Net Emissions Analysis Tool (NEAT) Working Group

Formally the Residential Commercial Appliance Life Cycle Analysis Working Group

Meeting #2
Nov 16, 2017

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Marc Carreras-Sospedra Ph.D.

South Coast
Air Quality Management District

Outline

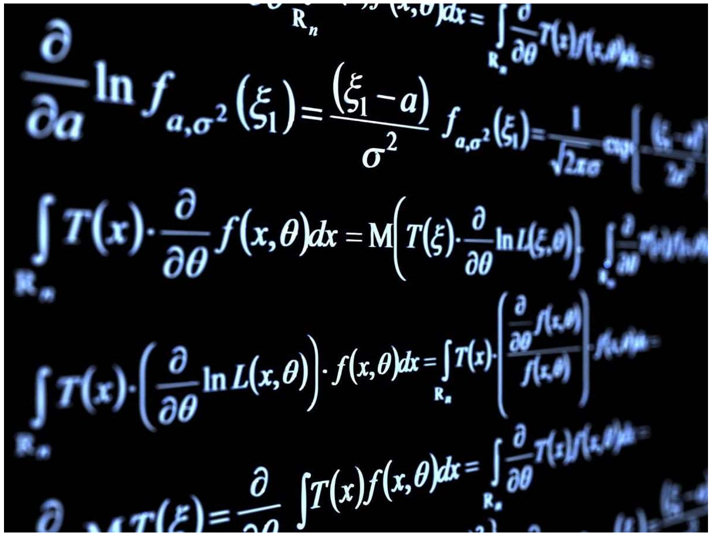
1. Project Objectives
2. The role of the NEAT workgroup
3. Development progress
4. Overview of “Demand” segment of the Residential NEAT
5. Overview of the Residential solar PV calculator module
6. Topics for open discussion
7. Public comments

Project Objectives

- Develop an analytical software tool that will help to evaluate the most cost-effective strategies for NOx and GHG emission reductions from the commercial and residential sector.
- The ideal characteristics of the tool:
  - Comprehensive, yet user-friendly for general-public
  - Level of complexity determined by the user
  - Intuitive workflow with extensive documentation embedded into the software

The Role of the NEAT Workgroup

- Bring to light applicable data from peer-reviewed or government studies
- Ensure that assumptions and methodologies are scientifically valid and appropriate
- Help maximize tool usability
- *Policy discussions are most appropriate after the model development phase*



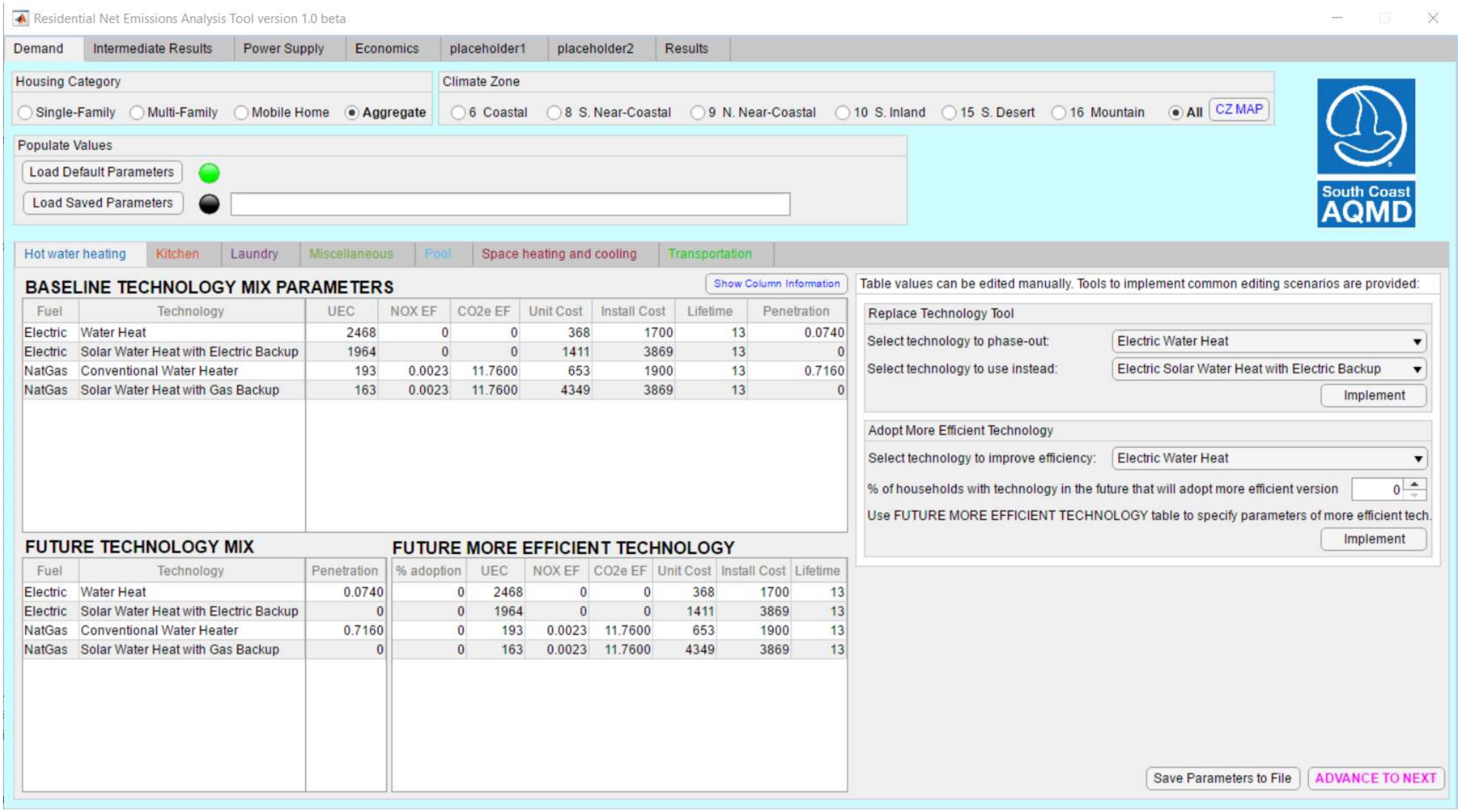
Development Progress

Residential NEAT	Not Yet Started	In Progress	Draft Complete
Building of tool framework (GUI, file I/O)			X
Collection of input data			X
Demand segment of tool			X
Implementation of distributed solar			X
Implementation of distributed battery storage			X
Electric Rate Calculator			X
Natural Gas Rate Calculator		X	
Implementation of net metering	X		
Solar and battery cost calculator			X
Electric generation emission factors		X	
Gas leak and electricity transportation loss	X		

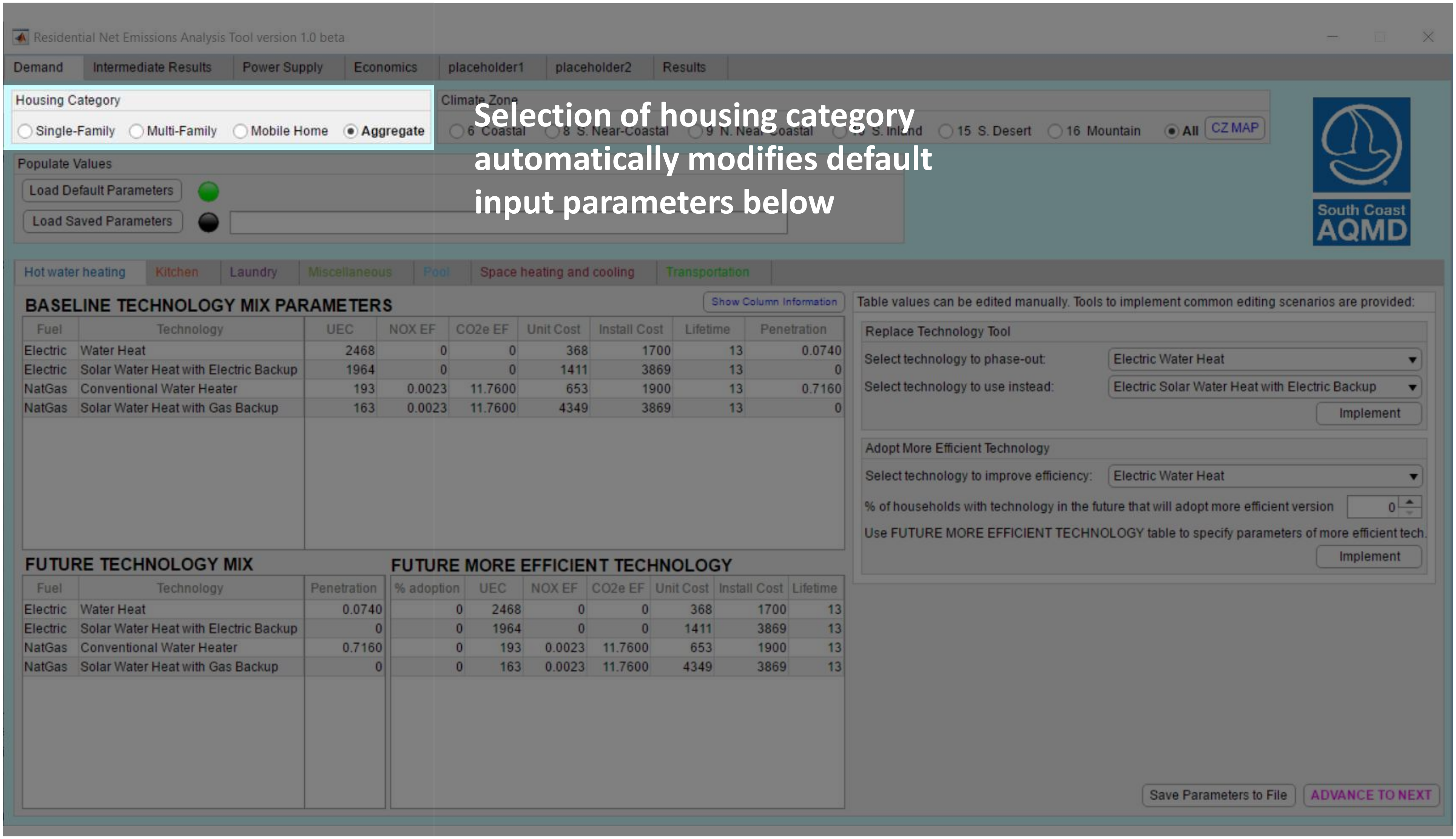
Topics for Today's Meeting

Residential NEAT	Not Yet Started	In Progress	Draft Complete
Building of tool framework (GUI, file I/O)			**X**
Collection of input data			**X**
Demand segment of tool			**X**
Implementation of distributed solar			**X**
Implementation of distributed battery storage			X
Electric Rate Calculator			X
Natural Gas Rate Calculator		X	
Implementation of net metering	X		
Solar and battery cost calculator			X
Electric generation emission factors		X	
Gas leak and electricity transportation loss	X		

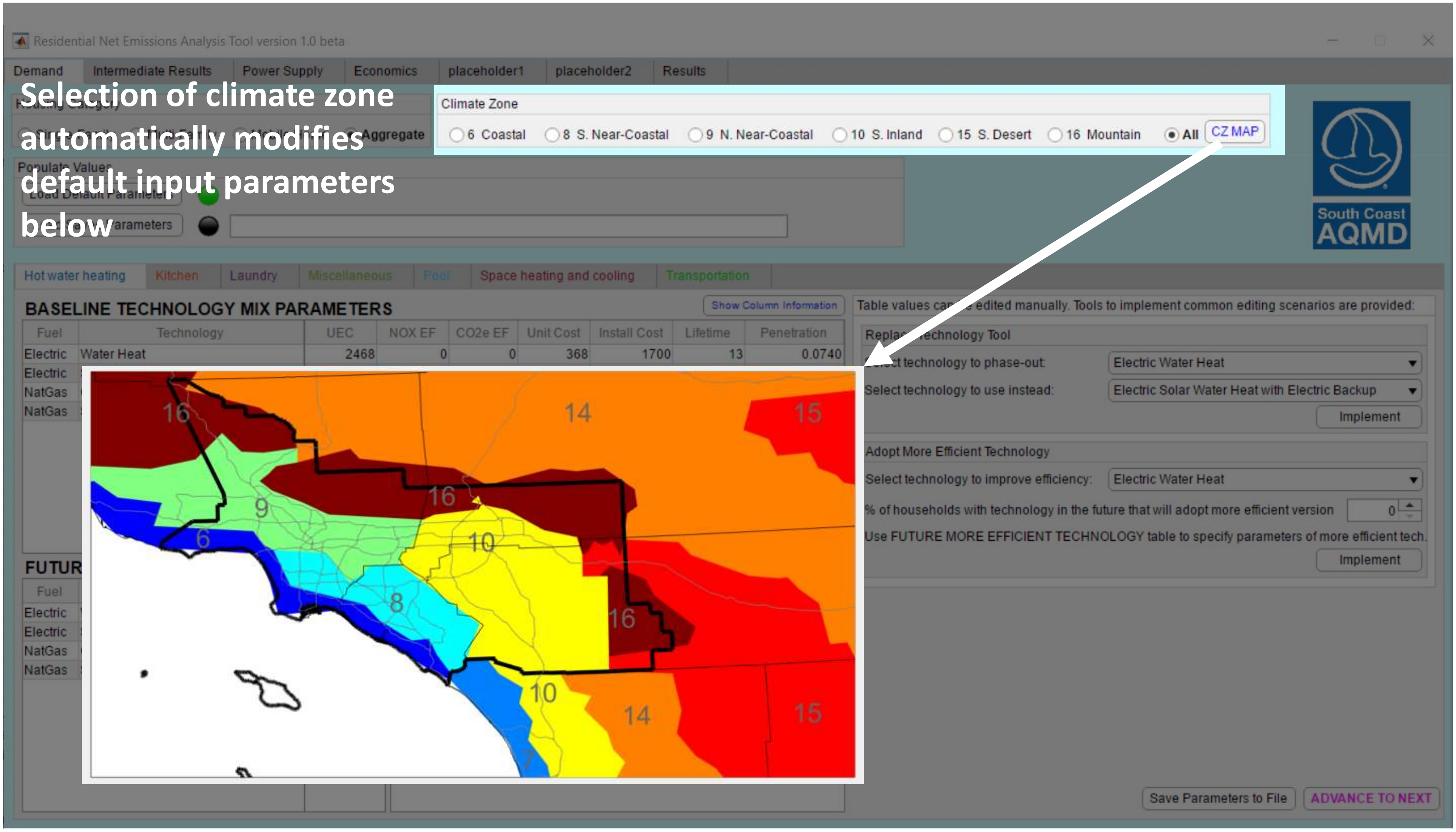
Demand Module Design



Demand Module Design



Demand Module Design



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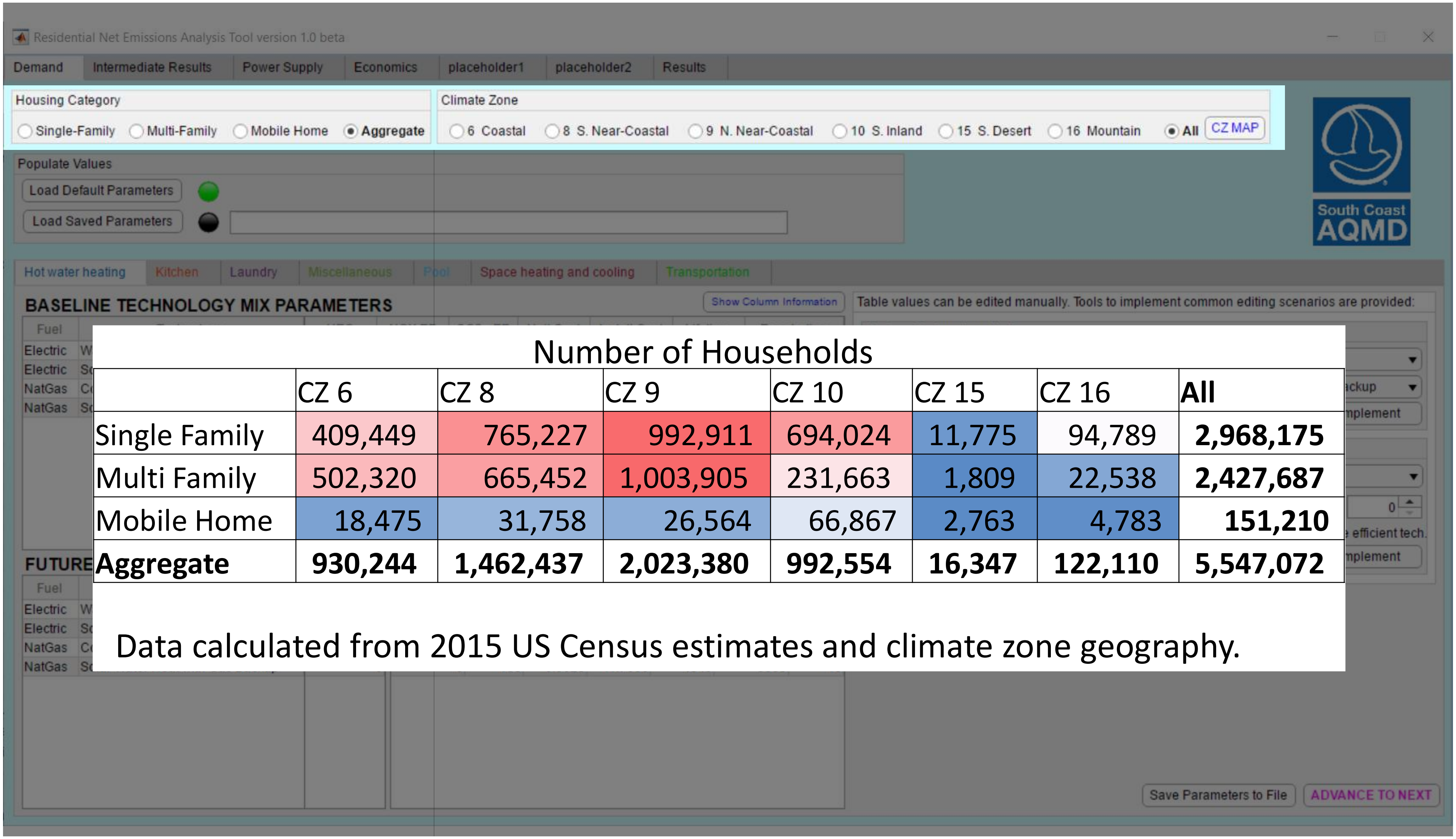
Demand Module Design

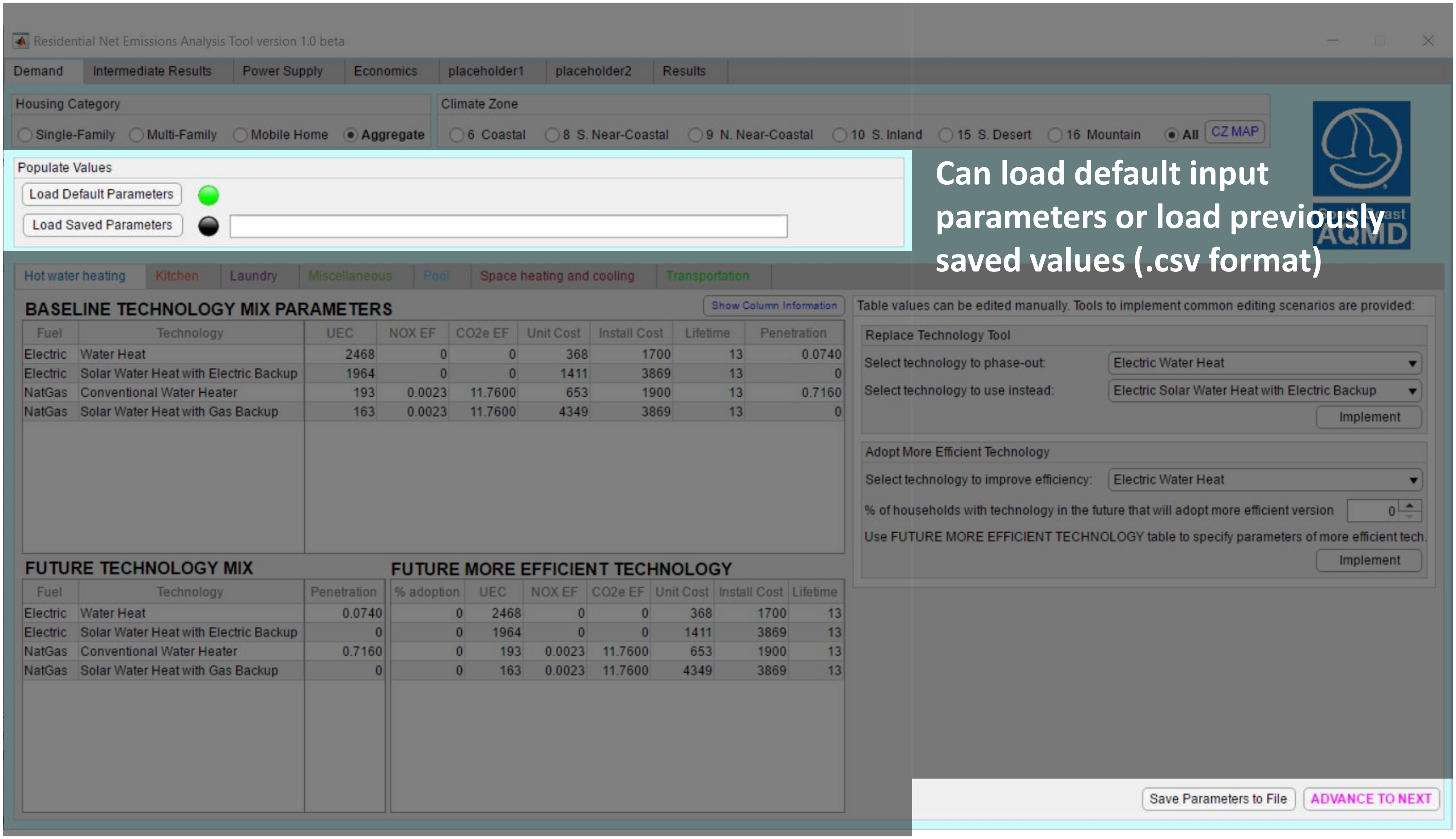


Number of Households

	CZ 6	CZ 8	CZ 9	CZ 10	CZ 15	CZ 16	**All**
Single Family	409,449	765,227	992,911	694,024	11,775	94,789	**2,968,175**
Multi Family	502,320	665,452	1,003,905	231,663	1,809	22,538	**2,427,687**
Mobile Home	18,475	31,758	26,564	66,867	2,763	4,783	**151,210**
Aggregate	**930,244**	**1,462,437**	**2,023,380**	**992,554**	**16,347**	**122,110**	**5,547,072**

Data calculated from 2015 US Census estimates and climate zone geography.

Demand Module Design



Can load default input parameters or load previously saved values (.csv format)

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Demand Module Input Parameters

	Definition	Units	Source
UEC	Units of energy consumption	kWh/year for electric therms/year for NG gal/year for gasoline, diesel	CEC RASS 2009 for appliances EMFAC 2014 analysis for vehicles
NOX EF	Point of Use NOx emission factor	lb/therm for NG lb/gal for gasoline, diesel	AQMD Rule 1121, 1111, 1147 AP-42 from EPA, CEC funded LBNL study, BAAQMD methodology
CO2e EF	Point of Use CO2e emission factor	lb/therm for NG lb/gal for gasoline, diesel	AP-42 from EPA

Demand Module Input Parameters

	Definition	Units	Source
Unit Cost	Cost to purchase appliance	$	Appliances: Consumer Reports, Amazon, Sears, Home Depot, 4—350 quotes per appliance Vehicles: weighted average calculated with fuel economy.gov, insideevs.com, hybridcars.com, goodcarbadcar.net
Install Cost	Cost to install appliance	$	Appliances: Homeadvisor.com, home.costhelper.com, homewyse.com
Lifetime	Appliance lifetime	years	Appliances: epa.gov, nachi.org Vehicles: CARB EMFAC survival rates
Penetration	Fraction of households with specific technology	unitless	Appliances: CEC RAAS 2009 Vehicles: CARB EMFAC

Demand Module Input Parameters

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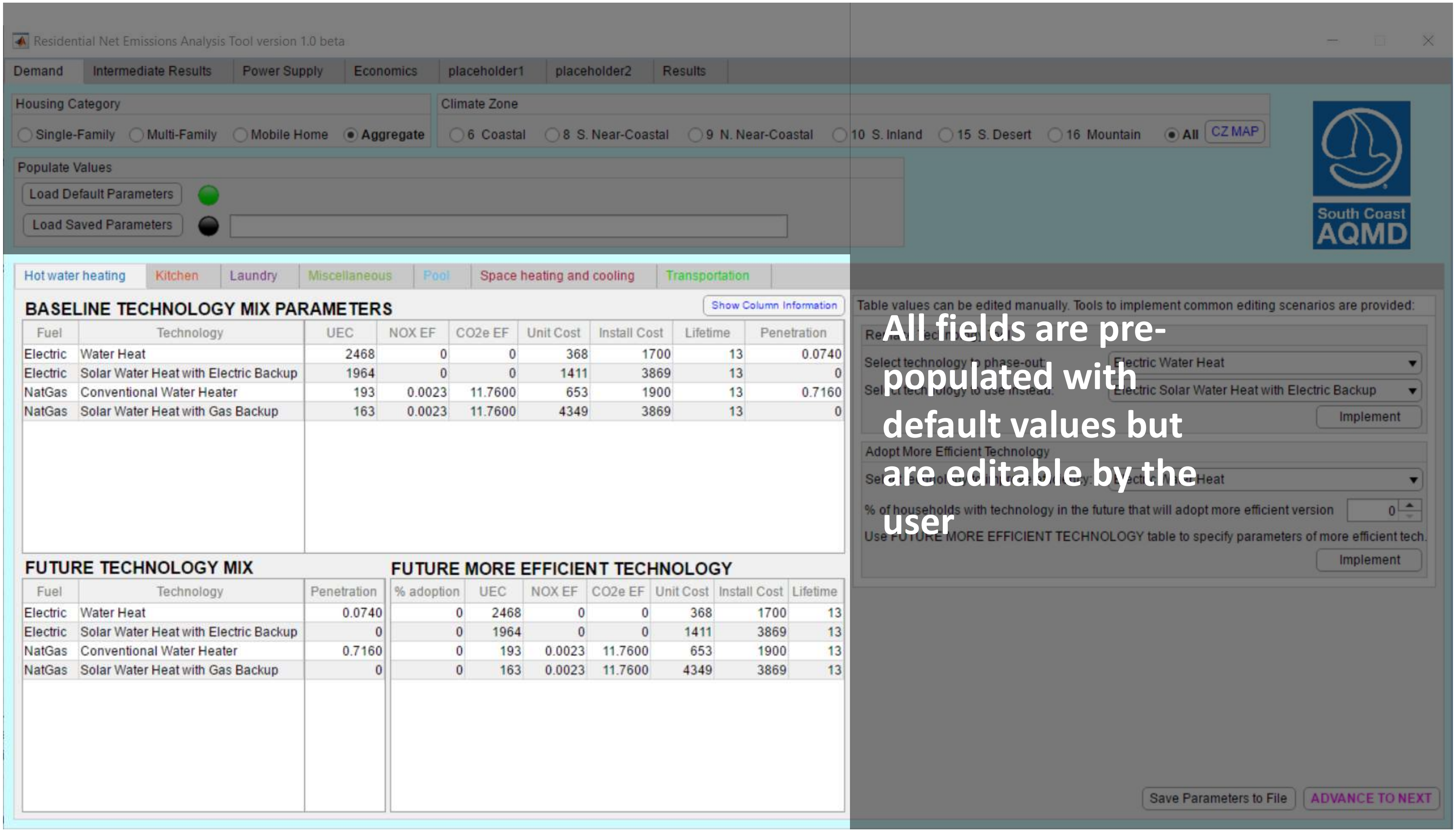
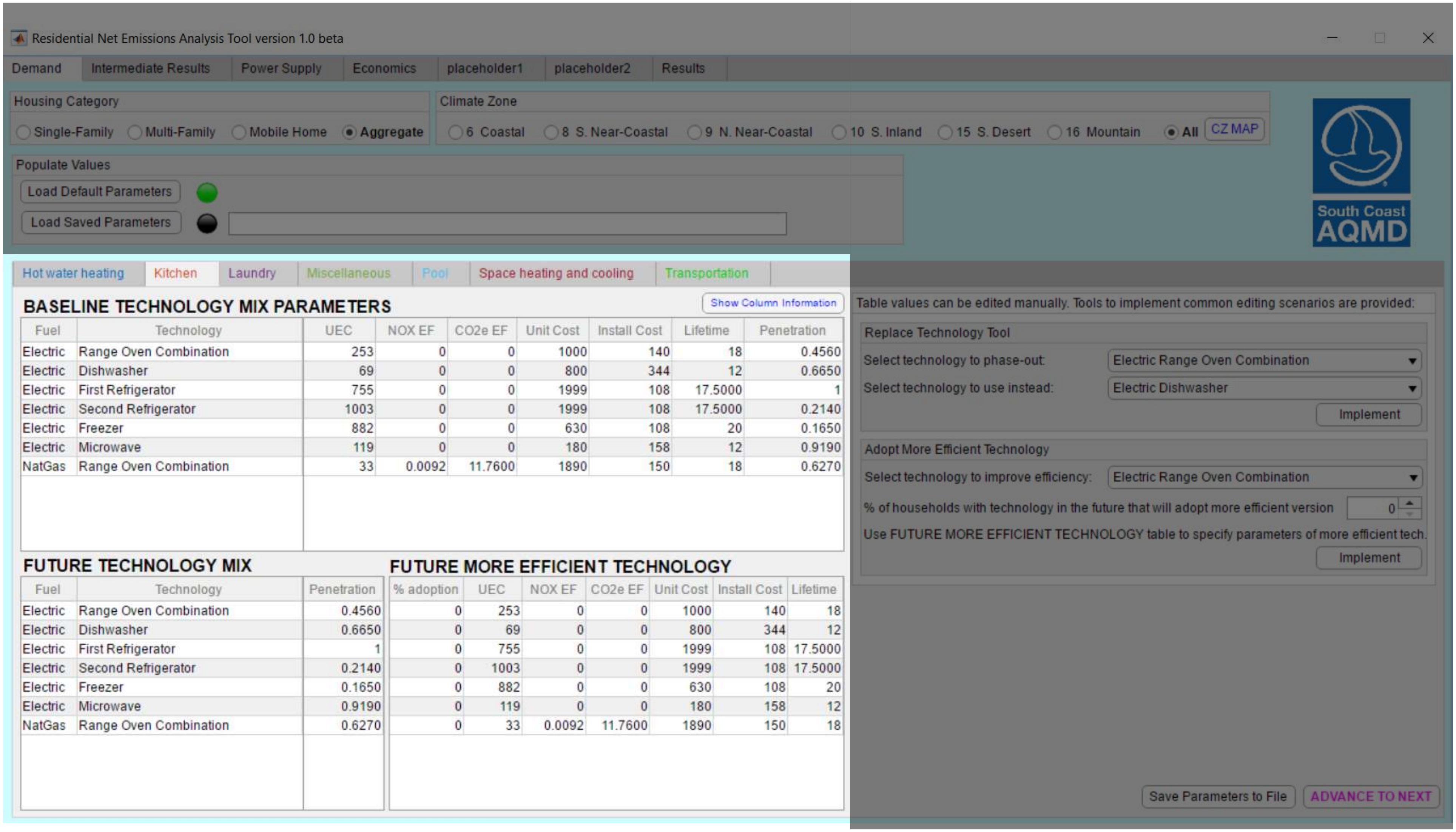
Lifetime	Appliance lifetime	years	Appliances: epa.gov, nachi.org Vehicles: CARB EMFAC survival rates
Penetration	Fraction of households with specific technology	unitless	Appliances: CEC RAAS 2009 Vehicles: CARB EMFAC
% Adoption	Fraction of households with new/more efficient technology	unitless	Defined by user based on scenario

Hot water heating



All fields are pre-populated with default values but are editable by the user

Kitchen


Residential Net Emissions Analysis Tool version 1.0 beta
Demand
Intermediate Results
Power Supply
Economics
placeholder1
placeholder2
Results
Housing Category
Single-Family
Multi-Family
Mobile Home
Aggregate
Climate Zone
6 Coastal
8 S. Near-Coastal
9 N. Near-Coastal
10 S. Inland
15 S. Desert
16 Mountain
All
CZ MAP
Populate Values
Load Default Parameters
Load Saved Parameters
South Coast AQMD
Hot water heating
Kitchen
Laundry
Miscellaneous
Pool
Space heating and cooling
Transportation
BASELINE TECHNOLOGY MIX PARAMETERS
Show Column Information
Fuel | Technology | UEC | NOX EF | CO2e EF | Unit Cost | Install Cost | Lifetime | Penetration
Electric | Range Oven Combination | 253 | 0 | 0 | 1000 | 140 | 18 | 0.4560
Electric | Dishwasher | 69 | 0 | 0 | 800 | 344 | 12 | 0.6650
Electric | First Refrigerator | 755 | 0 | 0 | 1999 | 108 | 17.5000 | 1
Electric | Second Refrigerator | 1003 | 0 | 0 | 1999 | 108 | 17.5000 | 0.2140
Electric | Freezer | 882 | 0 | 0 | 630 | 108 | 20 | 0.1650
Electric | Microwave | 119 | 0 | 0 | 180 | 158 | 12 | 0.9190
NatGas | Range Oven Combination | 33 | 0.0092 | 11.7600 | 1890 | 150 | 18 | 0.6270
FUTURE TECHNOLOGY MIX
Fuel | Technology | Penetration
Electric | Range Oven Combination | 0.4560
Electric | Dishwasher | 0.6650
Electric | First Refrigerator | 1
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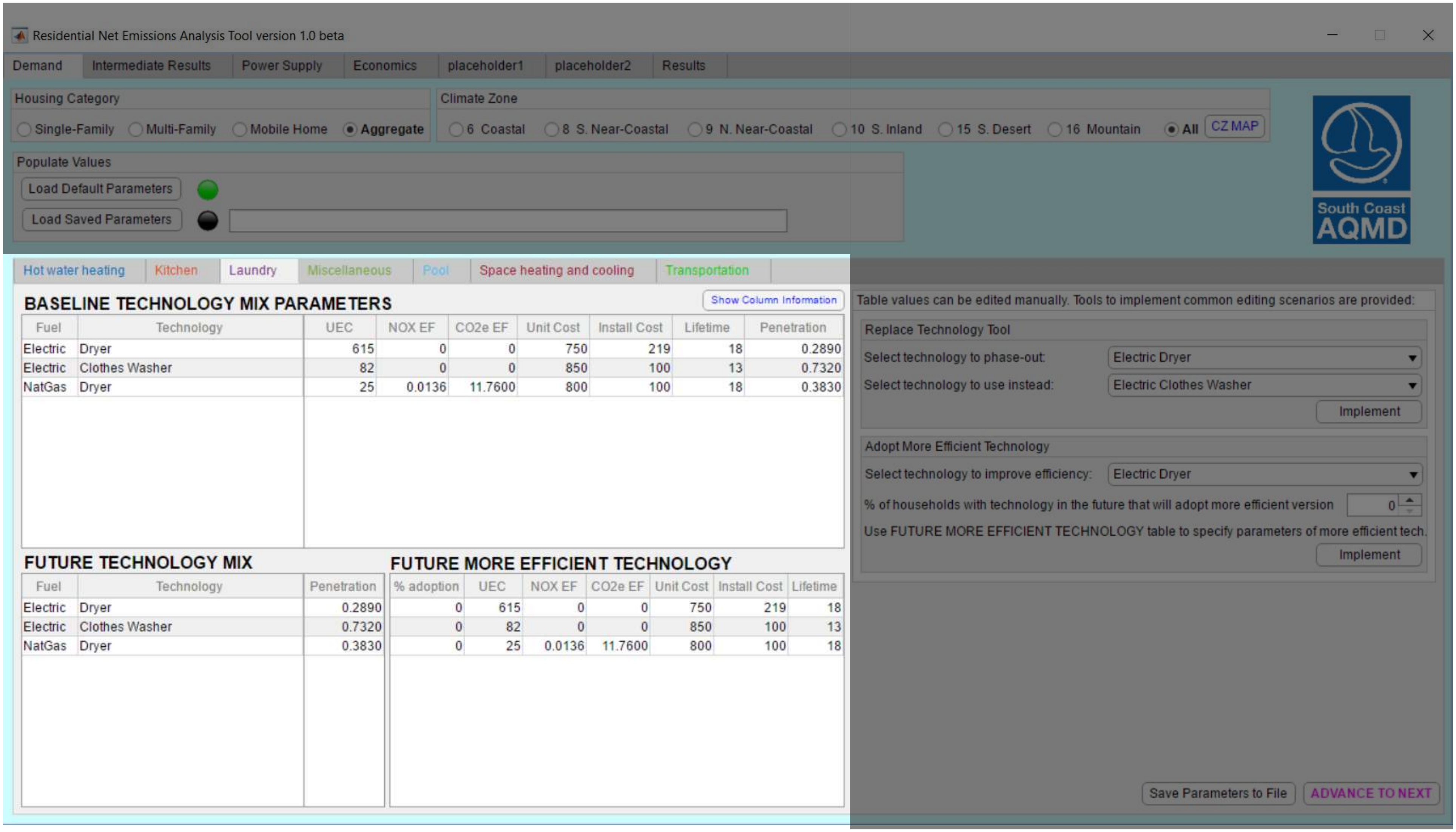
FUTURE MORE EFFICIENT TECHNOLOGY
% adoption | UEC | NOX EF | CO2e EF | Unit Cost | Install Cost | Lifetime
0 | 253 | 0 | 0 | 1000 | 140 | 18
0 | 69 | 0 | 0 | 800 | 344 | 12
0 | 755 | 0 | 0 | 1999 | 108 | 17.5000
0 | 1003 | 0 | 0 | 1999 | 108 | 17.5000
0 | 882 | 0 | 0 | 630 | 108 | 20
0 | 119 | 0 | 0 | 180 | 158 | 12
0 | 33 | 0.0092 | 11.7600 | 1890 | 150 | 18
Table values can be edited manually. Tools to implement common editing scenarios are provided:
Replace Technology Tool
Select technology to phase-out: Electric Range Oven Combination
Select technology to use instead: Electric Dishwasher
Implement
Adopt More Efficient Technology
Select technology to improve efficiency: Electric Range Oven Combination
% of households with technology in the future that will adopt more efficient version 0
Use FUTURE MORE EFFICIENT TECHNOLOGY table to specify parameters of more efficient tech.
Implement
Save Parameters to File
ADVANCE TO NEXT

Laundry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South Coast AQMD
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Load Default Parameters
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Transportation
BASELINE TECHNOLOGY MIX PARAMETERS
Show Column Information
Fuel | Technology | UEC | NOX EF | CO2e EF | Unit Cost | Install Cost | Lifetime | Penetration
Electric | Dryer | 615 | 0 | 0 | 750 | 219 | 18 | 0.2890
Electric | Clothes Washer | 82 | 0 | 0 | 850 | 100 | 13 | 0.7320
NatGas | Dryer | 25 | 0.0136 | 11.7600 | 800 | 100 | 18 | 0.3830
FUTURE TECHNOLOGY MIX
Fuel | Technology | Penetration
Electric | Dryer | 0.2890
Electric | Clothes Washer | 0.7320
NatGas | Dryer | 0.3830
FUTURE MORE EFFICIENT TECHNOLOGY
% adoption | UEC | NOX EF | CO2e EF | Unit Cost | Install Cost | Lifetime
0 | 615 | 0 | 0 | 750 | 219 | 18
0 | 82 | 0 | 0 | 850 | 100 | 13
0 | 25 | 0.0136 | 11.7600 | 800 | 100 | 18
Table values can be edited manually. Tools to implement common editing scenarios are provided:
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Select technology to phase-out: Electric Dryer
Select technology to use instead: Electric Clothes Washer
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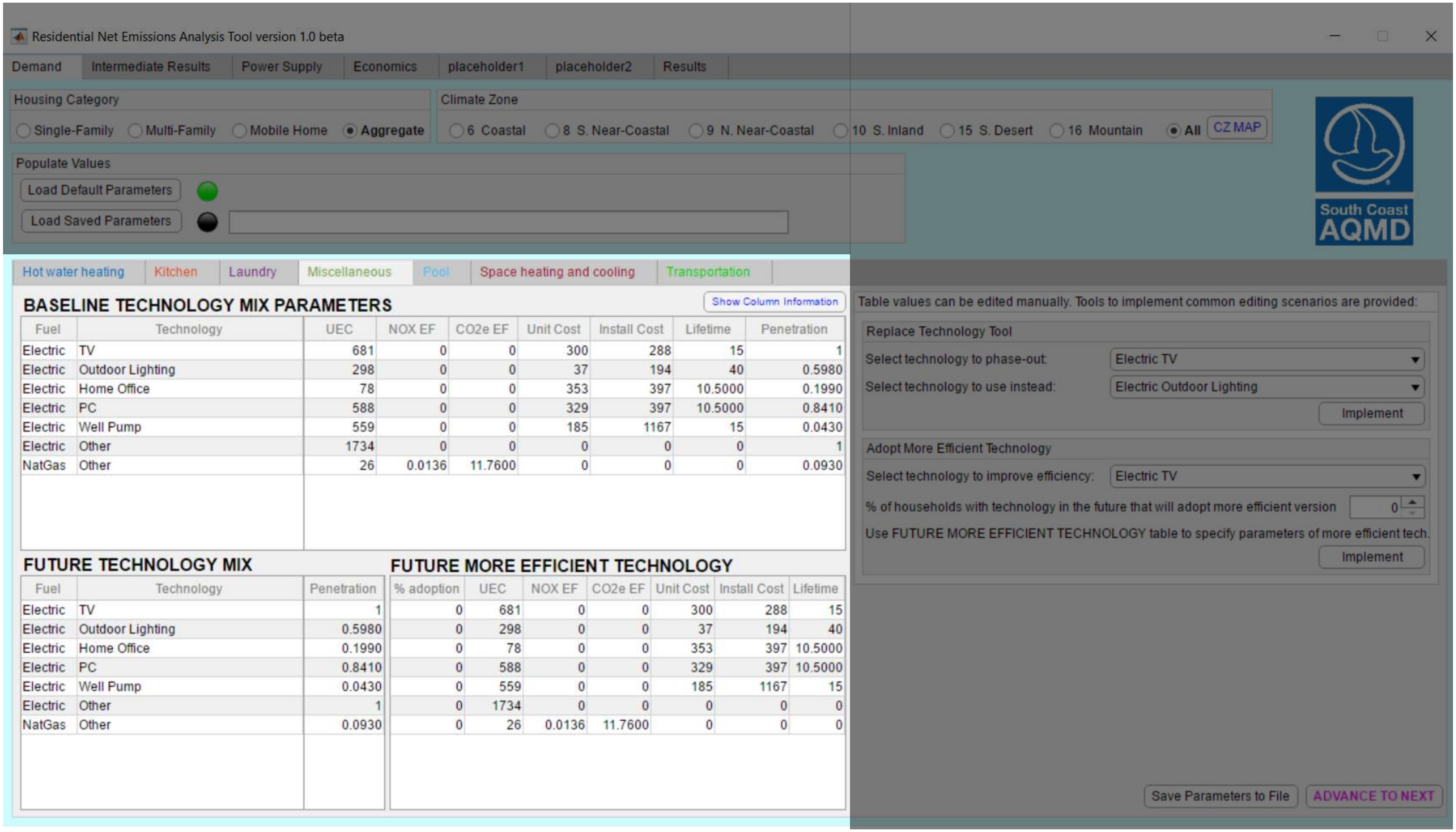
Adopt More Efficient Technology
Select technology to improve efficiency: Electric Dryer
% of households with technology in the future that will adopt more efficient version 0
Use FUTURE MORE EFFICIENT TECHNOLOGY table to specify parameters of more efficient tech.
Implement
Save Parameters to File
ADVANCE TO NEXT

Miscellaneous



BASELINE TECHNOLOGY MIX PARAMETERS

Fuel	Technology	UEC	NOX EF	CO2e EF	Unit Cost	Install Cost	Lifetime	Penetration
Electric	TV	681	0	0	300	288	15	1
Electric	Outdoor Lighting	298	0	0	37	194	40	0.5980
Electric	Home Office	78	0	0	353	397	10.5000	0.1990
Electric	PC	588	0	0	329	397	10.5000	0.8410
Electric	Well Pump	559	0	0	185	1167	15	0.0430
Electric	Other	1734	0	0	0	0	0	1
NatGas	Other	26	0.0136	11.7600	0	0	0	0.0930

FUTURE TECHNOLOGY MIX

Fuel	Technology	Penetration
Electric	TV	1
Electric	Outdoor Lighting	0.5980
Electric	Home Office	0.1990
Electric	PC	0.8410
Electric	Well Pump	0.0430
Electric	Other	1
NatGas	Other	0.0930

FUTURE MORE EFFICIENT TECHNOLOGY

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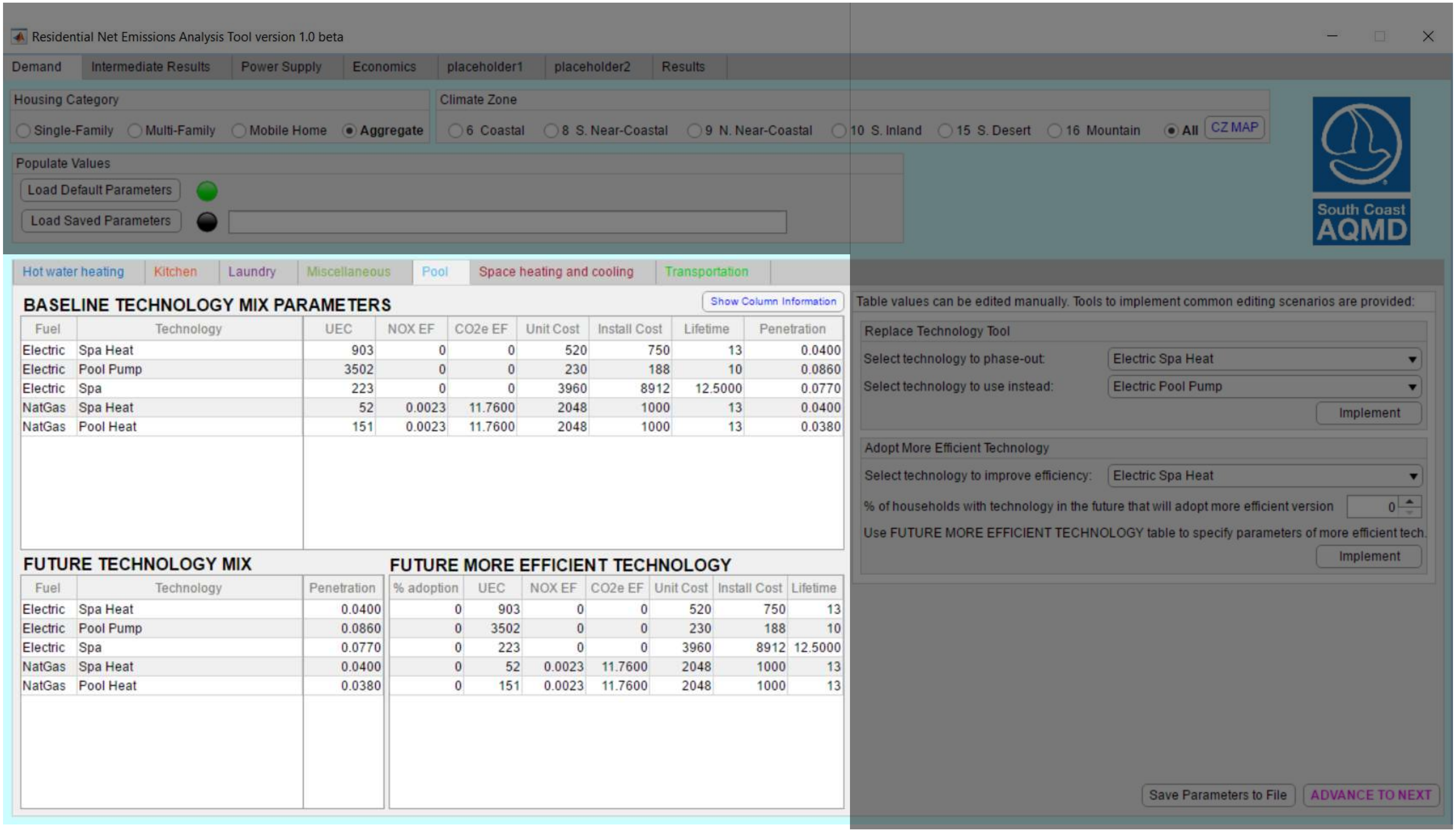
0	559	0	0	185	1167	15
0	1734	0	0	0	0	0
0	26	0.0136	11.7600	0	0	0

Pool



BASELINE TECHNOLOGY MIX PARAMETERS

Fuel	Technology	UEC	NOX EF	CO2e EF	Unit Cost	Install Cost	Lifetime	Penetration
Electric	Spa Heat	903	0	0	520	750	13	0.0400
Electric	Pool Pump	3502	0	0	230	188	10	0.0860
Electric	Spa	223	0	0	3960	8912	12.5000	0.0770
NatGas	Spa Heat	52	0.0023	11.7600	2048	1000	13	0.0400
NatGas	Pool Heat	151	0.0023	11.7600	2048	1000	13	0.0380

FUTURE TECHNOLOGY MIX

Fuel	Technology	Penetration
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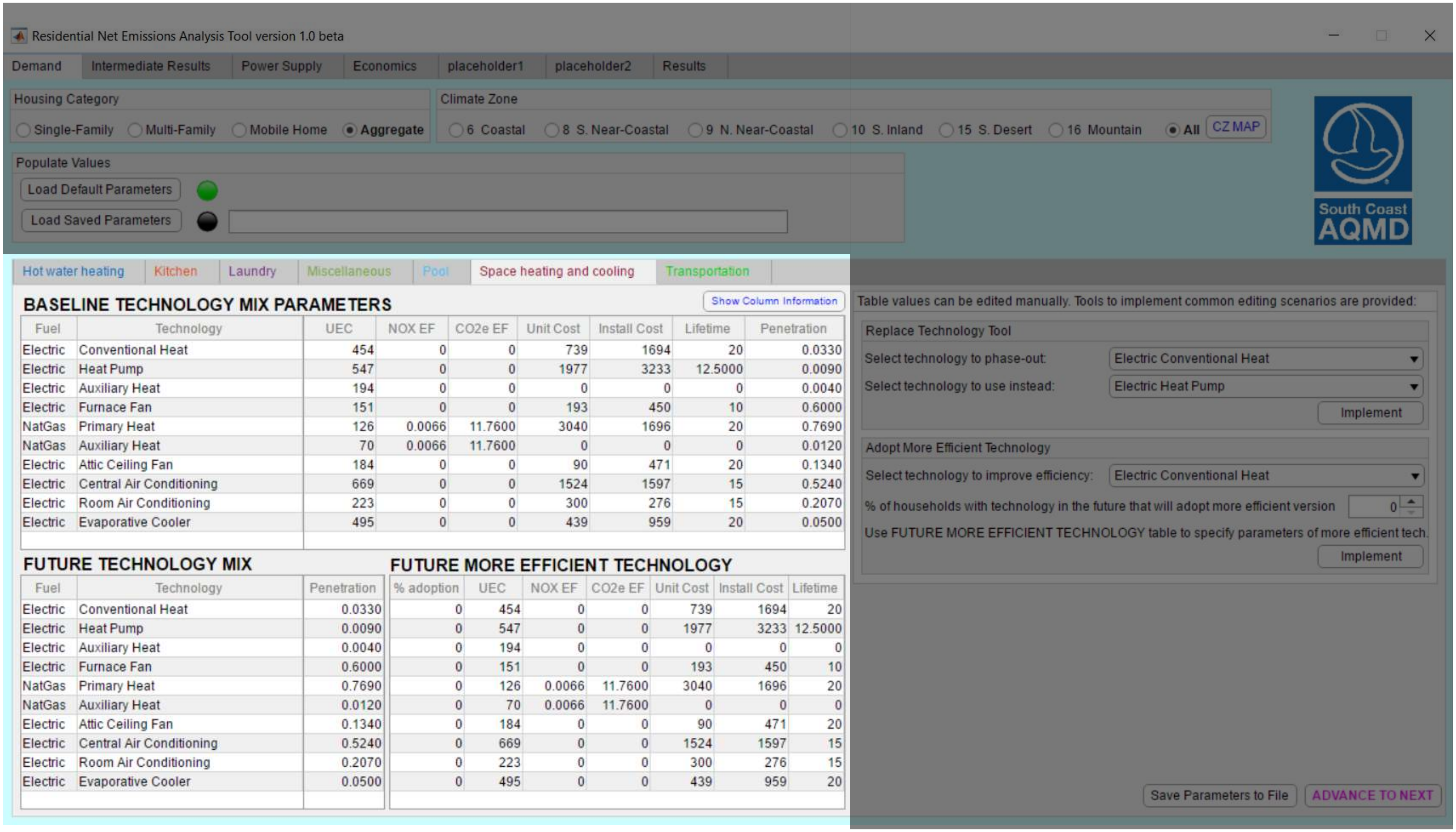
0	52	0.0023	11.7600	2048	1000	13
0	151	0.0023	11.7600	2048	1000	13

Space heating and cooling



Residential Net Emissions Analysis Tool version 1.0 beta

Demand | Intermediate Results | Power Supply | Economics | placeholder1 | placeholder2 | Results

Housing Category: Single-Family | Multi-Family | Mobile Home | Aggregate

Climate Zone: 6 Coastal | 8 S. Near-Coastal | 9 N. Near-Coastal | 10 S. Inland | 15 S. Desert | 16 Mountain | All | CZ MAP

Populate Values: Load Default Parameters | Load Saved Parameters

South Coast AQMD

Hot water heating | Kitchen | Laundry | Miscellaneous | Pool | Space heating and cooling | Transportation

BASELINE TECHNOLOGY MIX PARAMETERS

Show Column Information

Fuel	Technology	UEC	NOX EF	CO2e EF	Unit Cost	Install Cost	Lifetime	Penetration
Electric	Conventional Heat	454	0	0	739	1694	20	0.0330
Electric	Heat Pump	547	0	0	1977	3233	12.5000	0.0090
Electric	Auxiliary Heat	194	0	0	0	0	0	0.0040
Electric	Furnace Fan	151	0	0	193	450	10	0.6000
NatGas	Primary Heat	126	0.0066	11.7600	3040	1696	20	0.7690
NatGas	Auxiliary Heat	70	0.0066	11.7600	0	0	0	0.0120
Electric	Attic Ceiling Fan	184	0	0	90	471	20	0.1340
Electric	Central Air Conditioning	669	0	0	1524	1597	15	0.5240
Electric	Room Air Conditioning	223	0	0	300	276	15	0.2070
Electric	Evaporative Cooler	495	0	0	439	959	20	0.0500

FUTURE TECHNOLOGY MIX

Fuel	Technology	Penetration
Electric	Conventional Heat	0.0330
Electric	Heat Pump	0.0090
Electric	Auxiliary Heat	0.0040
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NatGas	Primary Heat	0.7690
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Electric	Attic Ceiling Fan	0.1340
Electric	Central Air Conditioning	0.5240
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FUTURE MORE EFFICIENT TECHNOLOGY

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0	194	0	0	0	0	0
0	151	0	0	193	450	10
0	126	0.0066	11.7600	3040	1696	20
0	70	0.0066	11.7600	0	0	0
0	184	0	0	90	471	20
0	669	0	0	1524	1597	15
0	223	0	0	300	276	15
0	495	0	0	439	959	20

Table values can be edited manually. Tools to implement common editing scenarios are provided:

Replace Technology Tool

Select technology to phase-out: Electric Conventional Heat

Select technology to use instead: Electric Heat Pump

Implement

Adopt More Efficient Technology

Select technology to improve efficiency: Electric Conventional Heat

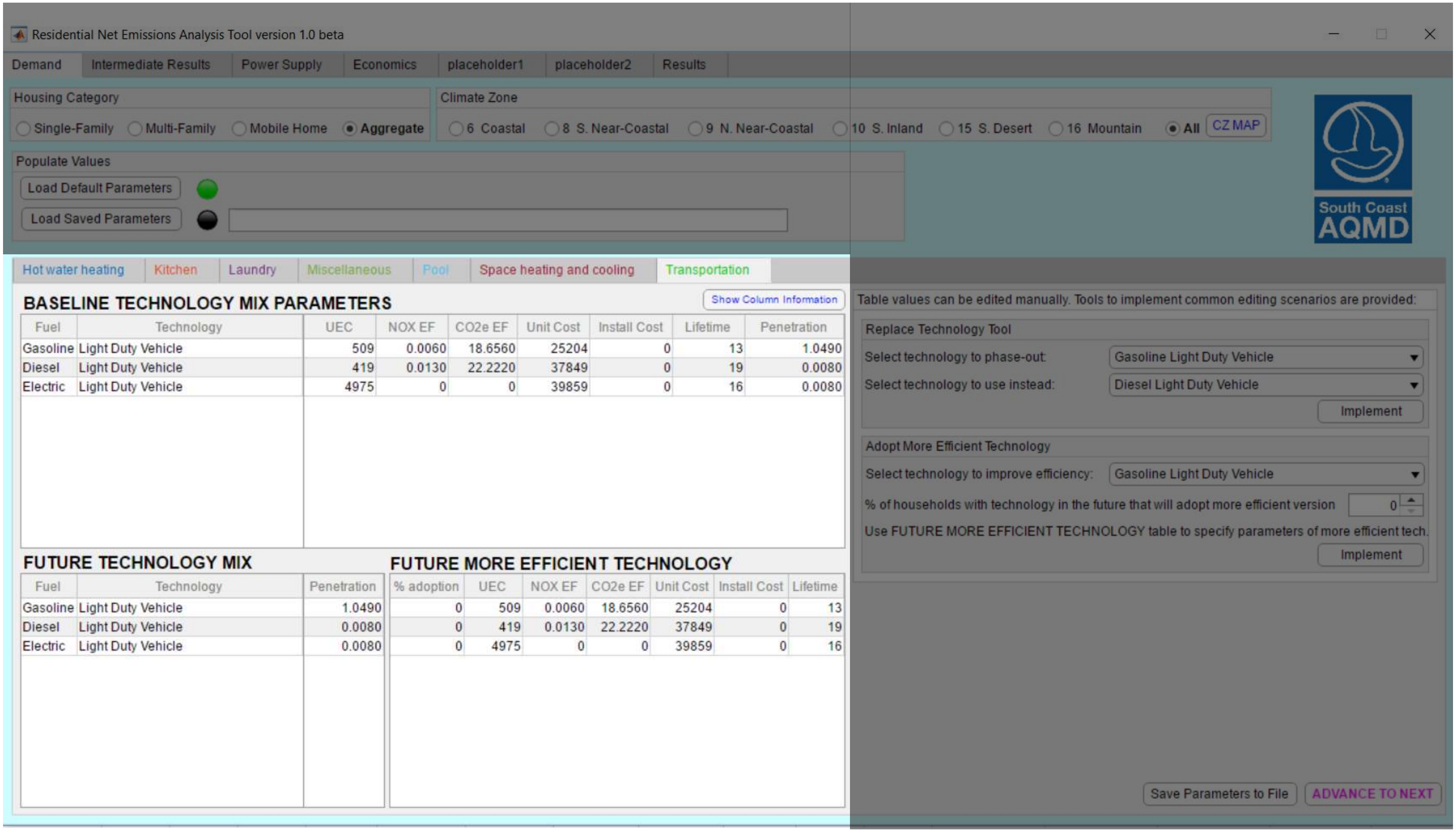
% of households with technology in the future that will adopt more efficient version: 0

Use FUTURE MORE EFFICIENT TECHNOLOGY table to specify parameters of more efficient tech.

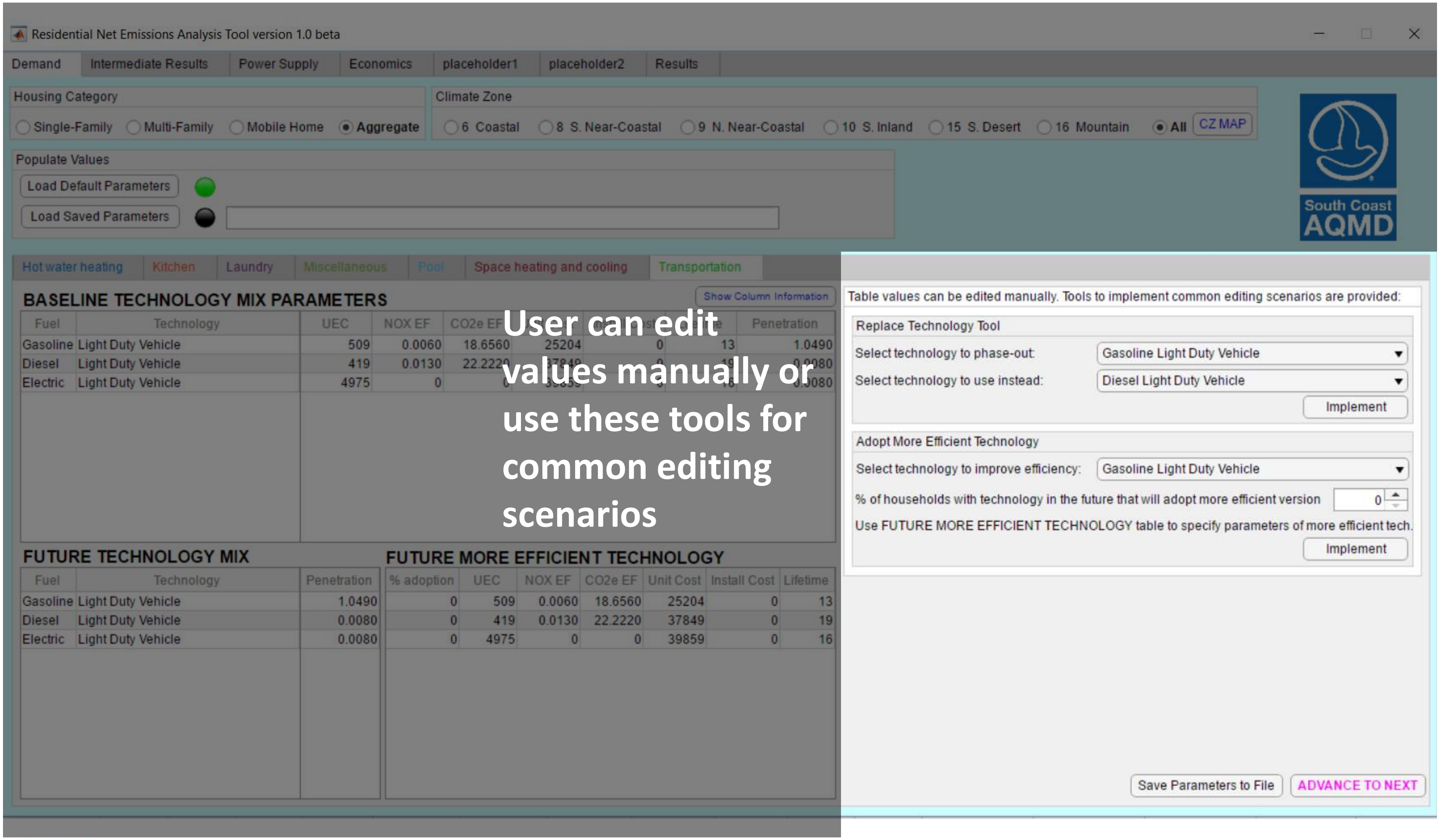
Implement

Save Parameters to File | ADVANCE TO NEXT

Transportation



Technology Mix Editing Tools



User can edit values manually or use these tools for common editing scenarios

Baseline Demand

- For all electric appliances, i:

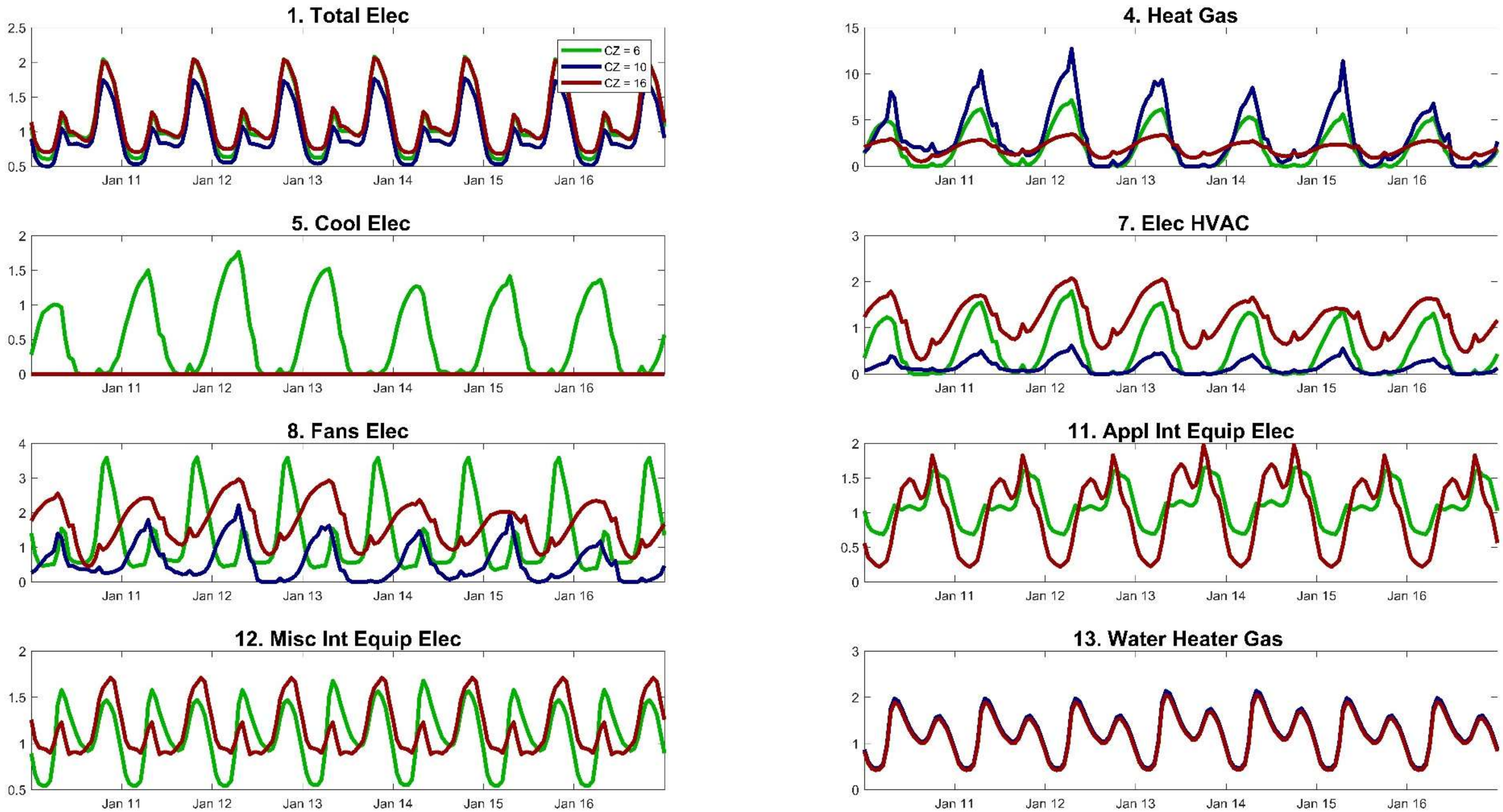
$$Elec_{Base,i,h} = Penetration_{Base,i} \times UEC_{Base,i} \times Load_h$$

- For all gas appliances, j:

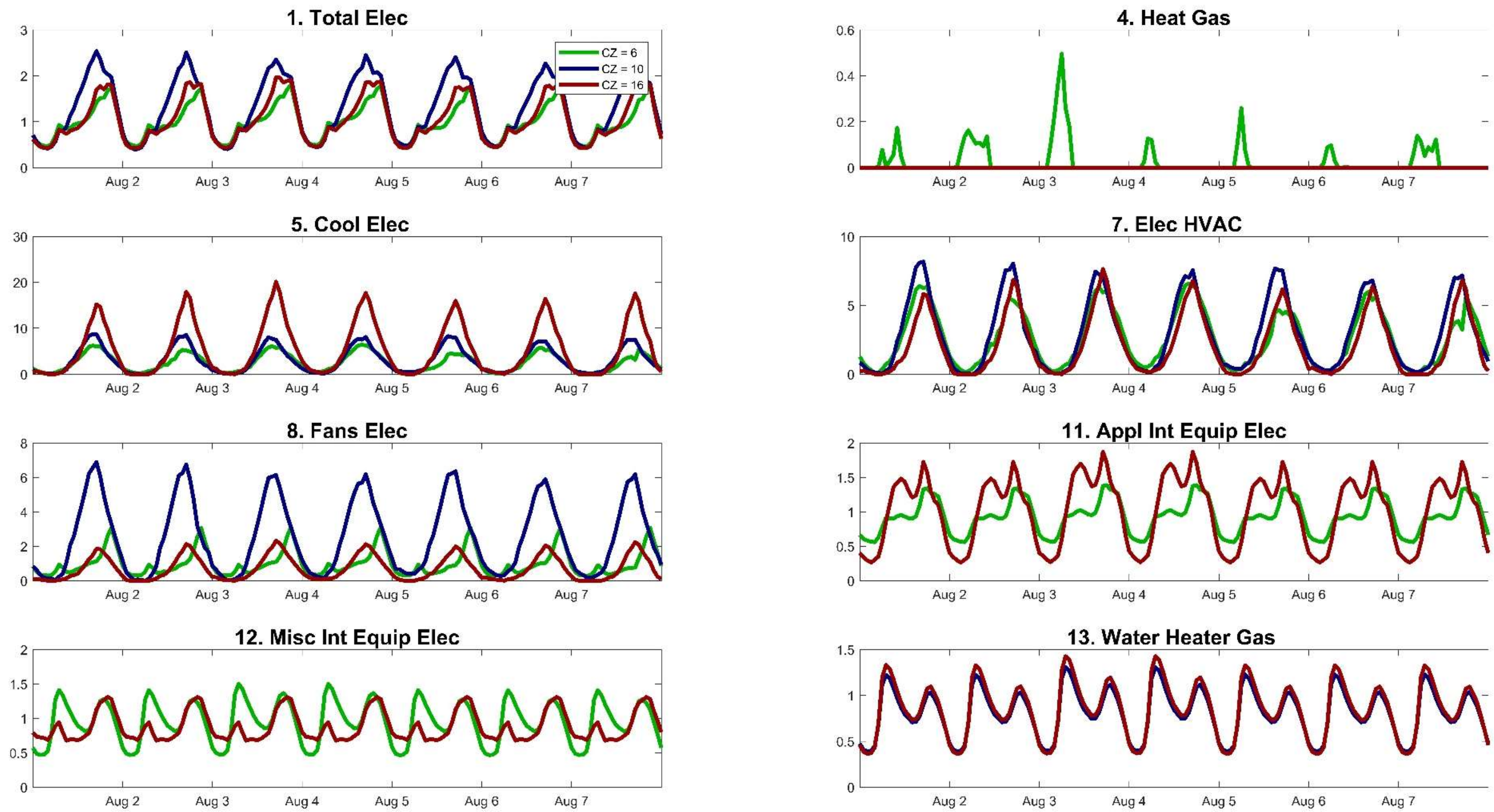
$$Gas_{Base,j,h} = Penetration_{Base,j} \times UEC_{Base,j} \times Load_h$$

Hourly Loads, $Load_h$, are obtained from Building America House Simulation Protocol, NREL 2010

Hourly Loads by Climate Zone – January



Hourly Loads by Climate Zone – August



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Future Case Demand

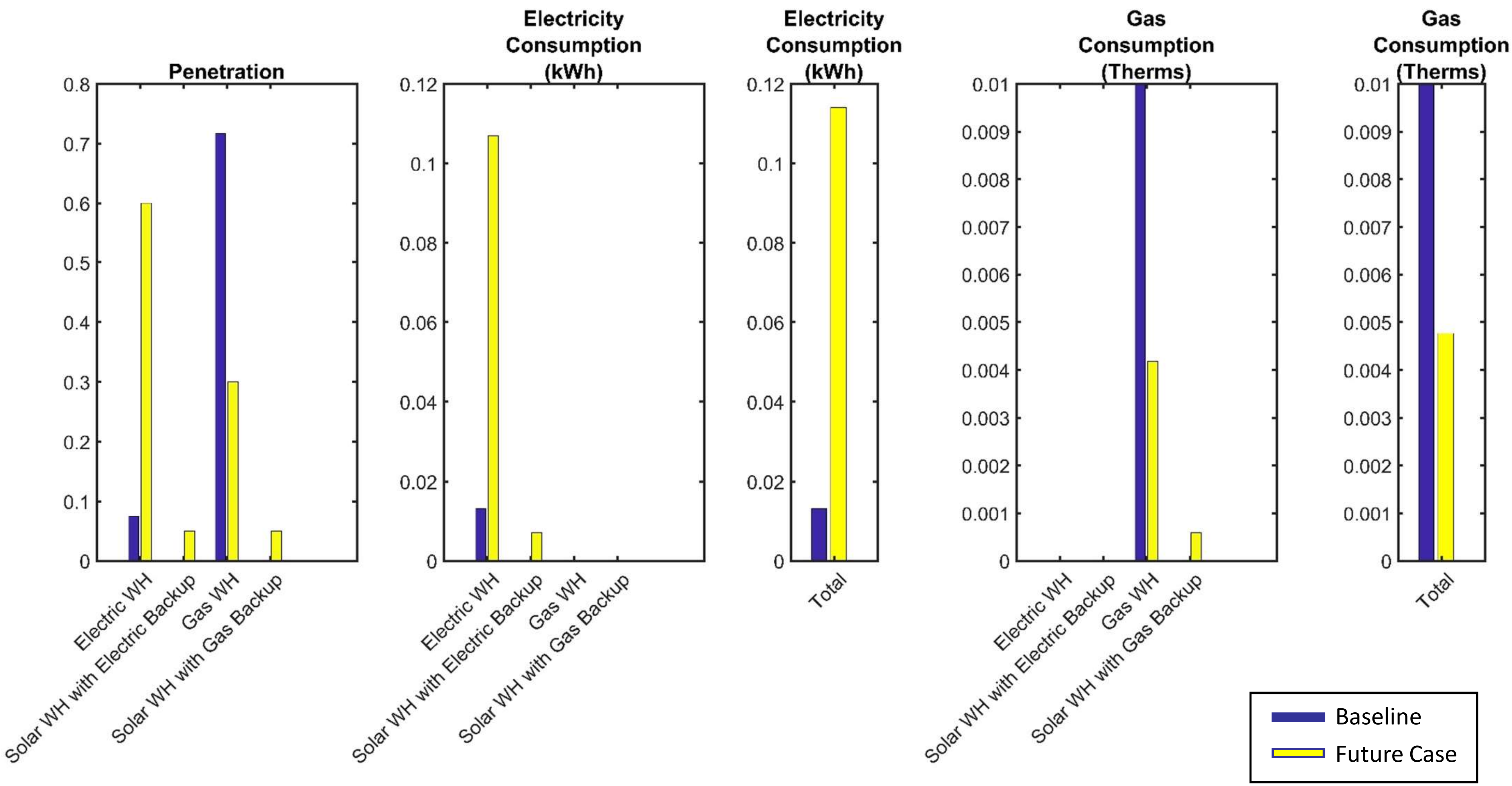
- For all electric appliances, i:

$$Elec_{Future,i,h} = \\ \big(Penetration_{Future,i} \times UEC_{Base,i} \times (1 - \%Adoption_i) \\ + Penetration_{Future,i} \times UEC_{Future,i} \times \%Adoption_i \big) \times Load_h$$

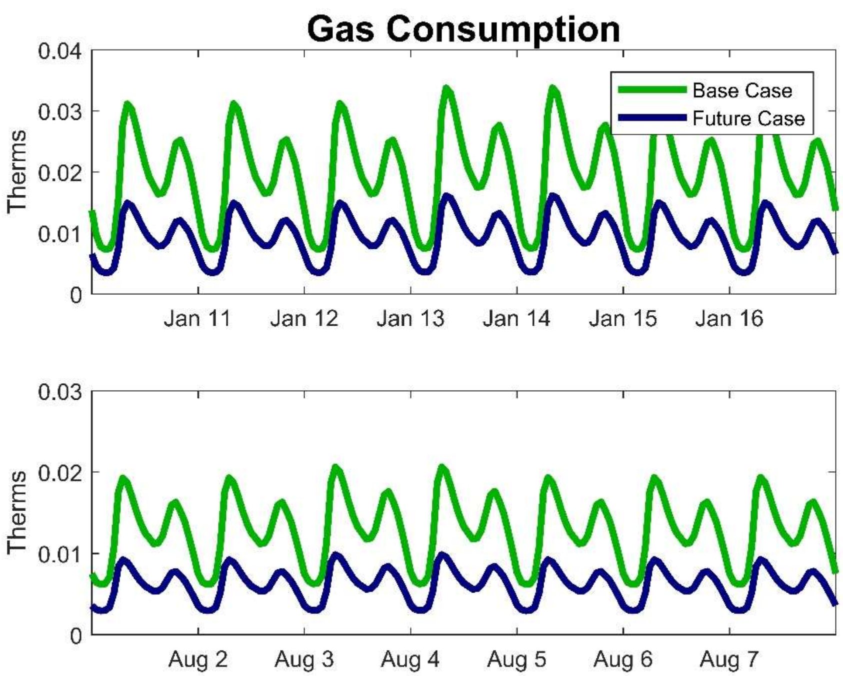
- For all gas appliances, j:

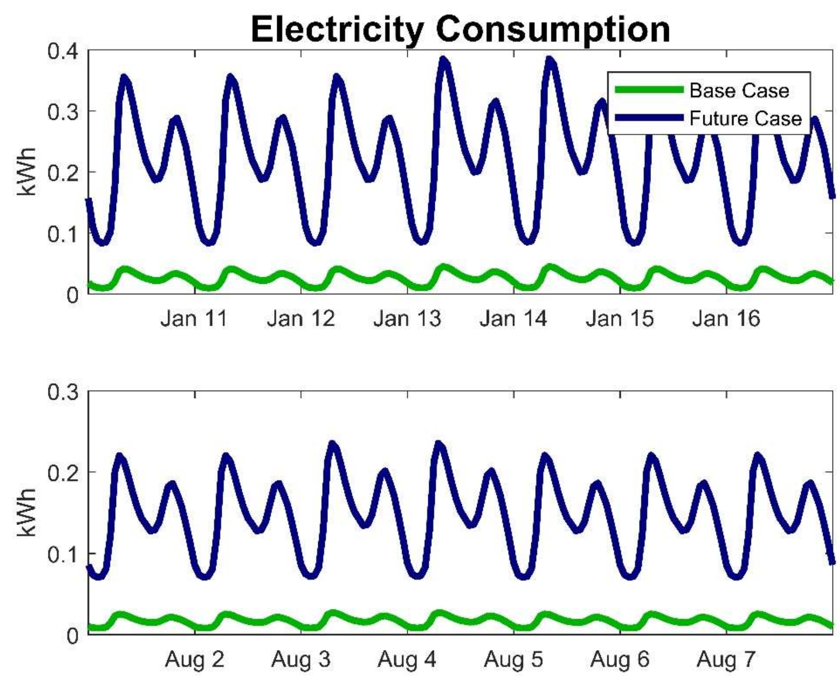
$$Gas_{Future,j,h} = \\ \big(Penetration_{Future,j} \times UEC_{Base,j} \times \big(1 - \%Adoption_j\big) \\ + Penetration_{Future,j} \times UEC_{Future,j} \times \%Adoption_j \big) \times Load_h$$

Example Calculation: Water Heating



Example Calculation: Water Heating





Emissions

- Baseline emissions:

$$Emissions_{Base,j,h,pol} = Gas_{Base,j,h} \times EF_{\ Base,j,pol}$$

- Future emissions:

$$Emissions_{Future,j,h} =$$
$$\left(Penetration_{Future,j} \times UEC_{Base,j} \times \left(1 - \%Adoption_j\right) \times EF_{\ Base,j,pol} + Penetration_{Future,j} \times UEC_{Future,j} \times \%Adoption_j \times EF_{\ Future,j,pol} \right) \times Load_h$$

Costs

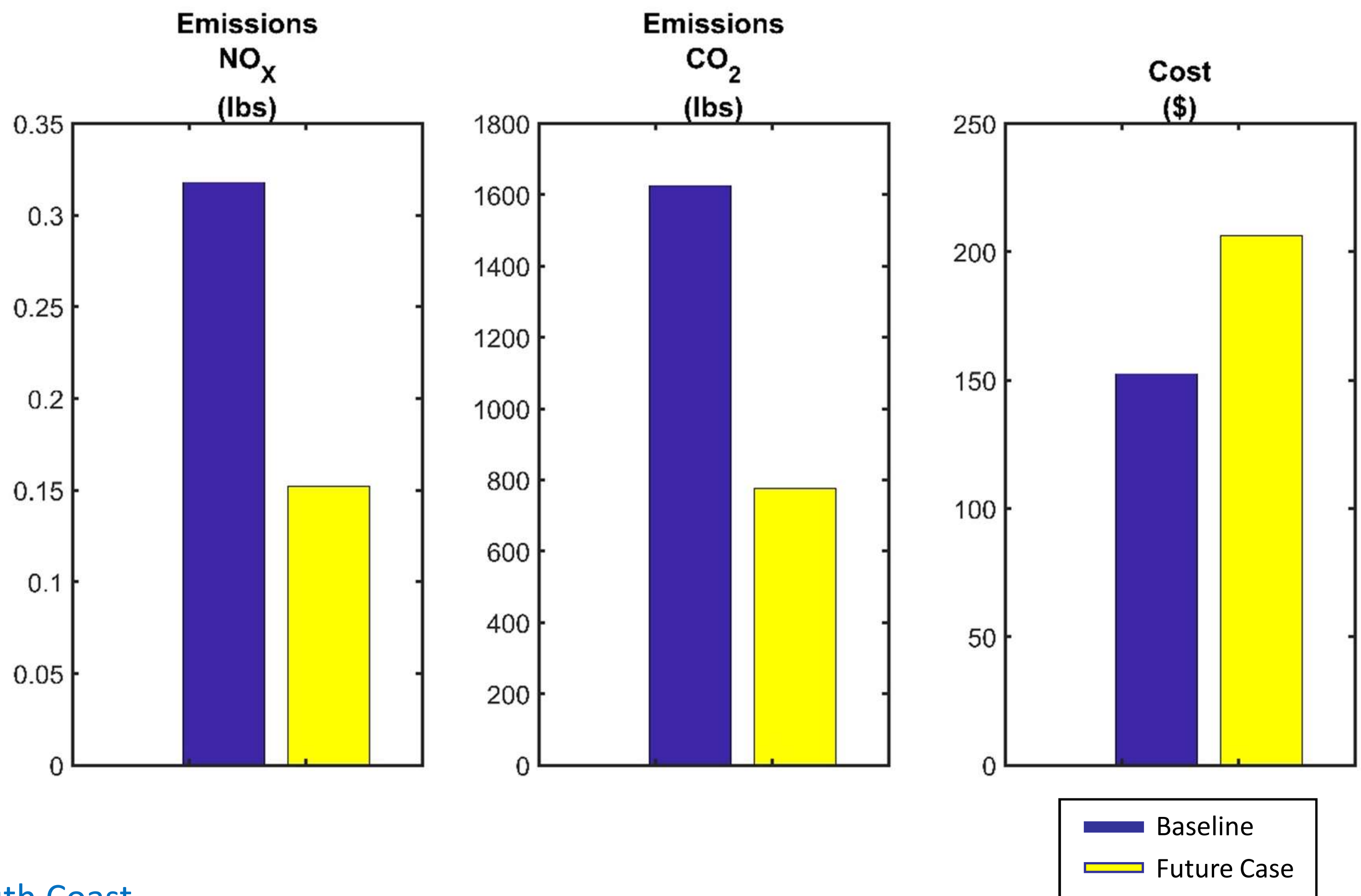
- Baseline costs:

$$Costs_{Base,i} = Penetration_{Base,i} \times \left(InstallCost_{Base,i} + UnitCost_{Base,i}\right)/lifetime_{Base,i}$$

- Future costs:

$$Costs_{Future,i} = \left(Penetration_{Future,i} \times \left(InstallCost_{Base,i} + UnitCost_{Base,i}\right)/lifetime_{Base,i} \times (1 - \%Adoption_i) + Penetration_{Future,i} \times \left(InstallCost_{Future,i} + UnitCost_{Future,i}\right)/lifetime_{Future,i} \times \%Adoption_i \right)$$

Example Calculation: Water Heating



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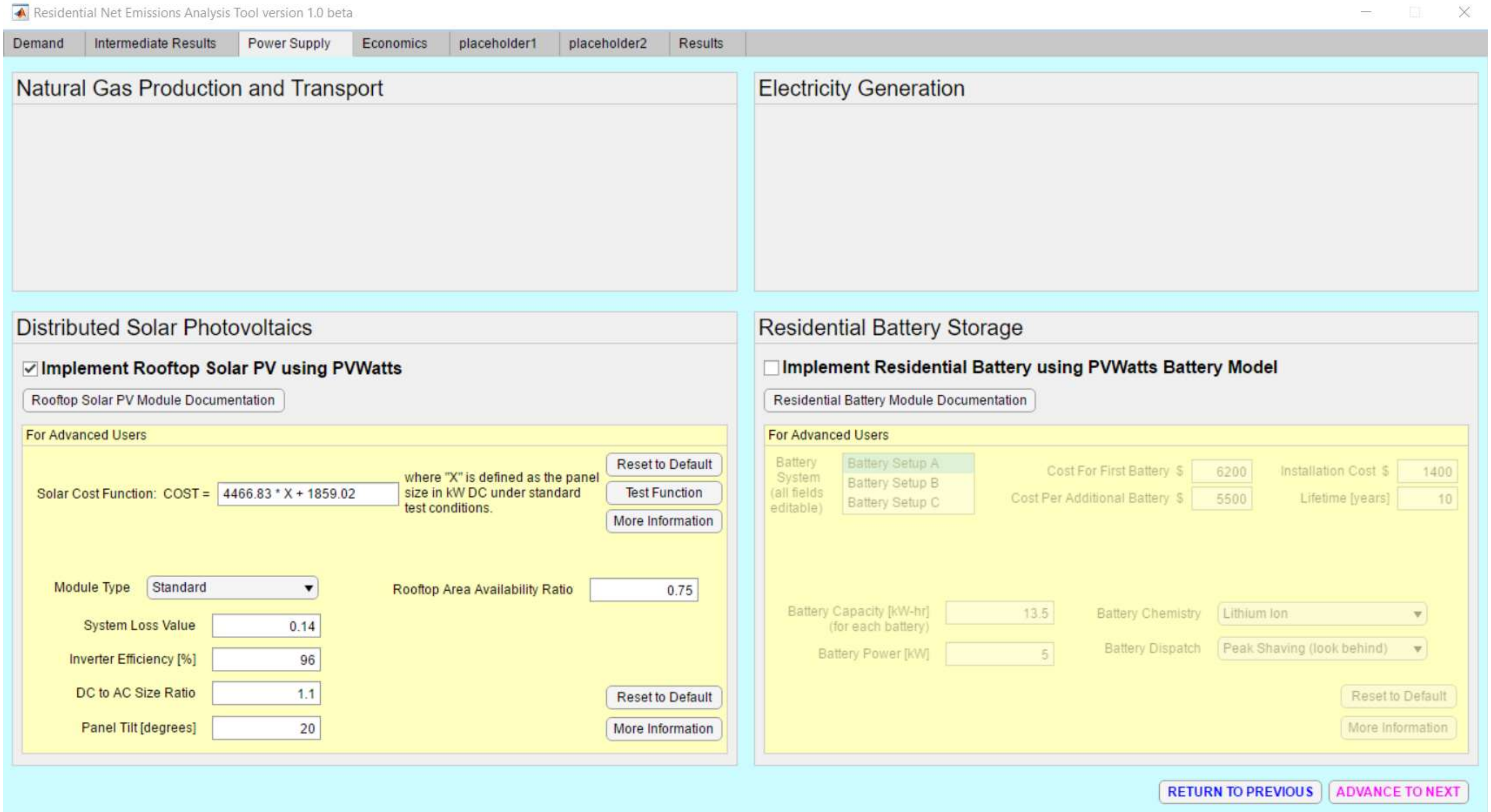
Implementation of Distributed PV



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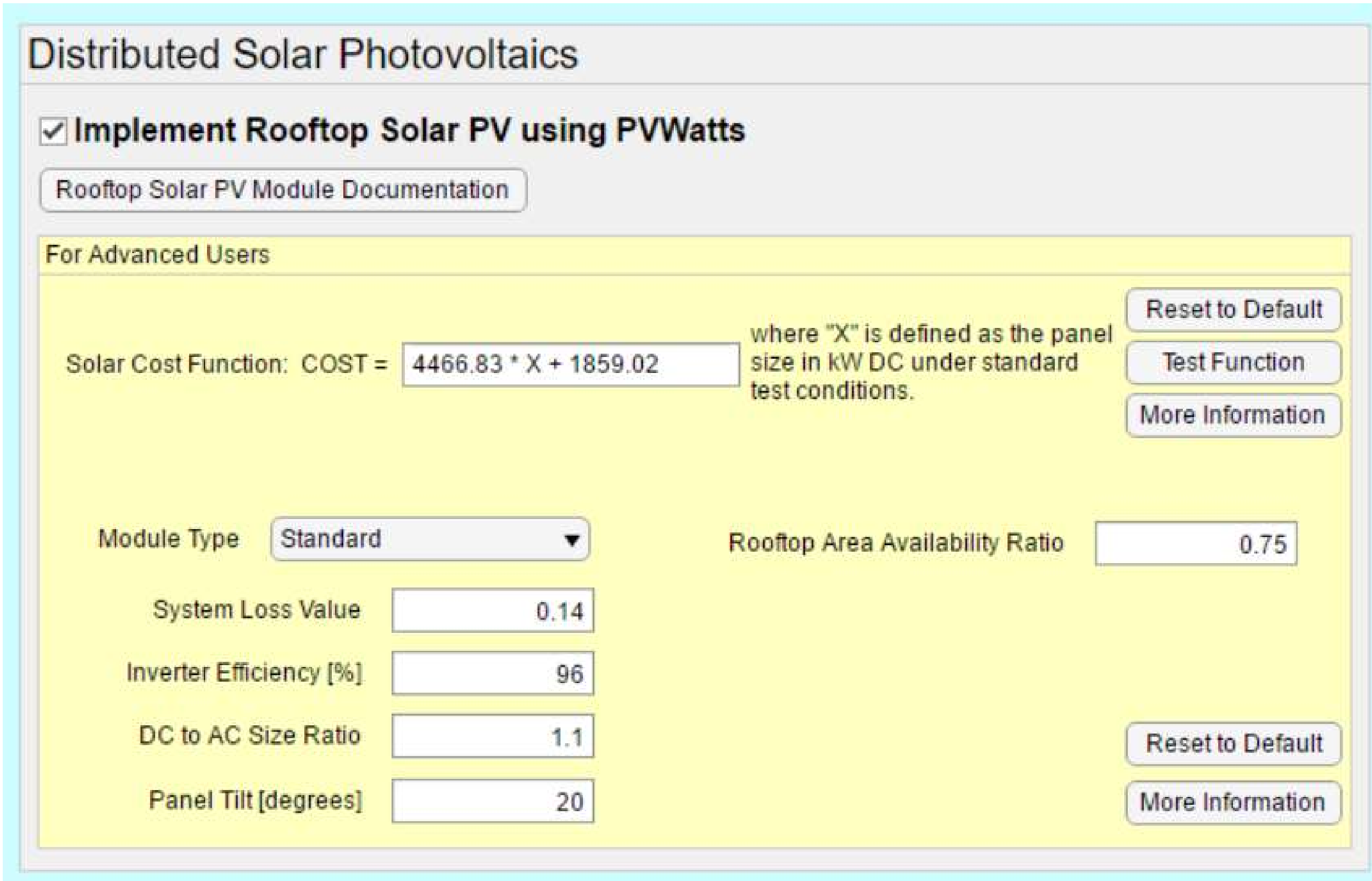
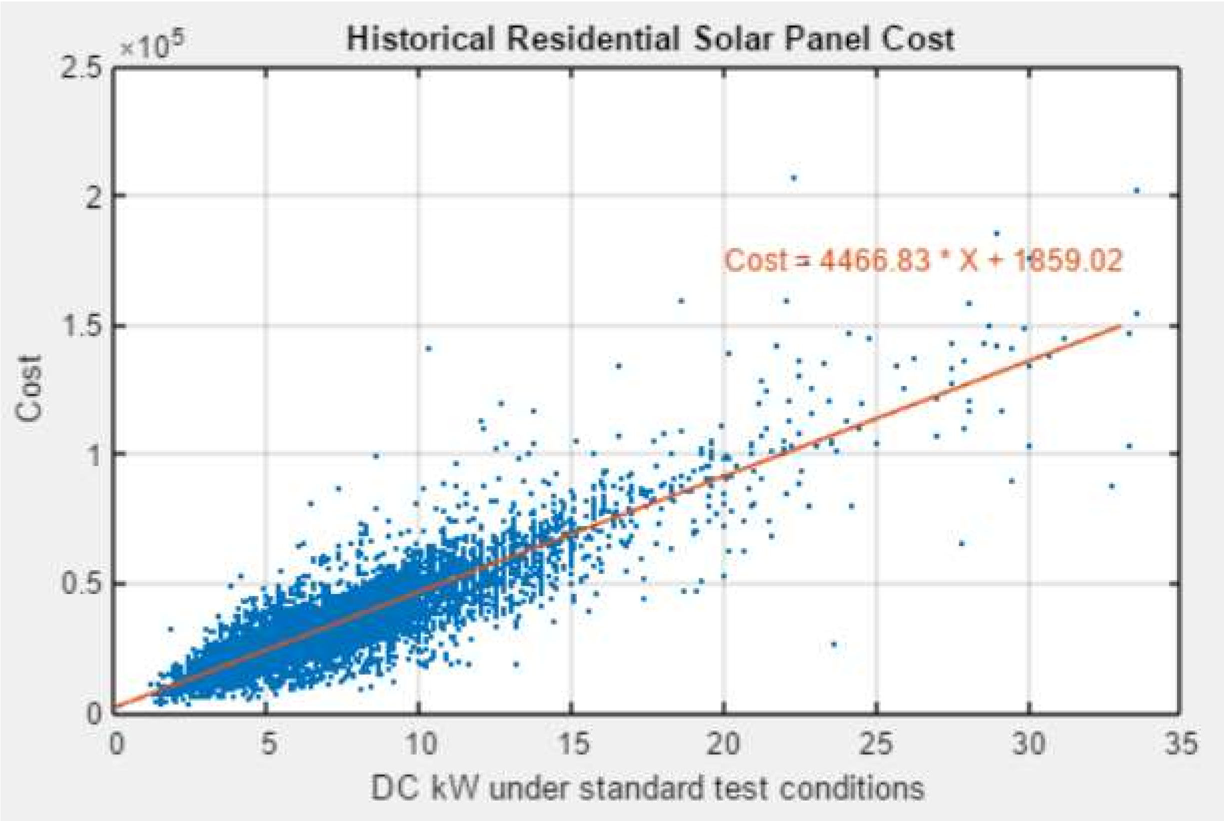


Implementation of Distributed PV

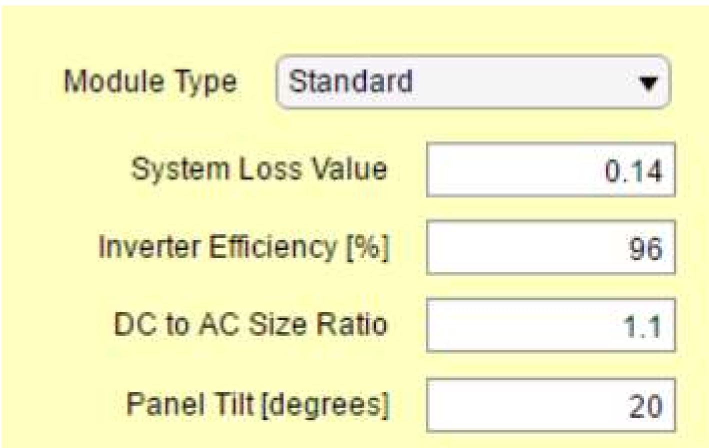
- How much panel area is available to the average single family and mobile home household in each climate zone?
- How much electricity can be generated by the average single family and mobile home household in each climate zone?
  - NREL's PVWatts used for calculation
- How many panels will minimize cost (construction and electricity bills)?

Solar Cost Function

- Function can be edited by advanced users
- CA distributed generation statistics
- Residential PV installations in SCE territory completed after 1/1/2014 were analyzed



Solar PV Module Input Parameters
(for advanced users)

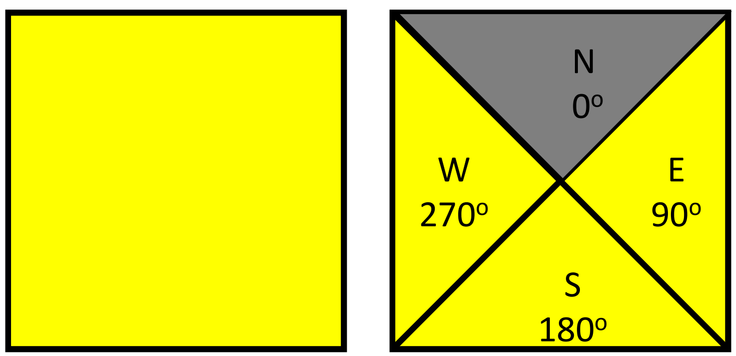


- Module type choices include “standard”, “premium”, and “thin-film”. This determines the panel efficiency and the power dependence on temperature
- System Loss Value is the product of several performance losses, i.e. shading, soiling, age, etc.
- Inverter Efficiency is the nominal rated DC-to-AC conversion efficiency
- Panel tilt is the angle from horizontal of all the panels in the PV array

Solar PV Module Input Parameters
(for advanced users)

Rooftop Area Availability Ratio | 0.75

Aerial view of average house



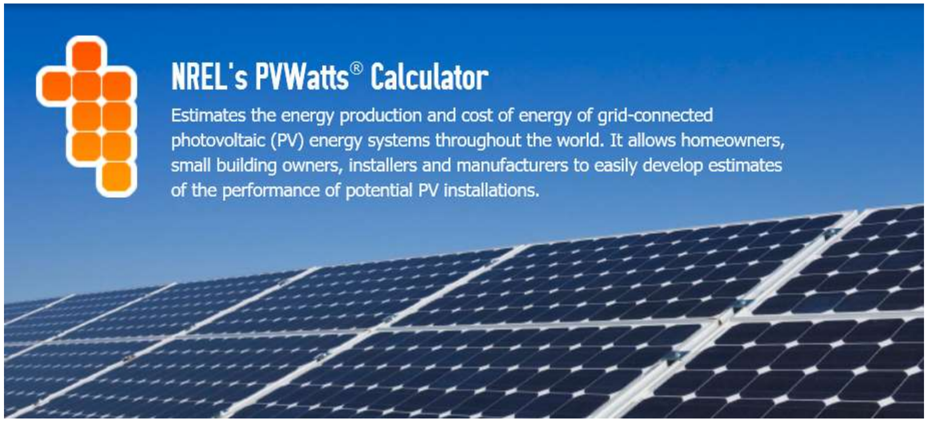
Low slope
Slope < 2:12

High slope
Slope > 2:12

- Maximum panel area / area of the average rooftop footprint
- Only applied to flat roofs and non-North facing sloped rooftops
- Takes into account space needed for roof vents, skylights, etc
- Only a minor impact on final calculation—used to determine theoretical maximum panel area on each building

Calculation of Solar PV Generation

- Based on PVWatts from NREL
- PVWatts is typically applied for individual buildings
- We apply PVWatts on a regional basis
- Calculate PV Generation for single family and mobile homes



Calculation of Solar PV Generation

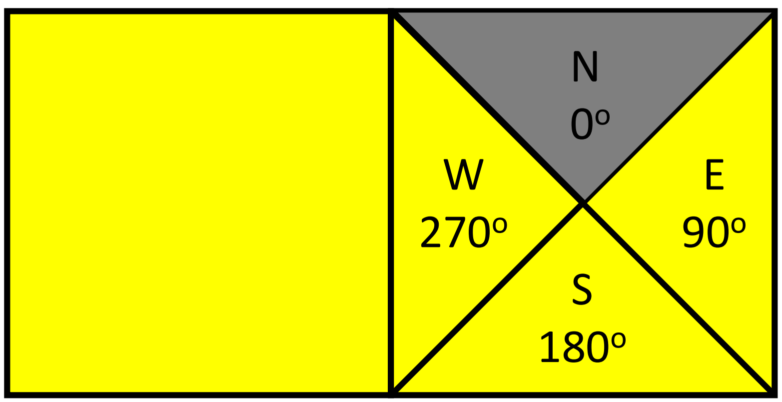
- Hourly solar resource and meteorological data
  - Representative Typical Meteorological Year 3 measurement station selected for each climate zone
- Average high-slope and low-slope rooftop area of single family and mobile homes in each climate zone used to determine max panel area
  - Used building footprint data from the US Army Corps of Engineers
  - Used high-resolution land use data from SCAG

Average area [m^2]	CZ 6	CZ 8	CZ 9	CZ 10	CZ 15	CZ 16
single family high slope	177	172	168	178	178	174
single family low slope	159	139	164	145	145	152
mobile home high slope	136	126	130	141	141	133
mobile home low slope	152	135	172	154	154	153

Calculation of Solar PV Generation

- Max PV generation for single family and mobile homes in each climate zone calculated with 4 simulations

Aerial view of average house



Low slope
Slope < 2:12

High slope
Slope > 2:12

1. (Low slope area) x (rooftop area availability fraction) facing 180°
2. ¼ x (high slope area) x (rooftop area availability fraction) with azimuth of 270°
3. ¼ x (high slope area) x (rooftop area availability fraction) with azimuth of 180°
4. ¼ x (high slope area) x (rooftop area availability fraction) with azimuth of 90°

Implementation of Solar PV Results

- Hourly solar generation electricity profiles are subtracted from demand profiles to determine electricity needed from the grid
- Costs of the panel installation are calculated with the cost function and electricity costs are calculated with the electricity rates
- Process is repeated with several panel areas multipliers (0.1, 0.2,…) to determine panel area where costs are minimized

U.S. Air Force photo by Kenji Thuloweit

Topics for Open Discussion

- Documentation embedded in the software vs. a large documentation file
- Feedback on this meeting (structure, level of detail, etc.)

Pixabay.com

Public Comments

blog.cleanenergy.org