WebOpt User Manual

DER Web Optimization Service (WebOpt): a project partly financed by the U.S. Department of Energy

for Version 2.5.1.26

Lawrence Berkeley National Laboratory (LBNL)

Project Scientific Lead:	Michael Stadler and Chris Marnay
Software design:	Michael Stadler
Optimization algorithm:	Michael Stadler, Gonçalo Cardoso, Jonathan Donadee, Afzal Siddiqui, Shi Wang, and Chris Marnay
Data:	Wei Feng, Judy Lai, Prajesh Bhattacharya, Olivier Mégel, and Markus Groissböck
Layout testing:	Gonçalo Cardoso, Michael Stadler, Wei Feng, Judy Lai, and Chien Yu-Ko

This work was partly funded by the Public Interest Energy Research (PIER) program of the California Energy Commission under California Interagency Agreement 500-02-004 to the California Institute for Energy and the Environment (CIEE) and Memorandum Agreement POM081-L01 between The Regents of the University of California and Lawrence Berkeley National Laboratory. The Berkeley Lab is managed and operated by the University of California for the U.S. Department of Energy under contract DE-AC02-05CH11231.

Table of Contents

List of Figures

List of Tables

1. Introduction to WebOpt

This document is the user manual for WebOpt in its current version, 2.5.1.26, and gives examples of its functionality and options.

What is it?

WebOpt is the free, non-commercial/academic, limited and downscaled web-accessible version of the Distributed Energy Resources Customer Adoption Model (DER-CAM) created by Berkeley Lab. Since it is accessible via a web browser (Firefox, Internet Explorer, Safari, etc), it is available from both Microsoft and Macintosh environments. However, users accessing WebOpt from a browser on a Macintosh platform will have limited ability to copy and paste data. Further, WebOpt does not provide all the features of DER-CAM, e.g., electric vehicles or 5 minute time-step optimization. For information on DER-CAM and its variants, please refer to Appendix.

WebOpt File menu

Before the user begins, it is important to know how to input and save data to expedite the progress and prevent data loss. The user can load configurations that had been previously saved in WebOpt using the "Load configuration" option and can save all the work from the session by selecting "Save configuration", see Figure 1 and Figure 2, left.

All WebOpt information is saved on WebOpt's remote server(s) and not on the user's local hard drive. To delete a saved configuration, select the "Load configuration" option, select the appropriate .conf file, and then right-click see Figure 2, right.

Please note that additional information may be saved along with a configuration file and this increases the usability of the files for others, and that a saved configuration file is load-able by all WebOpt users and is a way of building up a database of WebOpt example files. If no password is specified, the configuration file may be deleted by any user.

If the user decides to delete all the changes that were made in the session, he/she can select the "Discard all changes" option and WebOpt will revert to the original start-up conditions (user can also select the "Discard all changes" option on the bottom left hand corner). By selecting the "Exit" option, the DER-CAM WebOpt program will end.

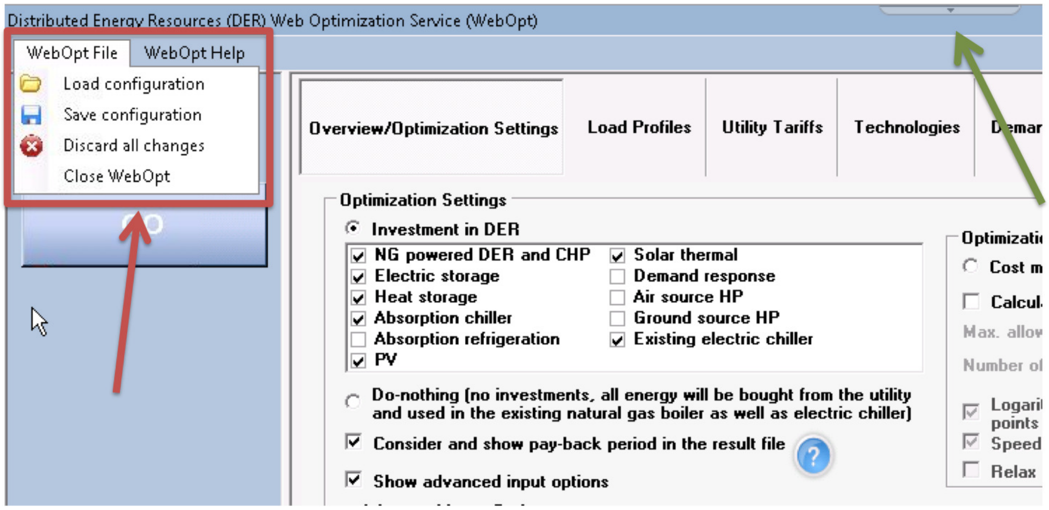

Figure 1. WebOpt program commands (WebOpt File)

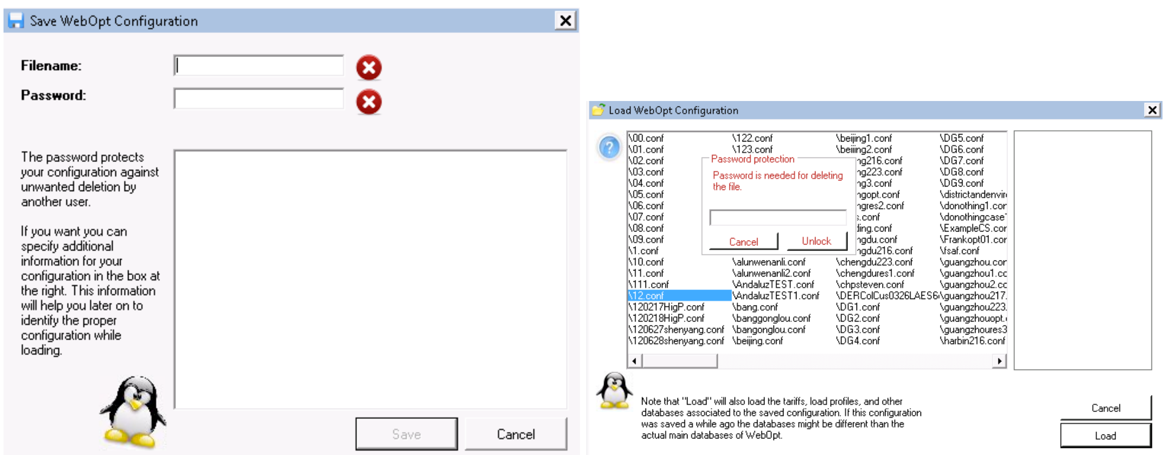

Figure 2. The "Save configuration" and "Load configuration" pop-up boxes.

The green arrow in Figure 1 points to a pop-up that can be expanded to show Figure 3 commands. Both "Refresh" and "Scale" may be used to adjust the display from the web-server, and "Disconnect" ends the session. The "Close WebOpt" selection can also be used to close the WebOpt session.

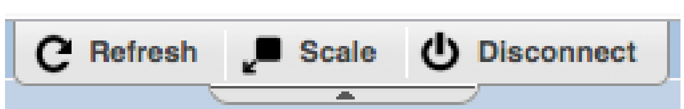

Figure 3. Pop-up for adjusting WebOpt display disconnecting

Data transfer between WebOpt and your local computer (copy and paste of input and result data)

Please note that data transfer between WebOpt and your local computer can be done by using the "Copy" and "Paste" from your web-browser. Some browsers hide the "Copy" and "Paste" menu items, and therefore, you might need to enable the menu-view on your browser. Shortcuts are not supported and you need to use the mouse and click the "Copy" and "Paste" menu item on your browser. However, users accessing WebOpt from a browser on a Macintosh platform will have limited ability to copy and paste data.

When copying a large number of data from WebOpt to your local system, the process can be slow and it is recommended to wait a minute before you paste the data on your local computer into e.g. Excel.

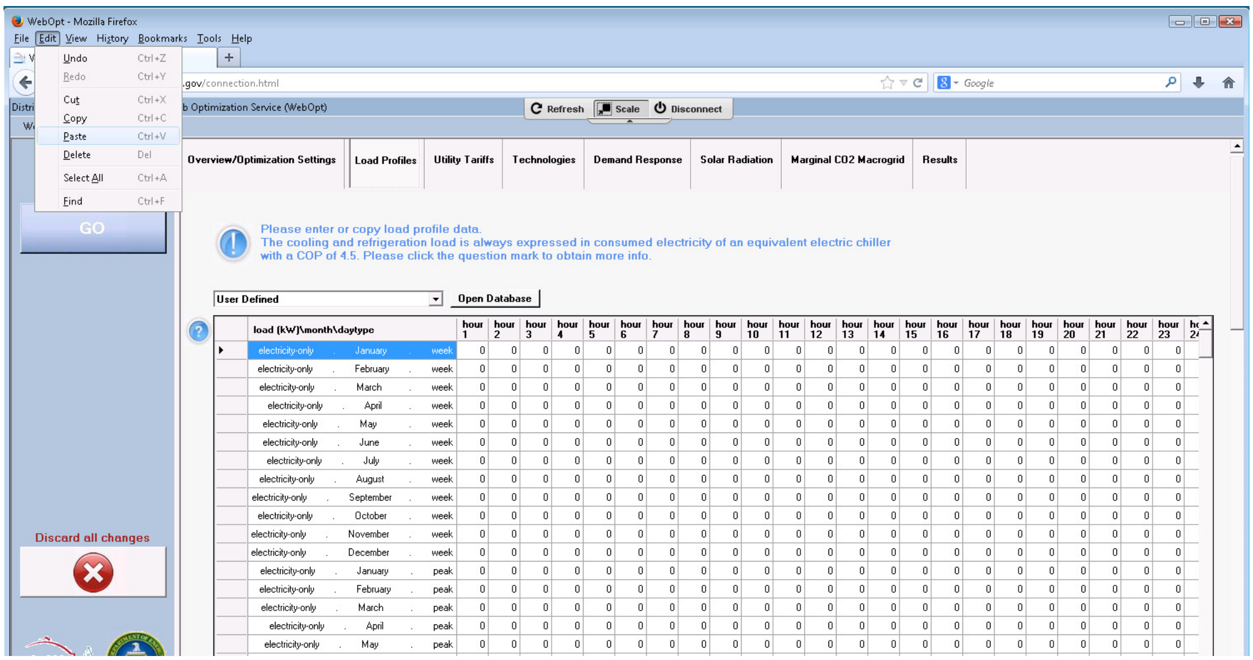

Figure 4. Use the Edit menu from the browser for data transfer between your local computer and the website

Please note that you are not allowed to copy results to your local system when a load profile or solar radiation database is loaded and used in the optimization. To enable this feature you need to apply for an Advanced User Profile at mstadler at lbl dot gov.

Advanced Users

When you register as a WebOpt user on microgrid dot lbl dot gov we only grant access to the basic WebOpt features and advanced features are available when applying for an advanced user account at mstadler at lbl dot gov.

Advanced features are:

- User Management: each advanced user has his/her own private storage folder for WebOpt projects. No other user has access to your WebOpt config files. Regular users can save WebOpt project files too, but they are saved in a common user folder.
- Technology forcing: advanced users can force continuous technologies (PV; solar thermal, storage, heat pumps, etc.) into the solution. This feature allows you do assess different technology preferences.
- Copy results to your local system when a load or solar profile database is loaded.

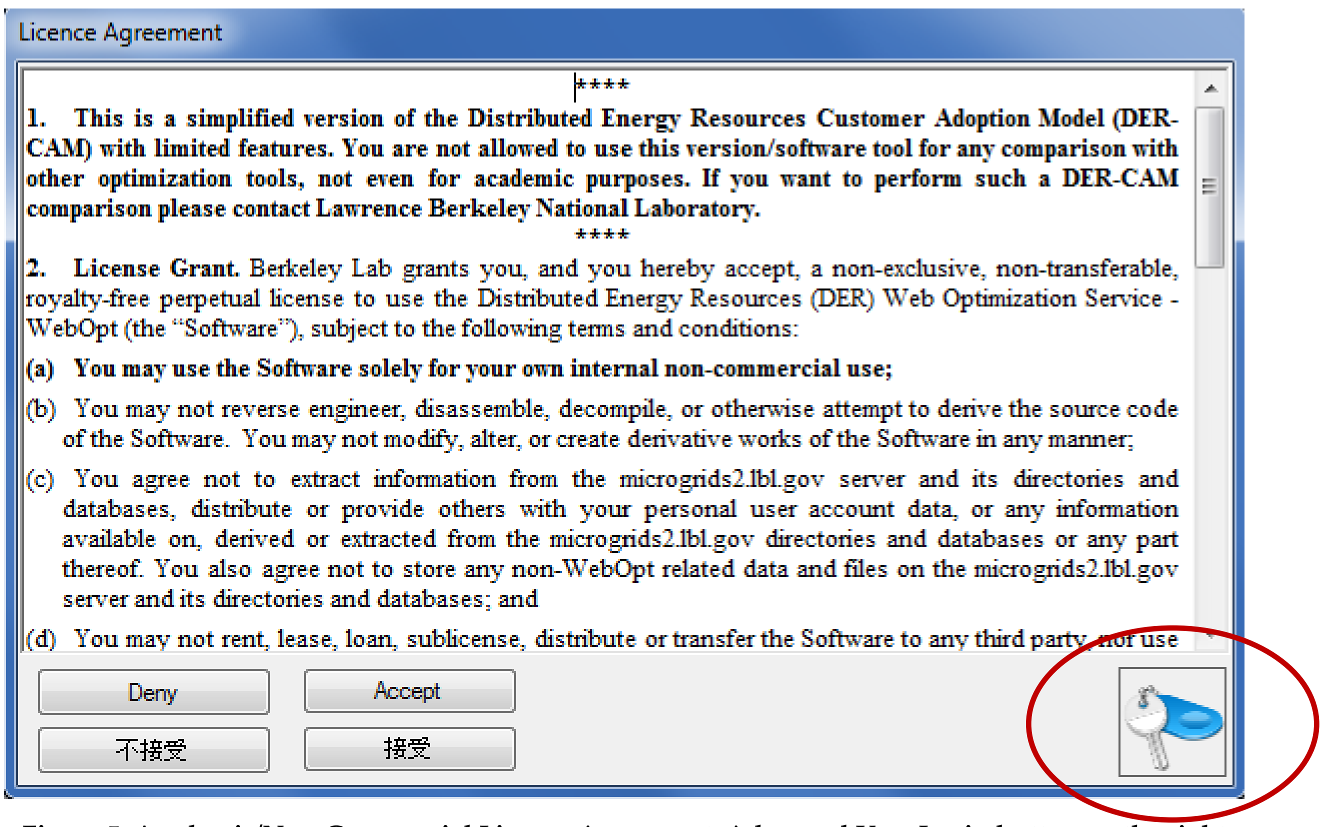

Figure 5. Academic/Non-Commercial Licence Agreement, Advanced User Login button on the right

WebOpt Help menu and how to get help

The WebOpt Help menu shows the contact information (email) and links to the microgrid website at Berkeley Lab. The Help menu provides very specific information to WebOpt details while this Manual provides a high level overview.

Although WebOpt has been designed to be intuitive and user-friendly, confusion and misunderstandings can and do happen. In order to offer the user the best experience, tips are available throughout the web service wherever something needs to be clarified. Please click on the blue question mark and a penguin will provide tips and help messages. In any case please feel free to send an email to Michael Stadler at mstadler at lbl dot gov.

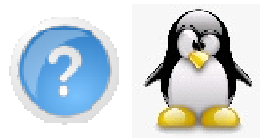

Figure 6. Tips and Help in WebOpt

Search the WebOpt Help menu and Manual

Please note that you can search the Help menu and Manual by entering a search string in the "Search Help for:" text box on the Help window as well as on the "Search Manual for:" text box on the Manual window.

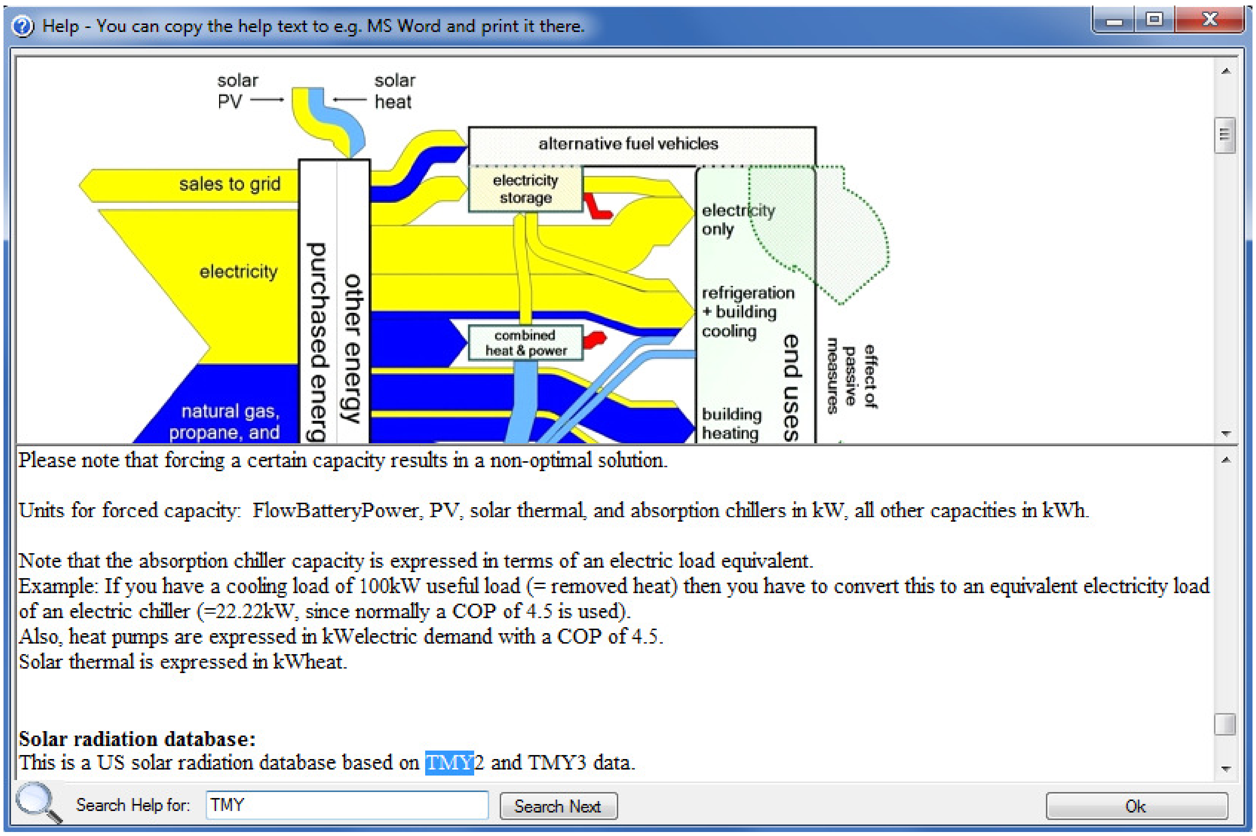

Figure 7. Search box in the Help menu

WebOpt start-up page

Figure 8 is shown after the user accepts the WebOpt licensing agreement.

The left pane has only two buttons:
The *Run optimization* <GO> button starts the optimization process.
The *Discard all changes* <X> button resets all user defined settings to the default values.

The right pane has eight tabs across the top. The first seven tabs are options/settings that are necessary for the optimization runs and the last tab shows the results. Each of the tabs and its settings are covered in subsequent sections of this document.

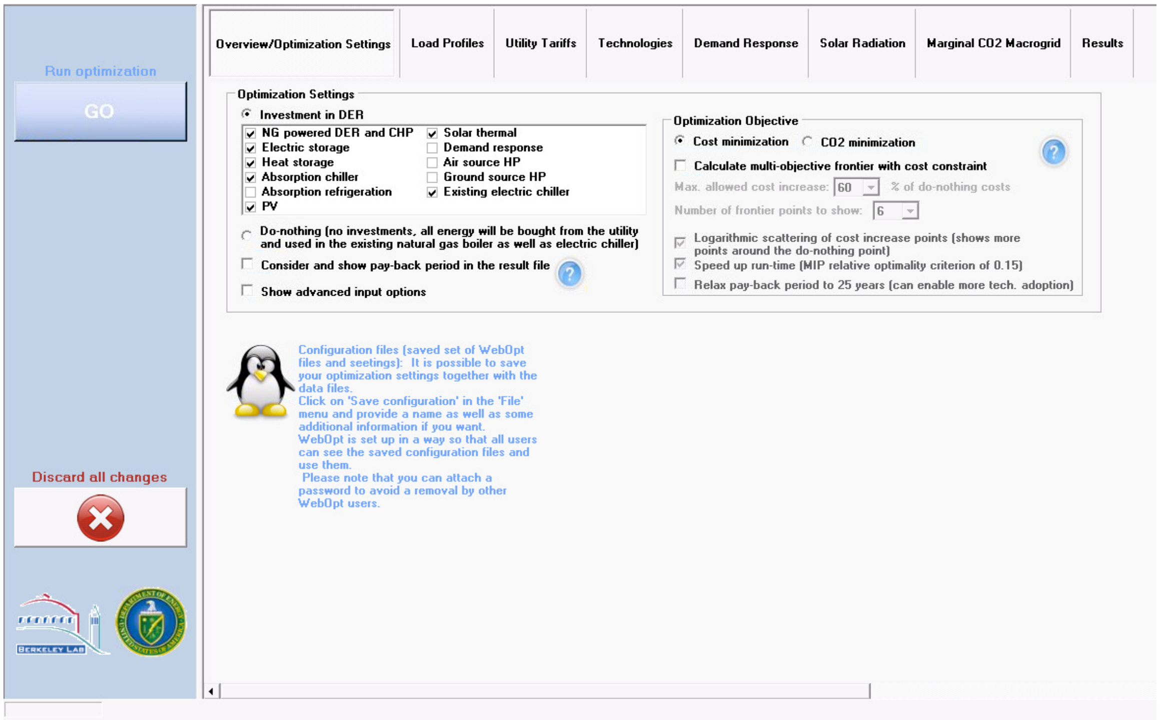

Figure 8. Overview/Optimization Settings

2. Overview/Optimization Settings

This tab is where DER technology investments and the optimization settings are specified.

Optimization Settings

Different settings are available to evaluate a project. First, the user chooses which technologies to model or if he/she wants to *Do-nothing (no investments, all electricity will be bought from the utility)*.

Investment in DER options:

- Natural Gas Powered DER and CHP
    - Locating Natural Gas Powered Distributed Energy Resources (DER) generation close to the consumer eliminates the transmission and distribution losses typically experienced in distributing power to consumers.
    - Combined Cooling, Heating, and Power (CHP) combines generator heat recovery with customer heating and cooling loads. CHP incorporates a natural gas-fired electric generator next to the customers building with heat recovery from the engine exhaust and/or engine-jacket and lube oil-cooling water. Combined cooling heating and power (CHP) systems have

demonstrated overall efficiencies in excess of 80%, providing a nice boost to gains provided by DER.

- Electric Storage
  - Energy Storage allows buildings to balance the supply and demand of energy.
- Heat Storage
  - Thermal energy is often accumulated from active solar collector or more often combined heat and power plants, and transferred to insulated repositories for use later in various applications, such as space heating, domestic or process water heating.
- Absorption Chiller
  - The process to cool a building with an absorption chiller is similar to that used by conventional air conditioning systems in that there is compressor, condenser, and evaporator equipment within the system.
- Absorption Refrigeration
  - An Absorption Refrigeration uses a heat source (i.e. solar, kerosene-fueled flame, waste heat from factories or district heating systems) to provide the energy needed to drive the cooling system. Note that the same would be true for abs. chiller. The difference is that one is for building cooling and the other for refrigeration.
- Photovoltaic (PV)
  - PV is a method of generating electrical power by converting solar insolation into direct current electricity using semi-conductors that exhibit the photovoltaic effect. PV power generation employs solar panels.
- Solar Thermal
  - Solar Thermal technology uses the sun's energy, rather than fossil fuels, to generate low-cost, environmentally friendly thermal energy. This energy is used to heat water or other fluids, and can also power solar cooling systems. Solar thermal systems differ from PV system, which generates electricity rather than heat.
- "Other" or Abstract Demand Response
  - Demand Response manages customer consumption of electricity in response to supply condition. The demand response mechanisms respond to explicit requests to shut off and can involve actually curtailing power used or by starting on-site generation which may or may not be connected in parallel with the grid. However, the "Abstract Demand Response" is just load shifting due to behavioral changes and no technology investment is needed.

- Air Source Heat Pump
    - The ASHP is a heating and cooling system that uses outside air as its heat source or heat sink. Under the principles of vapor, compression, refrigeration, an ASHP uses a refrigerant involving a compressor and a condenser to absorb heat at one place and release it at another.
- Ground Source Heat Pump
    - The GSHP is a heating and/or cooling system that pumps heat to or from the ground. It uses the earth as a heat source (in the winter) or a heat sink (in the summer). The design takes advantage of the moderate temperatures in the ground to boost efficiency and reduce the operational costs or heating and cooling systems, and may be combined with solar heating to form a geosolar system with even greater efficiency. However, this version of WebOpt does not track the heat in the ground and basically acts as a ASHP, but with different Coefficient of Performance (COP).
- Existing Electric Chiller
    - The conventional electric chiller removes heat from a liquid via evaporation-compression-refrigeration method. This technology is needed in WebOpt to balance supply and demand if no other cooling technology is selected. Please note that no investment costs are considered for the Existing Electric Chiller since the technology is assumed to be already installed in the building (the same is true for heating and boilers).

Do-nothing

If *Do-nothing* is selected, the WebOpt has no degree of freedom as all electricity has to be bought from the utility. This option should be used only to estimate the energy bill in the absence of batteries or PV. This case assumes that a natural gas boiler is in place that provides heat and also an electric chiller to supply air conditioning.

Invest in DER technologies

Two optional settings can further help the user with analysis.

- *Consider and Show pay-back period in result file*

  If **checked**, WebOpt will only consider solutions that reduce energy bill below their estimated initial levels. Two runs will be performed automatically. First a base case (do-nothing) run will be performed and then the investment case. Please note that this feature overwrites the *Max. allowed annual energy costs (including annualized capital costs)* from *Show advanced input options* by the base case (do-nothing) costs from the first run. Thus, if no investments are observed with this setting checked, the user may uncheck *Show pay-back period in result file* and redo the run with higher *Max. allowed annual energy costs (including annualized capital costs)* from *Show advanced input options*.

If **unchecked**, WebOpt will use the *Maximum allowed energy costs (including annualized capital costs)* as an upper boundary for the cost. This maximum total cost is also part of the ***Advanced input options***.
Unchecking the "***Show pay-back period in result file***" box and increasing the *maximum allowed energy costs* is useful if the user wants to assess scenarios with higher costs than the base case/do-nothing, e.g. CO2 minimization runs.

- *Show advanced input options*:

  If **checked**, Figure 9 will be displayed. The initial investment costs for all DER will be annualized using the specified *interest rate* and this annualized investment cost added to the energy bill. The *maximum allowed annual energy cost* is the maximum amount the user is willing to pay, and the *maximum pay-back period for the initial investment* is the maximum length of time required to recover the cost of an investment.

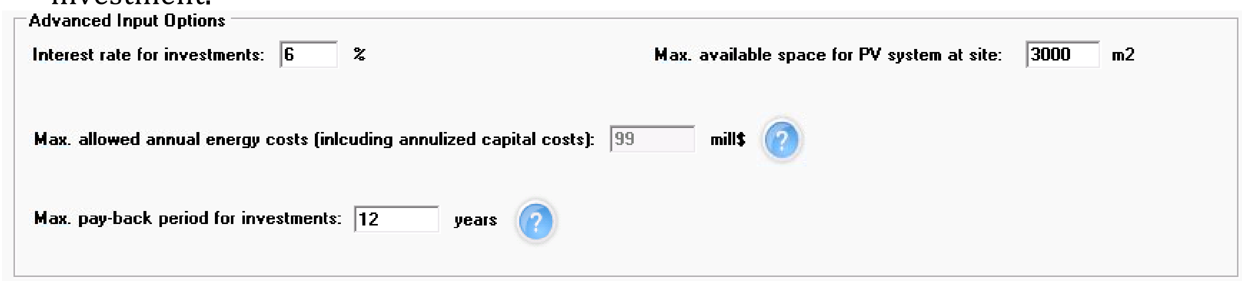

Figure 9. Advanced Input options under Overview/Optimization settings

The *Maximum available space for PV system at site* specifies an upper boundary for PV and solar thermal system installation. The available space on the rooftop may be a good estimate of this figure.

Optimization objective:

The user can specify a cost minimization or CO2 minimizing objective as well as a multi-objective frontier with cost constraint, e.g., a combination of cost and CO2 minimization.
In case of cost minimization, it is possible that the optimization will result in few or no installed DER, meaning that it is cheaper to not invest and only purchase from the utility.

In case of CO2 minimization, care should be taken to specify reasonable maximum allowable energy costs including annualized capital costs, maximum allowable space for PV systems at the site, and the maximum payback period. Results may show unrealistically high DER installations if the constraints are not set to appropriate levels.

In case of CO2 minimization multi-objective frontier with cost constraint, the results will be constrained by the user specified percent-over-do-nothing (in increments between 5 and 500 percent). This means that maximum allowable energy costs including annualized capital costs will be set automatically by WebOpt, and is therefore, grayed out.
Because of the tendency for lower CO2 results to approach the cost ceiling (emissions minimized by installing as many low-emission onsite generation equipment as possible),

the user may elect to check the "logarithmic scattering of cost increase points (show more points around the do-nothing point)" to force WebOpt to show more results along the lower bound of the cost frontier.

3. Load Profiles

Here the user can (1) choose a default building load profile from the examples in the scroll down menu, (2) input custom load data for the model building by selecting "User Defined" in the scroll down menu, or (3) access the extended load profile database by clicking the "Open Database".

The standard load profiles in the database are normalized to one GWh (=1,000,000 kWh) of electricity and one GWh of natural gas per year, and defined in hourly time interval on a monthly averaged style, and separated into electricity-only, cooling, refrigeration, space-heating, water-heating, and natural gas-only loads and as weekend, week, or peak (three days with the highest demand within a month) loads. User defined profiles need to be in the same format in order for WebOpt to work properly. However, the same data can be entered for peak and weekly profiles if there is no difference (or the difference not important to the optimization).

Default building load profile

The predefined load profiles can be used to perform fast and easy investigations to get a first estimate. Figure 10 shows a predefined load profile table in WebOpt, and Figure 11 shows the same data in a graphic.

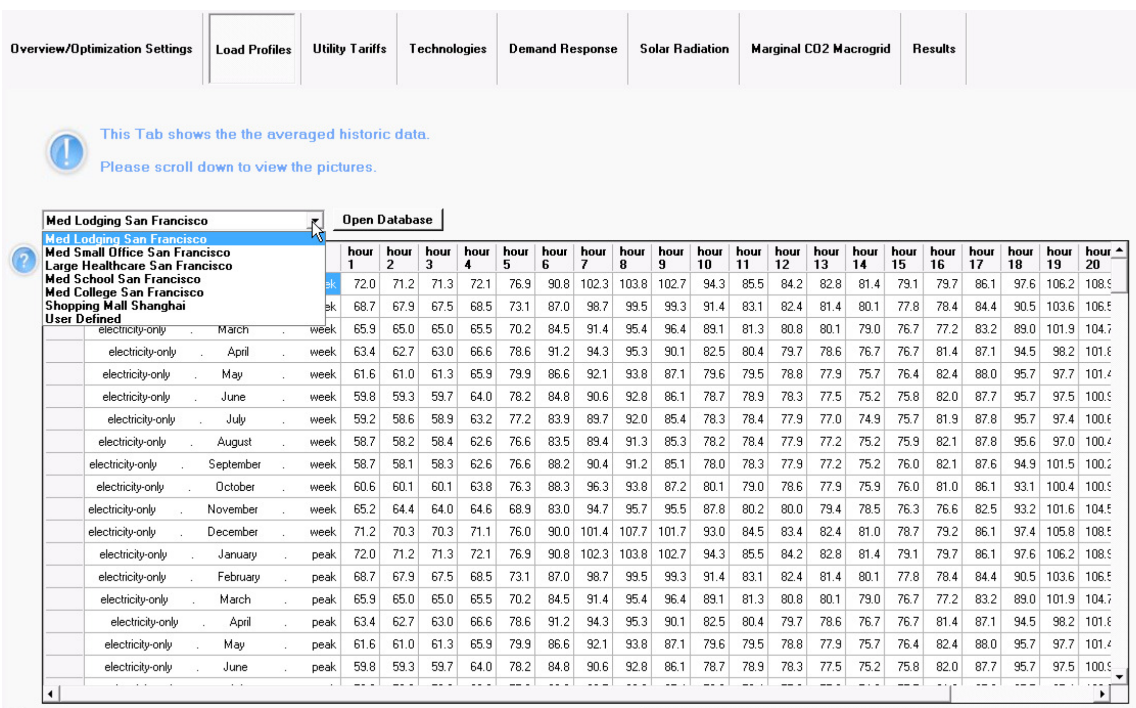

Figure 10. Load profile table

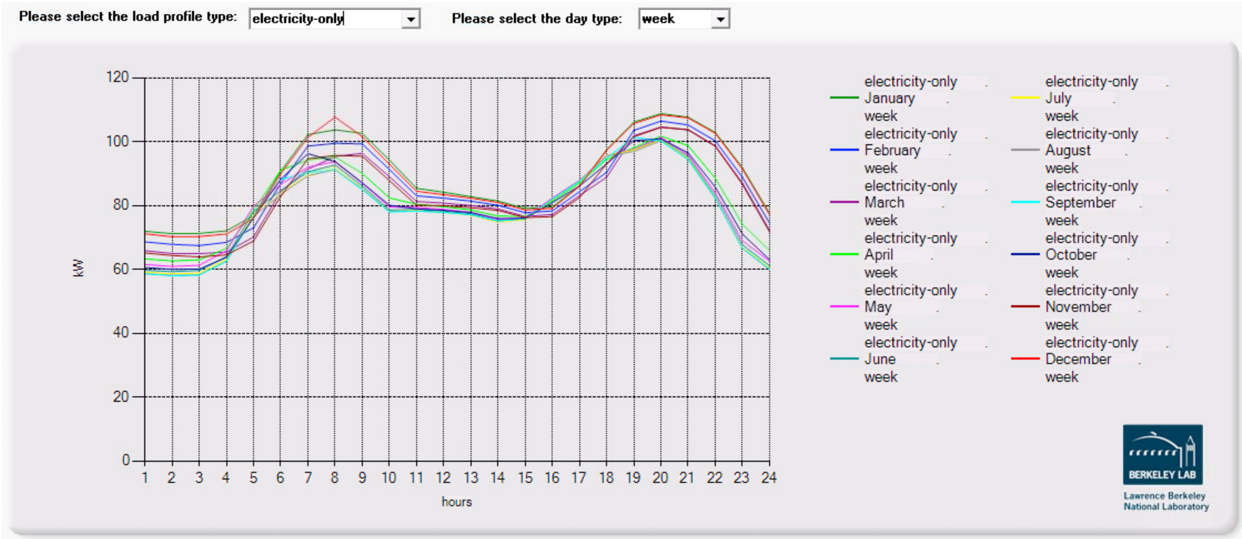

Figure 11. Load profile graphic

User defined building load profile

If the user selects the "***User Defined***", the load data will have to be entered manually or copied via *copy of the browser menu* (Please note that some browsers need proper configuration so that you can see the copy in the browser menu). The following load data can be considered: electricity-only, cooling, refrigeration, space-heating, water-heating, and natural gas only. The load data is needed from each month of the year and during each hour of week (Monday to Friday), weekend (Saturday and Sunday), and peak (three days with the highest demand within a month).

Make sure that the monthly average hourly load data is entered in the table. To calculate the monthly average hourly load data, the user takes each hour from every week, weekend, or peak for the entire month and calculates the average.

Please note that the cooling and the refrigeration load are always expressed in consumed electricity of an equivalent electric chiller with a COP of 4.5. For example, if there is a useful cooling load of 100kWh, then to convert this to an equivalent electricity load of electric chiller, the user must divide the load by the COP of 4.5, resulting in a 22.22 kWh electric load. Also, the heating and domestic hot water loads need to be provided as useful energy and not as energy purchased.

Extended US load profile database

The extended database contains load profiles from three vintages (pre-1980, post-1980, and new construction) from the ASHRAE U.S. climate regions. Figure 12 left shows the menu. The annual electricity and natural gas usage in terms of GWh should be entered in the two boxes shown. When loaded, the table will automatically update and the pull-down menu of pre-defined building types will change, see Figure 12 right. You can load the database by clicking on the "Open Database" button on Tab Load Profiles.

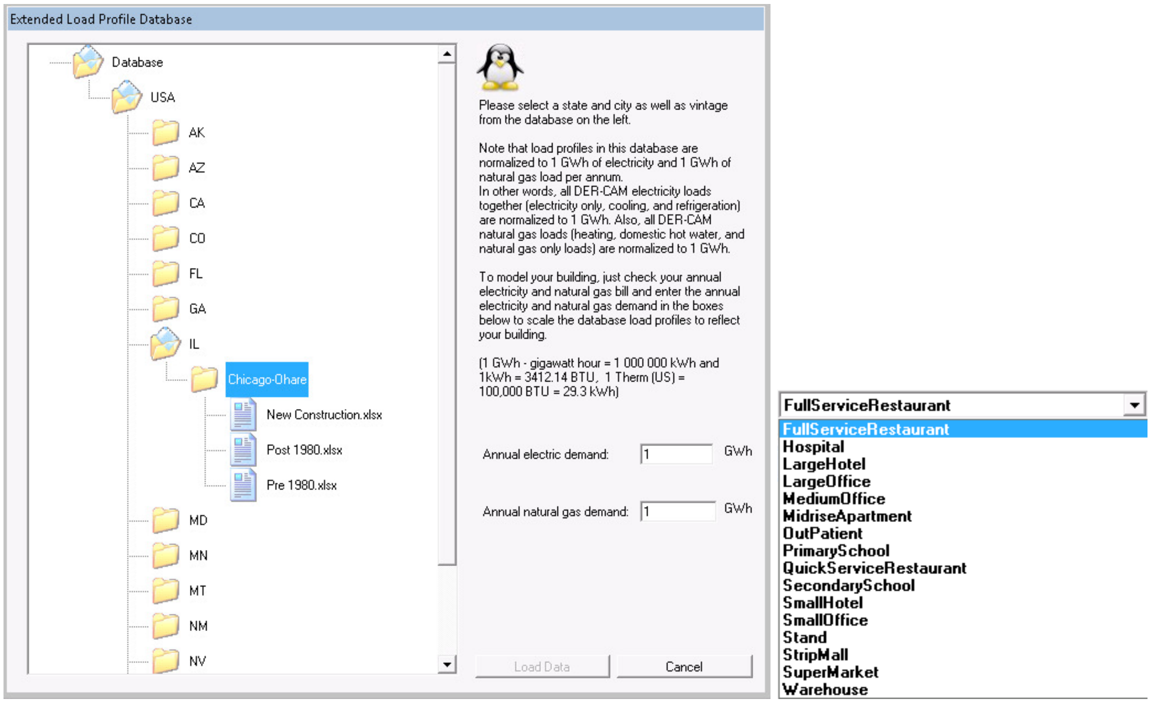

Figure 12. The extended load profile database (left) and building type option (right). Please click on the folder icons to expand the folders.

Note that after loading a profile from the extended database, the "user defined" will not be available unless the user discards all changes by clicking on "Close database and switch back to original conditions" at the top right of WebOpt.

Extended US solar radiation database

This is a US solar radiation database based on TMY2 and TMY3 data.

Data files of Typical Meteorological Year (TMY) are available on the web for 1020 stations in the USA from the National Renewable Energy Laboratory (NREL). They can also be obtained as a single zip file or on a CD-ROM from NREL. These data sets are derived from the National Solar Radiation Database (NSRDB) and produced by the National Renewable Energy Laboratory's (NREL). A complete User's manual is available on the NREL web site.

Formerly available as TMY2 (239 stations, 1961-1990 data), since 2008 this database has been extended to TMY3 (1020 stations, 1991-2005 data). These new TMY3 are based on more recent and accurate data. TMYs are data sets of hourly values of solar radiation and meteorological elements. They are juxtapositions of months or periods of real data, chosen in the multi-year data set in such a way that they represent a typical 1-year period. Their intended use is for computer simulations of solar energy conversion systems and building systems to facilitate performance comparisons of different system types, configurations, and locations in the United States and its territories. Because they represent typical rather than extreme conditions, they are not suited for designing systems to meet the worst-case conditions occurring at a location

You can load the database by clicking on the "Open Database" button on Tab Solar Radiation.

Note that after loading a profile from the extended database, the "user defined" will not be available unless the user discards all changes by clicking on "Close database and switch back to original conditions" at the top right of WebOpt.

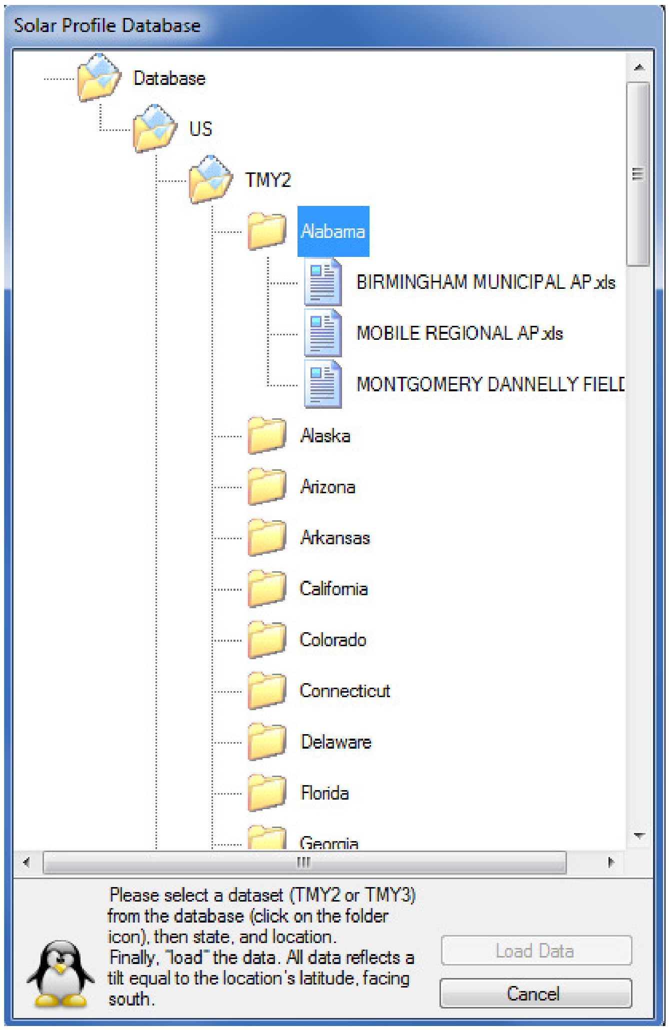

Figure 13. The extended US solar profile database

4. Utility Tariffs

The user can either (1) select one of the example tariffs listed in or (2) create one by selecting *"User Defined"* tariff. Figure 14 shows the layout of the tariff tab. Prices are in US Dollars; please convert accordingly.

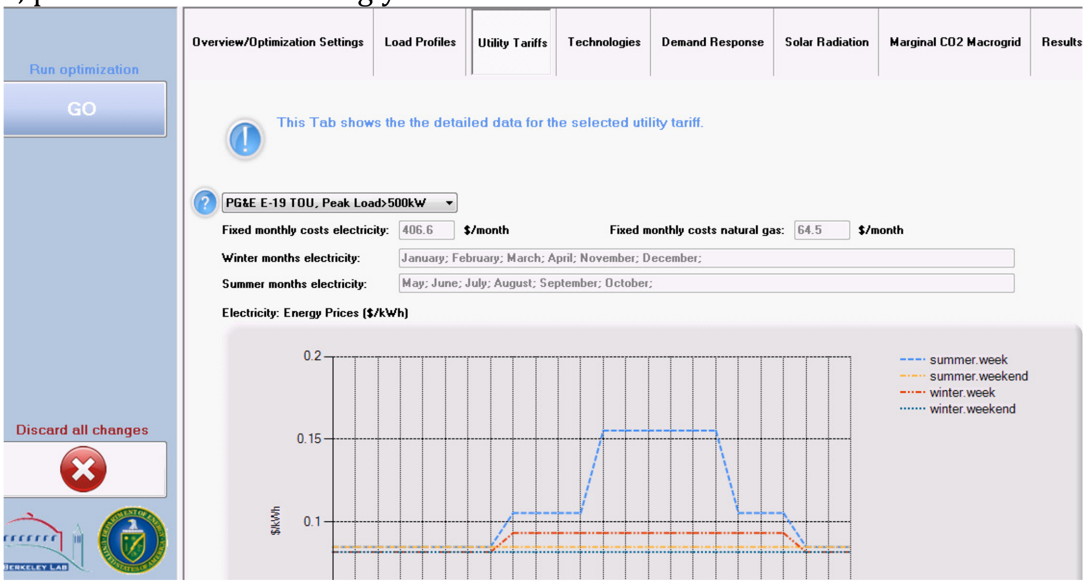

Figure 14. Utility Tariff (prices in USD, please convert accordingly)

Example tariffs

Please note that only the California tariffs are provided at this point by the pull-down menu, and the new Peak Day Pricing (PDP) tariff for California will be implemented in future WebOpt versions. Table 1 describes the predefined tariffs.

Table 1. Description of predefined California tariffs

Utility	Name	Peak load range	Description
Pacific Gas and Electric (PG&E)	E-19 TOU	500kW-1000kW	Time-Of-Use (TOU) tariff. Demand charge and energy price have 3 different values during winter and 2 during summer, depending of the time (on, mid or off-peak, and weekday or weekend)
	A-10 TOU	200-500kW	TOU tariff for energy price, flatter than above. Demand charge only depends on the season (winter or summer), not on the time of the day
	A-1 Flat Rate	<200kW	Flat rate for energy price, no demand charge.
Southern California Edison (SCE)	TOU-8	>500kW	Similar to PG&E E-19 TOU, except that winter demand charge is constant throughout the day
	GS-3 TOU	200-500kW	Similar to SCE TOU-8
	GS-2 Flat Rate	20-200kW	Flat rates for energy price and demand charge, different values for winter and summer

San Diego Gas and Electric (SDGE)	AL-TOU	>500kW	TOU tariff for energy and demand charges. 3 different levels for energy, 2 for demand charge, tariff pattern change between summer and winter
	AL-TOU	20-500kW	Same as above, but with different monthly fixed costs

User defined tariffs

If the user chooses "User defined" from the pull-down menu, the *Tariff Wizard*, Figure 15, will pop up.

The Electric Tariff Wizard allows building tariffs of increasing complexity. By checking the *"seasonal difference"* box, a differentiation is created between summer and winter tariffs and the user can select which months belong to which season. By checking the *"Time-of-use weekdays"* (TOU) box, a differentiation is created between on, mid and off-peak hours during weekdays. The user can specify which time of the day falls in which time of use period. Thus, by selecting seasonal and TOU options the user can create a tariff composed of up to 6 different price levels.

By clicking the *"Demand pricing / demand charges"* box, a demand charge component will be added to the tariff. As for the energy pricing, the demand charge can be composed of 1, 2, 3 or 6 values, depending on if seasonal and TOU options are selected or not. The definitions of summer, winter, on, mid and off-peak hours apply to energy pricing and demand charges.

Finally, the user can choose to add a monthly fixed cost by checking the corresponding box. If a more complex tariff is desired, please contact the WebOpt team directly by email.

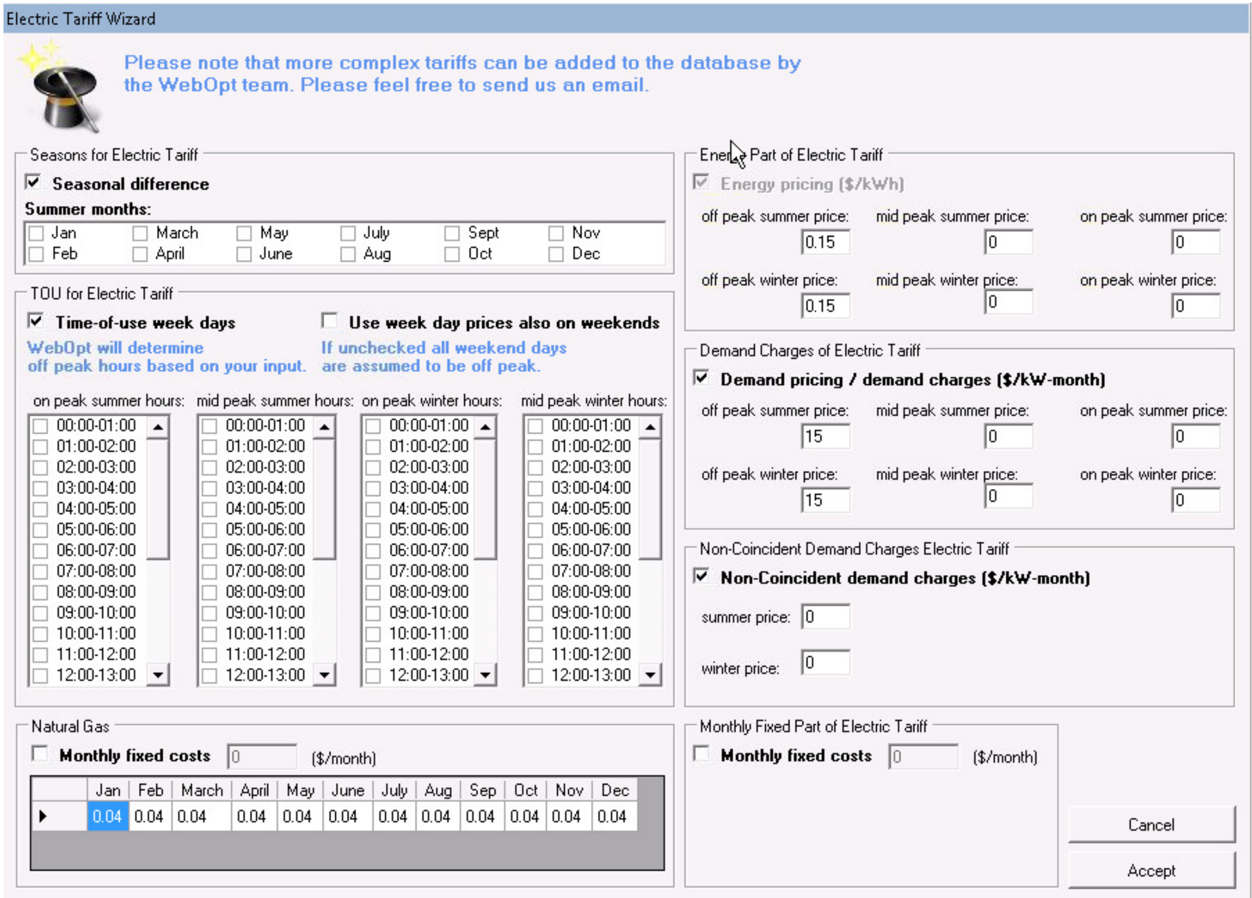

Figure 15. Tariff Wizard (prices in USD, please convert accordingly)

5. Technologies

This tab can be used to view or edit the economic and technical parameters of regular batteries, flow batteries, heat storage, solar thermal, and PV. Please note that it is possible to edit a predefined set of technologies, and that WebOpt will detect the modification and display *"User Defined"* instead of the name of the standard set. In other words, the user can use a predefined set as a starting point and modify selected parameters only instead of starting from scratch. To edit any cell, click on a cell and type in a new value.

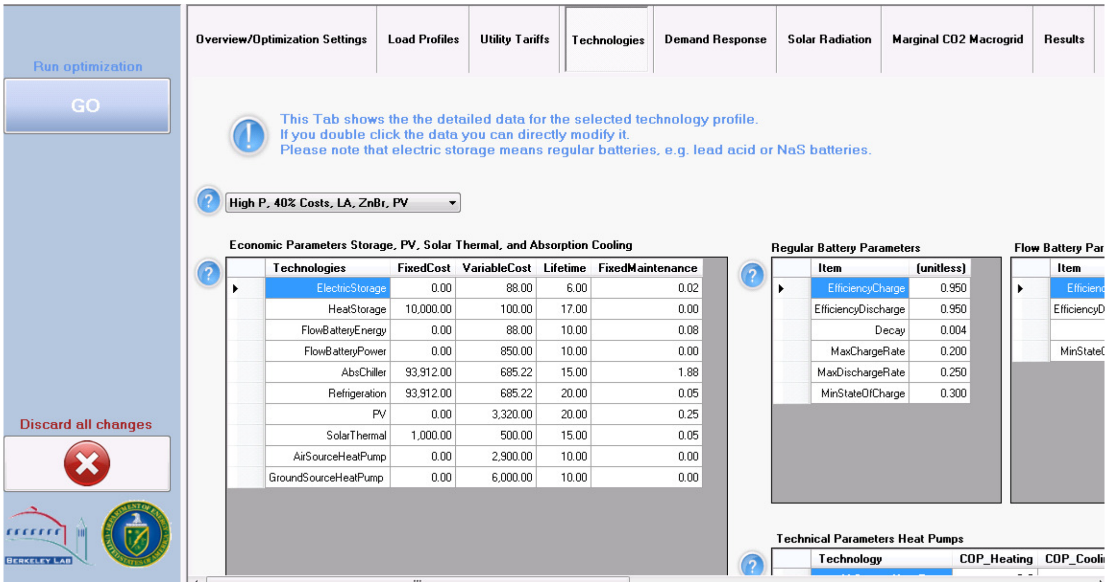

Figure 16. Technologies

Economic parameters[1]

- *Fixed cost*: in $, applied as soon as the technology is selected, regardless of the size. This can be used to model engineering and permitting costs.
- *Variable cost*: in $/kW for PV and the power part of the flow battery and in $/kWh for the regular battery and the energy part of the flow battery. Please note that this parameter also includes costs for power electronics necessary for charging and discharging. High charging and discharging rates require more expensive power electronics, and therefore, increase the variable cost. To account for this fact, WebOpt offers different technology set with fast or slow charging and discharging rates.
- *Lifetime*: in years.
- *Fixed maintenance per month*: expressed in the same units as the variable costs but applied to a full month.

Regular Battery Parameters

- *Efficiency of charge*: fraction of the electricity sent to the battery that is effectively stored in the battery.
- *Efficiency of discharge*: fraction of the electricity discharged from the battery that is effectively available.
- *Decay (self-discharging)*: fraction of the energy stored in the battery that is lost by self-dicharging in one hour.

[1] Here, electric storage means regular battery (not flow battery).

- *Maximum charging rate*: maximum fraction of the battery capacity that can be charged up in one hour. Please note that this also depends on the charging infrastructure.
- *Maximum discharging rate*: maximum fraction of the battery capacity that can be discharged in one hour. Please note that this also depends on the charging infrastructure.
- *Minimum state of charge*: minimum level of charge to avoid damaging the battery.

Flow Battery Parameters

The parameters of the flow battery are the same as for the regular battery but without the maximum charge and discharge rate, as flow batteries are not limited in this regard.

High P, 40% Costs, LA, ZnBr, PV

Economic Parameters

Technologies	FixedCost	VariableCost	Lifetime	FixedMaintenance
ElectricStorage	0.0	88.0	6.0	0.0
FlowBatteryEnergy	0.0	88.0	10.0	0.1
FlowBatteryPower	0.0	850.0	10.0	0.0
PV	0.0	3,320.0	20.0	0.3

Regular Battery Parameters

Item	(unitless)
EfficiencyCharge	0.950
EfficiencyDischarge	0.950
Decay	0.004
MaxChargeRate	0.200
MaxDischargeRate	0.250
MinStateOfCharge	0.300

Flow Battery Parameters

Item	(unitless)
EfficiencyCharge	0.840
EfficiencyDischarge	0.840
Decay	0.000
MinStateOfCharge	0.250

Figure 17. Technology Parameters for High P, 40% Costs, LA, ZnBr, PV

For convenience WebOpt provides economic and technical parameters for eight commonly available battery technologies, as well as for ZnBr flow battery and PV. The costs are based on EPRI-DOE, Schoenung et al. 2003, SGIP 2008, and Stadler et al. 2009. To show the impact of battery and PV adoption 40% costs are introduced as standard data. These sets of parameters may be modified later, or manually specified if the user select the *"User Defined"* option.

Description of predefined PV and storage cases in WebOpt:

- High P, 40% Costs, LA, ZnBr, PV
    - Lead-Acid (LA) battery with higher than realistic performance (charging and discharging efficiencies)
    - ZnBr flow battery and PV
    - 60% cost reduction for LA battery, ZnBr flow battery and PV, the prices are only 40% of the 2009/2010 currently observed costs
- 40% Costs, LA, ZnBr, PV
    - Lead-Acid (LA) battery, ZnBr flow battery and PV
    - 60% cost reduction for LA battery, ZnBr flow battery and PV
- 100% Costs, LA, ZnBr, PV
    - Same as above with 2009 observed costs
- 40% Costs, VRLA, ZnBr, PV
    - Valve-Regulated Lead-Acid (VRLA) battery, ZnBr flow battery and PV
    - 60% cost reduction for VRLA battery, ZnBr flow battery and PV
- 100% Costs, VRLA, ZnBr, PV
    - Same as above with 2009 observed costs
- 40% Costs, NiCd-fc, ZnBr, PV
    - Nickel-Cadmium fast-charging (NiCd-fc) battery, higher costs due to power electronics for fast charging/discharging, ZnBr flow battery and PV
    - 60% cost reduction for NiCd-fc battery, ZnBr flow battery and PV
- 100% Costs, NiCd-fc, ZnBr, PV
    - Same as above with 2009 observed costs
- 40% Costs, NiCd-sc, ZnBr, PV
    - Nickel-Cadmium slow-charging (NiCd-sc) battery, lower costs due to cheaper electronics for charging/discharging, ZnBr flow battery and PV
    - 60% cost reduction for NiCd-sc battery, ZnBr flow battery and PV
- 100% Costs, NiCd-sc, ZnBr, PV
    - Same as above with 2009 observed costs
- 40% Costs, NaS-fc, ZnBr, PV

    - Sodium-Sulfur fast-charging (NaS-fc) battery, higher costs due to power electronics for fast charging/discharging, ZnBr flow battery and PV
    - 60% cost reduction for NaS-fc battery, ZnBr flow battery and PV
- 100% Costs, NaS-fc, ZnBr, PV
    - Same as above with 2009 observed costs
- 40% Costs, NaS-sc, ZnBr, PV
    - Sodium-Sulfur slow-charging (NaS-sc) battery, lower costs due to cheaper electronics for charging/discharging, ZnBr flow battery and PV
    - 60% cost reduction for NaS-sc battery, ZnBr flow battery and PV
- 100% Costs, NaS-sc, ZnBr, PV
    - Same as above with actual observed costs
- 40% Costs, Li-Ion-fc, ZnBr, PV
    - Lithium-Ion fast-charging (Li-Ion-fc) battery, higher costs due to power electronics for fast charging/discharging, ZnBr flow battery and PV
    - 60% cost reduction for Li-Ion-fc battery, ZnBr flow battery and PV
- 100% Costs, Li-Ion-fc, ZnBr, PV
    - Same as above with 2009 observed costs
- 40% Costs, Li-Ion-sc, ZnBr, PV
    - Lithium-Ion slow-charging (Li-Ion-sc) battery, lower costs due to cheaper electronics for charging/discharging. ZnBr flow battery and PV
    - 60% cost reduction for Li-Ion-sc battery, ZnBr flow battery and PV
- 100% Costs, Li-Ion-sc, ZnBr, PV
    - Same as above with 2009 observed costs

6. Demand Response

On this tab the user can enter the demand response (DR) parameters, see Figure 18. To modify a cell, double click on the cell and directly enter the parameter value. Please note that only abstract DR measures are possible and that the value of MaxLoadInHour and MaxIncrease must be less than 1000. The percentage schedulable values are equivalent to the percentage of load (kW) that can be rescheduled (without any technology investments) to shoulder or off peak in a demand response event. WebOpt will determine within the user specified parameters the best solution to minimize costs.

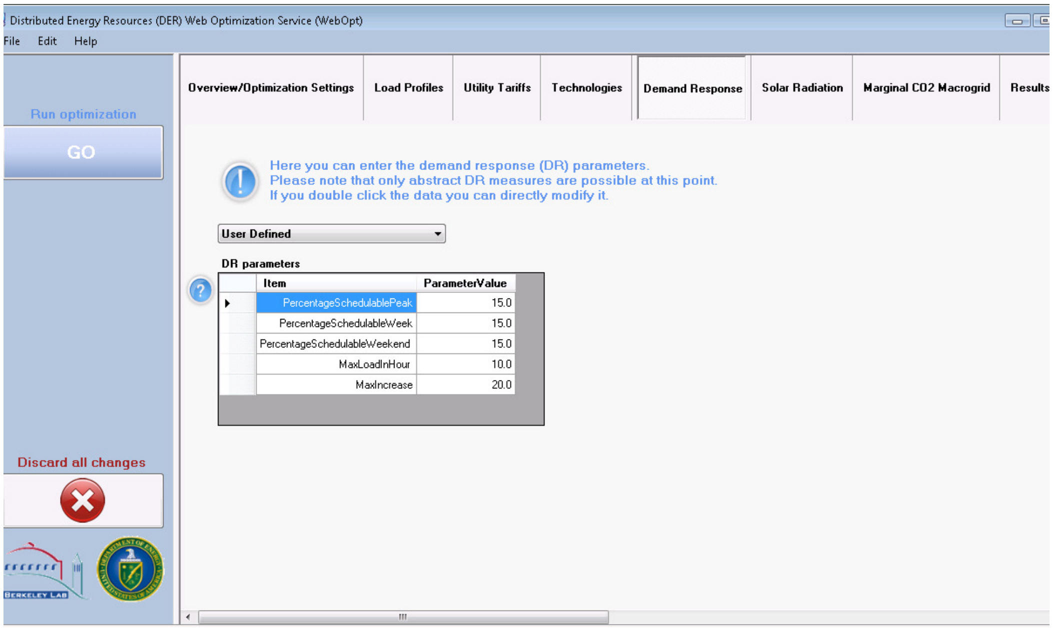

Figure 18. Demand Response parameters

7. Solar Radiation

The data are defined in hourly time interval on a monthly averaged style, in kW/m^2. For quick estimates, the user can select predefined solar radiation data for selected California locations. For more accurate results, custom data maybe used by selecting "*User Defined"* in the drop-down menu, and then manually input it. However, for future versions we anticipate a solar radiation database.

The table on the upper part can be edited by copying-pasting data from an external spreadsheet or directly typing in the values. The unit of each cell is kW/m^2, where "1.0" is considered to be the maximum solar radiation on an optimally tilted PV panel.

Users can obtain annual radiation profile information from PVWatts, an online software tool by the National Renewable Energy Laboratory (NREL). For international locations, please use PVWatts version 1. By specifying the PV panel installation tilt, azimuth angle, and the PV system type in PVWatts, the annual hourly data will be given. The monthly values given by PVWatts need to be averaged and then copy-pasted into WebOpt.

As indicated in WebOpt, the solar radiation data is assumed to represent the solar radiation on a fixed PV panel having the same tilt as the latitude of the selected location. If the user wishes to input customized data, this assumption should be revisited.
The lower part of the tab allows the user to visualize the solar radiation for each hour and each month.

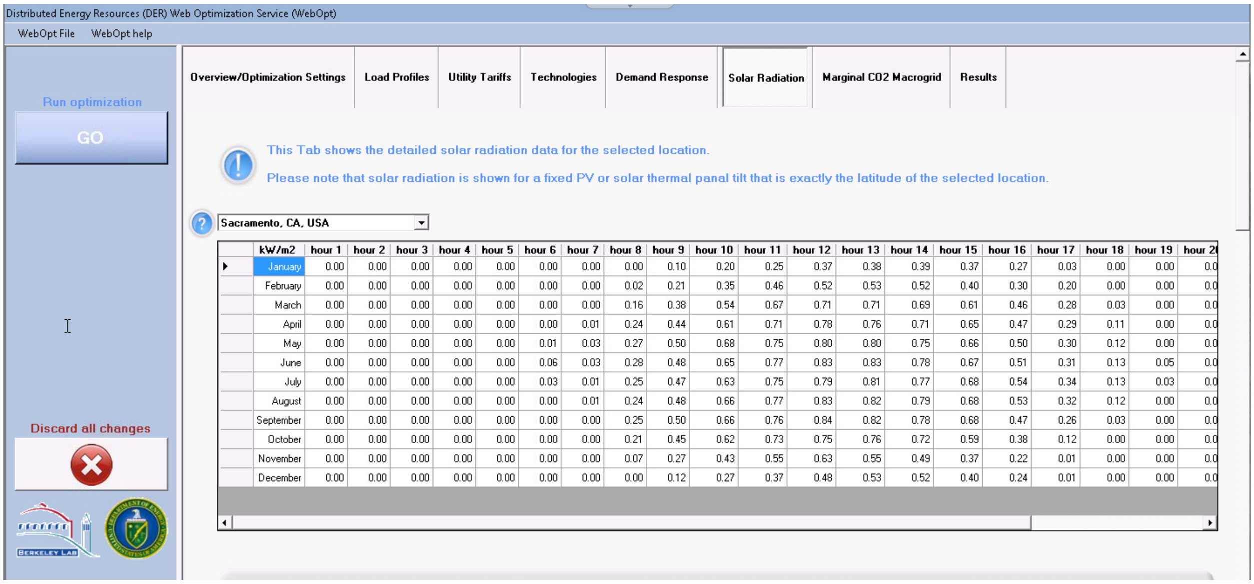

Figure 19. Solar Radiation

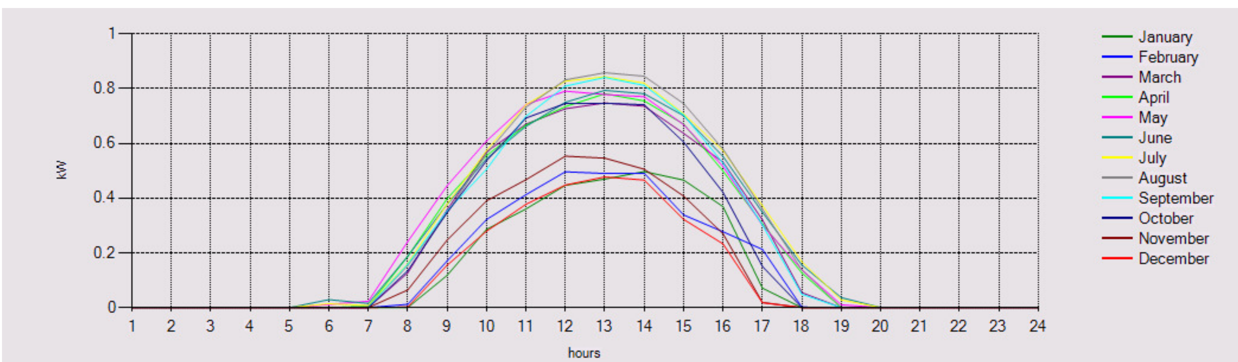

Figure 20. Example Solar Radiation

8. Marginal CO_2 Macrogrid

This tab can be used to view or edit the marginal CO2 emission data. These data is needed to access the impact of utility electricity purchases on the CO2 emissions.
The data are defined in hourly time interval on a monthly averaged style. For quick estimates, the user can select predefined Marginal CO2 Emission data for the locations listed: USA California 2008, USA California 2020, and China Estimate. It is not possible to modify pre-defined macrogrid emissions. For more accurate results, the user can input customized solar data by selecting "*User Defined*" in the drop-down menu, and then manually input it in. Please note that the value entered must be between 0 and 1.5 in units of kg CO2/kWh.

The lower part of the tab allows the user to visualize the marginal CO2 emission of the macrogrid for each hour and each month.

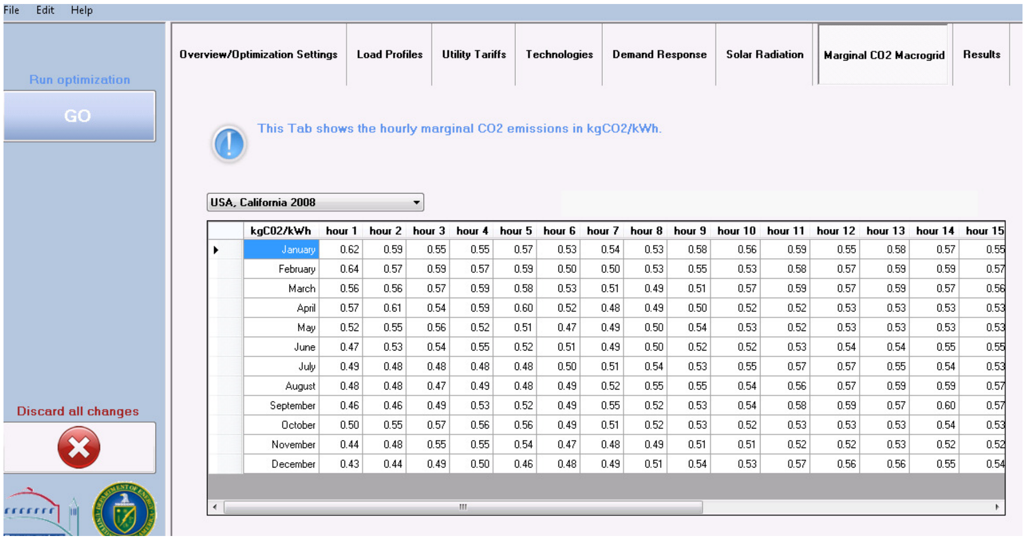

Figure 21. Marginal CO2 Macrogrid

9. Results

Once the user has input all the required information, the optimization can be launched by clicking the "GO" button on the upper left part of the window. After a few seconds to couple of minutes, the Results tab will be shown, see Figure 22.

Copy/paste of results from the results tab is possible if WebOpt is accessed from a PC computer and by using the Copy from the web-browser. This functionality is currently not supported for users accessing WebOpt from Apple computers.

Figure 22. Example Result Tab of WebOpt

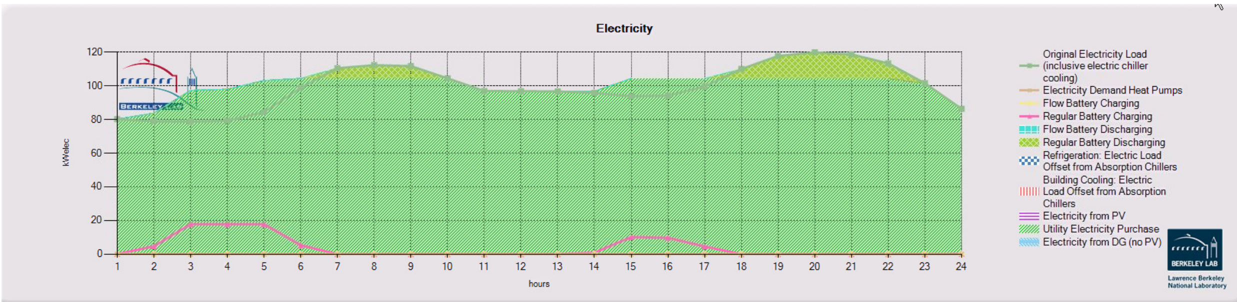

Figure 23. Example Result Electricity Chart of WebOpt

The result tab provides summarized result as well as detailed hourly schedule and information.
The top part of the table provides the user with the following information (see Figure above):

- *Total Annual Energy Costs, including annualized investment costs ($)*
- *Payback period of investments (years)*, if it has been selected in the “Overview/Optimization Settings” tab
- *Installed Capacity natural gas fired CHP and other DG (kW)*
- *Installed Battery Capacity (kWh)*
- *Installed Flow Battery Capacity (kWh)*
- *Installed Flow Battery Power (kW)*
- *Installed Heat Storage (kWh)*
- *Installed Capacity: Photovoltaic (kW), peak power under test conditions*
- *Size of Photovoltaic (m^2)*
- *Installed Capacity: Solar Thermal (kW), peak power under test conditions*
- *Size of Solar Thermal (m^2)*
- Other adopted technologies as *absorption cooling, heat pumps*
- *Electricity Generated Onsite (kWh/a)*, amount of electricity generated by PV
- *Utility Electricity Consumption (kWh/a)*
- *Efficiency of Entire Energy Utilization (Onsite and Purchase)*
- *Annual Electricity-Only Load Demand (kWh),* input data
- *Annual Costs Electricity ($)*

- *Annual Off-site CO2 Emissions (Macrogrid) (kgCO2)*, CO2 from utility
- and way more.

The detailed hourly optimal schedule for week-, peak-, and weekend days are shown lower on the page. The following components are provided:

- *Utility electricity consumption (kW)*
- *Electricity Generation from Photovoltaics (kW)*
- *Electricity Generation from CHP (kW)*
- *(Stationary) Battery*: electricity input, output and decay losses, refers to regular (non flow) battery
- *Flow Battery*: electricity input, output and decay losses
- *Electricity Load (kW)*: building electricity load profile
- and way more.

The lower part of the *result* tab displays a graph based on these optimal schedules. The user can select which month and type of day to visualize in the chart area.

8. References

EPRI-DOE Handbook of Energy Storage for Transmission and Distribution Applications, EPRI, Palo Alto, CA, and the U.S. Department of Energy, Washington, DC: 2003. 1001834

Schoenung S. M. and W. V. Hassenzahl (2003), "Long- vs. Short-Term Energy Storage Technologies Analysis, A Life-Cycle Cost Study, "Sandia Report SAND2003-2783 Unlimited Release, August 2003.

SGIP (2008), Statewide Self-Generation Incentive Program Statistics, California Center for Sustainable Energy, updated December 2008

8. Appendix, DER-CAM features list (Version 2 July 2013)

Only the most recent versions of DER-CAM are shown and described below.

Legend for table:
I&P: Investment and Planning version: determines optimal equipment combination and operation based on *historic* load data, weather, and tariffs
O: Operations version: determines optimal multi-day-ahead scheduling for installed equipment and *forecasted* loads, weather and tariffs
web: WebOpt
det: deterministic version, all data is assumed to be known perfectly

stoch: stochastic version in which some input data can be specified as scenarios and is used in stochastic programming
research: research license which needs a collaboration license agreement
comm: non-exclusive commercial license is available

Contact: Dr. Michael Stadler, mstadler at lbl dot gov.

Table 2. DER-CAM features list

Version: 3.9.4 Characteristic: I&P Public Release Date: 24 April 2012 Accessibility: research / comm. Uncertainty: det	• 36 load profiles characterizing a year (week, weekend, peak profiles for every month) • optimizes one typical year based on the 36 load profiles • 5 load profile types: electricity only, cooling, refrigeration, heating, domestic hot water, and natural gas only • only natural gas as energy carrier for combined heat and power (CHP) • CHP, electric and heat storage, PV, solar thermal, absorption cooling, heat pumps, basic load shifting, basic efficiency measures, electric vehicles • fuel cell run-time constraint to model SOFC and PEM fuel cells • multi-objective (costs and CO_2) • policy measures as feed-in tariffs or Self Generation Incentive Program in California • allows to force technologies into the solution • electricity sales • ZNEB and ZCB PUBLICATIONS to get more information: LBNL-4929E, LBNL-6071E, LBNL-6354E
Version: 3.9.4a Characteristic: I&P Public Release Date: 24 April 2012 Accessibility: research / comm. Uncertainty: det	• based on 3.9.4 from above, but with California Peak Day Pricing modeled PUBLICATION: LBNL-6267E
Version: WebOpt version 2.4.0.24 Characteristic: I&P Public Release Date: June 2013 Accessibility: research / comm. Uncertainty: det	• based on 3.9.4 from above • without electric vehicles • without policy measures as feed-in tariffs or Self Generation Incentive Program in California • without electricity sales • no technologies can be forced • without ZNEB and ZCB • with load profile database for ASHRAE Climate zones (762 buildings in the US) • automatic multi-objective frontier feature • English and limited Chinese version available
Version: 4.0.0 Characteristic: I&P Public Release Date: July 2013 (separate pieces are already available) Accessibility: research Uncertainty: det	• based on 3.9.4 from above • with cold storage • with passive measure (window change, building shell upgrades) • passive measures influencing heating and cooling loads • multi temperature heat storage (65C and 95C) • multi-energy carrier for distributed energy resources and heating

Version: 3.9.4.m Characteristic: I&P Public Release Date: Sept. 2013 Accessibility: research Uncertainty: det	• based on 3.9.4 from above, but • with multiple year optimization horizon which • optimizes building total energy cost over several years (the number of years is a set that can be modified by the user) • has an option that does/does not renew investments (same technologies, same capacities) in installed technologies after the lifetime is reached • with linear model for battery degradation (i.e. capacity loss due to ageing)
Version: 1.1.0.m Characteristic: I&P Public Release Date: April 2012 Accessibility: research Uncertainty: det	• based on 3.9.4 from above, but • with 12 typical week profiles to better model load shifting between week days and weekend days
Version: 2.0.0.w Characteristic: I&P Public Release Date: Sept 2013 Accessibility: research Uncertainty: det	• based on 1.1.0.w, but • with multiple year optimization horizon which • optimizes building total energy cost over several years (the number of years is a set that can be modified by the user) • has an option that does/does not renew investments (same technologies, same capacities) in installed technologies after the lifetime is reached • with linear model for battery degradation (i.e. capacity loss due to ageing)
Version: Operations DER-CAM 6.0.0 Characteristic: O Public Release Date: 2011 Accessibility: research / comm Uncertainty: det	• basic operations DER-CAM code for scheduling pre-determined DER configurations including the following: electric storage, flow batteries, solar thermal, PV, fuel cell, heat and cold storage, absorption chilling PUBLICATIONS: LBNL-6127E, LBNL-4497E, LBNL-81939

Version: Operations DER-CAM 6.1.0.ev Characteristic: O Public Release Date: TBD Accessibility: research / comm Uncertainty: det	• Operations DER-CAM code based on Operations DER-CAM 6.0.0 (see above) with additional modules for charging of EV fleet and determining cost-optimal frequency regulation bid for day-ahead ancillary services market • variable time-step 1hr, 15min, 5min
Version: Operations DER-CAM stochastic version 6.1.2.s Characteristic: O Public Release Date: 2011 Accessibility: research Uncertainty: stoch	• added stochastic capabilities based on Operations DER-CAM 6.0.0 • enabled choice for individual DG technologies to behave as deterministic or stochastic • added hourly max output parameter to model outages in DG (applied to fuel cell) • stationary storage behaves as deterministic to compensate for uncertainty in DG output PUBLICATIONS: LBNL-6309E
Version: Operations 1.0.0.s Characteristic: I&P Public Release Date: 1 March 2013 Accessibility: research Uncertainty: stoch	• based on 1.1.0.w from above • but with 12 typical week profiles to better model load shifting between week days and weekend days • new electric vehicle fleet management module • uncertainty in EV driving pattern • stochastic capabilities enabled PUBLICATION: LBNL-5937E
Version: Operations 2.0.0.s Characteristic: I&P Public Release Date: fall 2013 Accessibility: research Uncertainty: stoch	• based on 1.0.0.s • consideration of uncertainty for wind and PV • islanding and microgrid reliability • variable time-step 1hr, 15min, 5min