Modeling the Effects of Urban Heat Island Mitigation Strategies

1. Mitigation Impact Screening Tool (MIST)
2. Building Energy Impacts of Ecoroofs

EPA Heat Island Reduction Initiative (HIRI)
April Conference Call

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Mitigation Impact Screening Tool (MIST)

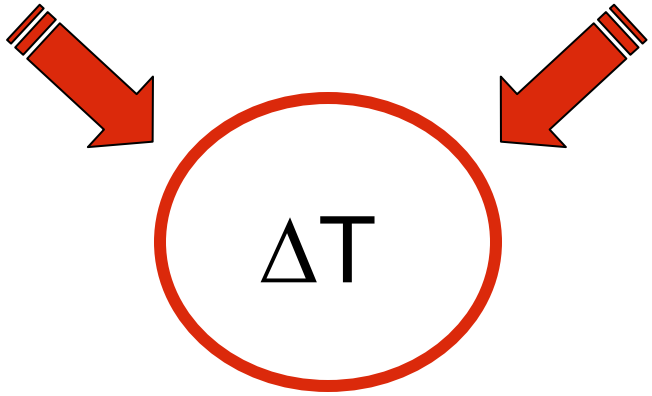
- Project Goal
  - Develop an easy-to-use web-based tool that estimates the air temperature, air quality, and building energy impacts of various city-scale mitigation strategies for any large US city.

Acknowledgements

- Niko Dietsch, Eva Wong @ US EPA; Haider Taha @ Altostratus; Hashem Akbari and colleagues @ LBNL; Cadmus and PQA

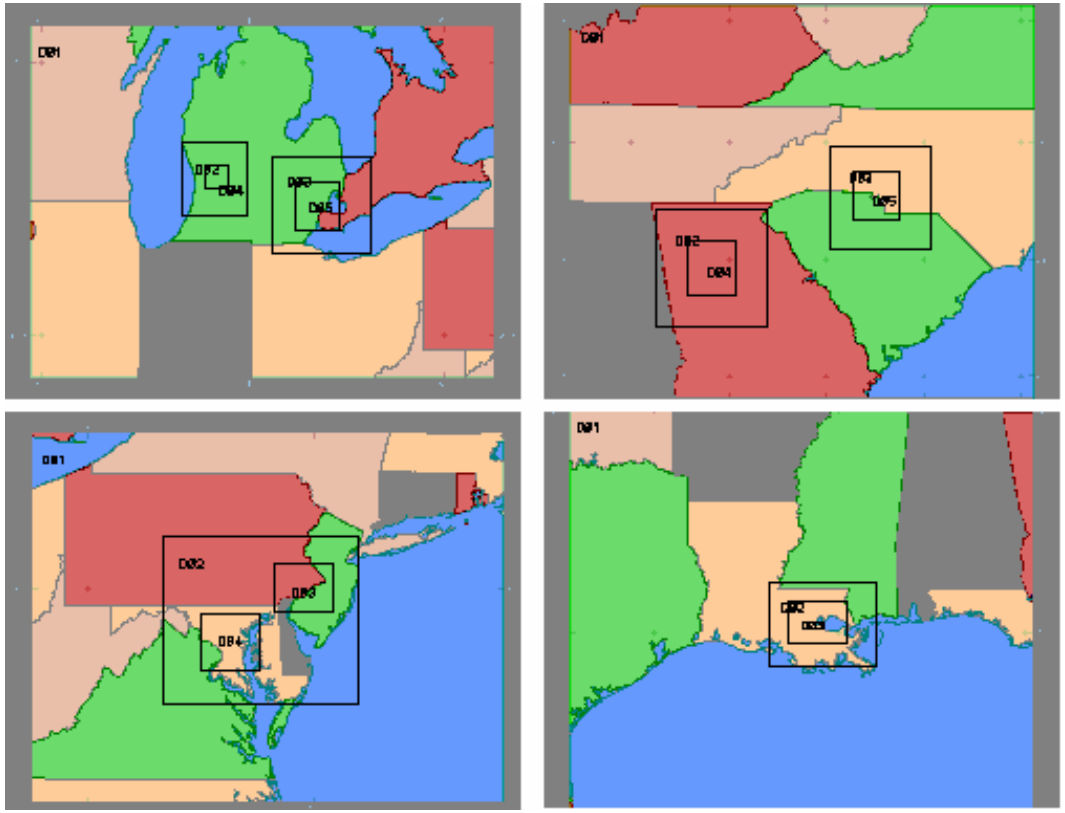
MIST Development Overview

- Define Mitigation Options
- Estimate Meteorological Impacts
- Estimate Air Quality Impacts
- Estimate Energy Consumption Impacts
- Extrapolate results from a small set of simulated cities to a large number of US cities
- Integrate results into a web-based tool

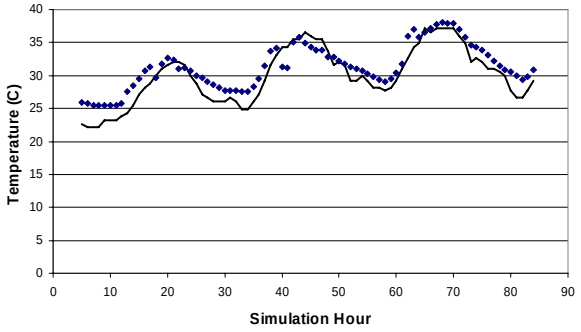


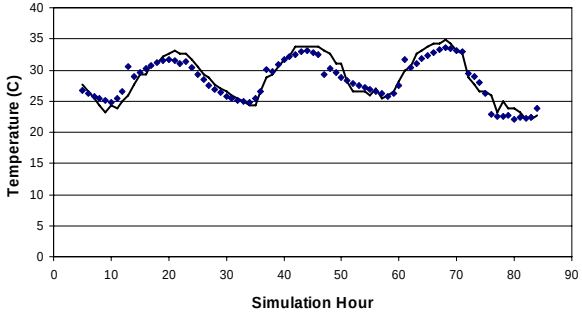
How do city-wide changes in vegetative cover or albedo affect urban climate, and air temperatures in particular?

Streamlined mesoscale modeling

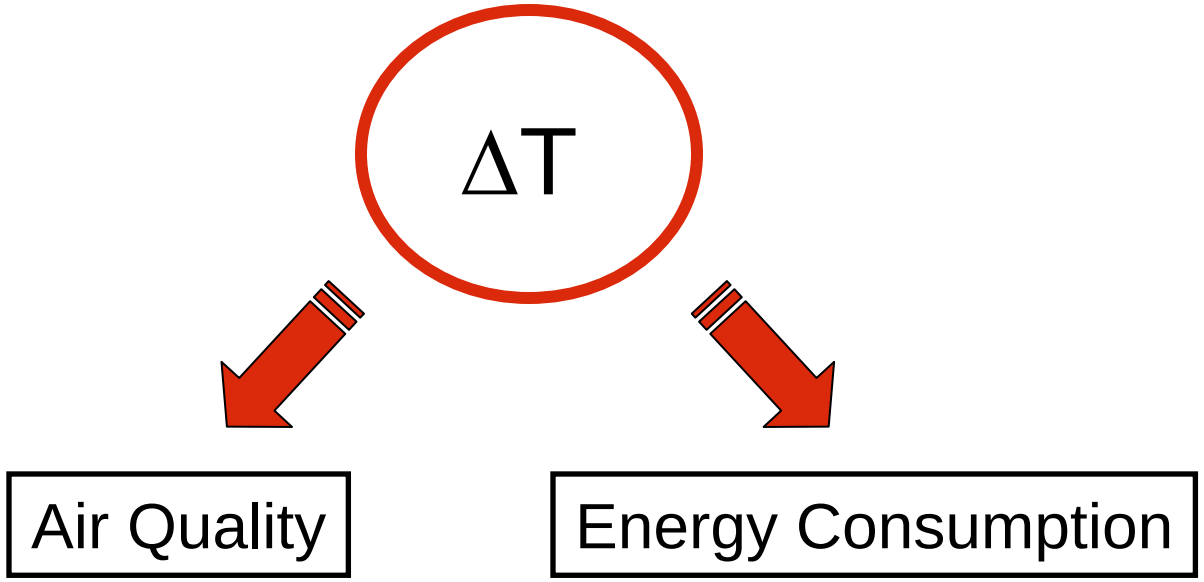


- MM5 atmospheric model
- Some urban LU refinement
- Nested domains
- 20+ cities modelled
- Modest validation efforts

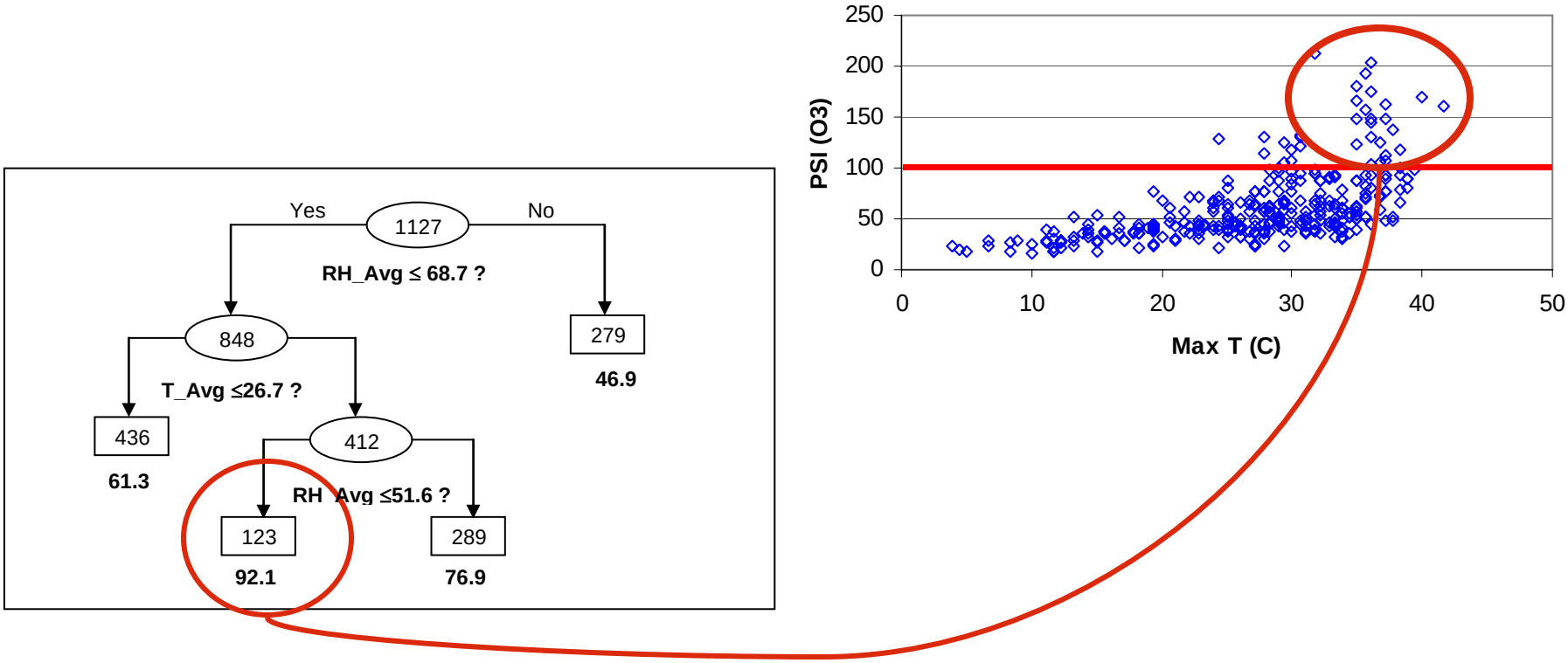




How do city-wide changes air temperatures affect air quality and energy consumption?



Classification and Regression Tree Analysis for Ozone

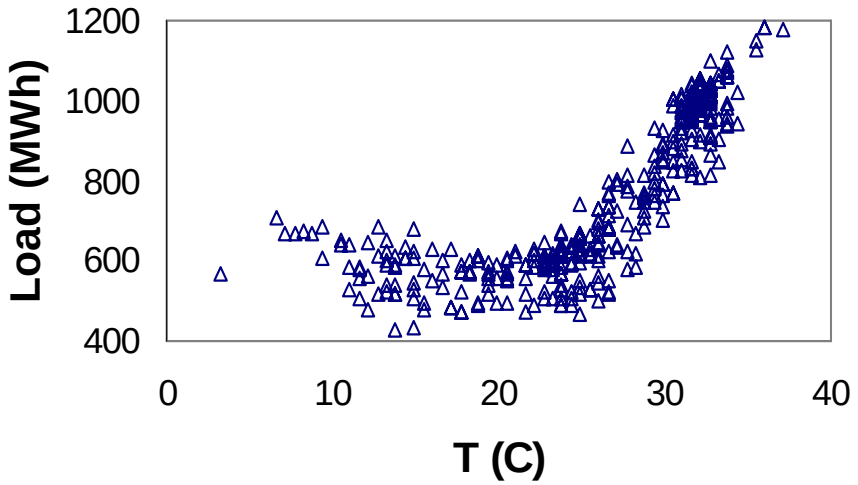


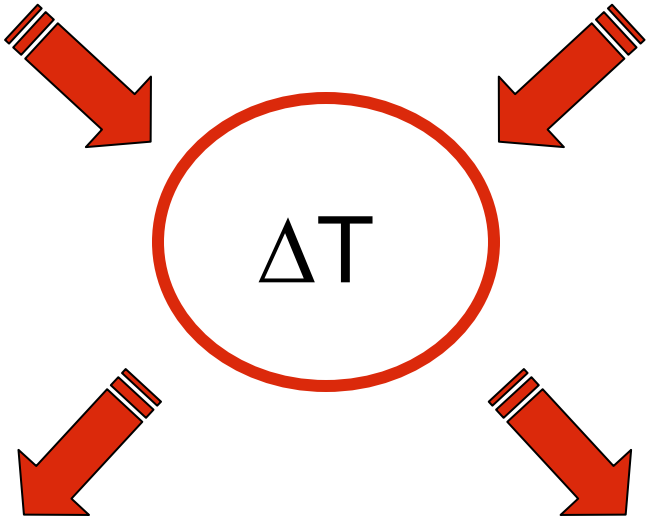
Numbers within ovals/boxes indicate number of days satisfying a particular set of conditions (weather pattern). Numbers below square nodes indicate the corresponding mean ozone concentrations within those weather patterns.

Energy

- Detailed building energy simulations of annual energy consumption response to mitigation for a small set of cities.
- Extrapolation based on climate similarity (11 CDD groups and 15 HDD groups)
- Reference:

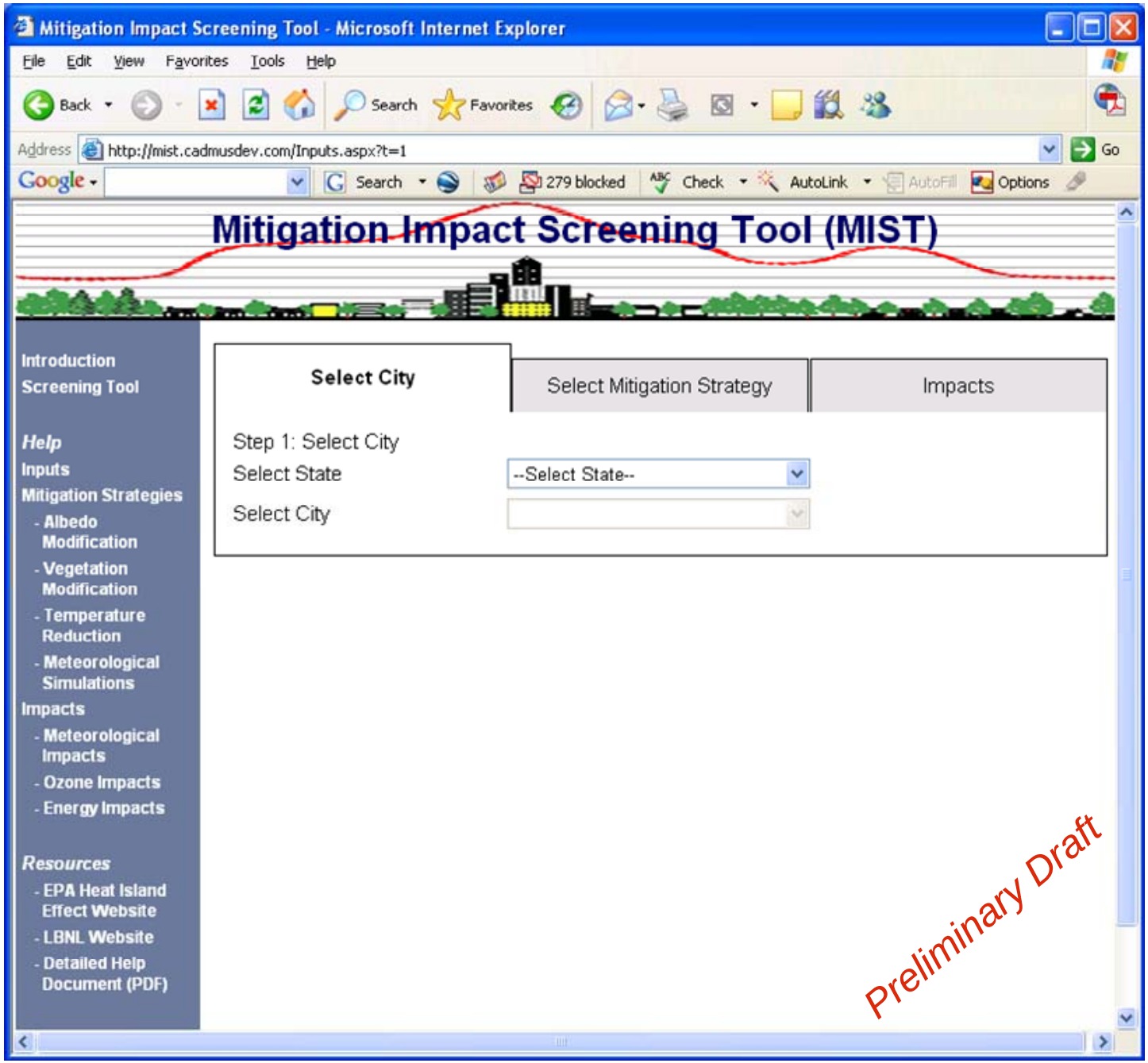
  Streamlined Energy-Savings Calculations for Heat Island Reduction Strategies, Hashem Akbari and Steven Konopacki, LBNL-47307





Air Quality

Energy Consumption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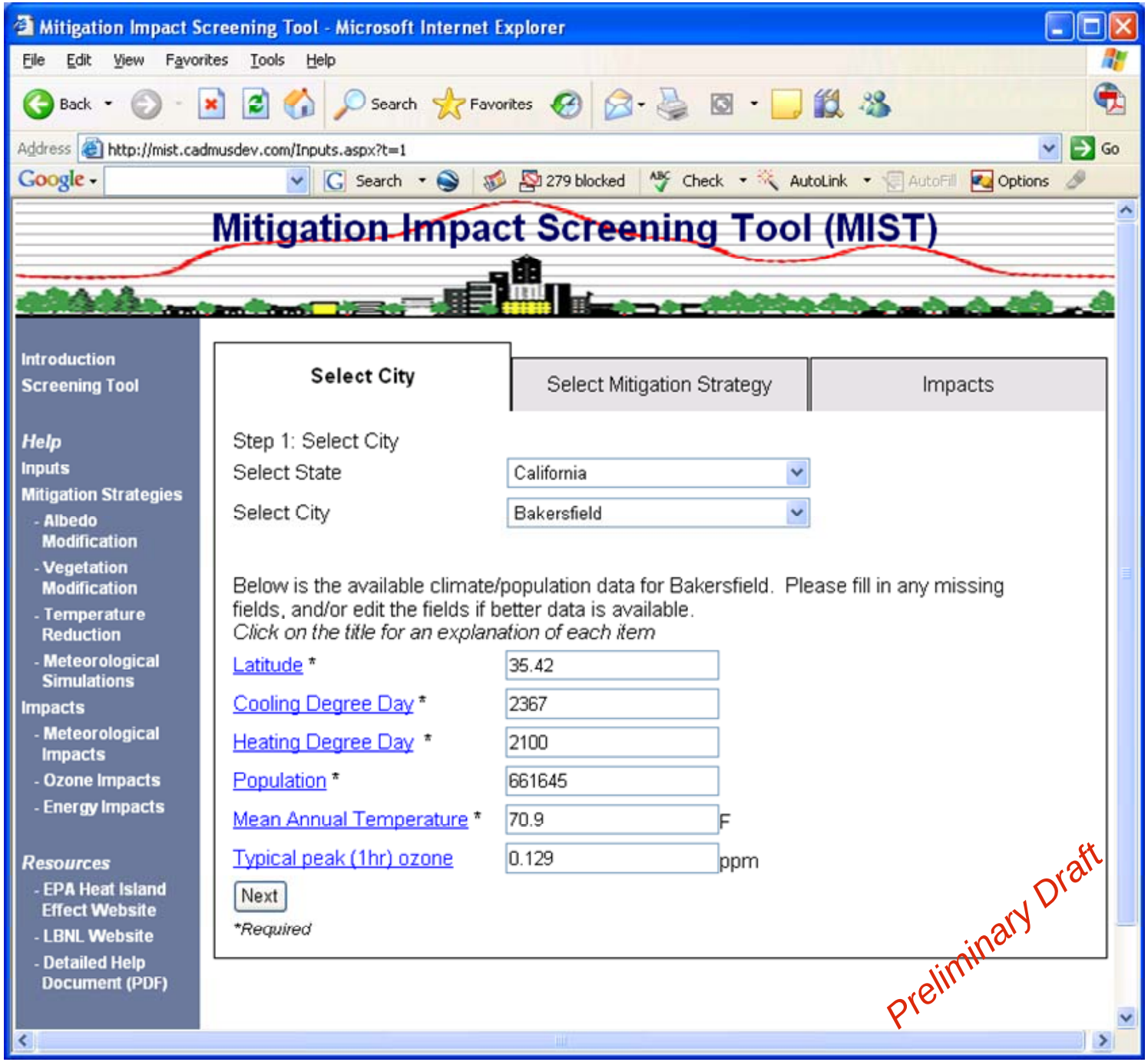
Mitigation Impact Screening Tool (MIST)
Introduction
Screening Tool
Help
Inputs
Mitigation Strategies
- Albedo Modification
- Vegetation Modification
- Temperature Reduction
- Meteorological Simulations
Impacts
- Meteorological Impacts
- Ozone Impacts
- Energy Impacts
Resources
- EPA Heat Island Effect Website
- LBNL Website
- Detailed Help Document (PDF)
Select City
Select Mitigation Strategy
Impacts
Step 1: Select City
Select State
--Select State--
Select City
Preliminary Draft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Mitigation Impact Screening Tool (MIST)
Introduction
Screening Tool
Help
Inputs
Mitigation Strategies
- Albedo Modification
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- Meteorological Simulations
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- Meteorological Impacts
- Ozone Impacts
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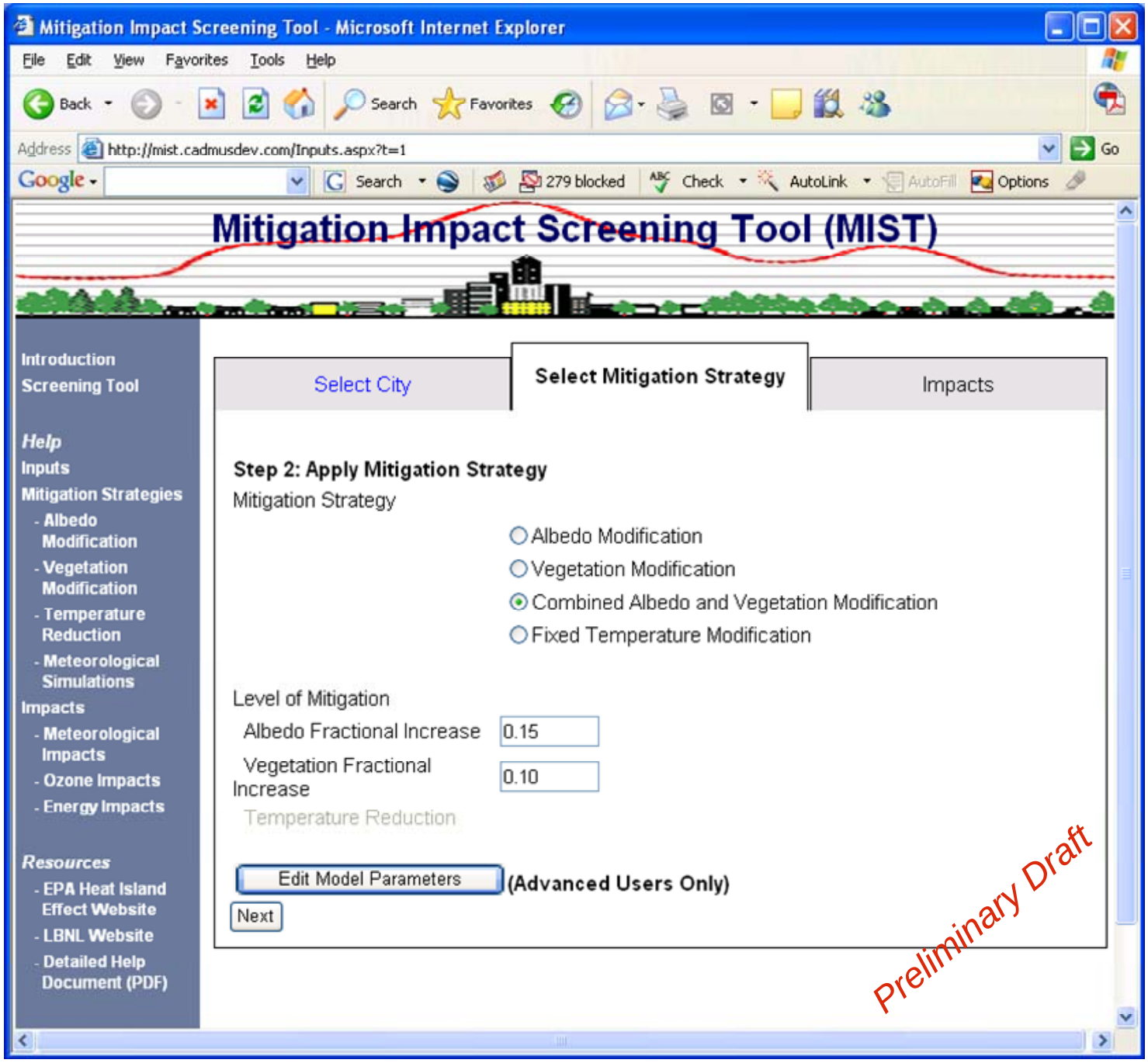
- EPA Heat Island Effect Website
- LBNL Website
- Detailed Help Document (PDF)
Select City
Select Mitigation Strategy
Impacts
Step 1: Select City
Select State
California
Select City
Bakersfield
Below is the available climate/population data for Bakersfield. Please fill in any missing fields, and/or edit the fields if better data is available.
Click on the title for an explanation of each item
Latitude *
35.42
Cooling Degree Day *
2367
Heating Degree Day *
2100
Population *
661645
Mean Annual Temperature *
70.9
F
Typical peak (1hr) ozone
0.129
ppm
Next
*Required
Preliminary Draft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Introduction
Screening Tool
Help
Inputs
Mitigation Strategies
- Albedo Modification
- Vegetation Modification
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- Meteorological Simulations
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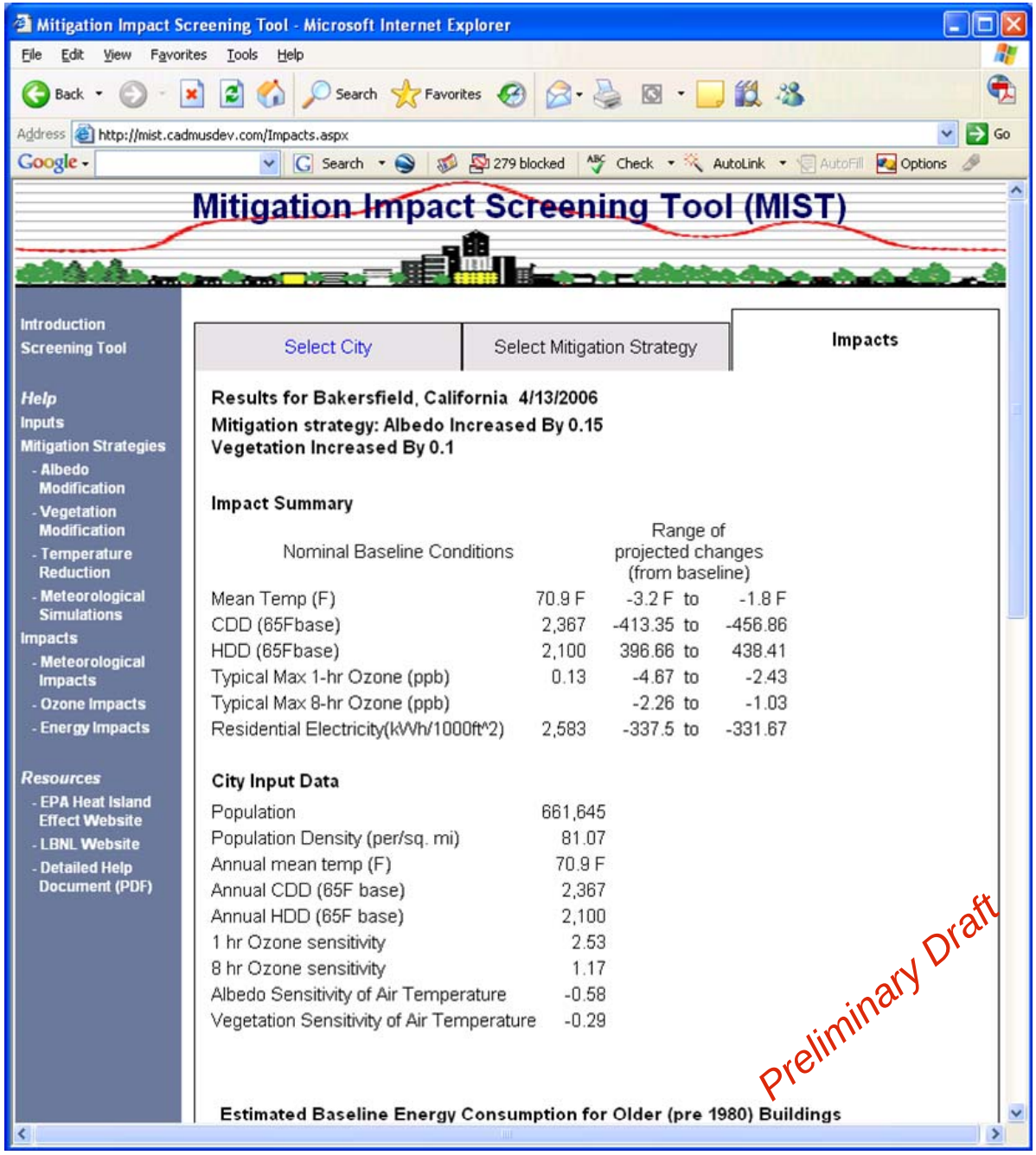
- Ozone Impacts
- Energy Impacts
Resources
- EPA Heat Island Effect Website
- LBNL Website
- Detailed Help Document (PDF)
Select City
Select Mitigation Strategy
Impacts
Step 2: Apply Mitigation Strategy
Mitigation Strategy
Albedo Modification
Vegetation Modification
Combined Albedo and Vegetation Modification
Fixed Temperature Modification
Level of Mitigation
Albedo Fractional Increase 0.15
Vegetation Fractional Increase 0.10
Temperature Reduction
Edit Model Parameters (Advanced Users Only)
Next
Preliminary Draft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Screening Tool
Help
Inputs
Mitigation Strategies
- Albedo Modification
- Vegetation Modification
- Temperature Reduction
- Meteorological Simulations
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- Detailed Help Document (PDF)
Select City
Select Mitigation Strategy
Impacts
Results for Bakersfield, California 4/13/2006
Mitigation strategy: Albedo Increased By 0.15
Vegetation Increased By 0.1
Impact Summary
Nominal Baseline Conditions
Range of projected changes (from baseline)
Mean Temp (F) 70.9 F -3.2 F to -1.8 F
CDD (65Fbase) 2,367 -413.35 to -456.86
HDD (65Fbase) 2,100 396.66 to 438.41
Typical Max 1-hr Ozone (ppb) 0.13 -4.67 to -2.43
Typical Max 8-hr Ozone (ppb) -2.26 to -1.03
Residential Electricity(kWh/1000ft^2) 2,583 -337.5 to -331.67
City Input Data
Population 661,645
Population Density (per/sq. mi) 81.07
Annual mean temp (F) 70.9 F
Annual CDD (65F base) 2,367
Annual HDD (65F base) 2,100
1 hr Ozone sensitivity 2.53
8 hr Ozone sensitivity 1.17
Albedo Sensitivity of Air Temperature -0.58
Vegetation Sensitivity of Air Temperature -0.29
Preliminary Draft
Estimated Baseline Energy Consumption for Older (pre 1980) Buildings

Mitigation Impact Screening Tool - Microsoft Internet Explorer

Address: http://mist.cadmusdev.com/Impacts.aspx

Estimated Baseline Energy Consumption for Older (pre 1980) Buildings

SECTOR	GAS HEATED BLDGS		ELECTRIC-HEAT BLDGS	PEAK POWER
	Elect: kWh	*Gas: Therms*	*kWh*	*Watts*
Residential	4,541 to 4,674	219 to 243	8,510 to 8,703	3,851 to 4,056
Office	12,812 to 13,196	102 to 109	14,115 to 14,394	8,030 to 8,428
Retail	12,724 to 13,090	40 to 46	13,277 to 13,562	5,485 to 5,750

Estimated Baseline Energy Consumption for Newer (post 1980) Buildings

SECTOR	GAS HEATED BLDGS		ELECTRIC-HEAT BLDGS	PEAK POWER
	Elect: kWh	*Gas: Therms*	*kWh*	*Watts*
Residential	2,518 to 2,583	75 to 85	3,690 to 3,788	2,143 to 2,272
Office	6,568 to 6,739	17 to 22	6,828 to 6,941	4,334 to 4,631
Retail	5,696 to 5,792	0 to 1	5,721 to 5,801	2,693 to 2,835

Estimated Typical Energy Savings for Older (pre 1980) Buildings

SECTOR	GAS HEATED BLDGS		ELECTRIC-HEAT BLDGS	PEAK POWER
	Elect: kWh	*Gas: Therms*	*kWh*	*Watts*
Residential	787.5 to 807.5 (17.31%)	-15 to -13.33 (-6.17%)	662.5 to 671.67 (7.75%)	506.67 to 515.83 (12.94%)
Office	936.88 to 994.38 (7.42%)	-3.75 to -3.75 (-3.56%)	900.63 to 957.5 (6.52%)	468.75 to 506.25 (5.92%)
Retail	1,035 to 1,063.13 (8.13%)	-1.88 to -1.88 (-4.38%)	1,015.63 to 1,041.88 (7.67%)	388.75 to 416.88 (7.17%)

Estimated Typical Energy Savings for Newer (post 1980) Buildings

SECTOR	GAS HEATED BLDGS		ELECTRIC-HEAT BLDGS	PEAK POWER
	Elect: kWh	*Gas: Therms*	*kWh*	*Watts*
Residential	365 to 373.33 (14.47%)	-4.17 to -3.33 (-4.74%)	331.67 to 337.5 (8.95%)	250.83 to 264.17 (11.67%)
Office	353.13 to 384.38 (5.54%)	-0.63 to -0.63 (-3.26%)	340.63 to 373.75 (5.19%)	190.63 to 232.5 (4.71%)
Retail	346.88 to 363.13 (6.18%)	0 to 0 (NaN%)	345.63 to 363.13 (6.15%)	139.38 to 155.63 (5.38%)

Ozone Results

Typical maximum (1-hour) ozone concentrations: 0.13 ppb

Projected change in maximum 1-hour ozone concentrations: -4.67 to -2.43 ppb

Projected change in maximum 8-hour ozone concentrations: -2.26 to -1.03 ppb

Print Results

For further information on MIST

- See www.epa.gov/heatisland for link to MIST (*in near future*).

- For details of model development see:

  Sailor, D.J. and N. Dietsch (in revision) "The urban heat island mitigation impact screening tool (MIST)", Environmental Modelling and Software, 2006.

Building Energy Effects of Ecoroofs

- Project Goals
  - To develop a physically-based model of how ecoroofs affect building energy consumption and incorporate this model within a state-of-the-art building energy simulation program.

Acknowledgements

- Dave Ervin & Graig Spolek, PSU; Allen Lee, Quantec LLC; US EPA, SBIR

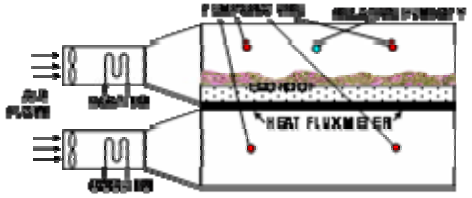
The Need

- Growing interest in ecoroof technologies
- Limited data related to building energy savings
- Design decisions are poorly informed
  - Soil type & depth
  - Construction details
  - Vegetation selection
  - Irrigation options
- Better quantification of energy impacts will facilitate the market penetration of ecoroof technologies.

Ecoroof Research at Portland State

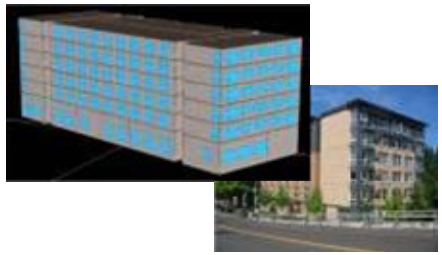
- Large-scale modeling of the impacts of ecoroofs on city-scale climate.

- Laboratory measurements to determine properties of soils/constructions



- Field measurements to gather rooftop energy budget data and building energy consumption data.

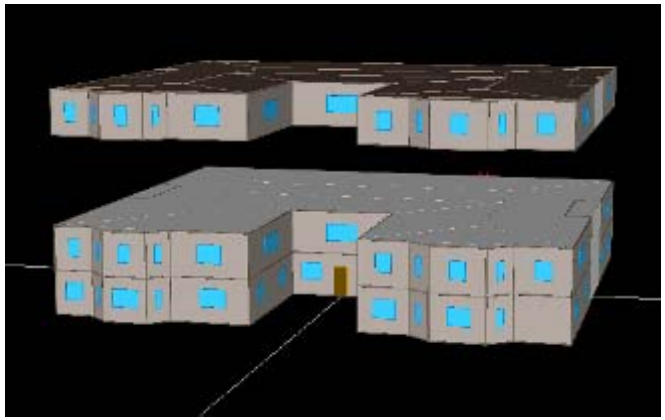
- Ecoroof module for building energy simulation

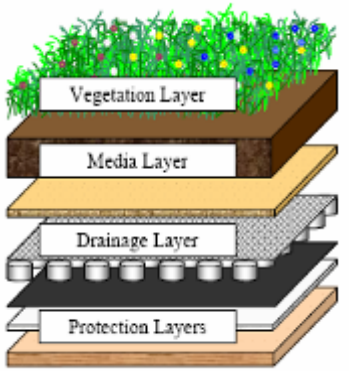


Ecoroof Modeling

- We have an existing developer's license agreement with the Department of Energy for Energy Plus (v. 1.3.0)

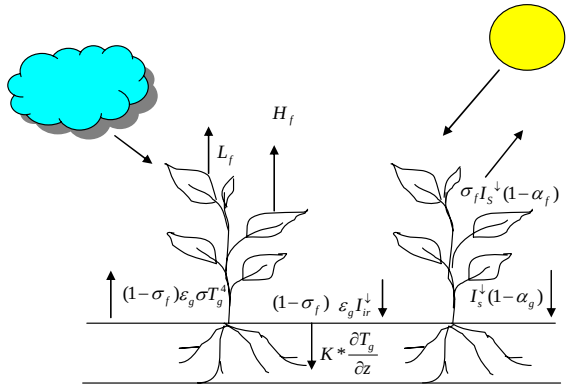
- We are developing an ecoroof module in EnergyPlus that tracks foliage/substrate temperatures, moisture, and heat fluxes to roof substrate



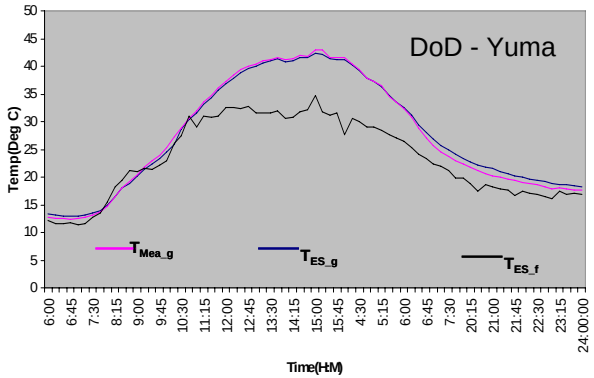


Ecoroof Module Development Status (1/2)

- Developed vegetation heat transfer equation set for use in building energy simulations.



- Tested vegetation module in stand-alone mode against field data.



Ecoroof Module Development Status (2/2)

- Implementing module in EnergyPlus
- Gathering property data for use in modeling.
- Gathering building energy consumption and flux data for use in validating module performance.

- Future plans
  - Deliver ecoroof module to DoE for inclusion in EnergyPlus (for use by energy modeling community)
  - Develop a web-based scoping tool (similar to MIST) to allow initial assessment of ecoroof designs for different building types and climates.