept, we show in figure 1 representations of P_{avg} and P_{emp} for a sample tariff. They are plotted as functions of the demand and load factor. For the marginal price P_{emp}, equation 8 is used assuming that the marginal load factor $MLF = 0.5$. The figures are similar to an elevation plot: the price (average or marginal) is analogous to the elevation and is indicated by the color, while demand is on the vertical axis (like latitude), and the load factor is displayed along the horizontal axis (similar to longitude). Because demand can vary so widely across a single tariff, the vertical axis is logarithmic. Note that if the value of the MLF used to compute the effective marginal price were changed, it would change the overall scale of the price, but would not affect the pattern observed in the figure.

This provides a brief example of how TAP allows a user to work directly with analytically well-defined quantities, without getting bogged down in the details of how individual tariffs are defined. A detailed application of these concepts to the calculation of commercial electricity prices is presented in the report LBNL-55551 [1], which includes a discussion of how to fit TOU tariffs into this type of framework.

2   The TAP Database

In this section we go over the TAP database design in detail. Tariffs are essentially a list of specific rates along with a set of rules and conditions which define when these rates should be applied. In designing the TAP database, the rules and conditions have been parsed into a set of standardized criteria. The rates and parameters defining these applicability criteria can then be stored in a set of linked tables. Not every feature that may appear in a tariff has been dealt with in the current database. The most common criteria which are included are: seasonal rates, block rates with fixed or variable block limits, time-of-use rates, and capacity charges. Each of these will be described in detail below.

The data are organized on four hierarchical levels, which are illustrated in the condensed entity-relationship (ER) diagram of figure 2. The first is the utility level, which includes the data needed to describe the company that issues the tariffs. This is collected primarily from the Energy Information Agency (EIA) Form 861 filings [6], which provide quite detailed information on all companies which sell electricity to final consumers. Utility-level data are stored in the UTILITY and STATE tables.

The second level is the tariff level. While a utility may have many tariffs, each customer is assigned to only one, so all the information needed to make this assignment must be included in the tariff-level data. In TAP these characteristics are the *market* (residential, general service, agricultural *etc.*), the kw and kwh limits, the service voltage, and the customer state of residence (for utilities which operate in multiple states). The definition of seasons and time-of-use periods occurs at the tariff level. The tariff table also includes a set of dates defining the legal period of validity for the tariff, and the dates when the data were collected. In certain cases, to enforce consistency with the TAP database structure, it may be necessary to subdivide a single utility tariff into several separate database tariffs. To distinguish the latter from the original utility definition, we refer to them as *TAP tariffs*. This is a data-management device and has no impact on the accuracy of prices calculated using TAP. The tables containing tariff-level data are TARIFF, MARKET and STATE.

The next two levels are where all the data defining specific rates, and the parameters used to specify the conditions when the rates apply, are collected. This information is subdivided into the third GROUP level, and the fourth BLOCK level. In general, a utility may apply multiple charges to the same kw of demand or kwh of consumption. For example, a utility may specify an energy charge for generation, and another energy charge for transmission, and apply both charges over the same consumption range. TAP uses the *groups* and *blocks* constructs to organize the data and allow multiple conditions to be applied to the same inputs. The group structure separates charges according to rate type, season, time-of-use period, and if appropriate the aspect of service the customer is being charged for. A block defines a limited range of input data values over which a given rate applies. A group always consists of a contiguous set of blocks that span the full range from zero to infinity.

The next four sections discuss each level more fully. A detailed ER diagram, and a complete listing of all the database tables, are collected in the Appendix.
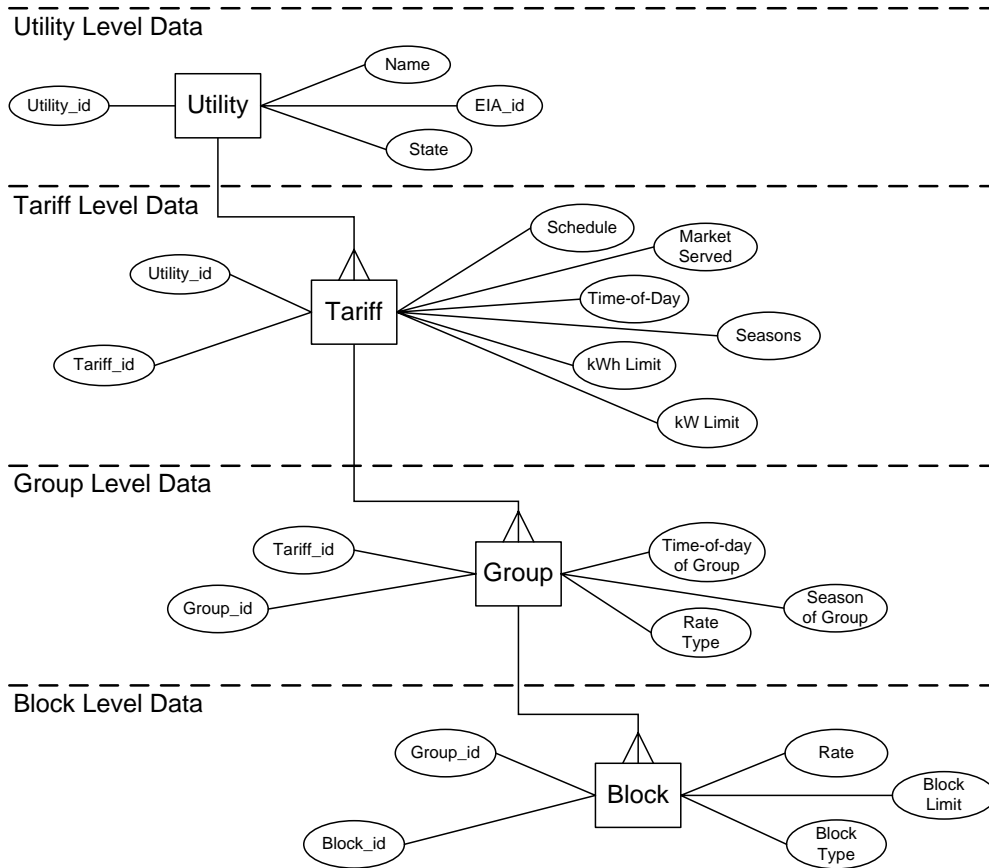
Figure 2: TAP data hierarchy

2.1   Utility level data

Information about individual utilities is stored at the highest level of the database. Here a utility is defined as a business entity that sells electricity to final consumers. Companies of this type are now known as *load-serving entities* or LSE's. Strictly speaking, utility data are not required to calculate bills, but in general the utility data are the only link to geographic information about customers and rates. In reality the regional variation of electricity prices is quite pronounced [1, 4], so it is important to have this information readily available. Geographic information is stored in TAP in the ZIP_CODE and EIA_FIPS tables.

The TAP utility data come primarily from the EIA Form 861 filings [6]. These are updated annually and easily available over the web. Attributes from the EIA data that are currently stored in TAP are the utility name, state, ownership type, and the five-digit utility_code used by EIA as a unique identifier. The state in this table refers to the state in which the company is incorporated. A utility may serve customers in several states, and each state will have its own tariff, so another state variable is included in the TARIFF table. The TAP website attempts to maintain current links to the websites of all the utilities in the sample.

One of the difficulties in maintaining a database of this type is that the structure of the electricity industry is always changing, and company mergers (and splits) are fairly common. EIA deals with this situation by maintaining within its data the identity of a given LSE, even if its parent company or legal name changes. This appears to be consistent with the tariff filing requirements of state public utility commissions. TAP also follows this practice, so that utilities included in the sample are defined as per the EIA list of companies. This means that some of the company names in TAP may no longer be in general public use; however, the LSE remains defined at the state level for the purpose of filing tariff documents.

2.2   Tariff level data

Tariff level data include fields needed to uniquely identify a tariff, the criteria used to assign customers to it, season definitions and TOU period definitions. These are explained in more detail in the sections below.

2.2.1   Tariff applicability

Utilities issue a variety of tariffs with each tariff geared to a specific class, or sector, of customers. These are often given informative names, such as residential, street-lighting, agricultural *etc.* , but the names have no specific technical meaning. These customer categories are defined in TAP using the *market* variable. The dominant distinction is between residential and non-residential, or general-service. The latter category applies to both commercial and industrial customers. The precise definition of customer class is referred to as the applicability of the tariff.

For residential tariffs there may be sub-classes based on location or the type of appliances used in the home (for example gas *vs.* electric heating). Some utilities offer optional time-of-use or

APPLICABILITY:

To all electric service of one standard voltage required by any customer receiving electric service at one point and metered at or compensated to that voltage who uses less than **3,000 kWh** monthly and who would have a maximum 30-minute measured demand of less than 30 kW. Where the Company determines installation of metering equipment is impractical or uneconomical, monthly kWh may be estimated by the Company and billed at the monthly rate. Billing under this option is designated as GS-2-U.

Figure 3: Example *Text of Applicability*

other experimental tariffs to residential customers. TOU tariffs are also commonly offered to non-residential customers, and in some cases are mandatory. In the non-residential sector, sub-classes are typically based on the physical limitations of the service that is delivered under the tariff, the most common of these being peak demand (kw), energy usage (kwh), and service voltage (kV). An example of text used to define the conditions of applicability is shown in figure 3.[3]

The TARIFF table includes fields for the demand limits and energy consumption limits defining tariff applicability. In the example of figure 3, the lower and upper limits for demand are 0 and 30 respectively, and the lower and upper limits for energy use are 0 and 3000. TAP also stores a logic (and/or) variable indicating whether either or both limits are to apply. In this example, the tariff specifies that both conditions must be met, so the logic field would be set equal to *and*.

The tariff applicability may also depend on the customer service voltage. For example, a high-rise office building will probably get service at a higher voltage than a small store. Service voltage is typically distributed in discreet steps and referred to by common names such as residential, secondary, primary, and transmission voltage. While the names are standard, the actual numerical limits associated with them are not. TAP stores both the service type name and the voltage limits associated with that service, if these are available.

2.2.2   Utility tariffs and TAP tariffs

Utilities define and publish their tariffs in individual documents referred to as schedules. These schedules do not always strictly follow the rules of applicability implemented in TAP. For example, a single utility tariff schedule may describe rates for customers at several service voltages. Figure 4 is an example of a tariff that covers several applicability categories.[4]

In the example of figure 4 a single document defines rates for different ranges of load size (demand) and delivery voltage (service voltage), for a total of eight customer classes according to the TAP applicability rules. This is handled in TAP by creating eight versions of the tariff, each with a unique schedule name and id. We refer to these as *TAP tariffs*. These sub-classes and associated TAP tariffs must be defined by the user at the time of data entry.

---

[3]This example comes from Georgia Power.
[4]This tariff comes from Pacific Power and Light.

Distribution Charge	Delivery Voltage	
	Secondary	Primary
Basic Charge		
Load Size ≤50 kW, per month	$ 16.00	$ 17.00
Load Size 51-100 kW, per month	$ 28.00	$ 30.00
Load Size 101 - 300 kW, per month	$ 65.00	$ 70.00
Load Size > 300 kW, per month	$ 93.00	$100.00
Load Size Charge		
≤50 kW, per kW load size	$ 0.94	$ 0.95
51 - 100 kW, per kW load size	$ 0.77	$ 0.78
101 – 300 kW, per kW Load Size	$ 0.41	$ 0.41
> 300 kW, per kW Load Size	$ 0.31	$ 0.31
Demand Charge, per kW	$ 2.68	$ 3.00
Distribution Energy Charge, per kWh	0.330¢	0.050¢

Figure 4: Example tariff showing several customer sub-classes

Utility	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Beauregard Electric	W	W	W	S	S	S	S	S	S	S	S	W
Idaho Power	W	W	W	W	W	S	S	S	W	W	W	W

Table 1: Season definition table, S=summer, W=winter

Utilities typically label tariff schedules with both a a name and a code; for example, "Large General Service 1" as the name and "LGS-1" as the code. TAP saves both of these fields for informational purposes. As there is not a one-to-one relationship between TAP tariffs and utility tariffs, TAP tariffs cannot be identified from these designations. Instead, the internally defined *tariff_id* is used to uniquely identify each tariff.

Utilities also frequently publish *riders*, which are additional documents with adjustments or amendments to the rates and rules specified in a tariff. A common example is a fuel cost surcharge. In TAP, riders are not treated separately. Instead, during the data entry process all applicable charges, from all source documents, are combined as appropriate into the rates stored in the GROUP and BLOCK tables. A *publish_note* field in the TARIFF table allows the user to add comments about the data as needed.

2.2.3   Tariff seasonal definitions

Many tariffs have seasonal rates, where the amount charged per kw or per kwh changes according to the season. The only seasons utilities appear to use are *summer* and *winter*. The specific periods covered by each season are defined in the tariff document. In TAP, we assume that seasons are always defined as a set of calendar months, and assign a season flag to each month. The data are stored in the SEASON table. Two examples are illustrated in table 1. Here, summer is defined

Utility	Season	Hour Ending											
		1	2	3	4	5	6	7	8	9	10	11	12
PG & E	Summer	F	F	F	F	F	F	F	F	F	S	S	S
PG & E	Winter	F	F	F	F	F	F	F	F	F	S	S	S
Conn Pwr & Lt	Winter	F	F	F	F	F	F	F	F	F	F	F	N
Utility	Season	Hour Ending											
		13	14	15	16	17	18	19	20	21	22	23	24
PG & E	Summer	N	N	N	N	N	N	S	S	S	S	F	F
PG & E	Winter	S	S	S	S	S	S	S	S	S	S	F	F
Conn Pwr & Lt	Winter	N	N	N	N	N	F	F	F	F	F	F	F

Table 2: TOU hours definition table, N=on-peak, F=off-peak, S=shoulder

as April through November for Beauregard Electric, while for Idaho Power summer consists of the months of June, July and August. Season definitions are also displayed at the TAP website.

2.2.4 Tariff time-of-use definitions

Time-of-use tariffs have rates that are conditionally applied based on the time of day that electricity use takes place. Utilities distinguish either two or three periods: on-peak, off-peak and if there is a third type, shoulder.[5] Customers on TOU tariffs have special meters that record their electricity consumption and peak demand separately for each period. The specific hours of the day and days of the week that correspond to each period type are defined in the utility tariff document. The TOU period definitions may vary seasonally–for example, peak hours may occur in the morning in winter, and in the afternoon in the summer. In TAP the TIME_OF_DAY table contains the assignment of the hours-of-day and period type by season. A table illustrating time-of-use periods is displayed along with the tariff at the TAP website. A schematic of the TOU periods definition is shown in table 2. Here F refers to off-peak, S to shoulder and N to on-peak, while hour-ending 1 means the hour that ends at 1am, *etc.* Each hour of the day is assigned to one of the categories. If the assignment is season-dependent, the SEASON table must be used to associate a calendar month with the season.

2.3 Group level data

In order to understand how the group and block tables are structured, it is necessary to go into a little more detail about how tariffs are specified. Tariffs generally apply multiple conditions and rates to be the same inputs. The group and block structures are used to organize this information and create groups of charges that are applied under standardized conditions. The group structure separates charges according to rate type, season, time-of-use period, and the aspect of service the customer is being charged for. The latter are chosen at the time of data entry from a finite set

---

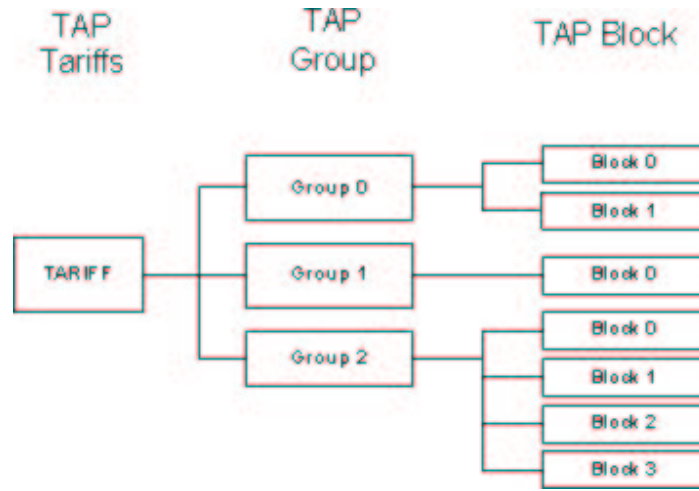[5]Some utilities may use the designation partial peak instead of shoulder.

Figure 5: Hierarchy of groups and blocks in a tariff

rate_type_id	rate_type	units
1	Energy	¢/kwh
2	Demand	$/kw
3	Fixed	$/day

Table 3: Rate types and associated units

which includes generation, transmission, fuel cost adders, *etc.* A group is a self-contained sub-unit of the tariff, which specifies rates over the entire range, from zero to infinity, of possible demand and consumption levels.

This organizational structure is illustrated graphically in figure 5, and using the simple example tariff of figure 6. In the example of figure 6, there are two rate types (fixed and energy) and three groups (fixed, energy-summer and energy-winter). The fixed rate group has only one block, and each energy rate group has four blocks. The *group_id* attribute of the GROUP table is used to uniquely identify each of the groups, and is carried into the BLOCK table to associate a set of blocks to a particular group. This attribute is assigned automatically by the web interface that is used to enter the data (see Section 4.7).

2.3.1   Rate types

The three basic inputs needed to calculate a bill are the billing period, the energy consumption and the peak demand. There are three corresponding types of charges or *rate types*: fixed, energy

and demand. Energy and demand charges are based on the kwh of consumption and kw of demand during the current billing period. Fixed charges are levied for access to electric service and are independent of the level of electricity use. Each tariff will contain some or all of these rate types. In the GROUP table the rate_type is used to assign each component to one of these rate types. The rate_type and units for each rate type are listed in table 3.

2.3.2 Temporal Conditions

Rates are applied conditionally depending on the season and TOU period. Each group is associated with a particular season and period, using the attributes *season* and *time-of-day*. The season attribute takes on the values *summer*, *winter*, or *all-year*. Summer and winter are related to the calendar month through the SEASON table (see also table 1). The all-year classification is used to identify rates that apply all year round. The time-of-day attribute takes the values *peak*, *off-peak*, *shoulder* or *all-day*. The TOU periods are assigned to hours of the day and days of the week using data from the TIME_OF_DAY table (see also table 2). The all-day value applies to any rate that is not attached to a particular period. Any combination of season and period can be attached to a row of the GROUP table. The bill calculation algorithm includes code to check the month and TOU period of the input data, so that the appropriate rates can be applied.

In order to calculate TOU bills correctly, the energy use data must be properly allocated to the seasons and TOU periods defined for the given tariff. This is straightforward in principle if hourly energy consumption data are available. Scripts that parse hourly data onto TOU periods have been developed for other applications, including the Home Energy Saver web-site [2], but are not yet included in the TAP.pm module.

2.4 Block level data

Each group has its own block structure, which reflects the way rates vary as a function of the level of energy use. A block defines a limited range of input data values over which a given rate applies. The block table includes a *sequence* variable that effectively numbers the blocks so that the upper limit of the 1st block is equal to the lower limit of the 2nd block and so on. TAP stores only the information needed to define the upper block limit. Blocks exist for both energy and demand charges. The lower and upper limits of the block can be constants or functions of the input data [6]. TAP has catalogued several of the most common functions and developed a system for parameterizing them within the database using the *block_type_id* attribute.

Three examples of different types of block limit are illustrated in table 4. In the upper section of the table, the first example has three energy blocks with constant limits. The first block has a rate of 4.247¢/kwh and is applicable to consumption in the range from 0 to 30,000 kwh; the next block has a rate 3.167 /kwh and is for consumption in the range 30,000 to 500,000 kwh; the last block has a rate of 3.118 ¢/kwh for all consumption above 500,000 kwh.

---

[6]In the tariffs surveyed to date only energy blocks use non-constant block limits

Figure 6: Sample tariff with three groups

The other two sections of tables 4 illustrate simple block functions. The second section shows a case where the block limits are defined as a multiple of the current month demand. We refer to these as *block-by-demand* energy charges (in the industry they are also known as *hours* charges). The components stored in the database are the multipliers needed to calculate the block limits. In this case, these are 100 for the first block, 175 for the second, 100 for the third, 125 for the fourth and 400 for the last, with units of kwh/kw. In the last section of table 4 we show an example of a conditional block limit. In this case the upper limit of the second block is either the sum $30,000 + 70,000$ or the sum $30,000 + 400 \times D_m$, whichever is greater (here D_m is the demand in the current month). TAP treats this conditional expression as a distinct block limit function.

Table 5 illustrates how the block groups defined in table 4 would be stored in the database. The first column is the *sequence* attribute that is used to order the sequence of blocks. The second shows the value of the rate. The next three columns, *block_type_id*, *param_kw* and *param_kwh*, store the information needed to define the block limits. The block_type_id is a flag that indicates which type of limit function should be used to define the block limit, while param_kw and param_kwh are the inputs to this function. These parameters may correspond to the upper limit of the current block, or define the length of the current block, depending on how the block types are defined. The bill calculation scripts use the block_type_id to define the appropriate interpretation of param_kw and param_kwh. The different block types and associated interpretations are presented in table 19 of the Appendix. If a given block type does not need a parameter, its value is set as NULL. The last block in a group is assigned the block_type_id=9999999 to indicate infinity, and the *end-of-group* function to indicate that no other blocks should follow it.

To clarify these notions, we will go through the three examples in more detail. The first case

Block Definition	Rate
For the first 30,000 kwh	4.247 ¢
For the next 470,000 kwh	3.167 ¢
For all over 500,000 kwh	3.118 ¢
Block Definition	Rate
For the first 100 kwh per kw of maximum demand	5.319 ¢
For the next 75 kwh per kw of maximum demand	4.549 ¢
For the next 100 kwh per kw of maximum demand	4.029 ¢
For the next 125 kwh per kw of maximum demand	3.629 ¢
For all over 400 kwh per kw of maximum demand	3.029 ¢
Block Definition	Rate
For the first 30,000 kwh	4.17 ¢
For the next 70,000 kwh *or* 400 kwh/kw of maximum demand, whichever is greater	3.26 ¢
For all remaining kwh	2.39 ¢

Table 4: Three types of energy groups. The first has three blocks with constant block limits, the second five blocks with block-by-demand limits, the third 3 blocks with conditional limit functions.

sequence	rate	block_type_id	param_kwh	param_kw
0	4.247	1	30,000	NULL
1	3.167	1	500,000	NULL
2	3.118	99	9999999	9999999
sequence	rate	block_type_id	param_kwh	param_kw
0	5.319	2	NULL	100
1	4.549	2	NULL	175
2	4.029	2	NULL	275
3	3.629	2	NULL	400
4	3.029	99	9999999	9999999
sequence	rate	block_type_id	param_kwh	param_kw
0	4.17	1	30,000	NULL
1	3.26	3	100,000	400
2	2.39	99	9999999	9999999

Table 5: Block-level data for the examples listed in table 4

has constant limit functions with block_type_id=1 for all three blocks. Here param_kwh represents the upper limit of the block, which is 30,000 for the first block, $30,000 + 470,000 = 500,000$ for the second block, and infinity for the third and last block. No demand data are needed so the param_kw values are NULL. The second section of table 5 shows how a block-by-demand energy group is stored. This type of limit function has block_type_id=2. Here param_kwh is NULL, and param_kw is used to store the multiplier that determines the upper limit of the block. It is 100 for the first block, $100 + 75 = 175$ for the second block, $175 + 100 = 275$ for the third block, *etc.* In the last section of table 5, the first block uses a constant limit function and so the first row of the table is structured as in the first example. The second row stores the data defining a conditional block with block_type_id=3. The param_kwh field is used to store the constant upper bound of $30,000 + 70,000 = 100,000$, and param_kw is used to store the multiplier that determines the length of the block-by-demand block. A summary of how param_kw and param_kwh are interpreted for different block types is given in the BLOCK_TYPE table, included in the Appendix.

3   TAP Inputs and Outputs

In this section we describe some procedures for getting data into and out of TAP. To begin with, we provide an overview of the tariff survey and data entry process. We then explain in more detail how tariffs are updated and expired tariffs are archived. This section concludes with a presentation of the existing TAP bill processing scripts.

3.1   Tap data collection

The TAP data collection process are summarized in the series of steps below. All data are entered through the web interface, which automatically populates the appropriate tables.

- Determine the sample of utilities to be sampled. For each utility, TAP requires the data listed in the UTILITY table (table 8).

- Select the particular tariffs from each utility that will be collected. Since each utility has its own criteria for defining service classes, this step may require some judgment calls. For TAP purposes, enough information must be included to identify clearly the group of customers which are covered by the tariff.

- For each of the selected tariffs make whatever sub-divisions may be necessary to be consistent with the database table structures used in TAP (see section 2.2.2). This step separates out tariffs that may be described in a single document by the utility, but which are logically distinct according to the way TAP defines a customer. The data needed to specify a tariff within TAP are detailed in the TARIFF table (table 10).

tariff_id	Schedule	status	doc_date_ _effective	doc_date_ _expired	date_ _effective	date_ _expired
17	Residential-1	Published	6/30/2003	6/30/2004	10/13/2004	NULL
17	Residential-1	Expired	6/30/2003	6/30/2004	9/17/2005	9/17/2005
805	Residential-1	Published	6/30/2005	6/30/2006	9/17/2005	NULL

Table 6: Example of how tariff documents are dated in TAP

- Data are entered using the website interface. The user creates customized forms for the tariff, and uses these to enter the rate and block limit information. The form structure automatically determines the group, block and rate_type attributes within the database. It is up to the user to review all relevant documents and make sure that all the charges are included. During the data entry process, the tariff is classified as *editing*. Data for tariffs with this status can be changed as often as desired.

- Once the tariff has been reviewed for accuracy and validated, its status is changed to *published*. Only published tariffs are displayed to the general public on the website.

- To update an existing tariff, a copy of the tariff can be made from the web interface. This copy will automatically be given the editing status. The status of the existing tariff can then be changed to *expired*, and the new version updated and published. This procedure is explained more fully in the next section.

3.2   TAP as a tariff archive

Tariffs are legal documents with a limited lifetime. When a tariff is issued it is given a legal effective date, and may include a future expiration date indicating when the tariff will become invalid. In general, the tariff database will be updated on a schedule that is independent of these official utility dates, so there will be some lag between when a tariff legally expires and when the corresponding TAP tariff is updated. For this reason, the TARIFF table stores two pairs of dates for each tariff. The first pair stores the legal dates as defined by the utility, which are labelled *doc_date_effective* and *doc_date_expired*. The second pair of dates refer to the TAP data entry process. The date when the tariff is published is defined as the *date_effective*, while the date that the tariff expires *in TAP* is the *date_expired*. If there is a delay in updating data, the date_expired may be later than the doc_date_expired. This means that while the tariff may no longer be legally valid, it is still considered valid within TAP, as it is the most recent data available. It may also happen that a utility will revise its tariff before the legal doc_date_expired, and the TAP tariff will be revised before this date. In our review of TAP tariffs we have not found that the rates change drastically over time, so that two years is probably a reasonable time scale for updating the database.

The life cycle of a tariff is illustrated in figure 7 and table 6. The events that appear above the
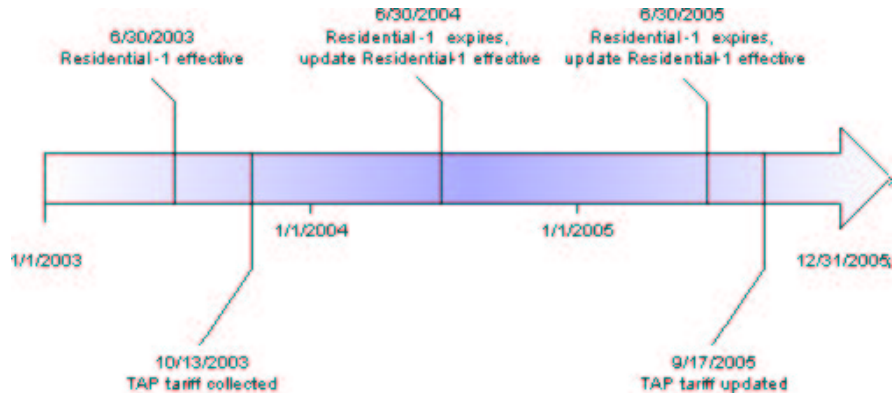
Figure 7: Tariff update timeline, see also table 6

blue arrow of figure 7 refer to the legal dates for the utility documents. The events below the blue arrow show dates when the tariff data are entered, expired and updated in TAP. The entries in table 6 show how this data would appear in the TARIFF table columns.

Expired tariffs are kept in the database, to eventually provide a historical record of rates. The *status* field in the TARIFF table is used to indicate whether a tariff is *published*, *expired*, or is in *editing*. The editing stage corresponds to data entry and verification, when small changes may be made to the tariff data. Once a tariff has been validated it is published. Only published tariffs are displayed on the website. If a tariff is revised during a database update, the status of the existing version of the tariff is changed from published to expired. The new version of the tariff (which may be identical if the rates don't actually change) becomes the published version.

3.3 Bill processing

The TAP project includes development of a set of subroutines or scripts that can be used to perform various functions, such as access the TAP database, assign customers to tariffs, and calculate customer bills. The bill calculation subroutines have been compiled into a Perl module called TAP.pm, which is described in this section. Five of the subroutines will typically be called by a user, while the others act as helper functions. The five user subroutines are:

- **openDB()** opens a connection to the TAP mySQL database

- **closeDB()** closes the connection to TAP

- **get_TAP()** retrieves a set of TAP database tables in CSV file format

- **get_bill()** calculates a bill using an open connection to the database
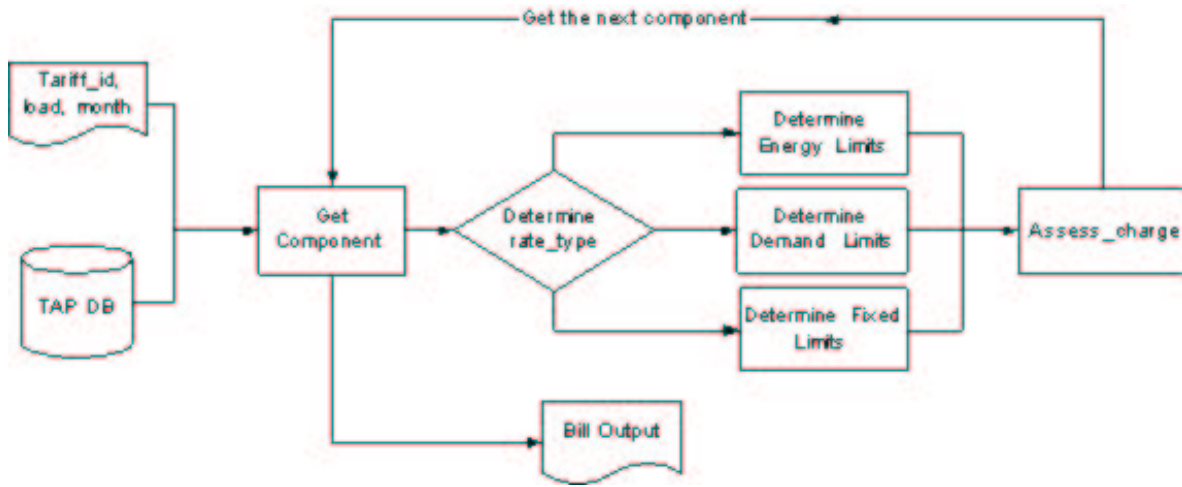
Figure 8: Bill calculator flow diagram

- **get_bill_hash()** calculates a bill using TAP CSV files

The bill calculation process is carried out identically by get_bill and get_bill_hash, and is illustrated in the flow diagram of figure 8. Each tariff is first sorted by group and by block and the component data are stored in local Perl variables. The code then steps through each of the sorted components and determines if the rate applies to the current input data, and if so what is the resulting charge. Conditions are applied in the following order: First the season and time-of-day are cross checked with the input billing month and time period. Next the block limit functions are run. The code then checks whether the current usage and demand fall within this block, and determines the charges if true. This step loops through each block and then each group, at each loop adding the charges to an accumulated total. The next section provides a more detailed discussion of each subroutine and how it fits into this process.

3.4   TAP.pm subroutines

The TAP code is written in Perl and uses standard Perl conventions [7] for variable scoping and subroutine calls. It also uses the Perl module DBI.pm, which allows direct access to a mySQL database from a Perl script. In the descriptions below, *Inputs* are parameters passed as arguments to the subroutine, *Outputs* are values returned by the subroutine, and *Global variables* are values that are accessible to all the subroutines in the module.

Name: openDB()
Description: Creates a database handle to the TAP database. The handle is essentially an open

link to the database. It is required by the TAP.pm functions get_bill and get_TAP.
Requirements: An active network connection is needed to access the database.
Inputs: None.
Outputs: None.
Global variable impacts: A database handle, $dbh, is created as a global variable.

Name: closeDB()
Description: Closes the $dbh database handle to the TAP database.
Requirements: An active network connection.
Inputs: None
Outputs: None
Global variable impacts: $dbh is closed as a global variable.

Name: get_TAP()
Description: Writes either the active TAP database or the tap_test_cases database to csv files. Only the elements required to calculate bills are written. Once the csv files are generated a remote user can run stand-alone calculations without an active network connection.
Requirements: A valid database handle to TAP, created by openDB.
Tables Accessed: GROUP, BLOCK, TIME_OF_DAY, SEASON, TARIFF, UTILITY.
Inputs: project_id, testdb. Project_id identifies the project, which in turn identifies the specific subset of the full tariff set to be used in the current calculations. If project_id=1 all tariffs in the TAP database are retrieved. If testdb=1 the test database is retrieved instead.
Outputs: The csv files component.csv, tariff.csv (minus the description, publish_note and date fields), hours_def.csv, season_def.csv and tariff_view.csv are written to the default directory.

Name: load_txt()
Description: Loads the data in the csv files created by get_TAP into TAP.pm hashes.
Requirements: The csv files created by get_TAP must be in the default directory.
Inputs: None
Outputs: None
Global variables impacted: Creates the following hashes with *tariff_id* as the key: @comp{$tariff_id}, @season_def{$tariff_id}, @tariff{$tariff_id}, @hours_def{$tariff_id}.

Name: get_bill(), get_bill_hash().
Description: Bill calculator functions. If the TAP data are read from csv files get_bill_hash should be used; get_bill is used with an open connection to the database. Otherwise, both subroutines are the same. Calculates the utility bill charges for one month given the tariff ID, the month of service, and the consumption and billing demand for that month. One row of the BLOCK table, with related seasonal and time-of-day information from the corresponding GROUP entry, is retrieved and loaded into the *@component* array. This corresponds to one block of one group for the tariff. The

subroutine loops through all the groups and blocks, calling add_charges to calculate the charges, which are then added to the @out_bill array.

Requirements: load_txt must be run before running get_bill_hash. An open database connection is needed to use get_bill.

Tables Accessed: GROUP, BLOCK, SEASON.

Inputs: tariff_id, month, off-peak demand, off-peak consumption, on-peak demand, on-peak consumption, shoulder demand, shoulder consumption, (testdb for get_bill only). The month is indexed by an integer between 0 (January) and 11 (December). If the tariff is not TOU, the consumption and demand data are entered in the off-peak slots, with the other values equal to zero.

Outputs: The array *@out_bill* contains the bill charges in the following order:

$out_bill[0]$ = Total Bill
$out_bill[1]$ = Total Energy Charge
$out_bill [2]$ = Total Demand Charge
$out_bill [3]$ = Total Fixed Charge
$out_bill [4]$ = Off Peak Energy Charge
$out_bill [5]$ = Off Peak Demand Charge
$out_bill [6]$ = On Peak Energy Charge
$out_bill [7]$ = On Peak Demand Charge
$out_bill [8]$ = Shoulder Energy Charge
$out_bill [9]$ = Shoulder Demand Charge
$out_bill [10]$ = All-day Energy Charge
$out_bill [11]$ = All-day Demand Charge

Global variable impacts: Uses the tables @comp{$tariff_id} and @season_def{$tariff_id} to load @component with the data needed to define the block limits, rate type, and rate. Initializes @charges, $lastmax and $more_charges. Updates the values in @charges.

Name: add_charges ()

Description: This subroutine calls assess_fixed, assess_energy and assess_demand to calculate the charges for the block. It then adds them to the @charges array. The elements of @charges are the energy and demand charges for the peak, off-peak, shoulder and all-day periods. The all-day values are computed locally, with all-day consumption equal to the sum of the consumption values in each period, and all-day demand equal to the maximum over the demand values in each period.

Requirements: Assumes the @component global variable has been loaded appropriately.

Inputs: Off-peak demand, off-peak consumption, on-peak demand, on-peak consumption, shoulder demand, shoulder consumption for the current month.

Outputs: None.

Global variables impacted: Writes to the array @charges.

Name: assess_charges()

Description: This subroutine assesses the charges for the current block. It also updates the values

of $lastmax and $more_charges.
Requirements: Assumes the @component global variable has been loaded appropriately. Uses $lastmax to determine the starting point of the current block.
Inputs: The upper limit of the current block, and the consumption or demand value for the current month and period.
Outputs: The dollar value of the charge for this block.
Global variables impacted: Resets $lastmax, changes the flag $more_charges if the current block is the last block in the current group.

Name: assess_demand ()
Description: This subroutine calculates the demand block limits to be used for the current demand block. It then calls assess_charges, which returns the value of the demand charge for this block.
Requirements: Assumes the @component global variable has been loaded appropriately.
Inputs: demand value for the current month and period.
Outputs: Returns the demand charge for the current block.
Global variables impacted: None.

Name: assess_energy ()
Description: This subroutine calculates the energy block upper limit to be used for the current energy block, using the function definitions listed in table 19. It then calls assess_charges, which returns the value of the energy charge for this block.
Requirements: Assumes the @component global variable has been loaded appropriately. Uses $lastmax to determine the starting point of the current block.
Inputs: Demand and energy values for the current month and period.
Outputs: Returns the energy charge for the current block.
Global variables impacted: None.

Name: assess_fixed ()
Description: This subroutine returns the fixed charge for the current month and period.
Requirements: Assumes the @component global variable has been loaded appropriately.
Inputs: None.
Outputs: The fixed charge for the current month and period.

3.5   Test Functions

To validate the TAP.pm code, a set of test tariffs has been defined. These essentially isolate each tariff construct so it can be checked explicitly. Because the bill is just the sum of charges for each component, this method is sufficient to validate the code for any tariff that fits into the existing table structure. They are stored in a separate tariff-level database called tap_test_cases. Tests can

be run using the get_bill code by setting a flag that tells it to connect to this database instead of the usual TAP database.

4   TAP Web Application

The TAP website is an interactive web application for browsing, managing and expanding the TAP database. These actions are performed by PHP [3] scripts that access and display the TAP data. The website also contains links to a number of documents explaining more about the TAP project. Figure 9 provides an overview of both the information available at the site, and the user applications. Each box represents one web page, which also corresponds to one web script. In this section, each of the web pages is described in detail. For technical reference, a set of tables summarizing the PHP scripts is provided in the Appendix.

Four categories of user are defined, with each user category having different levels of access to the database. Loosely, the user categories are:

- Readers: users with no special permissions. This category includes the general public. They may view the database but may not manipulate the data in any way.

- Authors: users who have been granted permission to add new data to the database, and edit data which has not yet been published.

- Publishers: users who check tariffs for accuracy and have been granted permissions to publish or remove them from the public realm.

- Administrators: super-users who are responsible for granting or revoking the permissions of all other users.

Currently, readers can browse the TAP database without creating an account. To become an author or publisher, a user must register with the TAP administrators, and undergo some training to ensure that they understand how to convert tariff document data to the TAP format. In principle, a widely dispersed set of users can contribute to maintaining and expanding the TAP data, which will hopefully make the application useful to a wider community. The next few sections describe the functionality currently implemented at the website.

4.1   Global configurations

The global configuration is a file used to store and call the basic functions needed to initialize each page of the TAP website. Theses functions perform the following tasks: manage connections to the TAP database, control the look and feel of the website, and manage the login status of users. Though it is not technically necessary to have this functionality in a single file, it is done for administrative convenience.
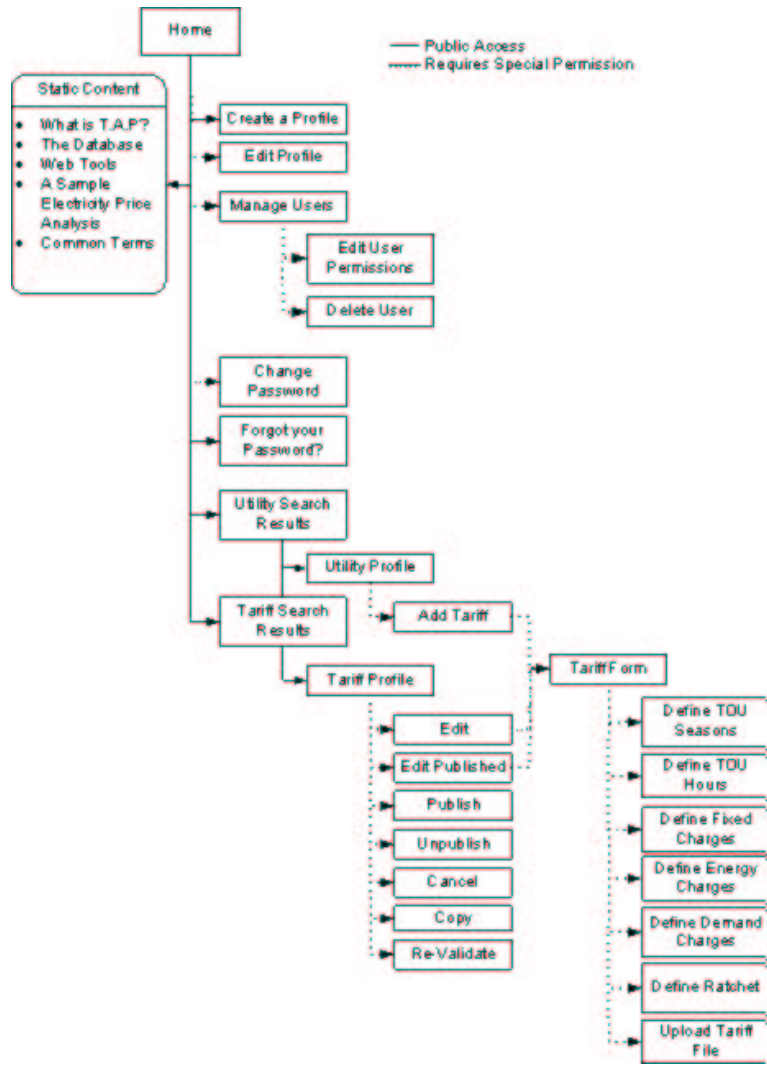
Figure 9: Overview of the TAP website

Permission Name	Description	Author	Publisher	Admin
Add tariffs	Add new tariffs; these will have *editing* status	X	X	X
Edit Tariffs	Edit any tariff that has the status *editing*	X	X	X
Edit Published Tariff	Edit any *published* tariff		X	X
Delete Tariff	Remove tariffs from the database or change status to *expired*		X	X
Publish Tariff	Change tariff status from *editing* to *published*		X	X
Download Tariff	View and download tariff document files stored on the web server archive		X	X
Browse Users	View the permissions and user information of all registered users			X
Edit User	Grant or revoke permissions for registered users			X
Delete User	Remove registered users from TAP			X

Table 7: Definition of user permissions

4.2 Managing users

The TAP administrator is responsible for defining which set of actions a user can access through the website. To ensure data integrity, the ability to manipulate data is granted only to registered users on a case by case basis. While permissions fall generally into the four user groups defined above, in reality any user can have any permission. User data and permissions are stored in the USER table of the TAP database. Table 7 provides a list of permissions, the associated action, and flags indicating whether or not different user groups typically have the permission (readers do not have any special permissions).

4.2.1 Creating a user profile

On any page a new user may register with TAP by clicking on the Create a Profile link, which appears in the upper right corner of the page. Users are asked to provide their first and last names, telephone number, and email address. Once this information has been submitted TAP will generate a password and email it to them. New users are created with reader level permissions.

4.2.2 Editing a user profile

Users can change their personal information by clicking on the Edit your Profile link. This is only available to registered users, and the link becomes available only after a user has logged into the TAP website.

4.2.3   Retrieving passwords

Users can request that their password be emailed to them at any time by clicking the Forgot
Password link.

4.2.4   Changing passwords

A registered user can change their password at any time by clicking the Change your Password link
that becomes available after logging in. The new password will be emailed to the user.

4.2.5   Browsing users

The Browse Users page is used by administrators to view the set of registered TAP users and their
permission settings. From this page an administrator can select a user profile to edit or delete.

4.2.6   Editing users

The Edit Users page is used to grant or revoke permissions from individual users. In order for
administrators to perform these operations they must have the Edit User permission.

4.2.7   Deleting users

Deleting users is an administrative function that permanently removes a user from TAP. It can be
done by clicking the Delete link next to the target user's name on the Browse Users page. To delete
a user, the administrator must have the Delete User permission.

4.3   Searching the TAP database

The TAP website was designed to make the display of utility and tariff information more intuitive
and accessible. Like the TAP database, it uses a standardized form for the tariff data. The top page
of the website displays two interfaces that allow a user to quickly search for tariffs in the database:
the tariff and utility search forms. These are shown in figure 10. The utility search returns the
results of a query on the UTILITY table, while a tariff search allows the user to do a query on the
TARIFF table.

4.3.1   Searching by utilities

The utility search interface can take any combination of the following inputs:

* *Utility Name* This input can be used to query the utility table on either a portion of a utility's
  name, or the EIA code. If a text string is entered, utility records are matched by the utility's
  name, or fragment there of; if an integer is entered, records are matched on the EIA code [6].

Figure 10: Utility and Tariff Search Forms

- *State* is a select menu of US states.

- *Ownership type* is a select menu of possible utility ownership types.

- *Customer type* is a select menu of possible utility customer classes.

The utility search results are returned as a list alphabetically sorted by utility name. Each list item is a hyperlink to the utility's profile page.

4.3.2   Searching by tariffs

The Tariff search interface can take any combination of the following inputs:

- *Demand between X and Y kw* will match all tariff records with X values greater than the min_kw, and Y values less than the max_kw fields of the Tariff table. If only X or Y is entered, it will act as either the upper or lower bound on the returned results.

- *Serving Markets* is a select menu of possible tariff electricity market segments (e.g. residential, non-residential, and agricultural).

- *Service Voltage* is a select menu of possible tariff electricity service classifications (e.g. secondary, primary).

- *U.S. State* is a select menu of US states.

The tariff search results are returned as a series of grouped lists three levels deep. The highest level of grouping is by the state in which the tariff is issued; followed by the utility that issues the tariff, followed by the tariff itself at the final level.

4.4   Viewing TAP data

4.4.1   The utility profile

The utility page is a report template for the data from the UTILITY table of the TAP database, and is illustrated in figure 11. It is divided into two sections: general utility information at the top, and a list of the TAP tariffs for this utility at the bottom. General utility information is drawn from all the TAP database tables that are related by the util_id key value.

The list of tariffs is drawn from the TARIFF table. The tariffs are grouped by market segments, and then sorted by service voltage and peak demand range. Each listed tariff is a link to the tariff profile page.

4.4.2   The tariff profile

The tariff page is a report template for the data from the TARIFF, GROUP and BLOCK tables of the TAP database, and is illustrated in figure 12. The template is divided into five sections:

1. Basic utility information is a display of the issuing utility's name, state, *etc.* It is intended for reference and as a navigational aid.

2. General tariff data is a display of information that describes the type of customer that would be assigned to this tariff.

3. Tim-of-use hours is a graphic representation of how the TOU periods are defined for the tariff. This section is only displayed for time-of-use tariffs, and is not shown in figure 12.

4. Description of rates is a list of rates. Rates are grouped into fixed, energy and demand. The data displayed here are selected from the GROUP, BLOCK, RATE_TYPE, and RANGE_TYPE tables.

5. The Bill Calculator is an interactive monthly bill calculator which interfaces with the TAP.pm module. Users can input values for the energy, demand, and calendar month, and the function will return a bill for the displayed tariff. The list of inputs changes as appropriate for time-of-use tariffs.

4.5   Manipulating tariff data

Entering and editing data in the TAP database is done through a series of web forms. The relationship between the forms is described below.

Figure 11: Utility profile as displayed at the website

Figure 12: Tariff profile as displayed at the website

4.5.1 Adding and editing tariffs: the tariff form

The primary data entry form is the *tariff form*. It is used to manipulate the data of the TARIFF table. Sub-forms for adding time-of-use hours and seasons, rate structures, ratchet descriptions, and archive files are all accessed from the tariff form.

4.5.2 Adding and editing rate structures: the tariff component form

The primary purpose of the TAP web application is to provide an interface that allows tariff data to be entered following the standardized format developed for TAP. The operational core of the interface is the tariff component form, which is used to enter a set of blocks forming a group (see also section 2.3). This form is complex, as it must be able to differentiate one rate type from another, allow different rates to be grouped, and allow for different time-of-use periods to be associated with these rate groups. Experience has shown that, to reduce errors in data entry, the tariff component form should be customized to the rate type, and should reflect the language that appears in actual tariff documents to the extent possible. This approach greatly facilitates the data entry process and also helps the user maintain consistency in tariff interpretation. Figure 13 shows how a section of the form (in this case for entering energy rates for a time-of-use tariff) would look to the user. A set of *rate control* buttons at the right edge of the window allow the user to easily add, delete, copy and reposition items in the form.

The tariff component form is used to input the three basic rate types as follows:

- Fixed Charges are the charges that appear on the bill independent of energy use levels. They are normalized in TAP to a per-day charge. The monthly charge is calculated by multiplying by the number of days in the month.

- Energy Charges are by far the most complicated part of any tariff. The TAP application currently handles 10 different block structures for energy charges, as listed in table 19.

- Demand Charges are the dollar per kW charges, based on the peak demand for a given billing period. These can be structured in blocks, but to date only blocks with constant limits have been seen in the tariff data.

4.5.3 Defining temporal conditions

The seasons form and the hours form are used to define the seasons of the year and time-of-day periods. As not all tariffs need this information, these forms are optional. They are very intuitive to use, as illustrated in figures 14 and 15.

Figure 13: Tariff component form detail

Figure 14: Season definition form

Figure 15: Time-of-use periods definition form

4.5.4   Defining a ratchet

A *ratchet*, also known as *determination of billing demand*, is a billing structure that utilities use to encourage customers to minimize their annual peak demand. A ratchet defines the billing demand for the current month as the maximum monthly demand over some previous period, typically one year. Currently, ratchets are not implemented in the bill calculation subroutines. Ratchet information is stored in TAP as text for informational purposes only.

4.5.5   Archiving tariff files

The original tariff documents in electronic format are uploaded to the web server to be kept as a reference. These files are only available to users with Download Tariff user privileges. TAP is not a public distributor of utility documents; for this reason special permission is needed to download these files. The document archive is managed as follows:

- files are stored on the web server.

- files are uploaded to the /tmp dir, they are then moved to the corresponding utility directory.

- files for an individual tariff are indexed starting at one; if there is more than one file for an individual tariff the index increases.

- the utility directory path is /state_abbrieviation/country_code+eia_code/

- tariff files are saved as country_code+eia_code+_+tariff_id+_+index+.+extension

- files are owned by the apache web server and can only be accessed through the web

4.6   Managing the tariff data

Management of the tariffs in the database is done using the functions described below.

4.6.1   Copy tariff

Copy tariff copies a tariff and all associated files into a duplicate record in the TAP database. The new copy has the status editing. This feature is most useful when updating published tariff data, or when several tariffs have the same or similar structures. The user can start with the copy and edit and then publish the tariff, rather than entering the tariff from scratch.

4.6.2   Cancel tariff

The Cancel tariff feature is used to remove correct but out of date tariffs from the public domain. After a tariff has been cancelled it remains in the database for archival purposes, with status *expired*.

4.6.3   Delete tariff

This action deletes a tariff and all associated records and files from the TAP database. Published tariffs are protected and must first be un-published before they can be deleted.

4.6.4   Publish tariff

This action changes the tariff status from *editing* to *published*. The tariff data entered into the TAP database are not directly released to the web. First it must be checked and validated by users with publisher permissions. These users are responsible for the integrity of the tariff data.

4.6.5   Re-validate tariff

Re-validating a tariff resets the last_upate field of the TARIFF table to the current date. It can be used to quickly update tariffs in the database if there are no changes to the tariff data. In this case, the tariff in the database is re-validated to mark that it has been checked. This information is used when determining the age of the tariff sample contained in TAP.

4.6.6   Un-publish tariff

The un-publish tariff function removes data from the public domain, *i.e.* it changes the status from *published* to *editing*. This feature is intended to be used when data are found to be in error.

4.7   The OnTAP SOAP Server

In order for third-party applications to use TAP as a resource, a communication method or web service called *OnTAP* has been developed. TAP's web service is based on the Simple Object Application Protocol (SOAP), a standard protocol used for executing remote procedures. SOAP web services employ a basic server-client relation; when interacting with TAP's web service TAP acts as the server, which processes requests from third-party systems who act as the clients.

The OnTAP server accepts HTTP POST requests written in XML. These requested are directed to one of the public methods of the OnTAP server. Requests that do not call a registered method will return the server's WSDL file (list of available methods).

The OnTAP server methods allow clients to calculate electricity bills from any tariff in the TAP database, given the appropriate inputs to TAP.pm (see section 3.4). There are also methods that allow the client to select a tariff to use, given either the name of a state or zip code. These methods have been developed to work with the Home Energy Saver website [2]. Figure 16 illustrates the chain of requests as currently implemented. For technical reference, the OnTAP methods are summarized below. No detail is given on the actions performed, as these should be clear from previous discussion.
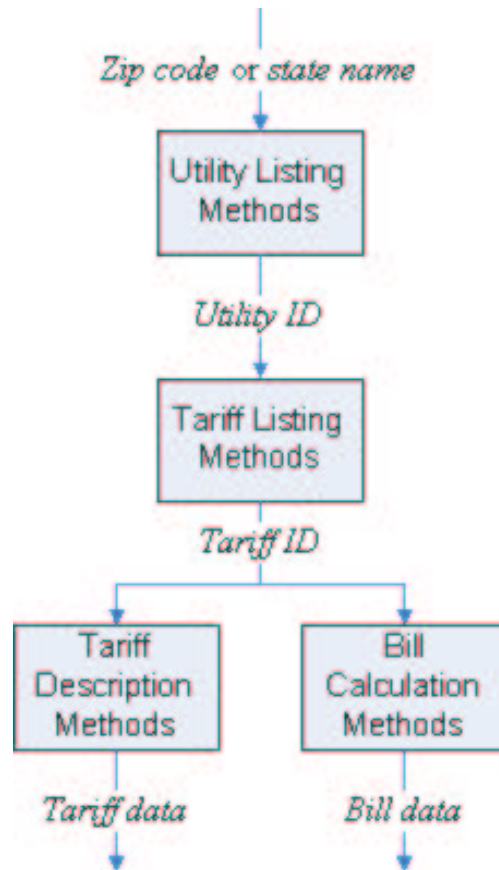
Figure 16: SOAP server process overview

4.7.1   Utility listing methods

doGetUtilityListByState accepts either a state's full name or it's 2 letter abbreviation as a string. *doGetUtilityListByZip* accepts a 5 digit zip code as an integer. Both methods return the following values:

- name: the name of the utility

- util_id: the internal TAP utility id

- state: the state in which the utility is headquartered

- url: a link the to the utility's home page within TAP

- eia_code: a unique code given to each utility in the United States by the E.I.A.

The key value returned is util_id, which can then used to run the tariff listing methods.

4.7.2   Tariff listing methods

doGetUtilityTariffs accepts the value util_id as a string. The following values are returned:

- util_id: the internal TAP utility id

- tariff_id: the internal TAP tariff id

- schedule: the name of the tariff used by the utility

- state: the state in which the tariff is valid

- market: the customer market served by the tariff

- service: the service classification for the tariff

- TOU: flags whether the tariff is time-of-use or not

- minDemand: the minimum demand for customers served by this tariff

- maxDemand: the maximum demand for customers served by this tariff

- url: a link the to the tariff's description page within TAP

The key value returned is tariff_id, which is used to run the bill calculation methods.

4.7.3   Tariff description methods

doGetTOU accepts the value tariff_id as an integer, and returns time-of-use information for this tariff as an array with items for each month of the year. Each of these items contains the following:

- monthName: the name of the calendar month

- peakDays: an array of the days of the week for which the time-of-use period apply

- hourEnding_01 - hourEnding_24: flags which hours should be assigned to which time-of-day: onPeak, offPeak, or shoulder.

4.7.4   Bill calculation methods

doGetMonthlyBill accepts eight values, all of them integers: tariff_id, onPeakDemand, onPeak-Consumption, shoulderDemand, shoulderConsumption, offPeakDemand, offPeakConsumption, and month. It returns bill information contained in a string indexed array. The bill data returned is in the same format for all tariffs. The values returned are as follows:

- totalCharges: the sum of all charges

- consumptionTotal: the sum of all consumption charges

- demandTotal: the sum of all demand charges

- fixedTotal: the sum of all fixed charges

- offPeakConsumptionTotal: the sum of all consumption charges for the off-peak period.

- offPeakDemandTotal: the sum of all demand charges for the off-peak period.

- onPeakConsumptionTotal: the sum of all consumption charges for the peak period.

- onPeakDemandTotal: the sum of all demand charges for the peak period.

- shoulderConsumptionTotal: the sum of all consumption charges for the shoulder period.

- shoulderDemandTotal: the sum of all demand charges for the shoulder period .

- annualConsumptionTotal: the sum of all other consumption charges for of the period.

- annualDemandTotal: the sum of all other demand charges that occur regardless of the period.

DoGetYearlyBill is a wrapper for the doGetMonthlyBill method. It allows a client to send a year's worth of inputs, and returns a year's worth of bills. It accepts and returns a 12-element array (one for each month) of doGetMonthlyBill inputs and outputs.

References

[1] Coughlin, K., R. G. White, C. A. Bolduc, R. D. Van Buskirk, G. J. Rosenquist & J. E. McMahon 2006. Tariff-Based Analysis of Commercial Marginal Electricity Prices. **LBNL-55551**. Lawrence Berkeley National Laboratory.

[2] Lawrence Berkeley Lab 2006. Home Energy Saver. *hes.lbl.gov.*

[3] PHP: Hypertext Preprocessor 2006. *www.php.net.*

[4] US-DOE Building Technologies Program, 2005. Commercial Unitary Air Conditioners and Heat Pumps Advanced Notice of Proposed Rulemaking. *www.eere.energy.gov/buildings/appliance_standards/commercial/cuac_anopr.html.*

[5] US-DOE Building Technologies Program, 2005. Distribution Transformers Energy Conservation Standard Advanced Notice of Proposed Rulemaking. *www.eere.energy.gov/buildings/appliance_standards/commercial/distribution_transformers_anopr.html.*

[6] US-DOE Energy Information Agency, 2005. Form EIA-861 Database, Annual Electric Power Industry Data. *www.eia.doe.gov/cneaf/electricity/page/eia862.html.*

[7] Wall, Larry, Tom Christianson & Jon Orwant 2000. **Programming Perl, 3rd edition**. O'Reilly & Associates, Inc., Sebastopol, CA.

A   Detailed tables
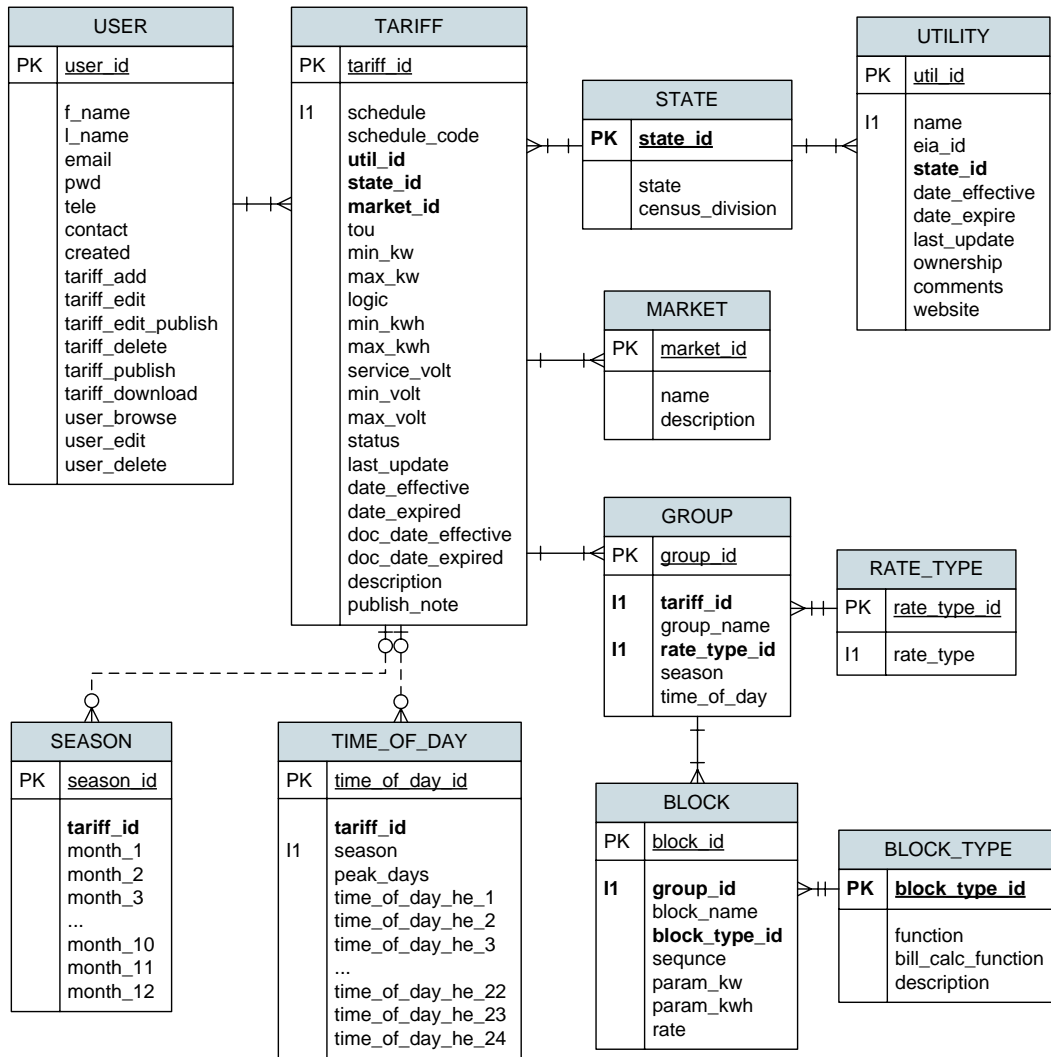
Figure 17: Detailed ER diagram for the TAP database

Field	Field Type	Field Values	Description
util_id	int(11)	positive integer	unique internal database ID for the utility
name	varchar(200)	name of the utility	as specified in form EIA-861, File 1
eia_id	varchar(10)	positive integer	standard numeric code for the utility used by EIA in all its data files
state_id	char(2)	two-letter state code	state where the head office of the utility is located as specified in EIA-861, File 1
date_effective	date		when the utility data was entered into TAP
date_expired	date		used to show when utility data ceases to be valid, for example when a utility changes its name
last_update	timestamp(12)		most recent date when information was updated for this utility
ownership	enum()	(PRIVATE, POWER MRKT, COOP, FEDERAL, MUNICIPAL, SUB-DIVISION, MUNICIPAL MRKT, STATE, UNKNOWN)	ownership type as specified by EIA-861, File 1
comments	varchar(255)		user comments
website	varchar(100)		URL for the utility home page

Table 8: The UTILITY table

Field	Field Type	Field Values	Description
state_id	char(2)	two-letter state code	standard abbreviation for state name
state	varchar(30)	name	full name of state
census	varchar(30)	name	census division for this state
population00	integer		census 2000 population for this state

Table 9: The STATE table. The state_id is the standard two-letter state code.

Field	Field Type	Field Values	Description
tariff_id	int(11)	automated integer	unique internal database ID for the tariff
schedule	varchar(100)	tariff name	utility-specified name for the tariff
schedule_code	varchar(50)	tariff code	utility-specified code for the tariff
util_id	int(11)	positive integer	internal database ID for the utility holding this tariff
state_id	char(2)	two-letter state code	state in which this tariff is used
market	enum()	(residential, non-residential, agricultural)	consumer market type
min_kw	float(12,1)	floating point number	minimum monthly demand in kw that can be served under this tariff
max_kw	float(12,1)	floating point number	maximum monthly demand in kw that can be served under this tariff
min_kwh	float(12,1)	floating point number	minimum monthly consumption in kwh that can be served under this tariff
max_kwh	float(12,1)	floating point number	maximum monthly consumption in kwh that can be served under this tariff
logic	varchar(8)	(and,or)	logical variable that defines how to combine kw and kwh limits
service_volt	varchar(20)	(primary, secondary, residential)	utility-defined service classification of this tariff
min_volt	float(12,1)	floating point number	minimum delivery voltage served under this tariff
max_volt	float(12,1)	floating point number	maximum delivery voltage served under this tariff
tou	tinyint(4)	(0,1)	flag set to (0,1) if this tariff (is not, is) time-of-use
status	tinyint(4)	(editing, review, published, expired)	flag indicating the data-entry status for this tariff
last_update	timestamp(12)		most recent date when information was updated for this tariff
date_effective	date	date	date when tariff was entered into TAP
date_expired	date	date	date when TAP status changes to expired
doc_date_effective	date	date	official utility date when the tariff goes into effect
doc_date_expired	date	date	official utility date when the tariff ceases to be valid
description	text		text description of the tariff used by the utility
publish_note	text		TAP internal comments regarding the tariff data

Table 10: The TARIFF table

Field	Field Type	Field Values	Description
group_id	int(11)	integer	unique internal database ID for this group
group_name	char(20)	enumerated list	standardized name denoting the type of group
tariff_id	int(11)	automated integer	internal database ID for the tariff that contains this group
rate_type_id	tinyint(4)	(1,2,3) 1=energy, 2=demand, 3=fixed	identifies the type of rate and units this group describes
season	enum()	(S,W,A) S=summer, W=winter, A=all-year	defines the season during which this group is used
time_of_day	enum()	(N,F,S,A) N=on-peak, F=off-peak, S=shoulder, A=all-day	defines the TOU period during which this group is used

Table 11: The GROUP table

Field	Field Type	Field Values	Description
block_id	int(11)	Integer	unique internal database ID for this block
group_id	int(11)	integer	internal database ID for the group containing this block
sequence	tinyint(4)	(0,1,2,...) automatically incremented	specifies the order of the blocks within a group
block_type_id	tinyint(4)	standard types defined in the block_type table	identifies the functional type of upper and lower limits for this block
param_kwh	float(12,1)	block limit parameter in kwh	tariff-defined value used to determine the block limits
param_kw	float(12,1)	block limit parameter in kw	tariff-defined value used to determine the block limits
block_name	varchar(100)	internally assigned name	descriptive name based on block_type and and block limits
rate	float(10,5)	rate charged per unit	the actual rate (per kw, per kwh or fixed) for this component of the tariff

Table 12: The BLOCK table

Field	Field Type	Field Values	Description
season_id	int(11)	automated integer	unique internal database ID for this season definition
tariff_id	int(11)	automated integer	internal database ID for the tariff using this season definition
month_n	enum()	(S,W)	S=summer, W=winter; season assignment for month_n, n=1 to 12

Table 13: The SEASON table. Season definitions are assigned to individual tariffs. Only tariffs with seasonal rates have rows in this table.

Field	Field Type	Field Values	Description
time_of_day_id	int(11)	automated integer	unique internal database ID for this hours definition
tariff_id	int(11)	automated integer	internal database ID for the tariff using this hours definition
season	enum()	(S,W,A)	season during which this hours definition is used
peak_days	tinyint(4)	enum(5,6,7)	number of peak days per week for this hours definition
time_of_day_he_n	enum()	(N,F,S)	defines the hour-type for each hour-ending_n, n = 1,2,... 24

Table 14: The TIME_OF_DAY table defines the on-peak, off-peak and shoulder periods for TOU tariffs only. Hour-ending (he) 1 means the hour that ends at 1am, *etc.*

Field	Field Type	Field Values	Description
zip_code	int	standard zipcode	used as unique internal identifier
city	text	city name	city or township for this zipcode
state_id	char	two-letter state code	standard abbreviation for the state name
county	mediumtext		county name
fips_code	int		standard county code

Table 15: The ZIP_CODE table

Field	Field Type	Field Values	Description
eia_fips_id	int	positive integer	unique internal database ID for this row
eia_id	varchar(10)	positive integer	standard numeric code for the utility used by EIA
fips_code	int	positive integer	standard county code

Table 16: The EIA_FIPS table is used to link utilities to counties.

Field	Field Type	Field Values	Description
project_id	int(11)	automated integer	unique internal database ID for a project
year	varchar(4)		project end year
href	varchar(30)		project account number
title	varchar(30)		project title
client	varchar(30)		project client
description	varchar(300)		project description

Table 17: The PROJECT table is used to archive information about projects using TAP tariffs.

Field	Field Type	Field Values	Description
user_id	mediumint		the unique identifier for a user
f_name	tinytext		user first name
l_name	tinytext		user last name
email	tinytext		user email address
pwd	tinytext		user password
tele	tinytext		user telephone number
contact	int	1, 0	if the user is willing to be contacted by LBNL
created	date		when the user record was created
tariff_add	int	1, 0	if the user has permission to add tariffs
tariff_edit	int	1, 0	if the user has permission to edit tariffs
tariff_edit_publish	int	1, 0	if the user has permission to edit published tariffs
tariff_delete	int	1, 0	if the user has permission to delete tariffs
tariff_publish	int	1, 0	if the user has permission to publish tariffs
tariff_download	int	1, 0	if the user has permission to download tariff files
user_browse	int	1, 0	if the user has permission to view user data
user_edit	int	1, 0	if the user has permission to edit user data
user_delete	int	1, 0	if the user has permission to delete user data

Table 18: The USER table contains personal and permission data for TAP registered users.

block_type_id	function name	bill calculator action
1	fixed usage	param_kWh
2	block-by-demand (BBD)	param_kW*kW
3	max(BBD increment, kWh)	max(param_kWh, param_kW*kW + lastlimit)
4	max(usage increment, BBD)	min(param_kWh + lastlimit, param_kW*kW)
5	usage increment plus BBD increment	param_kWh + param_kW*kW + lastlimit
6	max(usage increment ,BBD increment)	max(param_kWh + lastlimit, param_kW*kW + lastlimit)
7	usage increment	param_kWh+ lastlimit
8	BBD increment	param_kW*kW + lastlimit
9	max(usage increment, BBD increment)	max(param_kWh + lastlimit, param_kW*kW)
10	max(usage, BBD)	max(param_kWh, param_kW*kW)
99	all remaining	end-of-group

Table 19: Block-limit type definitions and corresponding bill calculator functions

Script Name	Description
functions.php	The common function library for the website
forms.php	Contains html forms which are called as functions
template.php	Contains html layout of the website, which is called as a set of PHP functions

Table 20: Script Synopsis: Global configurations. http://tariffs.lbl.gov/script/.

Script Name	Description	Dependency
change_pw.php	Change user passwords.	None
create.php	Create a user profile.	new_user.php
edit.php	Edit a user profile.	update_user.php
get_pw.php	Retrieve a user password.	None
new_user.php	Inserts the user information into the USER table and emails out their password.	None
update_user.php	Updates the user information into the USER table and emails out their password.	None
user_browse.php	Browse users.	None
user_delete.php	Delete users.	None
user_edit.php	Edit user.	None

Table 21: Script synopsis: User-related scripts. http://tariffs.lbl.gov/user/.

Script Name	Description	Dependency
utility.php	Utility profile.	none
utility_list.php	Utility search results.	utility_query.php
utility_query.php	A library of functions used to search the UTILITY database.	none

Table 22: Script synopsis: Utility-related scripts. http://tariffs.lbl.gov/utility/.

Script Name	Description	Dependency
tariff.php	Tariff profile.	classes/tariff.php
tariff.add.php	Add a new tariff.	classes/tariff.php
tariff.close.php	Cancel a tariff.	classes/tariff.php
tariff.copy.php	Copy a tariff.	classes/tariff.php
tariff.delete.php	Delete a tariff.	classes/tariff.php
tariff.edit.php	Edit a tariff.	classes/tariff.php
tariff.publish.php	Publish a tariff.	classes/tariff.php
tariff.ratchet.php	Define a ratchet.	classes/tariff.php
tariff.revalidate.php	Re-validate a tariff	classes/tariff.php
tariff.unpublish.php	Unpublish a tariff.	classes/tariff.php
tariff.group.php	Controls the html form elements and markup by tariff group.	classes/group.php
tariff_list.php	Tariff search results.	tariff_query
tariff_query.php	Contains the search query used on the TARIFF table.	none
time_of_day.edit.php	Define time-of-use periods.	classes/time_of_day.php
season.edit.php	Define billing seasons.	classes/season.php

Table 23: Script synopsis: Tariff-related scripts. http://tariffs.lbl.gov/tariff/.

Script Name	Description
tap.form	static methods which are used to generate HTML form elements
tariff.php	methods used by TAP to manipulate the TARIFF table
tariff.form.php	methods used by TAP to generate HTML data-entry forms
tariff.theme.php	methods used by TAP to display tariff
season.php	methods used by TAP to manipulate the SEASON table
season.form.php	methods used by TAP to generate HTML data-entry forms
season.theme.php	methods used by TAP to display season data
time_of_day.php	methods used by TAP to manipulate the TIME_OF_DAY table
time_of_day.form.php	methods used by TAP to generate HTML data-entry forms
time_of_day.theme.php	methods used by TAP to display time of day data
group.php	methods used by TAP to manipulate the GROUP table
group.form.php	methods used by TAP to generate HTML data-entry forms
group.theme.php	method s used by TAP to display group data
block.php	methods used by TAP to manipulate the BLOCK table
block.form.php	methods used by TAP to generate HTML data-entry forms
block.theme.php	methods used by TAP to display block data
file.php	methods used by TAP to manage uploaded tariff files
file.form.php	methods used by TAP to generate HTML data-entry forms
file.theme.php	methods used by TAP to display uploaded files

Table 24: Script synopsis: TAP Class listing. http://tariffs.lbl.gov/classes/.