South Coast Air Quality Management District

Net Emissions Analysis Tool (NEAT) Sample Scenarios

Contents

Introduction

This document provides documentation on how to run the Net Emissions Analysis Tool (NEAT) for three sample scenarios in which residential appliances are replaced by more efficient and less emitting alternatives. One of the sample cases demonstrate the use of NEAT to estimate the benefits of installing rooftop solar photovoltaic (PV) panels in conjunction with appliance upgrades.

Results are obtained using the NEAT tool version 1.11 Beta. Results presented here are meant to be illustrative and not suitable to inform policy or energy decisions. Users are advised to understand the assumptions and limitations behind the inputs and calculations used in these sample scenarios.

Residential Net Emission Analysis Tool (NEAT)

Version 1.11 Beta

Sample Case 1: Switch to High Efficiency Natural Gas Condensing Water Heater in Single-Family homes in Climate Zone 6

This sample scenario replaces all conventional natural gas water heater with new High Efficiency Natural Gas Condensing Water Heater. The scenario assumes also that 4.4% of natural gas comes from renewable sources from the state (2.4% from landfill gas, 0.3% from wastewater treatment plants, 0.9% from manure management and 0.8% from conversion of food and green waste).

Parameters for scenario:

High efficiency condensing water heaters have an energy factor of 0.9, in contrast with conventional water heaters that have an energy factor of 0.7. The assumptions for the new technology are shown in **Table *1***.

Table 1: Assumptions in the replacement of water heaters

Tech	UEC	NOX EF	CO2e EF	Unit Cost	Install Cost
NG Conv. Water Heater	199.21 th	0.0023 lb/th	11.76 lb/th	$647	$1,900
HE NG Condensing Water Heater	155.00 th	0.0023 lb/th	11.76 lb/th	$1,000	$1,900

First, we need to add the new technology by clicking on the "add technology" button, and input the parameters in each column:

Fuel:	NatGas
Technology:	High-Efficiency Condensing
Hourly Profile:	Water Heating
UEC:	155
NOX EF:	0.0023
CO2e EF:	11.76
Unit Cost:	1000
Install Cost:	1900
Lifetime:	13

Then implement the technology replacement by using the "Replace Technology Tool" box. Select "single family" as housing type and climate zone 6 (see **Figure *1***).

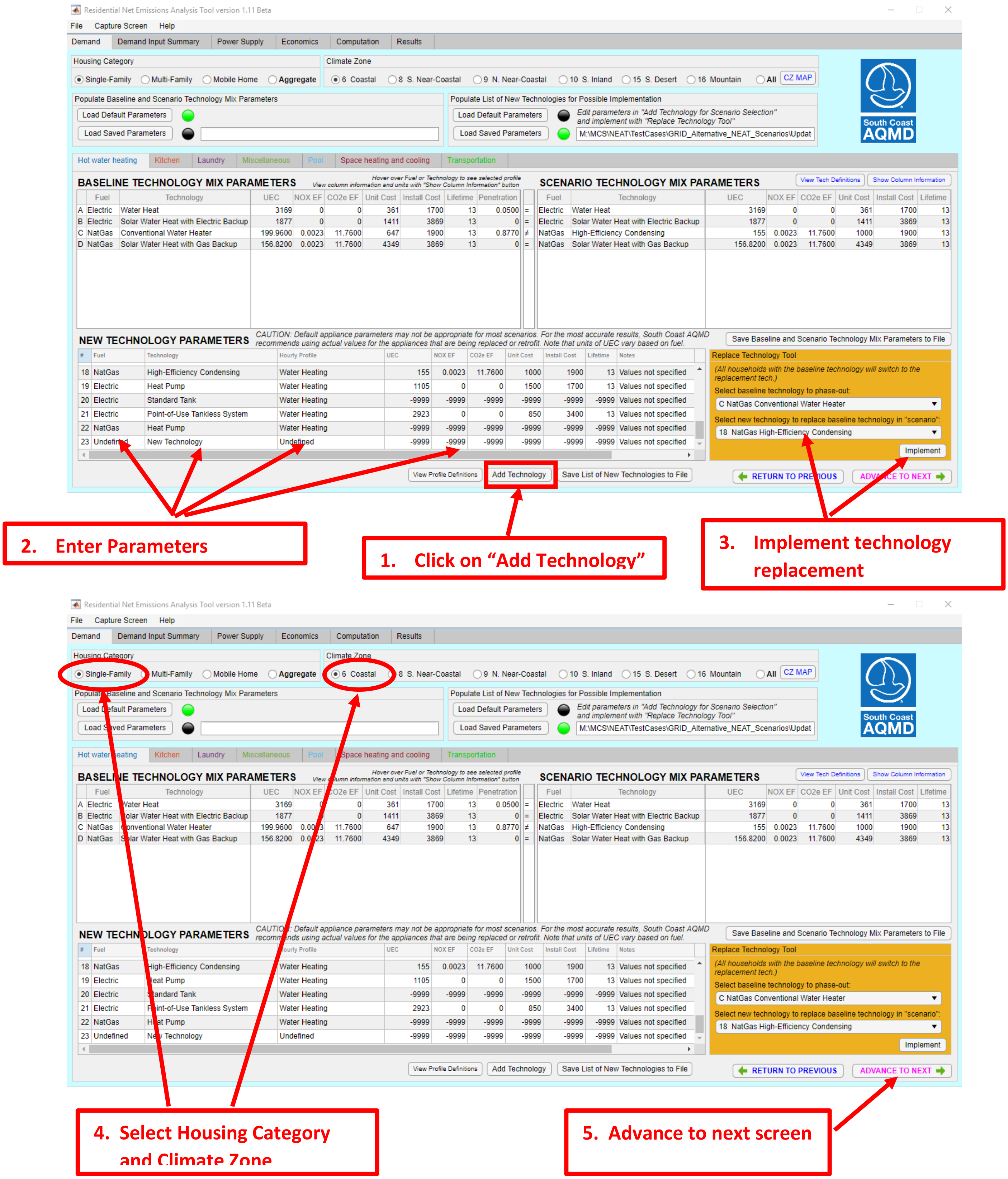

Figure 1: Define new technology and implement technology replacement

Advance to the next screen that displays the changes in appliances set up for the scenario, and if the changes are consistent with the scenario parameters, advance to the next screen to select the parameters for the electricity and natural gas grid (**Figure *2***).

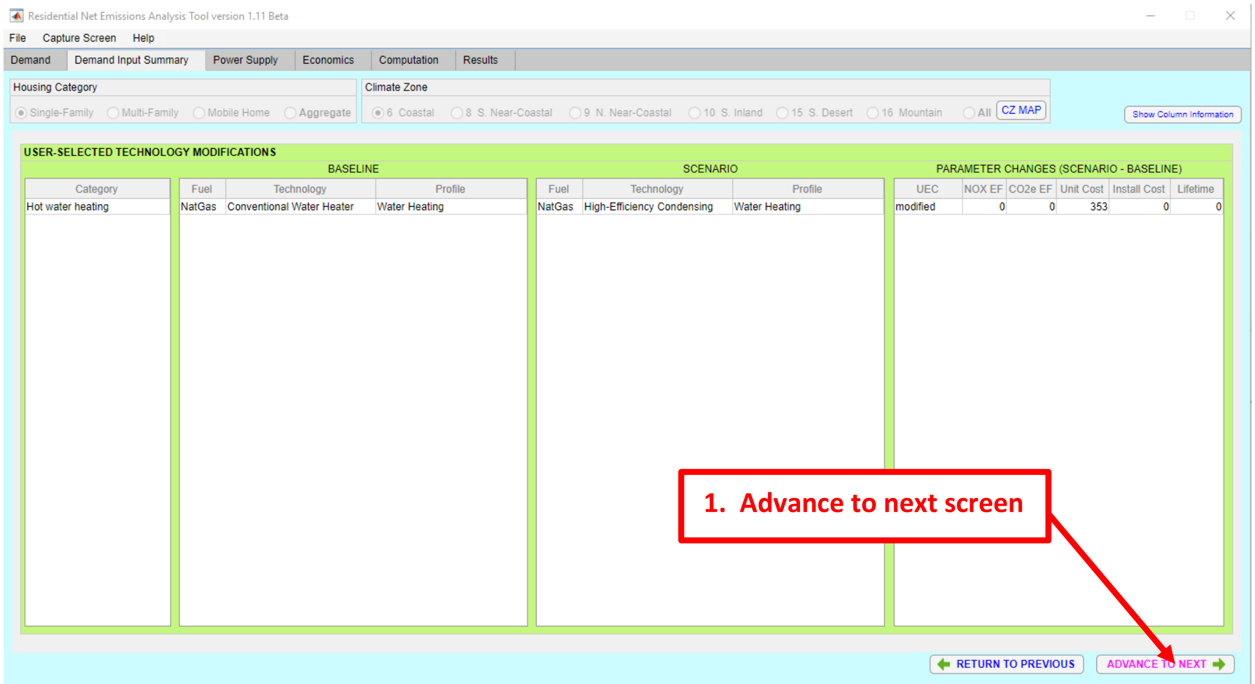

Figure 2: Confirm technology replacement scenario

Select the mix of natural gas resources for the scenario (**Figure *3***). In this case, the mix assumes that there is a 4.4% of natural gas from renewable sources in California. The breakdown of sources is as follows (based on California Biomass Collaborative, 2015; UC Davis, 2016):

- 2.4% from landfill gas,
- 0.3% from wastewater treatment plants,
- 0.9% from manure management and
- 0.8% from conversion of food and green waste
- 95.6% from conventional North American natural gas

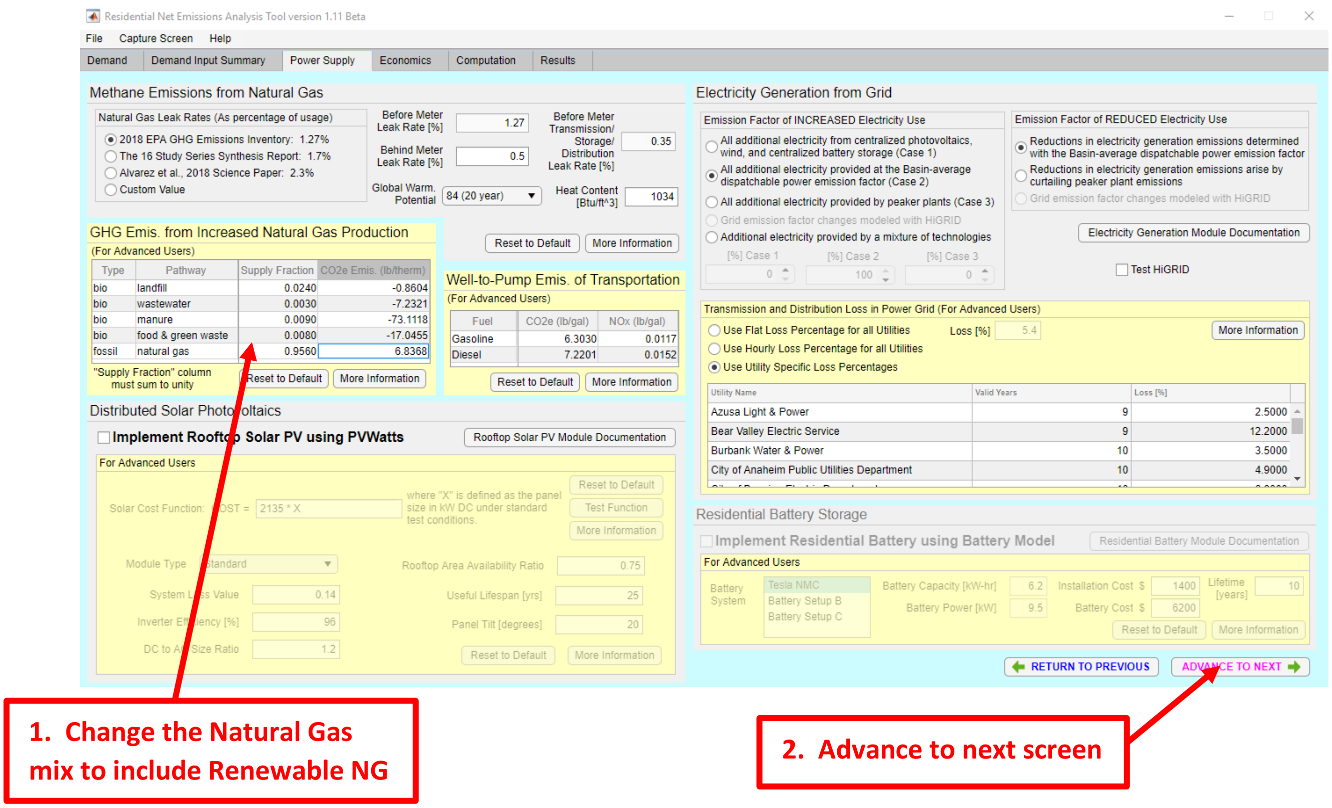

Figure 3: How to include renewable natural gas in the natural gas system

The scenario assumes default values for electricity and natural gas rates (**Figure *4***), so the user can advance to the 'Computation' tab (**Figure *5***). Here, the user clicks on the 'Compute Results' button, and some diagnostic messages appear in the prompt window. The time ruler should show progress, and after a minute, the simulation should be completed.

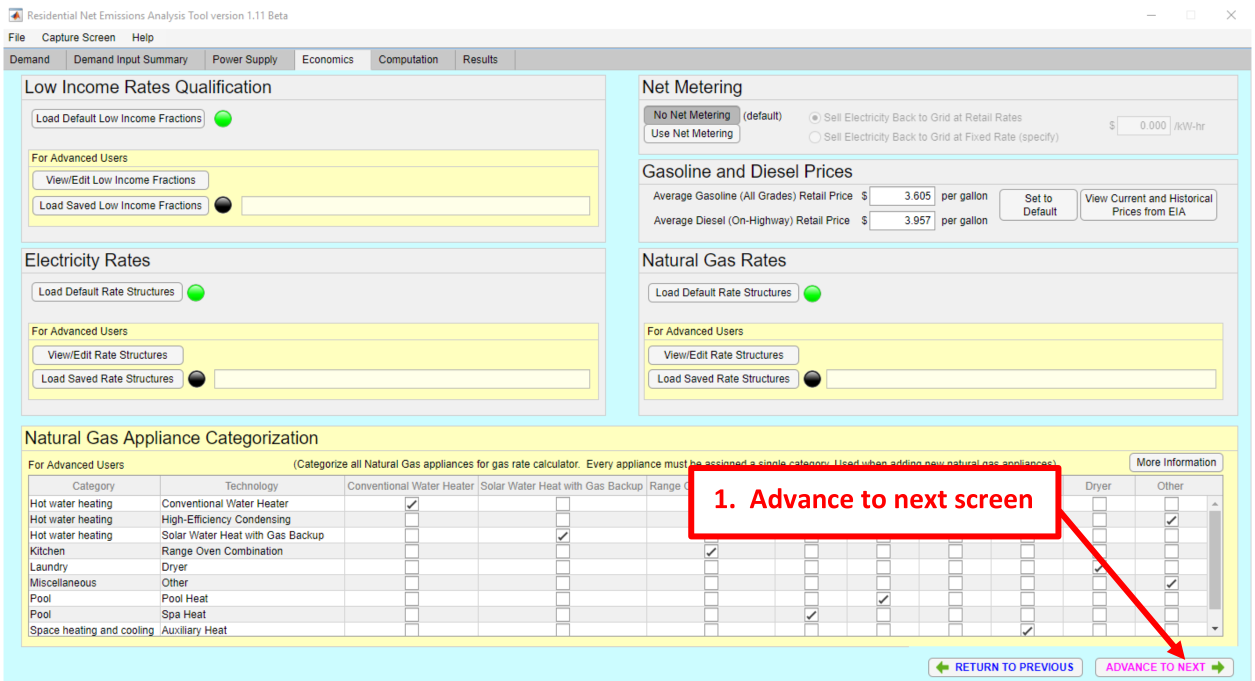

Figure 4: Confirm economic parameters (no need to change anything here)

Computation of Scenario:

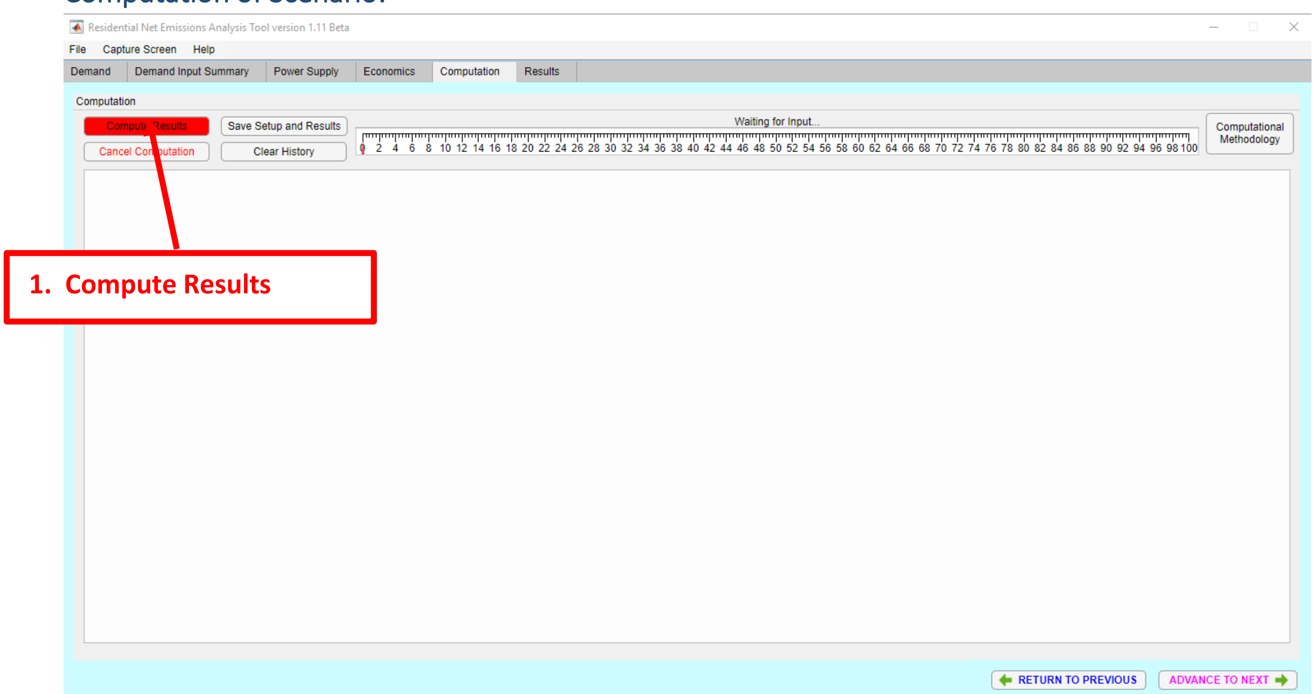

Figure 5: Compute results

Upon successful completion, the following message should appear at the top of the message list:

*** COMPUTATION COMPLETED SUCCESSFULLY! ***   elapsed time: 28.0689 s

Once the simulation is completed, the user can choose to save the setup and results in a file. Additional messages are displayed to show the files being saved (**Figure *6***). This file can be loaded at a later time to review the results. The NEAT tool keeps the latest run loaded, so the user can go directly to explore the results by clicking on the "Advance to Next" button.

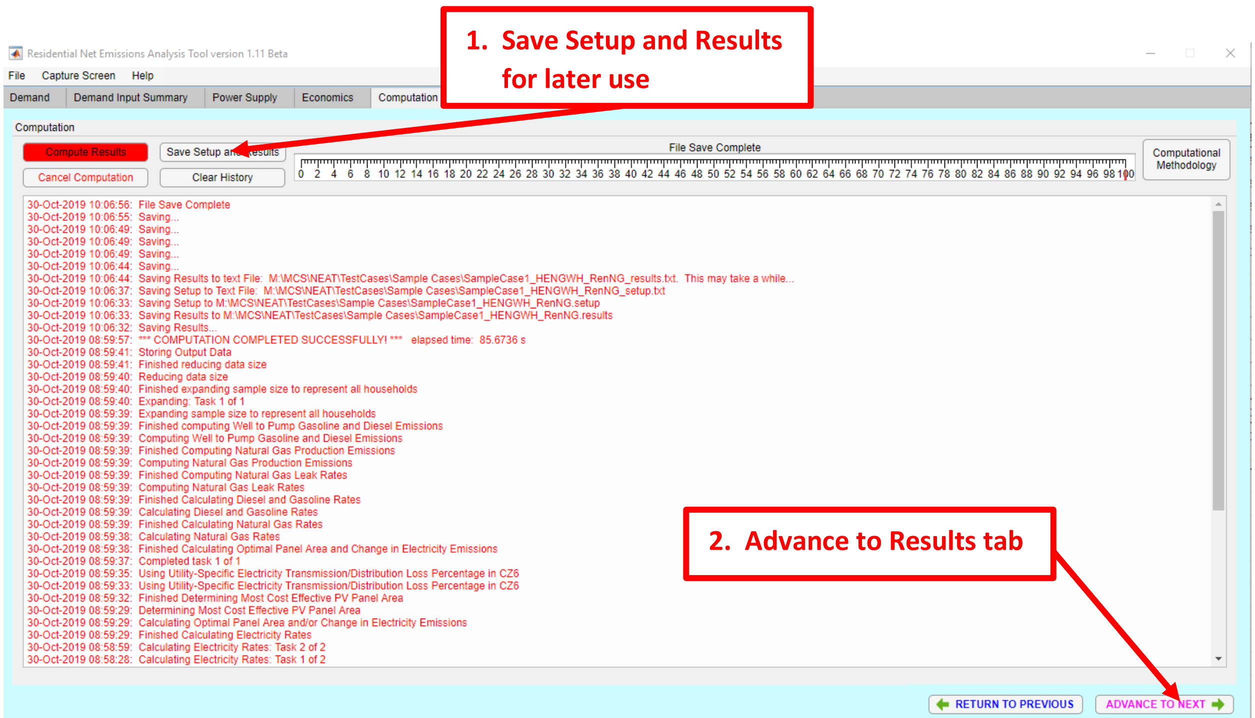

Figure 6: Save setup and results to able to analyze the results at a later time

Results:

In the results tab, the user can select a subset of climate zones, housing types, natural gas and electric utilities (**Figure *7***). Since this case was already constricted to single-family homes and climate zone 6, the user can only select among the utilities that fall within climate zone 6. After clicking on 'Analyze', the display moves to the cost effectiveness selector (**Figure *8***).

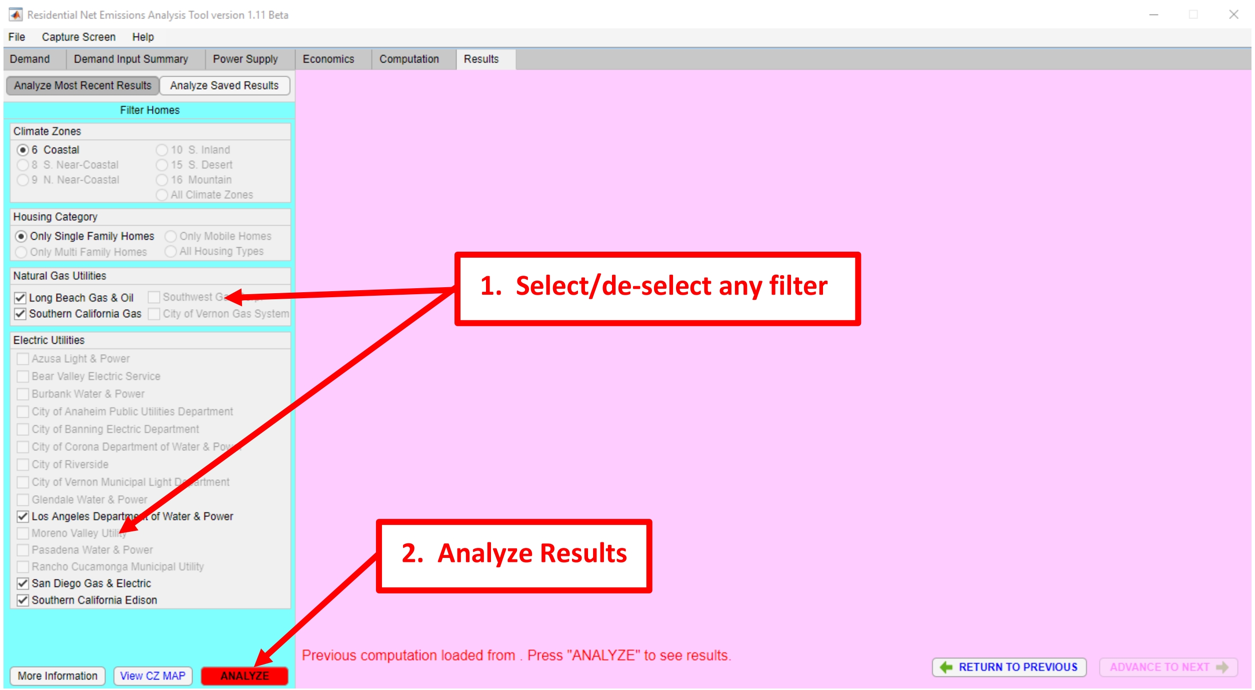

Figure 7: If desired, select a subset of climate zone, housing category, NG utility, and electric utilities, and analyze results

The user can select three different options to calculate cost effectiveness:

1) Cost effectiveness based on total annual cost, with annualized purchase and installation costs plus utility costs
2) Cost effectiveness based on utility and fuel costs only
3) Cost effectiveness based on upfront total cost of purchase and installation

The user can select among four options for the purchase and installation cost of the appliances, in order to account for their amortization:

1) Appliances that are replaced are at the end of their life
2) Appliances that are replaced have 25% of their life remaining
3) Appliances that are replaced have 50% of their life remaining
4) Appliances that are replaced are brand new

In this scenario, the retrofit results in emission reductions and annual savings when accounting for the annualized cost of purchase and installation plus the changes in utility costs, when the water heaters are changed at the end of their useful life.

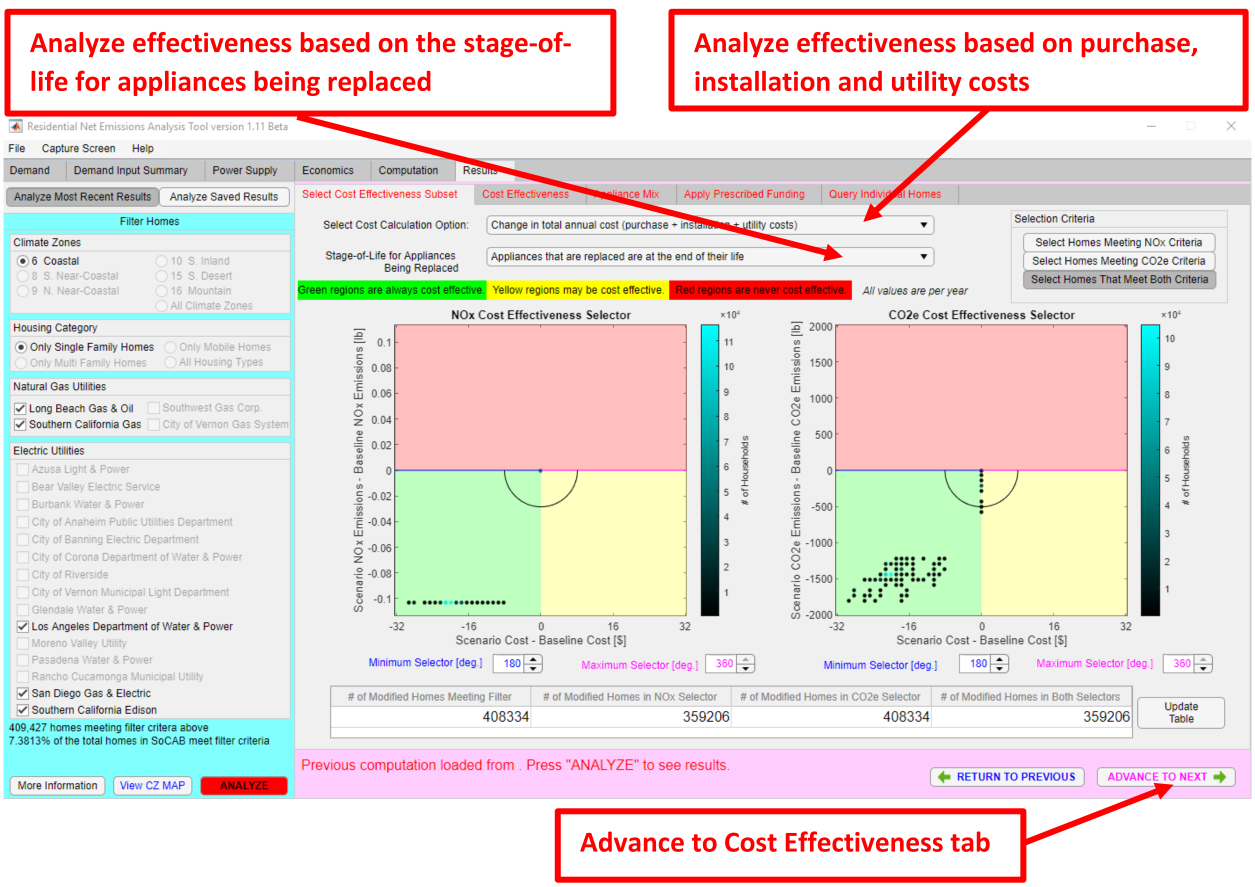

Figure 8: Analysis of the cost effectiveness space. Cost calculation has several options that include cost of equipment, installation and utility costs

The user can explore the distribution of cost-effectiveness amongst all the homes retrofitted with the new water heater (**Figure *9***). Results show that when an old NG water heater is replaced by a new high-efficiency condensing water heater, emissions of NOX and CO2 are reduced. In addition, annual costs would be lower than if the water heater was replaced by a conventional NG storage water heater, despite the higher price of the high-efficiency water heater.

Figure 9: Cost-effectiveness distribution among homes

The user can also explore the appliance mix that is present in the selected subset. This screen is useful when a combination of appliances is retrofitted. However, this scenario only replaces one appliance, so the results show only one bar that represents the water heater retrofit (**Figure *10***).

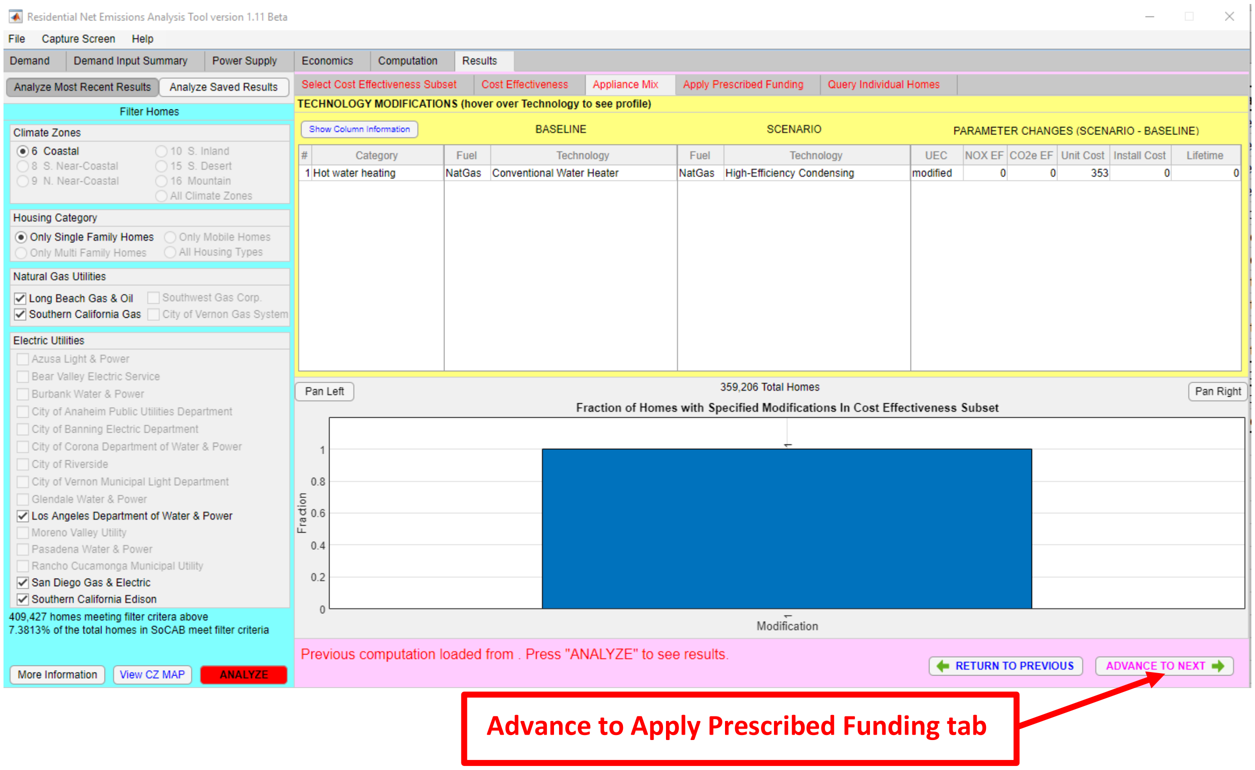

Figure 10: Summary of modifications (this scenario has only one modification)

In the next screen, the user can evaluate the emissions and costs of retrofit based on a prescribed amount of funding and assuming a specific cost-sharing percentage by the homeowner (**Figure *11***). For instance, if the funding amount is $1,000,000 and homeowners can pay for 50% of the cost of the appliance, the amount of funding would pay for 689 retrofits, which would result in emission reductions of 71.2 lbs/year of NOX and 260 tons/year of CO2e. The average savings in utilities among homes would be $46.90 per year, whereas the annualized cost of purchasing and installing the appliance is $13.58.

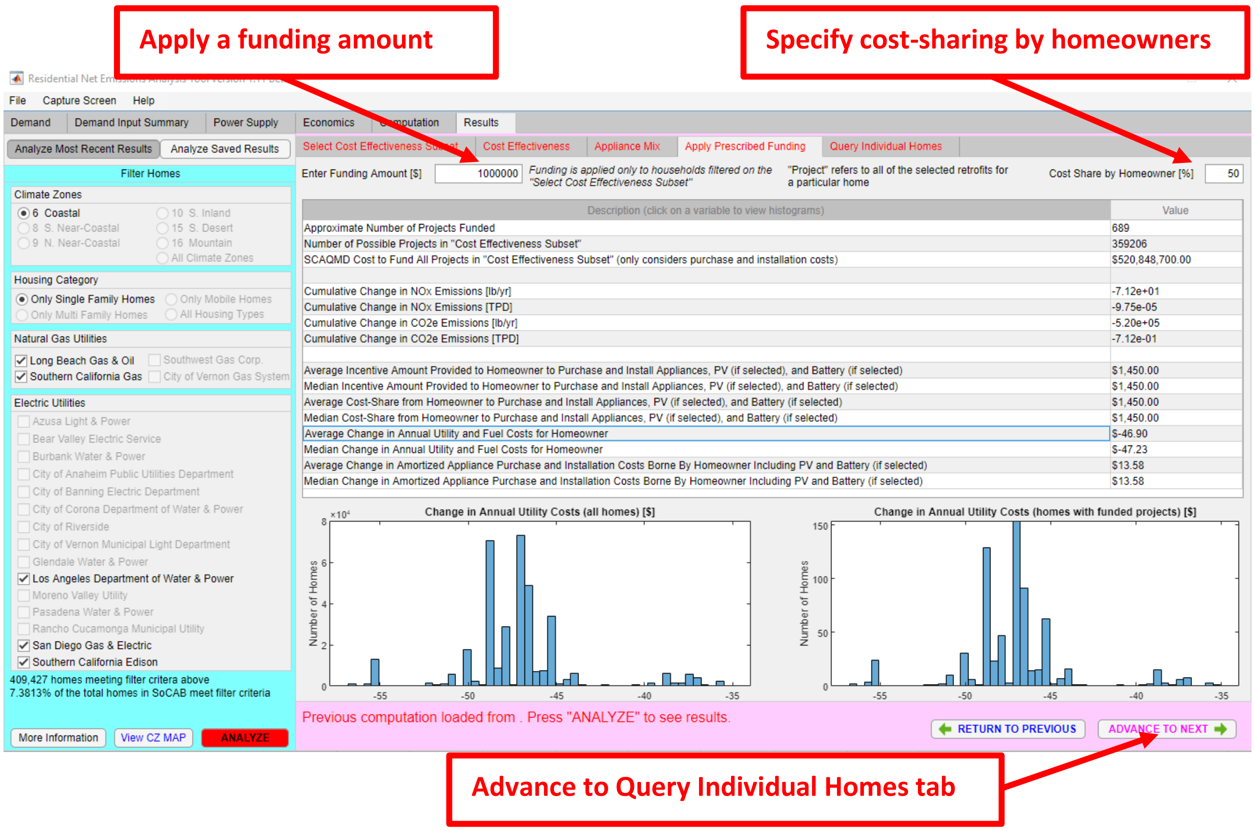

Figure 11: Analysis of prescribed funding and cost-sharing scenarios

In the next screen, the user can explore the characteristics of individual homes, and probe which households result in the most cost effective implementation (**Figure *12***). The NEAT tool provides the option to check the estimated appliance mix of the baseline and future scenario, the utilities that provide services to a particular house, and the average monthly changes in electricity and natural gas use due to the retrofit (**Figure *13***).

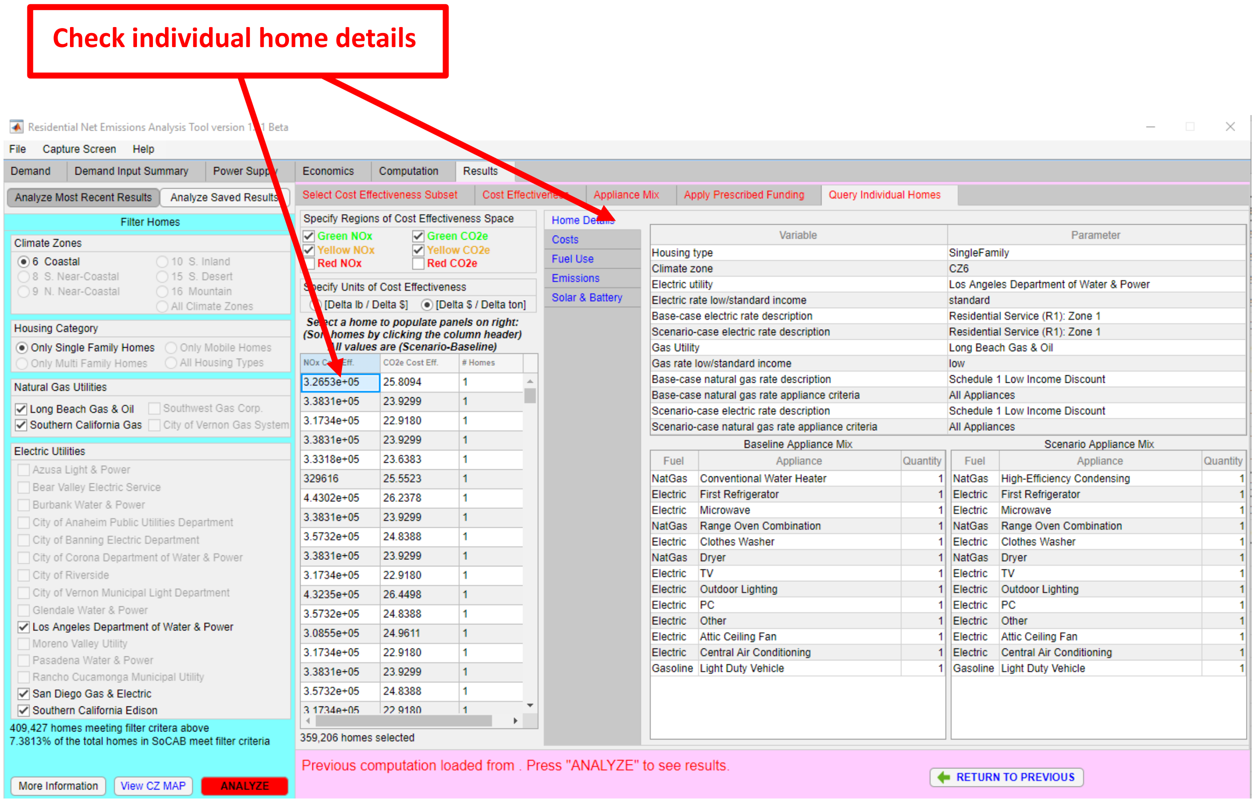

Figure 12: Analyze individual homes technology mixes, and how that affects cost effectiveness

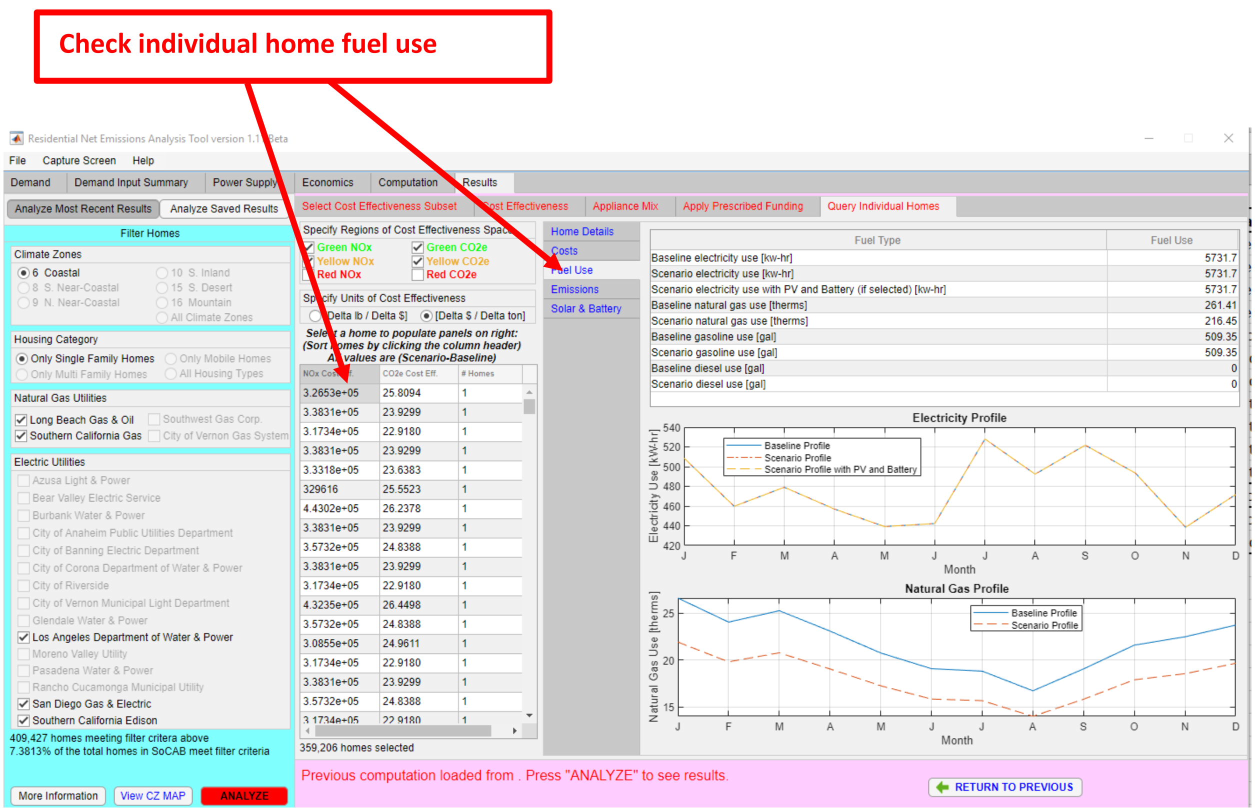

Figure 13: Analyze individual homes fuel use, and how that affects cost effectiveness

Sample Case 2: Electrification of water heating in single-family homes in Climate Zone 6

This sample scenario replaces all conventional natural gas water heaters with new Electric Heat Pump Water Heating.

Parameters for scenario:

Electric Heat Pump Water Heaters have a uniform energy factor (UEF) of 3.7, in contrast with conventional water heaters that have a UEF of 0.7. The assumptions for the new technology are shown in **Table *2***.

Table 2: Assumptions in the replacement of water heaters

Tech	UEC	NOX EF	CO2e EF	Unit Cost	Install Cost
NG Conv. Water Heater	199.21 th	0.0023 lb/th	11.76 lb/th	$647	$1,900
Electric Heat Pump WH	1,105 kWh	--	--	$1,500	$1,700

First, we need to add the new technology by clicking on the "add technology" button, and input the parameters in each column:

Fuel:	Electric
Technology:	Heat Pump
Hourly Profile:	Water Heating
UEC:	1,105
NOX EF:	0.00
CO2e EF:	0.00
Unit Cost:	1500
Install Cost:	1700
Lifetime:	13

Note that UEC in this case must be entered in kWh.

Then implement the technology replacement by using the "Replace Technology Tool" box. Select "single family" as housing type and climate zone 6 (see **Figure *1***).

This scenario uses all the other default values, so the user can advance through the 'Demand Input Summary', 'Power Supply' and 'Economics' tabs without any further modification, and advance to the 'Computation' tab.

Results:

Results show that annual costs (annualized purchase and installation + utility costs) would increase for most households, even with the assumption that the equipment is replaced at the end of life. The increase in annual costs is due to two factors: 1) the heat pump is more expensive than the NG water heater, and 2) electricity costs are higher than the savings in natural gas costs, despite the fact that the heat pump is substantially more efficient than the NG water heater. In this particular case, only 19,813 households out of 359,206 (5.5%) would experience savings in annual costs (**Figure *14***). If only utility costs are considered, 23,464 homes (6.5%) would experience savings in utility bills (**Figure *15***).

Figure 14: Analysis of the cost effectiveness space for the replacement of NG storage water heaters with electric heat pump water heaters, using annualized purchase and installation costs and annual utility costs, and considering replacement at the end of useful life

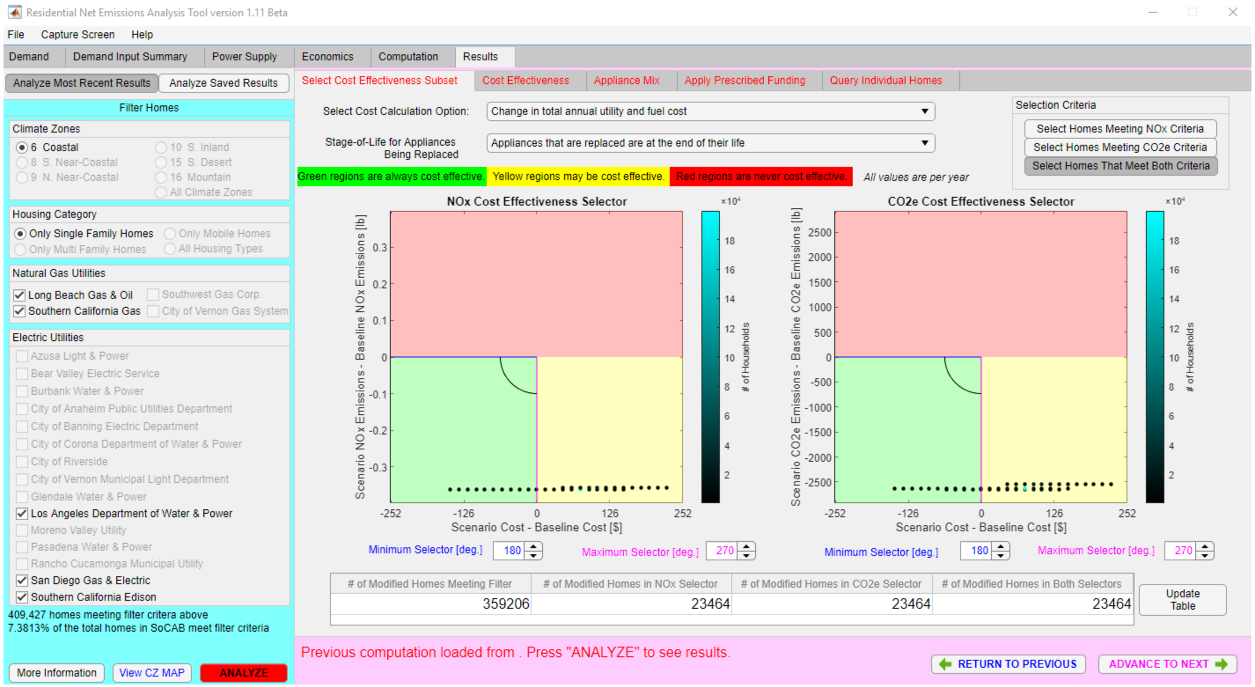

Figure 15: Analysis of the cost effectiveness space for the replacement of NG storage water heaters with electric heat pump water heaters, using annual utility costs only

Considering a funding amount of $1,000,000 and assuming that homeowners can pay for 50% of the cost of the appliance, the amount of funding would pay for 625 retrofits, which would result in emission reductions of 226 lbs/year of NOX and 393 tons/year of CO2e (**Figure *16***). These reductions in emissions due to heat pump water heaters are larger than the emission reductions accomplished by retrofitting water heaters with high-efficiency NG water heaters. However, this appliance retrofit would cause an average increase in annual utility costs of $69.63.

From querying individual homes, results show that the most cost-effective homes are the ones with low-income utility rates. The lower rates for electricity in those households reduce the impact on the electricity bill caused by the increased use of electricity by the new electric appliance (**Figure *17***).

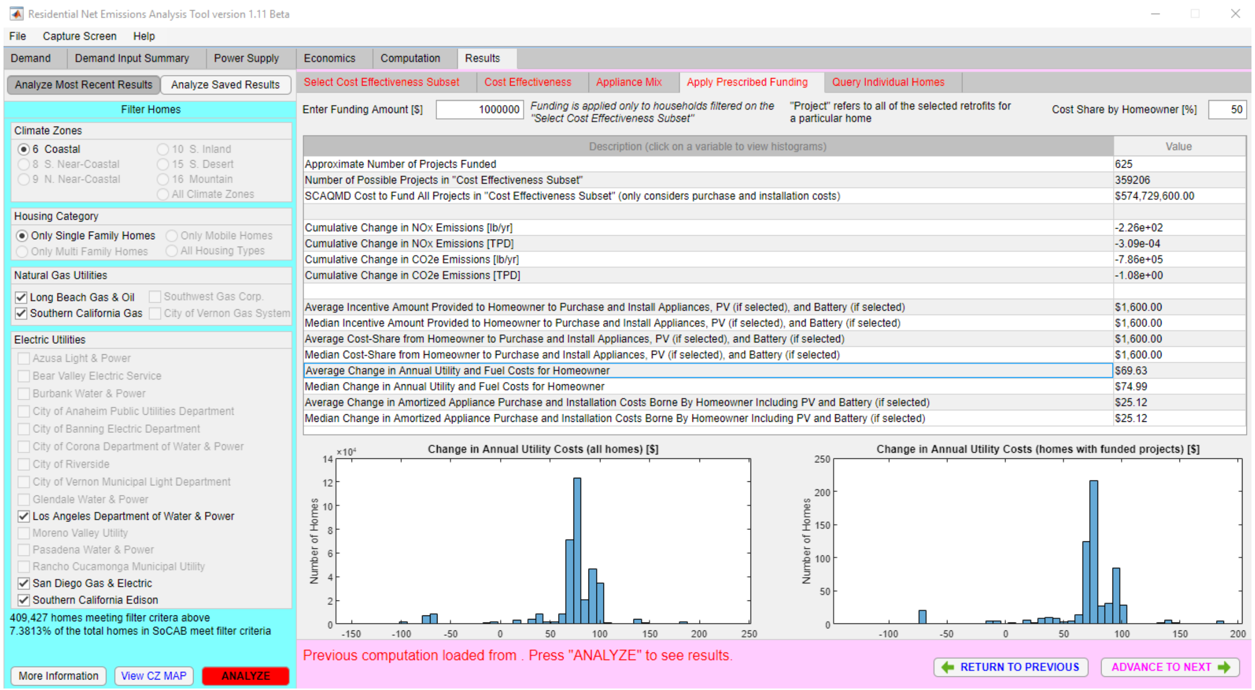

Figure 16: Analysis of prescribed funding and cost-sharing scenarios for Heat Pump Water Heater implementation

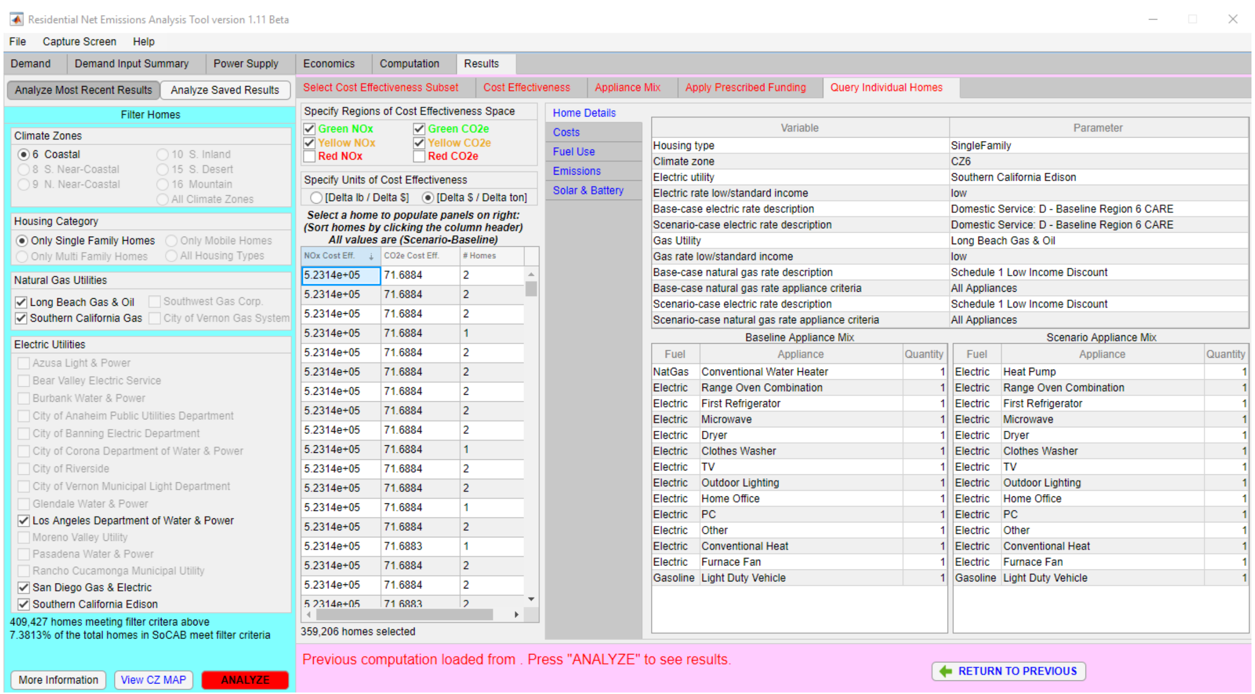

Figure 17: Analyze individual homes details, and how that affect cost effectiveness

Sample Case 3: Electrification of water heating, space heating and clothes dryer, and installation of rooftop solar PV in Single-Family homes in Climate Zone 6

This scenario replaces natural gas appliances for water heating, space heating and clothes drying with electric appliances, and installs rooftop solar PV panels in single-family homes in climate zone 6.

Parameters for scenario:

Storage NG water heaters are replaced with electric heat pump water heaters, natural gas primary heat is replaced by electric heat pump space heater, and NG clothes dryers are replaced with electric clothes dryers. The assumptions for the new technologies are in the tables below:

Table 3: Assumptions in the replacement of water heaters

Tech	UEC	NOX EF	CO2e EF	Unit Cost	Install Cost
NG Conv. Water Heater	199.21 therms	0.0023 lb/th	11.76 lb/th	$647	$1,900
Electric Heat Pump WH	1,105 kWh	--	--	$1,500	$1,700

Table 4: Assumptions in the replacement of space heaters

Tech	UEC	NOX EF	CO2e EF	Unit Cost	Install Cost
NG Primary Heat	184 therms	0.0066 lb/th	11.76 lb/th	$3,089	$1,696
Electric Heat Pump	994 kWh	--	--	$1,972	$3,233

Table 5: Assumptions in the replacement of clothes dryers

Tech	UEC	NOX EF	CO2e EF	Unit Cost	Install Cost
NG Clothes Dryer	26 therms	0.0136 lb/th	11.76 lb/th	$800	$100
Electric Clothes Dryer	719 kWh	--	--	$750	$219

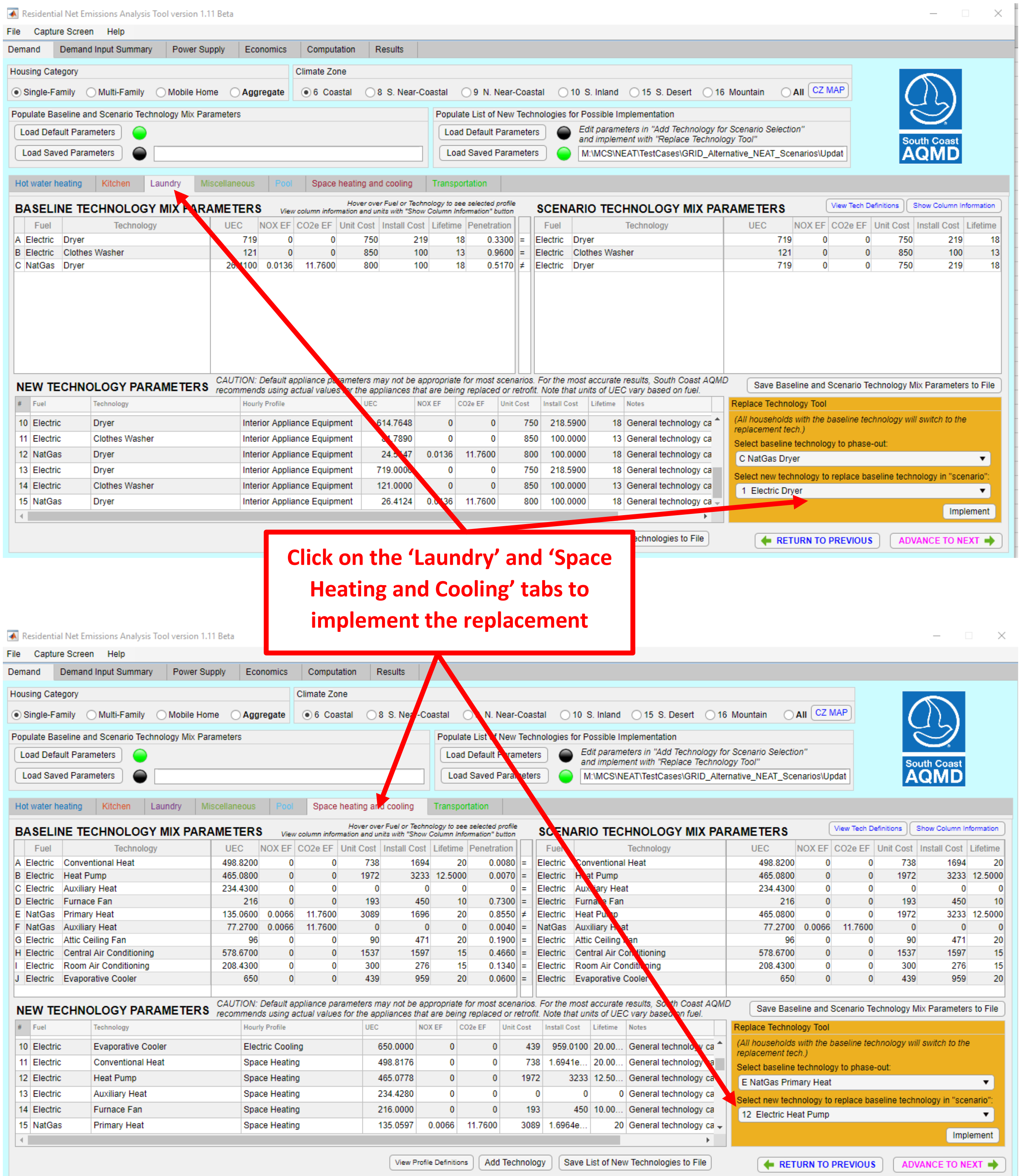

Figure 18: Implement technology replacement for Laundry and Space Heating and Cooling

Once the technology replacements have been selected, the user can confirm that the changes have been implemented in the next screen (**Figure *19***).

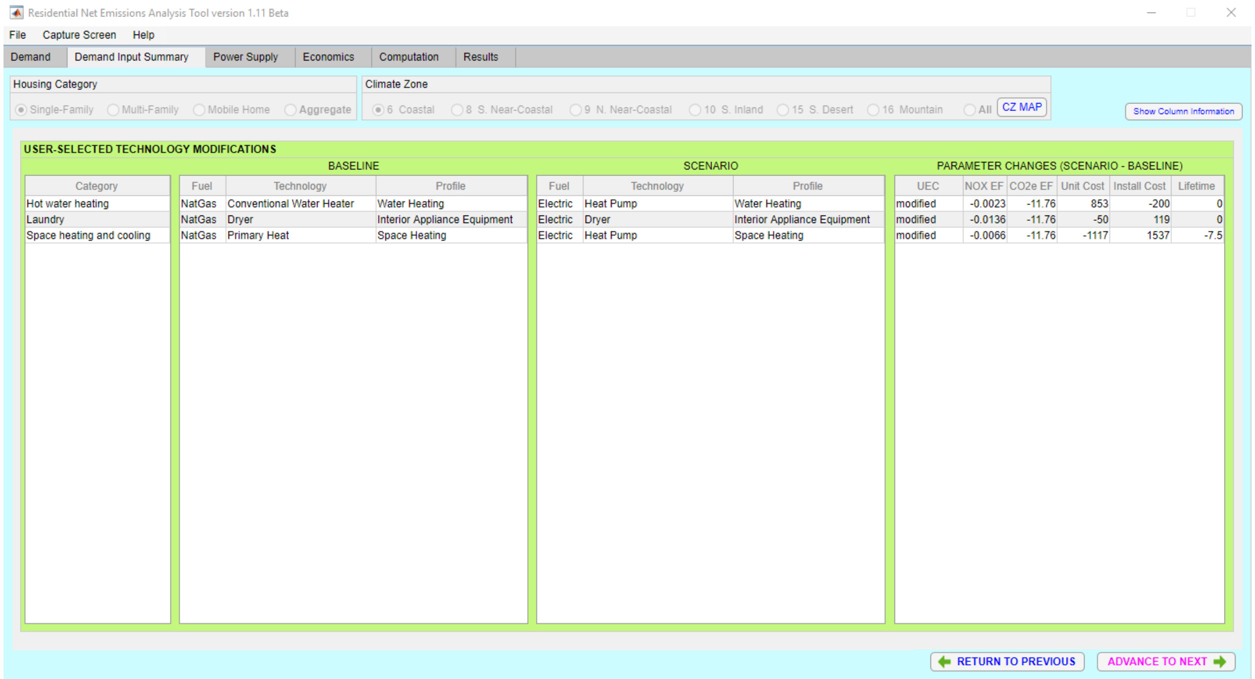

Figure 19: Demand Input Summary for Appliance Replacement Scenario

In the next screen, the user should check the 'Implement Rooftop Solar PV using PVWatts' box. The default set up assumes a cost function that depends on the PV panel size. Users are able to change this function should they find more updated information.

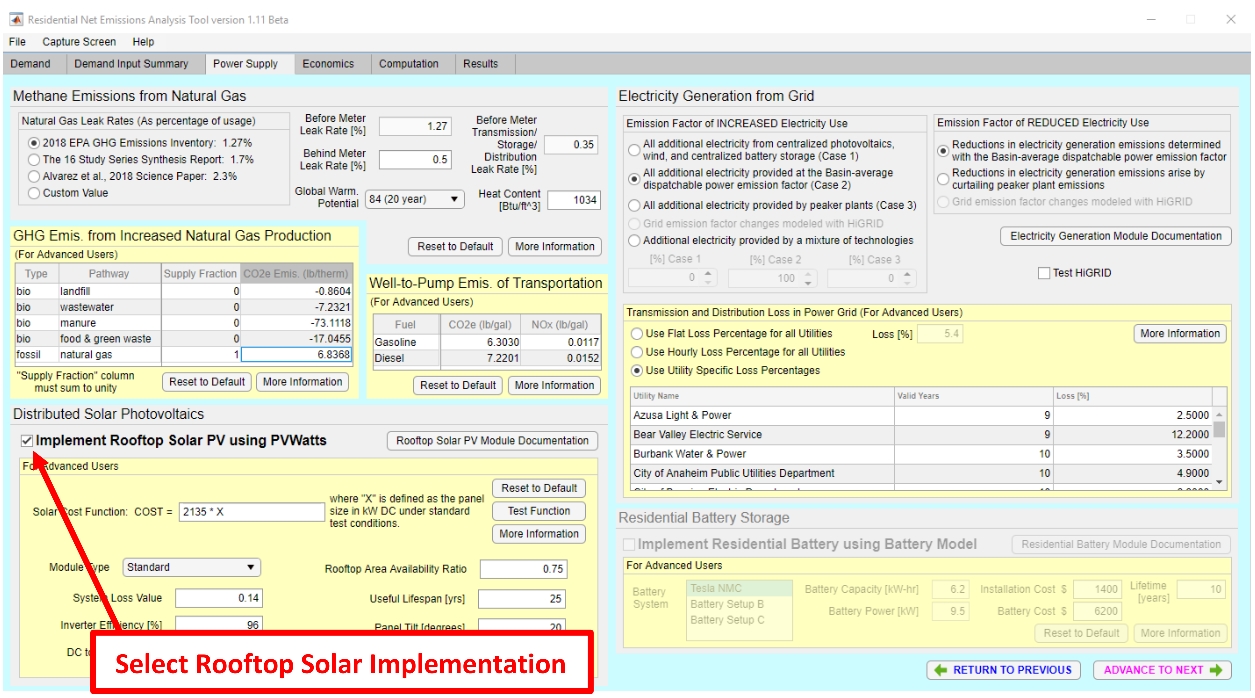

Figure 20: Power Supply Set-up: select 'Implement Rooftop Solar PV using PVWats'

Results:

After the simulation is computed, results for this scenario show that most households fall within the cost-effective quadrant (green region, **Figure *21***). All homes reduce emissions due to the retrofit, and 363,756 homes out of 409,427 (89%) experience reductions in annual costs when replacing equipment at the end of their useful life. Reductions in annual costs occur in most homes despite the cost of installation of solar panels. The reduction in annual costs is due to the savings in electricity costs that rooftop solar PV provides. This scenario is an example how solar PV can enable electrification of homes by providing overall savings to homeowners.

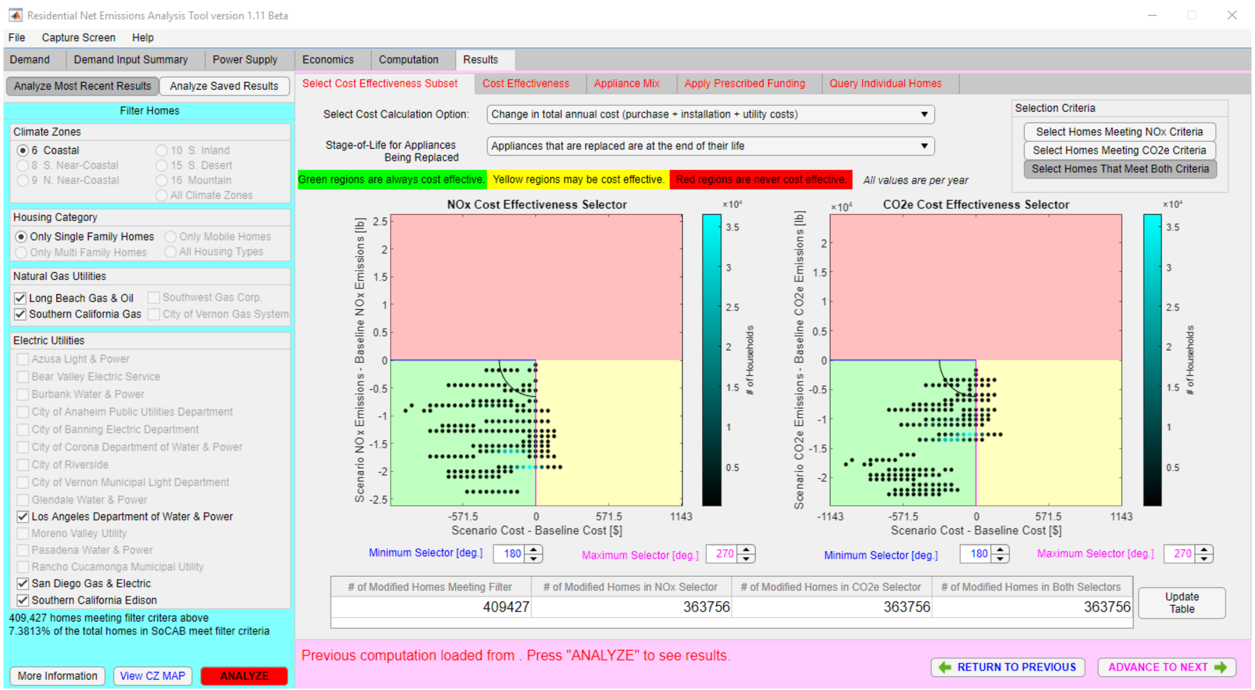

Figure 21: Analysis of the cost effectiveness space for the electrification of water and space heaters and clothes dryers, in conjunction with rooftop solar PV installation.

NEAT analyzes the implementation of appliance retrofits at a regional level, and considers the appliance technology distribution from the 2009 Residential Appliance Saturation Survey (RASS). In this particular scenario, NG appliances are replaced with electric alternatives. NG water heaters are present in 87.7% of all single-family homes, whereas NG space heaters and NG cloth dryers are present in 85.5% and 51.7% of the single-family homes. Results show that the fraction of homes with the three retrofits with resulting cost savings (green quadrant) is 33.9% (**Figure *22***).

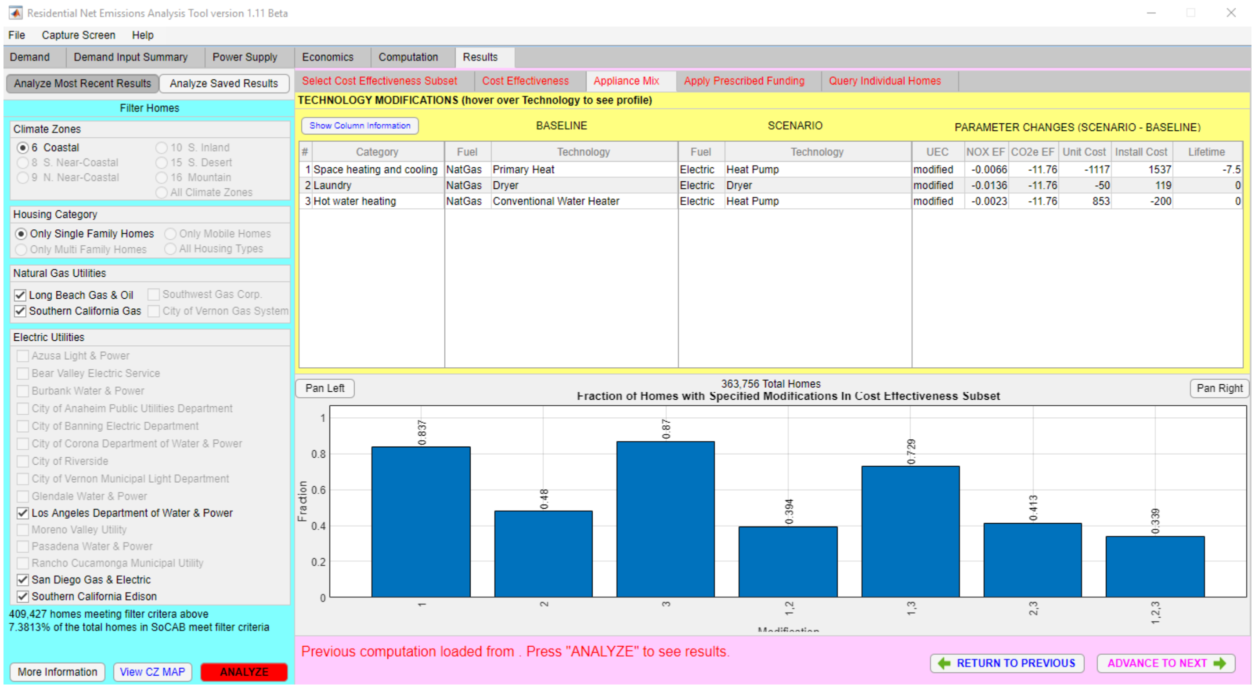

Figure 22: Appliance technology mix in the implementation scenario

User can analyze the potential effects of funding strategies to reduce emissions in the 'Apply Prescribed Funding' tab. Considering a funding amount of $1,000,000 and assuming that homeowners can pay for 50% of the cost of the appliance, the amount of funding would pay for 136 retrofits, which would result in emission reductions of 224 lbs/year of NOX and 750 tons/year of CO2e (**Figure *23***). On average, the annualized cost of the retrofit plus the PV system installation would cost homeowners $237.21 annually, assuming that the equipment is replaced at the end of their useful life. However, the total annual savings in utility costs are estimated to be $676.79 annually, which would result in net savings to homeowners. Because households have varying loads depending on their appliance mix and energy usage, the net savings would vary widely among homes (as shown in the bottom bar plot in **Figure *23***). Some homes could experience utility savings that are below the annual costs, whereas other homes could experience annual savings of up to $1,400, making the retrofit very cost effective.

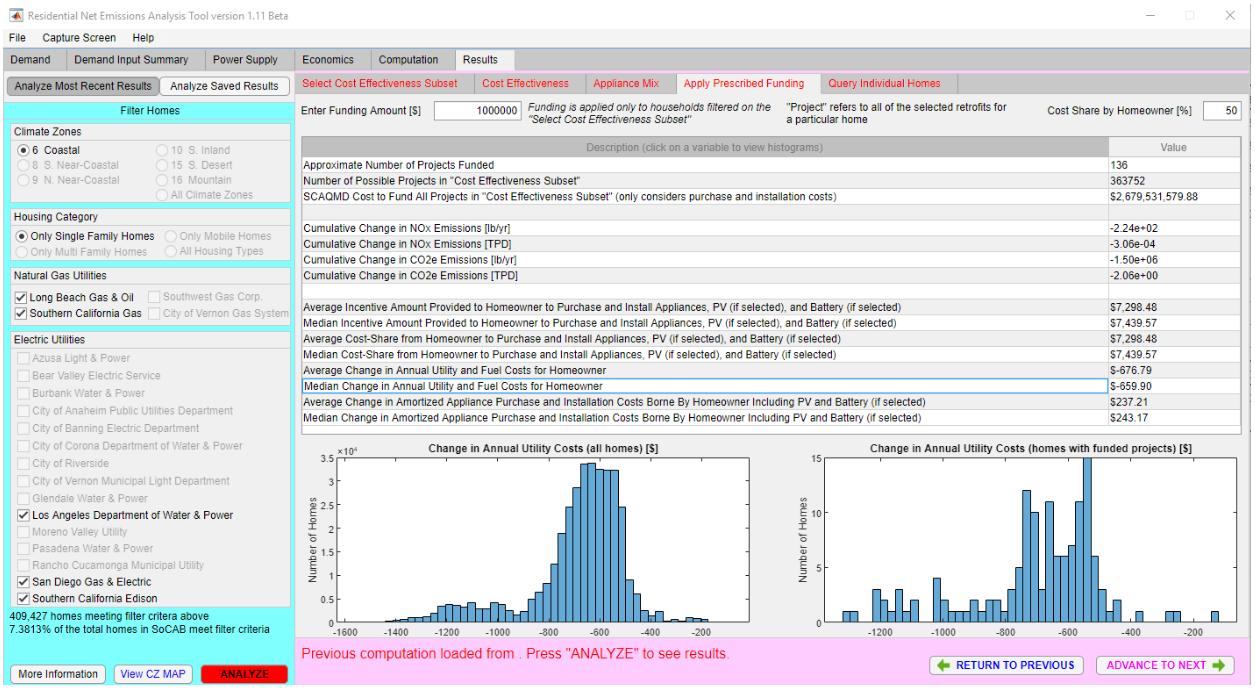

Figure 23: Analysis of prescribed funding and cost-sharing scenarios for electrification scenario with rooftop solar PV

In the 'Query Individual Homes' tab, cost-effectiveness results can be sorted to display the most cost effective homes. In this scenario, the most cost effective homes turn out to be the ones with PV installation and no NG appliance replacement. The most cost effective homes achieve savings of $3.5 million per ton of NOX reduced.

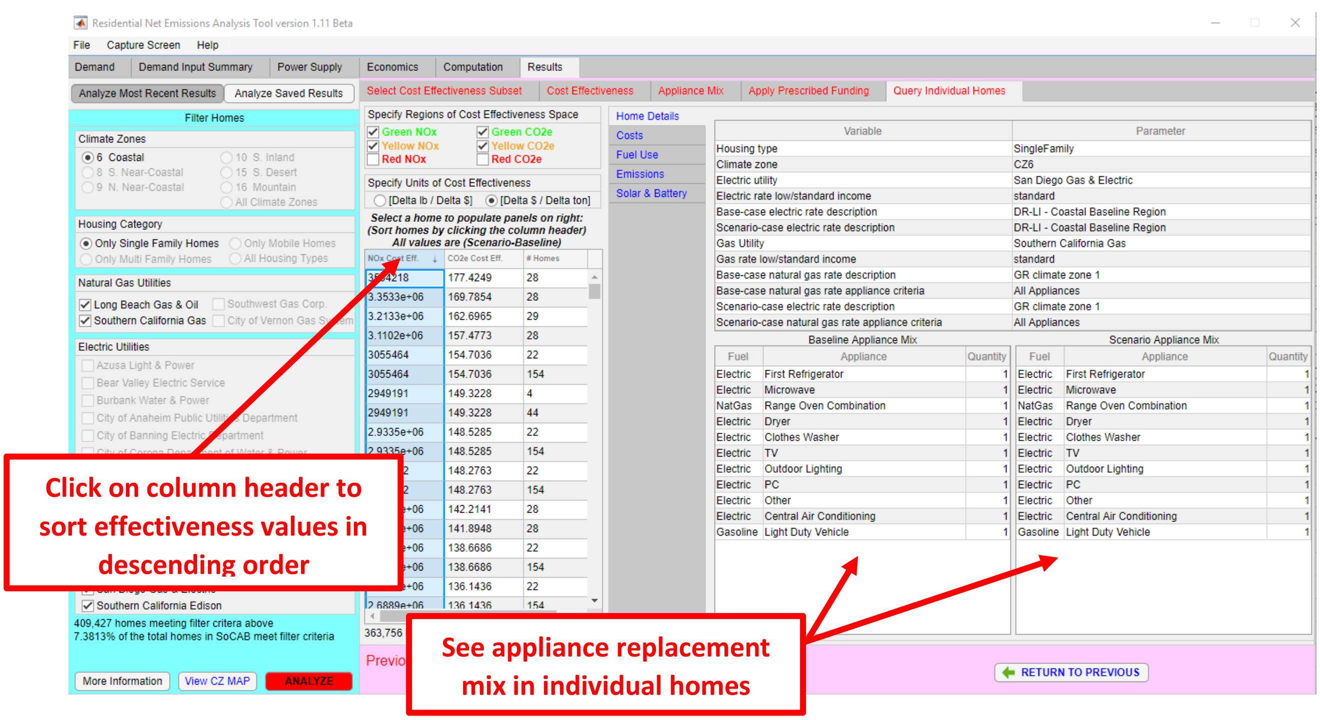

Figure 24: Analyze individual homes details, and how that affect cost effectiveness

Results show that the median size of solar panels installed in this scenario is 3 kW, whereas the most cost effective retrofit corresponds to homes with no NG appliance retrofit and a 1.5 kW solar PV installation (**Figure *25***).

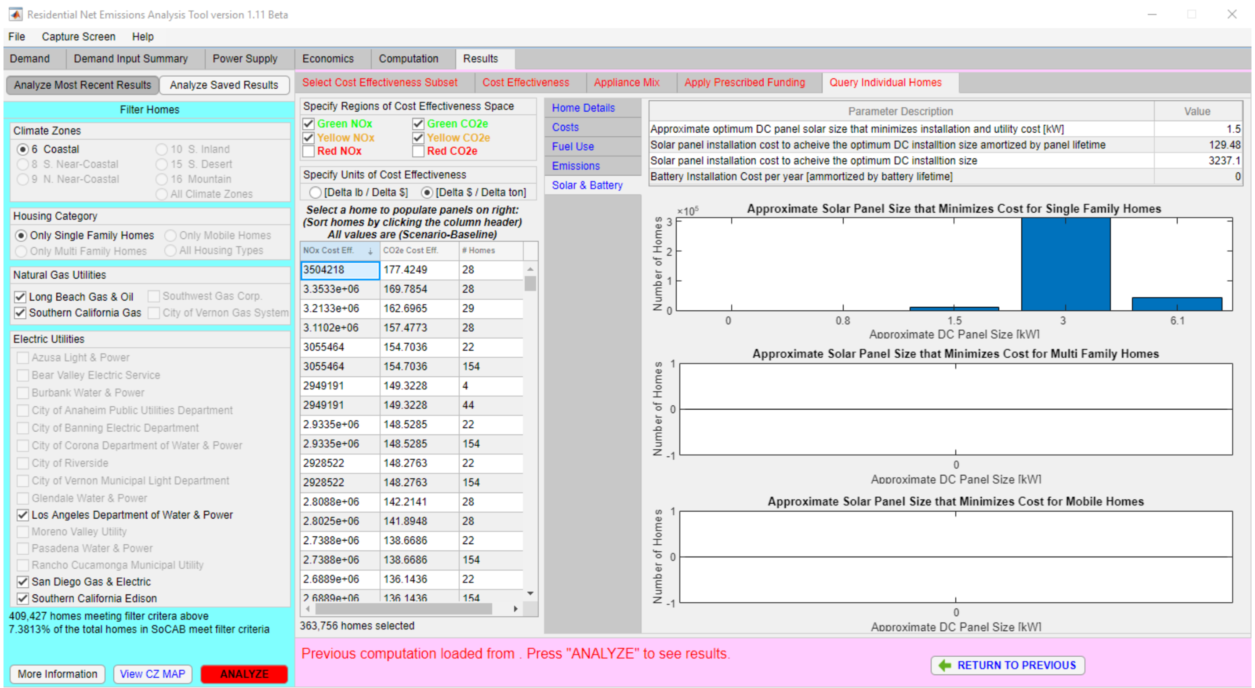

Figure 25: Individual home details showing the optimum size of PV panels

Homes with the three electric appliance retrofits result in cost-effectiveness values of $312K and below (**Figure *26***). The addition of electrical loads for water heating, space heating and clothes drying increases the overall electricity use in the home (**Figure *27***). But the addition of solar panels reduces the net demand of electricity from the grid. For the particular home shown in **Figure *27***, net electricity demand is reduced to zero in the months of June through August, because of the installation of a 6.1 kW system (**Figure *28***).

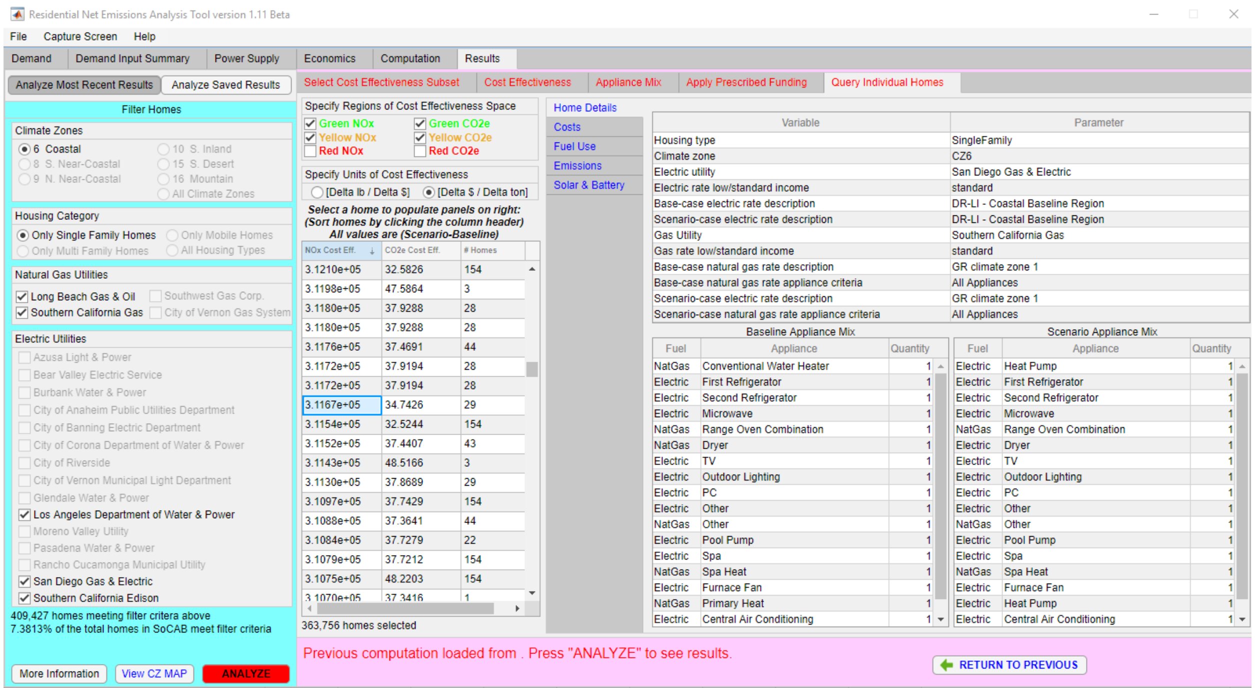

Figure 26: Example of home with the all three appliance retrofits, showing home details

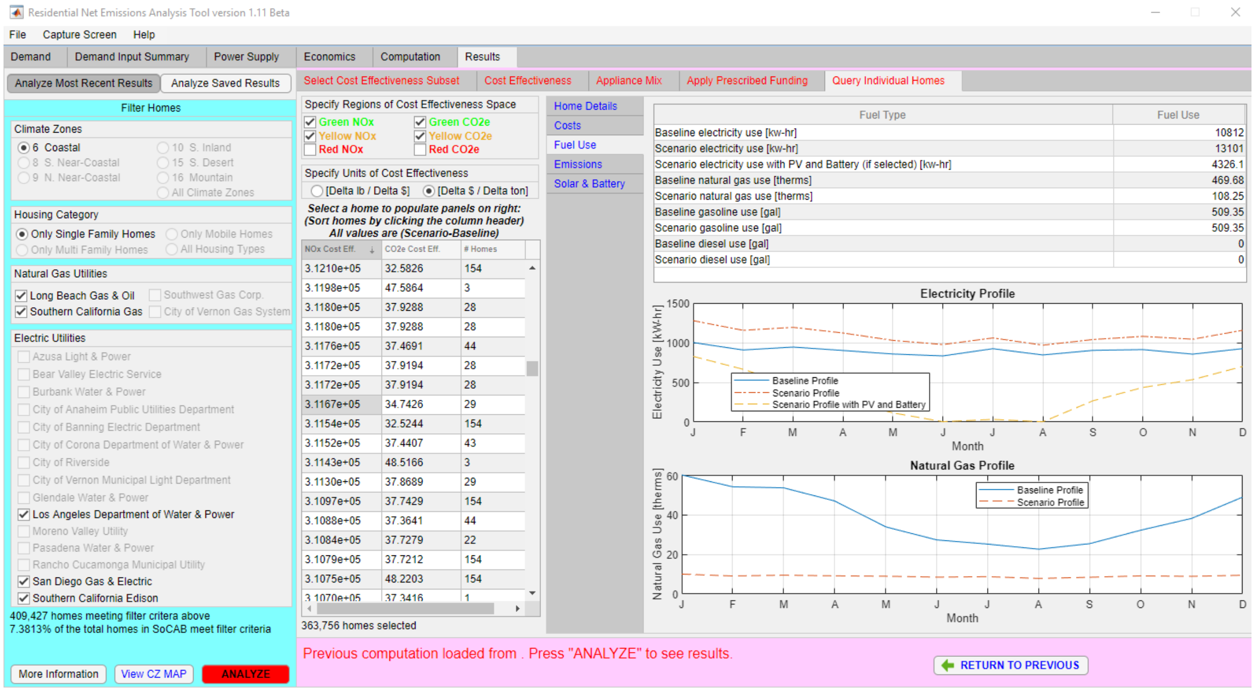

Figure 27: Example of home with the all three appliance retrofits, showing changes in fuel use

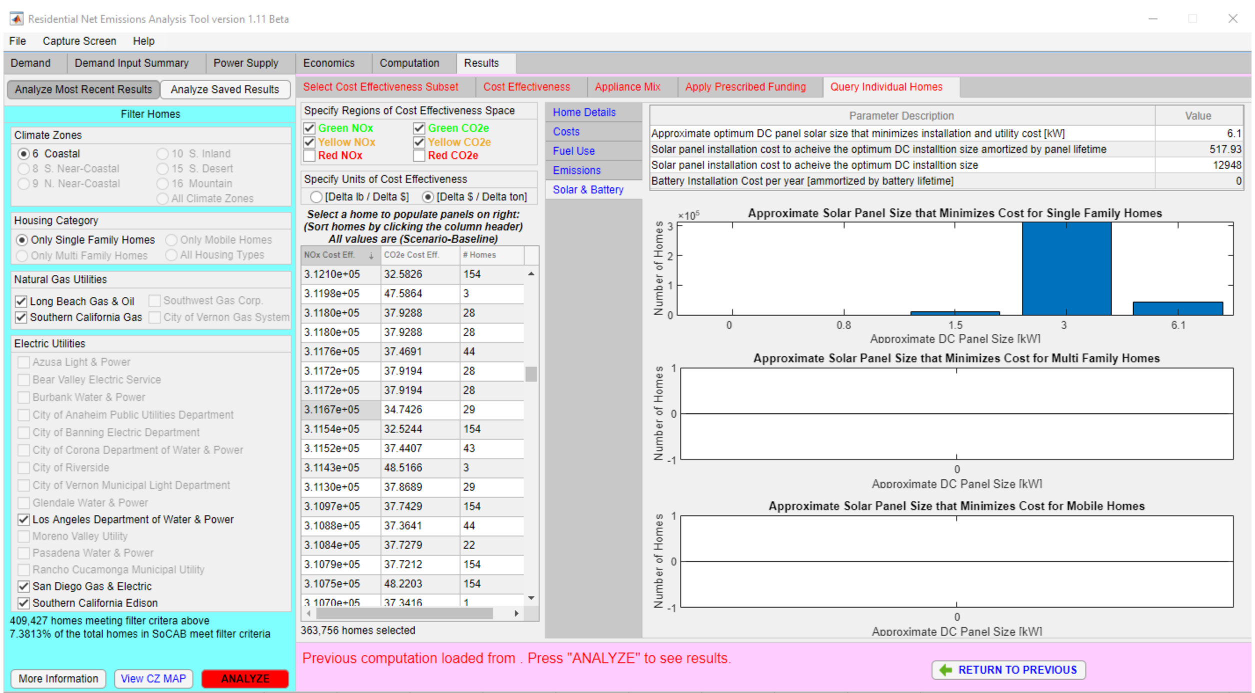

Figure 28: Example of home with the all three appliance retrofits, showing optimum PV panel size