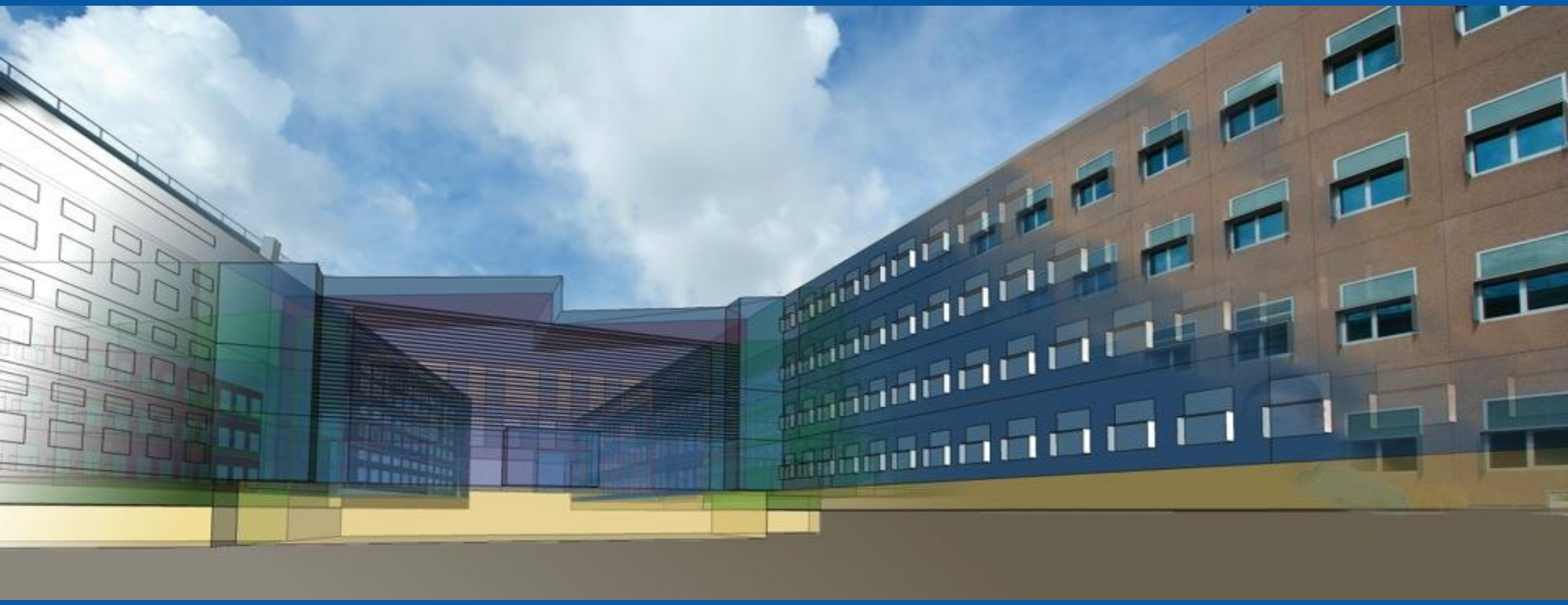
NREL
NATIONAL RENEWABLE ENERGY LABORATORY

Analysis Spreadsheet Concepts



Commercial Buildings Controls and Analysis Tools Team
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Spreadsheet Overview

The OpenStudio Analysis Spreadsheet is a tool used to apply algorithms to an OpenStudio measure based workflow and run those jobs on Amazons EC2 cloud based computing infrastructure. Typical analyses include the use of sampling algorithms to perform sensitivity studies, optimization algorithms to find an 'optimal' set of measures and/or calibrate a model to metered utility data.

The spreadsheet and basic installation instructions can be found at https://github.com/NREL/OpenStudio-analysis-spreadsheet. The /projects/ folder contains a template.xlsx spreadsheet which can be edited to satisfy the users needs. There are also three SEB spreadsheets which are example sampling and calibration problems related to the Site Entrance Building at NREL. All supporting files for that example can be found the in /Calibration_example/ folder.

The purpose of this document is to explain the functionality of each portion of the spreadsheet. The spreadsheet has three main user tabs: Setup, Variables and Outputs. The Setup tab defines all the algorithmic information, the Amazon EC2 configuration and the directory paths for all the supporting files. The Variables tab defines the measure based workflow to be applied to the seed model as well as defining the variable ranges and configurations for the algorithm. Finally the Outputs tab defines any objective function information, which variables should be available to visualize on the server instance and which variables that should be available in the downloadable database in csv or R-dataframe format.

Spreadsheet Overview

The Setup tab has several subsections to it, usually delineated by a **green color**. They are:

- Settings
- Running Setup
- Problem Definition
- Algorithm Setup
- Weather Files
- Models
- Other Library Files

The editable fields of the spreadsheet Setup tab are denoted by a **tan color**. There are several excel formulas being used in the Algorithm setup section to make sure that the right algorithmic settings are used for the right algorithms. All supporting data for the drop-down and algorithm section can be found on the Lookups tab of the spreadsheet. It is advised to only change make changes in the tan color sections if there is one for a particular row.

Setup Tab

Settings

	A	B	C	D	E
1					
2	Settings				
3	Spreadsheet Version	0.4.2			
4	User Id	new_user			
5	OpenStudio Server Version	1.10.0-rc1			
6	Cluster Name	Default Cluster			
7	Server Instance Type	m3.xlarge	Recommended for Server	4 Cores with 40 GB	$0.28/hour
8	Worker Instance Type	c3.8xlarge	Recommended for worker	32 Cores with 320 GB	$1.68/hour
9	Worker Nodes	1		Total Cost	$1.96/hour
10	AWS Tag	org=5500			
11					

- **Spreadsheet Version**: This is the version of the OpenStudio-analysis-gem. Available releases can be found at https://github.com/NREL/OpenStudio-analysis-gem/releases. This gem creates and configures the *analysis.json* files needed for running the OpenStudio Distributed Analysis workflow
- **OpenStudio Server Version**: This is the version of the OpenStudio-server which points to specific AMIs on Amazon. Available releases can be found at: http://developer.nrel.gov/downloads/buildings/openstudio/api/amis_v2.json (JSON plugin viewer for your web browser is recommended). Typical updates to the server include performance updates for the visualization capability, addition of new algorithms and updates to OpenStudio and EnergyPlus.
- **User ID** and **AWS Tag**: are not used outside of NREL

Setup Tab

http://aws.amazon.com/ec2/instance-types/
http://aws.amazon.com/ec2/pricing/

Settings

	A	B	C	D	E
1					
2	Settings				
3	Spreadsheet Version	0.4.2			
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9	Worker Nodes			Total Cost	$1.96/hour
10	AWS Tag				
11					

m3.large
m3.xlarge
m3.2xlarge
c3.large
c3.xlarge
c3.2xlarge
c3.4xlarge
c3.8xlarge

- **Server and Worker Instance Type**: These are dropdown menus to select the Amazon instance type to spin up. The number of cores and memory for each system is described in column D along with approximate cost information. The official prices and more detailed instance descriptions can be found at http://aws.amazon.com/ec2/instance-types/ and http://aws.amazon.com/ec2/pricing/.
- **Worker Nodes**: This is the number of worker nodes to launch. Select 0 if you only want a server.
- **Cluster Name**: This name will be the filename in the *'filename.json'* at the root of the spreadsheet directory upon starting an analysis and contains the Amazon instance IP addresses. The system will first check if this file exists, and if it does will try to submit the job to this Amazon configuration. To submit a job to a new cluster, simply delete this file or run 'rake clean' as outlined on the spreadsheet github page.

Setup Tab

Running Setup

12	Running Setup	
13	Analysis Name	Template
14	Measure Directory	../measures
15	Export Directory	../analysis
16	Allow Multiple Jobs	TRUE
17	Use Server As Worker	TRUE
18	Simulate Data Point Filename	simulate_data_point.rb
19	Run Data Point Filename	run_openstudio_workflow_monthly.rb
20		

- **Analysis Name**: This is the user defined name of the analysis to be run. This will be the identifier on the server dashboard so make sure its something that differentiates your analysis since several analyses can be run on the same server.
- **Measure Directory**: This is the path to the directory containing the project OpenStudio measures. This is a relative path from the /projects/ folder where the spreadsheet should reside. To include more than one measure directory, just copy / insert and edit the path below the first Measure Directory. In the case of multiple measure directories, search order for finding measures is done top down.
- **Export Directory**: This is the location of the analysis.json file describing the workflow (as created by the OpenStudio-analysis-gem) which is uploaded to the server as well as a .zip file of the measures needed for the analysis.
- **Use Server As Worker**: This is a flag to allow jobs to be run on the server. The default setting is true and must be true for the Optim and Rgenoud algorithms.

Setup Tab

Problem Definition

21	Problem Definition	Problem Type	
22	Analysis Type	lhs	
23			
24	Algorithm Setup		lowed Values and Description
25	Sample Method	individual_variables	individual_variables / all_variables
26	Number of Samples	40	positive integer (if individual, total simulations is this times each variable)
27			

lhs
optim
rgenoud
nsga_nrel
preflight
doe
single_run
repeat_run

Analysis Type: This is a dropdown listing all available algorithms. Once an algorithm is selected, the algorithmic parameters in the Algorithm Setup section below should change to match the needed inputs for the algorithm. **Changing the default values should be done in the tan section of Column D**. A detailed description of each algorithm follows below.

Setup Tab

Algorithm Setup

21	Problem Definition	Problem Type		
22	Analysis Type	preflight		
23				
24	Algorithm Setup	Configuration Values	Allowed Values and Description	Override Defaults (Enter values here to override the Defaults in Column B)
25				
26				

Preflight: This is an algorithm that will run three simulations:

1. All variables set to the minimum value
2. All variables set to the maximum value
3. All variables set to the mean value

All other variables will be set to their static or default value. This method is extremely useful for debugging the parameter space before a costly sampling or optimization is run. The assumption here is that if the problem will run at the variable boundaries and at the mean, it should safely run at points in between.

Setup Tab

Algorithm Setup

21	Problem Definition	Problem Type		
22	Analysis Type	lhs		
23				
24	Algorithm Setup	Configuration Values	Allowed Values and Description	Override Defaults (Enter values here to override the Defaults in Column B)
25	Sample Method	individual_variables	individual_variables / all_variables	
26	Number of Samples	40	positive integer (if individual, total simulations is this times each variable)	40
27				

LHS: This is a Latin Hyper Cube algorithm. The actual algorithm implemented can be found at http://cran.r-project.org/web/packages/lhs/lhs.pdf. There are two options for this algorithm:

- **Sample Method**: This has two settings:
  1. 'all_variables' will sample all of your variables all at once.
  2. 'individual_variables' will sample each variable individually while holding the other variables to their static value.

- **Number of Samples**: This is the number of samples to generate.
  1. For the 'all_variables' case this is the total number of simulations to create.
  2. For the 'individual_variables' case, the total number of simulations will be this number times the number of variables.

Setup Tab

Algorithm Setup

21	Problem Definition	Problem Type	
22	Analysis Type	doe	
23			
24	Algorithm Setup	Configuration Values	Allowed Values and Description
25	Experiment Type	full_factorial	full_factorial
26	Number of Samples	2	positive integer (this discretizes a continous variable)

DOE: This is a design of experiments algorithm. It will generate a full factorial experiment type. This algorithm can work with continuous variables. It will sample or discretize a continuous variable and then create the full factorial design from all the discrete values. The number of samples should be kept to a small number to keep the total number of simulations to a reasonable value. The algorithms implemented are from the DoE.base package http://cran.r-project.org/web/packages/DoE.base/DoE.base.pdf

- **Experiment Type**: 'full_factorial'
- **Number of Samples**: used to discretize a continuous variable.

Setup Tab

Algorithm Setup

21	Problem Definition	Problem Type		
22	Analysis Type	single_run		
23				
24	Algorithm Setup	Configuration Values	Allowed Values and Description	Override Defaults (Enter values here to override the Defaults in Column B)
25				
26				
27				

Single Run: This method will run one simulation with all variables set to their static or default value. This method is good for debugging and testing a measure workflow.

note: if the user only intends to do single runs, then select a medium to low cost server instance and set the number of workers to 0.

Setup Tab

Algorithm Setup

21	Problem Definition	Problem Type	
22	Analysis Type	repeat_run	
23			
24	Algorithm Setup	Configuration Values	Allowed Values and Description
25	Number of Runs	30	positive integer (if individual, total simulations is this

Repeat Run: This method will run one simulation with all variables set to their static or default value, N number of times. The simulations will be run in parallel, up to the number of cores that are selected by the instance types. This method is good for debugging and testing possible race conditions or non-deterministic errors that may occur.

- **Number of Runs**: total number of the static or default simulation to run.

Setup Tab

Algorithm Setup

21	Problem Definition	Problem Type		
22	Analysis Type	optim		
23				
24	Algorithm Setup	Configuration Values	Allowed Values and Description	Override Defaults (Enter values here to override the Defaults in Column B)
25	epsilonGradient	0.01	epsilon in gradient calculation	
26	pgtol	0.01	tolerance on the projected gradient	
27	factr	4.5036E+13	Tolerance on delta_F	
28	maxit	100	Maximum number of iterations	
29	normType	minkowski		
30	pPower	2	Lp norm power	
31	Exit On Guideline14	0	0 false / 1 true (for use with calibration report)	

Optim: This method will perform a quasi- Newton gradient search. Details can be found at https://stat.ethz.ch/R-manual/R-devel/library/stats/html/optim.html.

- **epsilonGradient**: delta-X in the finite difference gradient calculation.
- **pgtol**: Tolerance on the projected gradient in the current search direction.
- **factr**: Convergence occurs when the reduction in the objective is within this factor of the machine tolerance.
- **maxit**: The maximum number of iterations. (This is not the total number of simulations. That will be more than number of iterations * number of variables * 2.)
- **pPower**: Lp norm power to use on the objective functions. 1 is absolute value, 2 is RMSE.
- **Exit On Guideline14**: For use with the calibration reporting measure. This will terminate the search of any result satisfies guideline 14. Default is 0.

Setup Tab

Algorithm Setup

21	Problem Definition	Problem Type		
22	Analysis Type	rgenoud		
23				
24	Algorithm Setup	Configuration Values	Allowed Values and Description	Override Defaults (Enter values here to override the Defaults in Column B)
25	popSize	60	Size of initial population	60
26	Generations	5	Number of generations	
27	waitGenerations	2	If no improvement in waitGenerations of generations, then exit	
28	bfgsburnin	2	The number of generations which are run before the BFGS is first used	
29	gradientcheck	0	0 false / 1 true	0
30	solutionTolerance	0.01	Numbers within solutionTolerance are considered	
31	epsilonGradient	0.01	epsilon in gradient calculation	
32	pgtol	0.01	tolerance on the projected gradient	
33	factr	4.5036E+13	Tolerance on delta_F	
34	maxit	100	Maximum number of iterations	
35	normType	minkowski		
36	pPower	2	Lp norm power	
37	Exit On Guideline14	0	0 false / 1 true (for use with calibration report)	
38	balance	1	0 false / 1 true (load balancing)	

Rgenoud: This algorithm combines evolutionary search algorithms with derivative-based methods. Details can be found at http://cran.r-project.org/web/packages/rgenoud/rgenoud.pdf. The problem type should be all continuous variables. The algorithm will perform several generations with the evolutionary algorithm and then alternate between the quasi-newton based Optim method and the evolutionary search. The algorithm has a scalar objective function.

Setup Tab

Rgenoud continued:

- **popSize**: This is the size of the population for each evolutionary search.
- **Generations**: This is the maximum number of generations to run.
- **waitGeneration**s: If there is no improvement in the objective function in this number of generations, genoud will think that it has found the optimum.
- **bfgsburnin**: This is the number of generations to perform before the gradient search.
- **gradientcheck**: If this variable is TRUE, genoud will not start counting waitGenerations unless each gradient is solutionTolerance close to zero.
- **solutionTolerance**: Numbers within solutionTolerance are considered to be equal.
- **epsilonGradient**: delta-X in the finite difference gradient calculation.
- **pgtol**: Tolerance on the projected gradient in the current search direction.
- **factr**: Convergence occurs when the reduction in the objective is within this factor of the machine tolerance.
- **maxit**: The maximum number of iterations. (This is not the total number of simulations. That will be more than number of iterations * number of variables * 2.)
- **pPower**: Lp norm power to use on the objective functions. 1 is absolute value, 2 is RMSE.
- **Exit On Guideline14**: For use with the calibration reporting measure. This will terminate the search of any result satisfies guideline 14. Default is 0.
- **balance**: This logical flag controls if load balancing is done across the cluster. This should be set to 1 true.

Setup Tab

Algorithm Setup

21	Problem Definition	Problem Type		
22	Analysis Type	nsga_nrel		
23				
24	Algorithm Setup	Configuration Values	Allowed Values and Description	Override Defaults (Enter values here to override the Defaults in Column B)
25	Number of Samples	90	Size of initial population	90
26	Generations	6	Number of generations	6
27	cprob	0.85	Crossover probability [0,1]	
28	XoverDistIdx	5	Crossover Distribution Index (large values give higher probabilities of offspring close to parent)	
29	MuDistIdx	5	Mutation Distribution Index (large values give higher probabilities of offspring close to parent)	
30	mprob	0.8	Mutation probability [0,1]	
31	toursize	2	Tournament Size	
32	normType	minkowski		
33	pPower	2	Lp norm power	
34	Exit On Guideline14	0	0 false / 1 true (for use with calibration report)	

NSGA2: This algorithm is a box-constrained multiobjective optimization using the elitist non-dominated sorting genetic algorithm NSGA-II. The version used on the server is a modified version of the R package found at http://cran.r-project.org/web/packages/nsga2R/nsga2R.pdf with changes made to allow for parallelization of simulations for each generation and to allow for mixed continuous and discrete variables.

Setup Tab

NSGA2 continued:

- **Number of Samples**: This is the size of the population for each generation.
- **Generations**: The total number of search generations to perform. Total number of simulations will be number of samples times generations.
- **cprob**: Crossover probability. Should be between [0,1]
- **XoverDistIdx**: Crossover distribution index. Large values give higher probabilities of offspring close to parent.
- **MuDistIdx**: Mutation distribution index. Large values give higher probabilities of offspring close to parent.
- **mprob**: Mutations probability. Should be between [0,1]
- **toursize**: Tournament size.
- **pPower**: Lp norm power to use on the objective functions. 1 is absolute value, 2 is RMSE.
- **Exit On Guideline14**: For use with the calibration reporting measure. This will terminate the search of any result satisfies guideline 14. Default is 0.

Setup Tab

Weather Files

39	Weather Files	Path (relative to this spreadsheet or absolute path)	Weather files in the .zip format. Can list individually or use a wild card
40	Weather File	../weather/USA_CO_Denver.Intl.AP.725650_TMY3.epw	
41			

Weather File: This is the relative path to the weather file needed for simulation. A single weather file may be called out specifically as above, or wild cards can be used and the entire directory will be sent to the server as depicted below.

36	Weather Files	Path (relative to this spreadsheet or absolute path)	Weather files in the .zip format. Can list individually or use a wild card
37	Weather File	../weather_65445/*	
38			

Setup Tab

Models

39	Models	Identifier	File Type	Path (relative to this spreadsheet or absolute path)	If there are more than one seed models, then you will submit the same analysis for each seed
40	Model		OSM	../seeds/EmptySeedModel.osm	na
41					

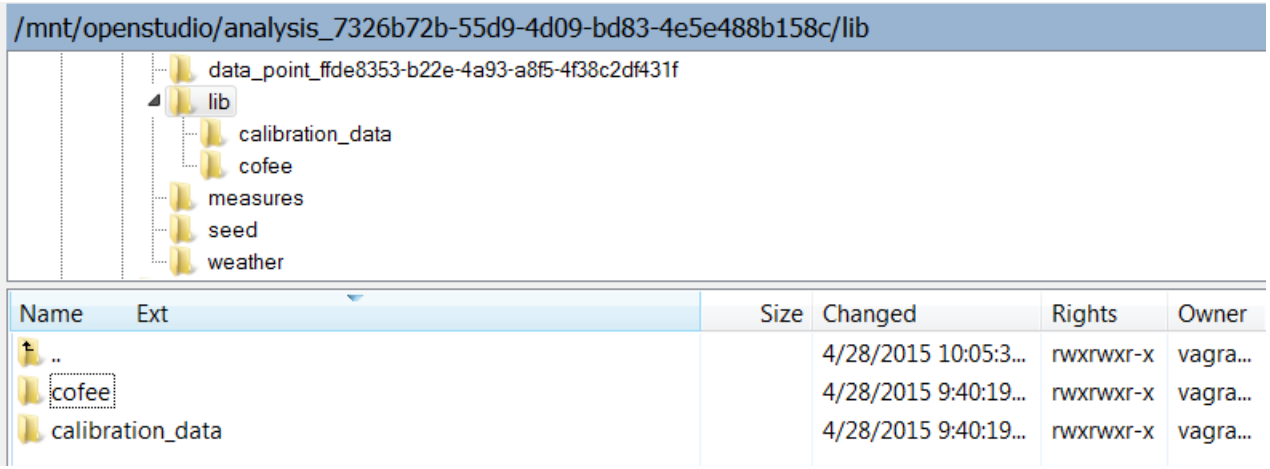
Model: This is the relative path to the OSM seed file needed for simulation.

Setup Tab

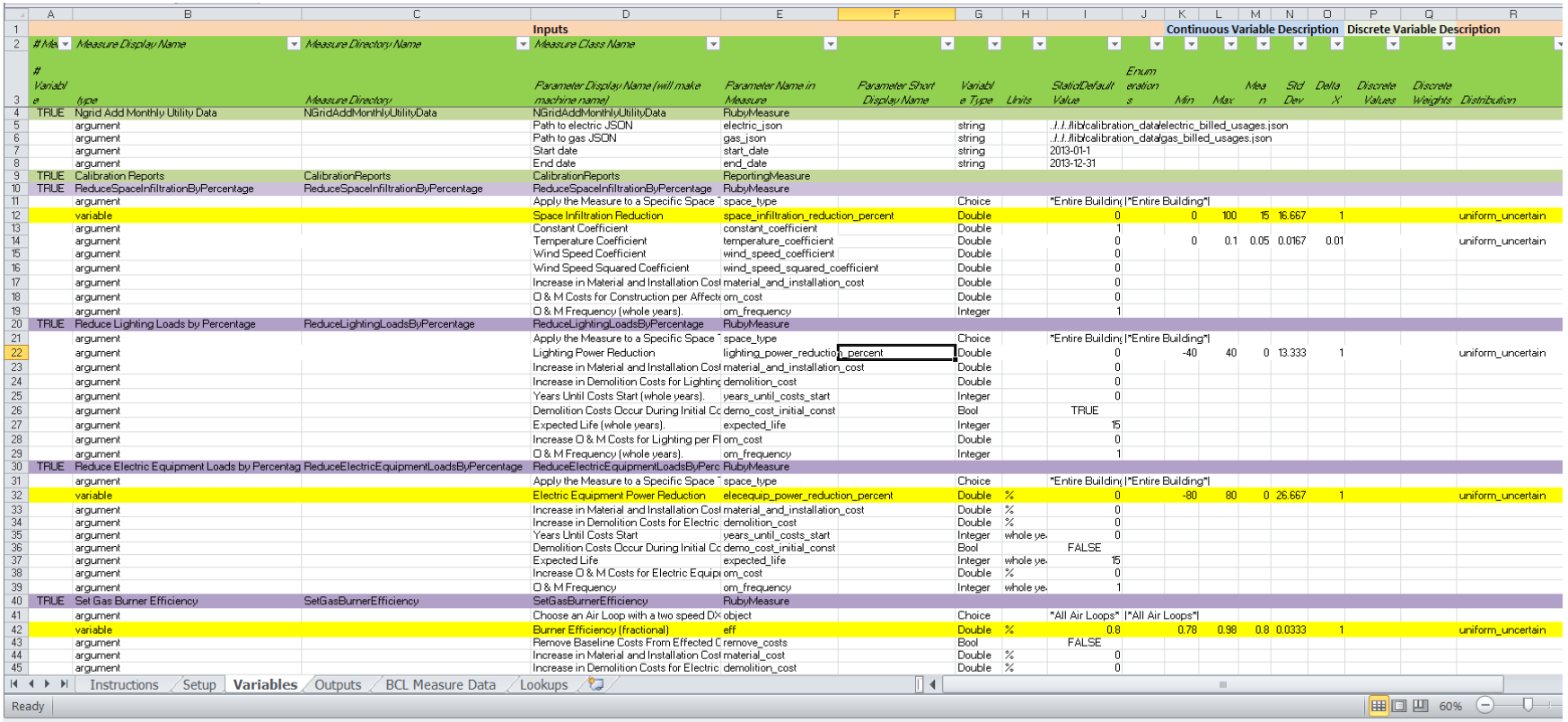
Other Library Files

42	Other Library Files	Directory to Unpack to	Files to include (relative to this spreadsheet or absolute path). If a directory then it will include all subfolders and files		If extra library files are needed then include them here. These are typically preprocessors or postprocessors and require custom measures to use.
43	Directory	calibration_data	../Calibration_example/lib		
44					

Directory: This is the relative path to any supporting data or files that any of the measures may need. The directory or files will be copied to the /lib/ folder on the server, which is 3 levels higher than the run directory on the server. As an example, the 'electric_billed_usages.json' file in the '../Calibration_example/lib/' folder would get moved to the '/lib/calibration_data/' folder on the server. Any measure looking for that file would find it at '../../../lib/calibration_data/electric_billed_usages.json' from the run directories on the server.



Variables Tab



#	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R
1				Inputs							Continuous Variable Description					Discrete Variable Description		
2	# Ma	Measure Display Name	Measure Directory Name	Measure Class Name														
3	# Variable	type	Measure Directory	Parameter Display Name (will make machine name)	Parameter Name in Measure	Parameter Short Display Name	Variable Type	Units	StaticDefault Value	Enumerations	Min	Max	Mean	Std Dev	Delta X	Discrete Values	Discrete Weights	Distribution
4	TRUE	Ngrid Add Monthly Utility Data	NGridAddMonthlyUtilityData	NGridAddMonthlyUtilityData	RubyMeasure													
5		argument		Path to electric JSON	electric_json		string		../../../lib/calibration_data/electric_billed_usages.json									
6		argument		Path to gas JSON	gas_json		string		../../../lib/calibration_data/gas_billed_usages.json									
7		argument		Start date	start_date		string		2013-01-1									
8		argument		End date	end_date		string		2013-12-31									
9	TRUE	Calibration Reports	CalibrationReports	CalibrationReports	ReportingMeasure													
10	TRUE	ReduceSpaceInfiltrationByPercentage	ReduceSpaceInfiltrationByPercentage	ReduceSpaceInfiltrationByPercentage	RubyMeasure													
11		argument		Apply the Measure to a Specific Space	space_type		Choice		*Entire Building*	*Entire Building*|								
12		variable		Space Infiltration Reduction	space_infiltration_reduction_percent		Double		0		0	100	15	16.667	1			uniform_uncertain
13		argument		Constant Coefficient	constant_coefficient		Double		1									
14		argument		Temperature Coefficient	temperature_coefficient		Double		0		0	0.1	0.05	0.0167	0.01			uniform_uncertain
15		argument		Wind Speed Coefficient	wind_speed_coefficient		Double		0									
16		argument		Wind Speed Squared Coefficient	wind_speed_squared_coefficient		Double		0									
17		argument		Increase in Material and Installation Cost	material_and_installation_cost		Double		0									
18		argument		O & M Costs for Construction per Affecte	om_cost		Double		0									
19		argument		O & M Frequency (whole years).	om_frequency		Integer		1									
20	TRUE	Reduce Lighting Loads by Percentage	ReduceLightingLoadsByPercentage	ReduceLightingLoadsByPercentage	RubyMeasure													
21		argument		Apply the Measure to a Specific Space	space_type		Choice		*Entire Building*	*Entire Building*|								
22		argument		Lighting Power Reduction	lighting_power_reduction_percent		Double		0		-40	40	0	13.333	1			uniform_uncertain
23		argument		Increase in Material and Installation Cost	material_and_installation_cost		Double		0									
24		argument		Increase in Demolition Costs for Lighting	demolition_cost		Double		0									
25		argument		Years Until Costs Start (whole years).	years_until_costs_start		Integer		0									
26		argument		Demolition Costs Occur During Initial Co	demo_cost_initial_const		Bool		TRUE									
27		argument		Expected Life (whole years).	expected_life		Integer		15									
28		argument		Increase O & M Costs for Lighting per Fl	om_cost		Double		0									
29		argument		O & M Frequency (whole years).	om_frequency		Integer		1									
30	TRUE	Reduce Electric Equipment Loads by Percentag	ReduceElectricEquipmentLoadsByPercentage	ReduceElectricEquipmentLoadsByPerc	RubyMeasure													
31		argument		Apply the Measure to a Specific Space	space_type		Choice		*Entire Building*	*Entire Building*|								
32		variable		Electric Equipment Power Reduction	elecequip_power_reduction_percent		Double	%	0		-80	80	0	26.667	1			uniform_uncertain
33		argument		Increase in Material and Installation Cost	material_and_installation_cost		Double	%	0									
34		argument		Increase in Demolition Costs for Electric	demolition_cost		Double	%	0									
35		argument		Years Until Costs Start	years_until_costs_start		Integer	whole ye	0									
36		argument		Demolition Costs Occur During Initial Co	demo_cost_initial_const		Bool		FALSE									
37		argument		Expected Life	expected_life		Integer	whole ye	15									
38		argument		Increase O & M Costs for Electric Equipr	om_cost		Double	%	0									
39		argument		O & M Frequency	om_frequency		Integer	whole ye	1									
40	TRUE	Set Gas Burner Efficiency	SetGasBurnerEfficiency	SetGasBurnerEfficiency	RubyMeasure													
41		argument		Choose an Air Loop with a two speed DX	object		Choice		*All Air Loops*	*All Air Loops*|								
42		variable		Burner Efficiency (fractional)	eff		Double	%	0.8		0.78	0.98	0.8	0.0333	1			uniform_uncertain
43		argument		Remove Baseline Costs From Effected C	remove_costs		Bool		FALSE									
44		argument		Increase in Material and Installation Cost	material_cost		Double	%	0									
45		argument		Increase in Demolition Costs for Electric	demolition_cost		Double	%	0									

Instructions | Setup | **Variables** | Outputs | BCL Measure Data | Lookups

Ready 60%

The Variables tab describes the measure based workflow to be applied to the seed model, which was defined on the Setup tab. The format of the Variables tab has changed over time and must be consistent with the OpenStudio-analysis-gem version that is set at the top of the Setup tab. The description of the Variables tab used in this document will be for version 0.4.2.

Variables Tab

The Variables tab lists the measures that are to be applied to the seed model and are applied in top-down order. All OpenStudio or RubyMeasures are applied first (in top-down order), followed by EnergyPlusMeasures and finally ReportingMeasures.

Column A is a 'Measure Enabled' flag to turn measures on or off in the workflow. A measure set to 'FALSE' will not be put into the workflow. This feature is useful for debugging if a certain measure is causing errors.

	A	B	C
1			
2	# Meas	*Measure Display Name*	*Measure Directory Name*
3	*# Variable*	*type*	*Measure Directory*
9	TRUE	Calibration Reports	CalibrationReports
10	TRUE	ReduceSpaceInfiltrationByPercentage	ReduceSpaceInfiltrationByPercentage
11		argument	
12		variable	
13		argument	
14		argument	
15		argument	
16		argument	
17		argument	
18		argument	
19		argument	
20	TRUE	Reduce Lighting Loads by Percentage	ReduceLightingLoadsByPercentage
21		argument	
22		argument	
23		argument	
24		argument	
25		argument	
26		argument	
27		argument	
28		argument	
29		argument	
30	TRUE	Reduce Electric Equipment Loads by Percentage	ReduceElectricEquipmentLoadsByPercentage

Instructions | Setup | **Variables** | Outputs | BCL Measure Data | Lookups

Variables Tab

Column B is the display name for the measure. This name will be used in plots and must be a unique name (If the same measure is being used more than once, each measure must have a unique distinguishing name). For measures that have arguments, **Column B** is also where the *argument* is turned into a *variable*. When turning an argument into a variable, **Columns K-R** also need to be filled out for the variable row.

Column D is the *Measure Class Name* for the measure which is found in the measure.rb file.

```
#start the measure
class ReduceSpaceInfiltrationByPercentage < OpenStudio::Ruleset::ModelUserScript
```

Column D is also the *Parameter Display Name* for the measure arguments which will make the machine name for the arguments. These are listed under the *Measure Class Name*. Any variable must have a unique *Parameter Display Name*.

	A	B	D	E
1			**Inputs**	
2	*# Meas*	*Measure Display Name*	*Measure Class Name*	
3	*Variable*	*type*	*machine name)*	*Measure*
9	TRUE	Calibration Reports	CalibrationReports	ReportingMeasure
10	TRUE	ReduceSpaceInfiltrationByPercentage	ReduceSpaceInfiltrationByPercentage	RubyMeasure
11		argument	Apply the Measure to a Specific Space Type o	space_type
12		variable	Space Infiltration Reduction	space_infiltration_reductior
13		argument	Constant Coefficient	constant_coefficient
14		argument	Temperature Coefficient	temperature_coefficient
15		argument	Wind Speed Coefficient	wind_speed_coefficient
16		argument	Wind Speed Squared Coefficient	wind_speed_squared_coeffi
17		argument	Increase in Material and Installation Costs for	material_and_installation_c
18		argument	O & M Costs for Construction per Affected Fl	om_cost
19		argument	O & M Frequency (whole years).	om_frequency

Variables Tab

Column E is the type of measure (RubyMeasure, EnergyPlusMeasure or ReportingMeasure). Underneath the measure type is the *Parameter Name* that's used in the measure. These values can be found in the argument section of the measure.rb file.

```
#make an argument for reduction percentage
space_infiltration_reduction_percent = OpenStudio::Ruleset::OSArgument::makeDoubleArgument("space_infiltration_reduction_percent",true)
space_infiltration_reduction_percent.setDisplayName("Space Infiltration Power Reduction (%).")
space_infiltration_reduction_percent.setDefaultValue(30.0)
args << space_infiltration_reduction_percent
```

The **Column D** *Parameter Display Name* will override the .setDisplayName() that is defined in the measure.rb file.

	A	B	D	E
1			**Inputs**	
2	*# Meas*	*Measure Display Name*	*Measure Class Name*	
3	*Variable*	*type*	*machine name)*	*Measure*
9	TRUE	Calibration Reports	CalibrationReports	ReportingMeasure
10	TRUE	ReduceSpaceInfiltrationByPercentage	ReduceSpaceInfiltrationByPercentage	RubyMeasure
11		argument	Apply the Measure to a Specific Space Type o	space_type
12		variable	Space Infiltration Reduction	space_infiltration_reductior
13		argument	Constant Coefficient	constant_coefficient
14		argument	Temperature Coefficient	temperature_coefficient
15		argument	Wind Speed Coefficient	wind_speed_coefficient
16		argument	Wind Speed Squared Coefficient	wind_speed_squared_coeffi
17		argument	Increase in Material and Installation Costs for	material_and_installation_c
18		argument	O & M Costs for Construction per Affected Fl	om_cost
19		argument	O & M Frequency (whole years).	om_frequency

Variables Tab

Column C is the directory name for the measure. The path to this directory is defined on the Setup tab in the Running Setup section. The name should be machine readable and should not contain any spaces or special characters.

	A	B	C
1			
2	# Meas	Measure Display Name	Measure Directory Name
3	# Variable	type	Measure Directory
9	TRUE	Calibration Reports	CalibrationReports
10	TRUE	ReduceSpaceInfiltrationByPercentage	ReduceSpaceInfiltrationByPercentage
11		argument	
12		variable	
13		argument	
14		argument	
15		argument	
16		argument	
17		argument	
18		argument	
19		argument	
20	TRUE	Reduce Lighting Loads by Percentage	ReduceLightingLoadsByPercentage
21		argument	
22		argument	
23		argument	
24		argument	
25		argument	
26		argument	
27		argument	
28		argument	
29		argument	
30	TRUE	Reduce Electric Equipment Loads by Percentage	ReduceElectricEquipmentLoadsByPercentage

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Variables Tab

Column F is the *Parameter Short Display Name* for the *Parameter Display Name* defined in **Column D**. This is an optional field and if defined will be used in the visualization tools on the server.

D	E	F
Inputs		
Measure Class Name		
Parameter Display Name (will make machine name)	*Parameter Name in Measure*	*Parameter Short Display Name*
CalibrationReports	ReportingMeasure	
ReduceSpaceInfiltrationByPercentage	RubyMeasure	
Apply the Measure to a Specific Space Type or t	space_type	
Space Infiltration Reduction	space_infiltration_reduction_percent	
Constant Coefficient	constant_coefficient	
Temperature Coefficient	temperature_coefficient	
Wind Speed Coefficient	wind_speed_coefficient	
Wind Speed Squared Coefficient	wind_speed_squared_coefficient	
Increase in Material and Installation Costs for B	material_and_installation_cost	
O & M Costs for Construction per Affected Floo	om_cost	
O & M Frequency (whole years).	om_frequency	
ReduceLightingLoadsByPercentage	RubyMeasure	
Apply the Measure to a Specific Space Type or t	space_type	
Lighting Power Reduction	lighting_power_reduction_percent	
Increase in Material and Installation Cost for Lig	material_and_installation_cost	
Increase in Demolition Costs for Lighting per Flo	demolition_cost	
Years Until Costs Start (whole years).	years_until_costs_start	
Demolition Costs Occur During Initial Constructi	demo_cost_initial_const	
Expected Life (whole years).	expected_life	
Increase O & M Costs for Lighting per Floor Area	om_cost	
O & M Frequency (whole years).	om_frequency	

Variables Tab

Column G is the argument or variable type. Possible values are Double, Integer, Bool, Choice and String. These values must match what is in the measure.rb file.

```
#make an argument for reduction percentage
space_infiltration_reduction_percent = OpenStudio::Ruleset::OSArgument::makeDoubleArgument("space_infiltration_reduction_percent",true)
space_infiltration_reduction_percent.setDisplayName("Space Infiltration Power Reduction (%).")
space_infiltration_reduction_percent.setDefaultValue(30.0)
args << space_infiltration_reduction_percent
```

Column H is an optional column for defining the units.

G	H	I	J	K	L	M	N	O
				Continuous Variable Description				
Variable Type	*Units*	*Static/Default Value*	*Enumerations*	*Min*	*Max*	*Mean*	*Std Dev*	*Delta X*
Choice		*Entire Building*	|*Entire Building*|					
Double		0		0	100	15	16.667	1
Double		1						
Double		0		0	0.1	0.05	0.0167	0.01
Double		0						
Double		0						
Double		0						
Double		0						
Integer		1						
Choice		*Entire Building*	|*Entire Building*|					
Double		0		-40	40	0	13.333	1
Double		0						
Double		0						
Integer		0						
Bool		TRUE						
Integer		15						
Double		0						
Integer		1						

Variables Tab

Column I is the static or default value for the argument. If the argument is turned into a variable, this value will be used when the variable is held constant during an 'individual_variables' LHS sampling or a 'single_run' analysis.

Column J is an optional list of enumeration of possible argument values. This column is slated for deprication.

G	H	I	J	K	L	M	N	O
				Continuous Variable Description				
Variable Type	*Units*	*Static/Default Value*	*Enumerations*	*Min*	*Max*	*Mean*	*Std Dev*	*Delta X*
Choice		*Entire Building*	|*Entire Building*|					
Double		0		0	100	15	16.667	1
Double		1						
Double		0		0	0.1	0.05	0.0167	0.01
Double		0						
Double		0						
Double		0						
Double		0						
Integer		1						
Choice		*Entire Building*	|*Entire Building*|					
Double		0		-40	40	0	13.333	1
Double		0						
Double		0						
Integer		0						
Bool		TRUE						
Integer		15						
Double		0						
Integer		1						

Variables Tab

Column k is the minimum value for a variable.
Column L is the maximum value for a variable.
Column M is the mean value for a variable.
Columns k-m must be filled out if an argument is turned into a variable, even if the values are discrete.
Column N is the standard deviation for the variable. A typical value is (max – min)/6.

G	H	I	J	K	L	M	N	O
				Continuous Variable Description				
Variable Type	*Units*	*Static/Default Value*	*Enumerations*	*Min*	*Max*	*Mean*	*Std Dev*	*Delta X*
Choice		*Entire Building*	|*Entire Building*|					
Double		0		0	100	15	16.667	1
Double		1						
Double		0		0	0.1	0.05	0.0167	0.01
Double		0						
Double		0						
Double		0						
Double		0						
Integer		1						
Choice		*Entire Building*	|*Entire Building*|					
Double		0		-40	40	0	13.333	1
Double		0						
Double		0						
Integer		0						
Bool		TRUE						
Integer		15						
Double		0						
Integer		1						

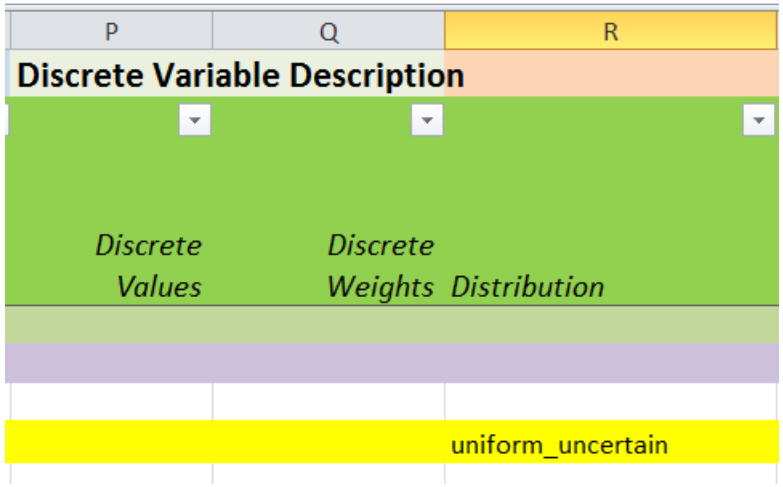
Variables Tab

Column O is the delta X (or change in X) that is used in the gradient calculation (in the Optim and Rgenoud algorithms). The default for this value is 1e-8. If the variable is not sensitive to changes that small, then this value should be changed to a small enough value to where EnergyPlus will result in an output change. This value is optional.

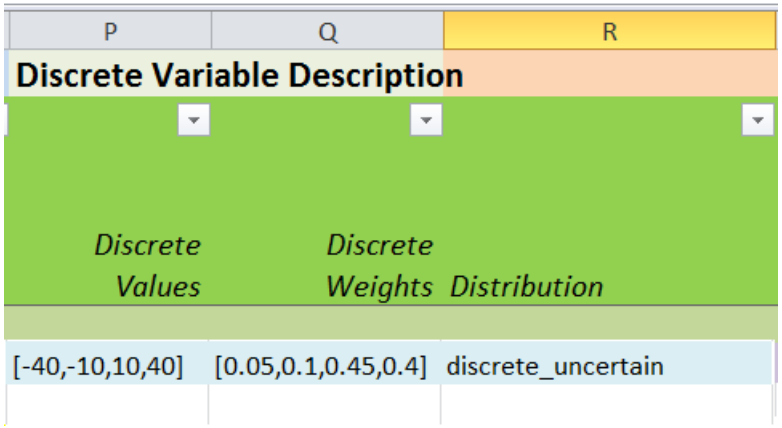
G	H	I	J	K	L	M	N	O
				Continuous Variable Description				
Variable Type	*Units*	*Static/Default Value*	*Enumerations*	*Min*	*Max*	*Mean*	*Std Dev*	*Delta X*
Choice		*Entire Building*	|*Entire Building*|					
Double		0		0	100	15	16.667	1
Double		1						
Double		0		0	0.1	0.05	0.0167	0.01
Double		0						
Double		0						
Double		0						
Double		0						
Integer		1						
Choice		*Entire Building*	|*Entire Building*|					
Double		0		-40	40	0	13.333	1
Double		0						
Double		0						
Integer		0						
Bool		TRUE						
Integer		15						
Double		0						
Integer		1						

Variables Tab

Column R is the distribution type for the variable. Valid types are: 'discrete_uncertain', 'uniform_uncertain', 'triangle', 'normal', 'lognormal' (note the '_uncertain' may be omitted).



Column P is the allowed values for a discrete variable.
Column Q is the corresponding weight for discrete values. If this is blank, the variable will assume to uniformly distributed.



Outputs Tab

	A	B	C	D	E	F	G	H	I	J
1					**Outputs**					
2	*Variable Display Name*	*Short Display Name*	*Taxonomy Identifier*	*Name*	*Units*	*Variable Type*	*Visualize*	*Export*	*Objective Funct*	*Objective Functi*
3	*Display Name for Reports*	*Short display names are used for plots and exported to metadata*	*Machine Name thats Link to Dencity Taxonomy*	*Measure/Variable Unique Name*		*double, integer, bool*	*true/false*	*true/false*	*true/false*	*double*
4	Total Site Energy Intensity		total_site_energy_intensity	standard_report_legacy.total_energy	MJ/m2	Double	FALSE	TRUE	FALSE	
5	Total Source Energy Intensity		total_source_energy_intensity	standard_report_legacy.total_source_energy	MJ/m2	Double	FALSE	TRUE	FALSE	
6	Total Natural Gas Intensity	NG EUI	total_natural_gas_intensity	standard_report_legacy.total_natural_gas	MJ/m2	Double	FALSE	TRUE	FALSE	
7	Total Electricity Intensity	Elec EUI	total_electricity_intensity	standard_report_legacy.total_electricity	MJ/m2	Double	FALSE	TRUE	FALSE	
8	Natural Gas Heating Intensity			standard_report_legacy.heating_natural_gas	MJ/m2	Double	FALSE	TRUE	FALSE	
9	Cooling Electricity Intensity			standard_report_legacy.cooling_electricity	MJ/m2	Double	FALSE	TRUE	FALSE	
10	Interior Lighting Electricity Intensity			standard_report_legacy.interior_lighting_electricity	MJ/m2	Double	FALSE	TRUE	FALSE	
11	Exterior Lighting Electricity Intensity			standard_report_legacy.exterior_lighting_electricity	MJ/m2	Double	FALSE	TRUE	FALSE	
12	Equipment Electricity Intensity			standard_report_legacy.interior_equipment_electricity	MJ/m2	Double	FALSE	TRUE	FALSE	
13	Equipment Natural Gas Intensity			standard_report_legacy.interior_equipment_natural_gas	MJ/m2	Double	FALSE	TRUE	FALSE	
14	Experior Equipment Electricity Intensity			standard_report_legacy.exterior_equipment_electricity	MJ/m2	Double	FALSE	TRUE	FALSE	
15	Fans Electricity Intensity			standard_report_legacy.fans_electricity	MJ/m2	Double	FALSE	TRUE	FALSE	
16	Pumps Electricity Intensity			standard_report_legacy.pumps_electricity	MJ/m2	Double	FALSE	TRUE	FALSE	
17	Heat Rejection Electricity Intensity			standard_report_legacy.heat_rejection_electricity	MJ/m2	Double	FALSE	TRUE	FALSE	
18	Humidification Electricity Intensity			standard_report_legacy.humidification_electricity	MJ/m2	Double	FALSE	TRUE	FALSE	
19	Water Systems Electricity Intensity			standard_report_legacy.water_systems_electricity	MJ/m2	Double	FALSE	TRUE	FALSE	
20	Water Systems Natural Gas Intensity			standard_report_legacy.water_systems_natural_gas	MJ/m2	Double	FALSE	TRUE	FALSE	
21	Refrigeration Electricity Intensity			standard_report_legacy.refrigeration_electricity	MJ/m2	Double	FALSE	TRUE	FALSE	
22	Unmet Cooling Hours			standard_report.time_setpoint_not_met_during_occupied_cooling	hrs	Double	FALSE	TRUE	FALSE	
23	Unmet Heating Hours			standard_report.time_setpoint_not_met_during_occupied_heating	hrs	Double	FALSE	TRUE	FALSE	
24	Total Unmet Hours			standard_report.time_setpoint_not_met_during_occupied_hours	hrs	Double	FALSE	TRUE	FALSE	
25	Building Area			standard_report.total_building_area	m2	Double	FALSE	TRUE	FALSE	
26	Total Electricity Consumption Modeled			calibration_reports.electric_bill_consumption_modeled	kWh	Double	FALSE	TRUE	FALSE	
27	Total Gas Consumption Modeled			calibration_reports.gas_bill_consumption_modeled	therms	Double	FALSE	TRUE	FALSE	
28	Electric RMSE			calibration_reports.electric_bill_rmse	%	Double	FALSE	TRUE	FALSE	
29	Gas RMSE			calibration_reports.gas_bill_rmse	%	Double	FALSE	TRUE	FALSE	
30	Electric CVRMSE			calibration_reports.electric_bill_consumption_cvrmse	%	Double	TRUE	TRUE	TRUE	
31	Electric NMBE			calibration_reports.electric_bill_consumption_nmbe	%	Double	TRUE	TRUE	TRUE	
32	Gas CVRMSE			calibration_reports.gas_bill_consumption_cvrmse	%	Double	TRUE	TRUE	TRUE	
33	Gas NMBE			calibration_reports.gas_bill_consumption_nmbe	%	Double	TRUE	TRUE	TRUE	
34	Electric CVRMSE within limit			calibration_reports.electric_bill_cvrmse_within_limit		Double	TRUE	TRUE	FALSE	
35	Electric NMBE within limit			calibration_reports.electric_bill_nmbe_within_limit		Double	TRUE	TRUE	FALSE	

Outputs Tab

	A	B	C	D
1				
2	*Variable Display Name*	*Short Display Name*	*Taxonomy Identifier*	*Name*
3	*Display Name for Reports*	*Short display names are used for plots and exported to metadata*	*Machine Name thats Link to Dencity Taxonomy*	*Measure/Variable Unique Name*
4	Total Site Energy Intensity		total_site_energy_intensity	standard_report_legacy.total_energy
5	Total Source Energy Intensity		total_source_energy_intensity	standard_report_legacy.total_source_energy
6	Total Natural Gas Intensity	NG EUI	total_natural_gas_intensity	standard_report_legacy.total_natural_gas
7	Total Electricity Intensity	Elec EUI	total_electricity_intensity	standard_report_legacy.total_electricity
8	Natural Gas Heating Intensity			standard_report_legacy.heating_natural_gas
9	Cooling Electricity Intensity			standard_report_legacy.cooling_electricity
10	Interior Lighting Electricity Intensity			standard_report_legacy.interior_lighting_electricity
11	Exterior Lighting Electricity Intensity			standard_report_legacy.exterior_lighting_electricity
12	Equipment Electricity Intensity			standard_report_legacy.interior_equipment_electricity
13	Equipment Natural Gas Intensity			standard_report_legacy.interior_equipment_natural_gas
14	Experior Equipment Electricity Intensity			standard_report_legacy.exterior_equipment_electricity

Outputs Tab

	D	E	F	G	H	I
1		**Outputs**				
2	*Name*	*Units*	*Variable Type*	*Visualize*	*Export*	*Objective Funct*
3	*Measure/Variable Unique Name*		*double, integer, bool*	*true/false*	*true/false*	*true/false*
26	calibration_reports.electric_bill_consumption_modeled	kWh	Double	FALSE	TRUE	FALSE
27	calibration_reports.gas_bill_consumption_modeled	therms	Double	FALSE	TRUE	FALSE
28	calibration_reports.electric_bill_rmse	%	Double	FALSE	TRUE	FALSE
29	calibration_reports.gas_bill_rmse	%	Double	FALSE	TRUE	FALSE
30	calibration_reports.electric_bill_consumption_cvrmse	%	Double	TRUE	TRUE	TRUE
31	calibration_reports.electric_bill_consumption_nmbe	%	Double	TRUE	TRUE	TRUE
32	calibration_reports.gas_bill_consumption_cvrmse	%	Double	TRUE	TRUE	TRUE
33	calibration_reports.gas_bill_consumption_nmbe	%	Double	TRUE	TRUE	TRUE
34	calibration_reports.electric_bill_cvrmse_within_limit		Double	TRUE	TRUE	FALSE
35	calibration_reports.electric_bill_nmbe_within_limit		Double	TRUE	TRUE	FALSE
36	calibration_reports.gas_bill_cvrmse_within_limit		Double	TRUE	TRUE	FALSE
37	calibration_reports.gas_bill_nmbe_within_limit		Double	TRUE	TRUE	FALSE

Outputs Tab

	A	B	I	J	K
1					
2	*Variable Display Name*	*Short Display*	*Objective*	*Objective*	*Scale*
3	*Display Name for Reports*	*Short display names are used for plots*	*true/false*	*double*	*double*
4	Total Natural Gas Intensity	NG EUI	TRUE	140	
5	Total Electricity Intensity	Elec EUI	TRUE	590	5
6	Unmet Cooling Hours		FALSE		
7	Unmet Heating Hours		FALSE		

Outputs Tab