

## CEAGOM User's Guide.

CEAGOM consists of four MATLAB .m files:

ConstantsXX.m  
constraintsXX.m  
objectiveXX.m  
ToyOptXX.m

There are five versions of the CEAGOM code, each corresponding to a different climate limit.

The corresponding .m files are identified by a two or four letter suffix at the end of the filename as follows:

Annual Emissions Limit Constraint (EM)  
Concentration Limit Constraint (CL)  
Cumulative Emissions Limit Constraint (CMEM)  
No Climate Limit (NL)  
Temperature Rise Limit Constraint (TL)

CEAGOM requires four input files in EXCEL .xls format:

combustion.xls - industrial combustion energy demand in EJ  
electric.xls - electrical energy demand in EJ  
f.xls - total energy demand in EJ  
liquid.xls - liquid energy demand in EJ

The data in these EXCEL files should be arranged as column vectors.

The ConstantsXX.m file contains all the user defined constants and parameters, including resource costs, engineering parameters and availability values. The user needs to specify the specific value of the desired climate constraint, as well as the number of years in the simulation (defined by the variable labeled time) in this file. These are all labeled for the user's convenience inside the file. In many cases, the user may want to specify cost or available energy efficiency data that varies with time. In this case, the user can specify the data in a simple EXCEL file with a .xls extension. The user should then comment out the single value entry for that parameter in

the ConstantsXX.m file and replace it with the appropriate MATLAB xlsread statement. The ToyOptXX.m file is the main CEAGOM control file which generates the CEAGOM run.

The energy and geoengineering resources have specific identifiers that are used to identify their respective variables within the MATLAB code. Furthermore, the code employs a number of matrices in order to perform its computations. The resources follow a set numbering within these matrices. It should be noted that some matrices include reserve resources while others do not. The numbering of the resources within the matrices varies as a result. Table D.1 below specifies these identifiers and numberings.

Table 1. Resource Identifiers and Matrix Numbering.

Resource	Identifier	Matrix Number
Oil-Transport	o	1
Gas-Combustion	g	2
Coal-Combustion	c	3
Nuclear	n	4
Hydro	h	5
Wind	w	6
Geothermal	gt	7
Solar-PV	sp	8
Solar-Thermal	st	9
Biofuel-Transport	bf	10

Table 1 (Cont.)

Resource	Identifier	Matrix Number
Biomass	bm	11
Energy Efficiency	e	12
Sulfur Injection	s	13
Iron Seeding	i	14
Tree Planting	t	15
Oil-Reserves	or	16
Gas-Reserves	gr	17
Coal-Reserves	cr	18
Hydro-Reserves	hr	19
Geothermal-Reserves	gtr	20
Biofuel-Reserves	bfr	21
Biomass-Reserves	bmr	22
Sea Spray Injection	ss	23 (16 without reserves)
Oil-Combustion	oc	24 (17 without reserves)
Gas-Electric	ge	25 (18 without reserves)
Coal-Electric	ce	26 (19 without reserves)
Coal-to-Liquids	ct	27 (20 without reserves)
Biofuel-Combustion	bfc	28 (21 without reserves)

A CEAGOM simulation is run by first running the ConstantsXX.m file. This creates a MATLAB .mat data file. Next, the ToyOptXX.m file is run. This pulls in the .mat data file and the five EXCEL input files. ToyOptXX.m also automatically calls the constraintsXX.m and

objective.m files. These two files specify the constraints and objective function, respectively, that are used by the MATLAB fmincon optimization engine.

Once the CEAGOM simulation has run, it automatically outputs various plots and data files. The data files are output in EXCEL .xls format. The plots can be saved in a variety of formats, including .emf format or MATLAB .fig format. The plots and output files are specified at the end of the ToyOptXX.m file and can be changed as the user desires.

It is recommended that a no climate limit run be run as the first step in any CEAGOM analysis in order to establish a baseline. As part of this no climate limit run, it is also recommended that the availability values of the geoengineering resources be set to a very low value (such as 1E-6) in order to completely eliminate them from the simulation.

Once the baseline is established, the user should review the resource deployments to determine if any of the energy resources peaks and then drops off. This could indicate that there are unrecovered costs. In order to determine these potential unrecovered costs, there are four special MATLAB files available as part of the CEAGOM tool suite that are designed to do this analysis. Which one is used depends on where the peak of the resource occurs in the simulation based upon the resource lifetime lambda. The four files are:

Unrecov.m - used when the resource peak occurs more than lambda years from the start of the simulation.

Unrecov2.m - used in conjunction with Unrecov.m when the resource use is still decreasing more than lambda years after the peak.

Unrecov3.m - used when the peak occurs less than lambda years from the end of the simulation.

Unrecov4.m - used when the peak occurs less than lambda years from the start of the simulation.

These unrecovered cost files require two input files, both in EXCEL .xls format. The first is the called peakq.xls and simply consists of the deployed amount of the resource at each time step from the initial CEAGOM run. The second is a small set of parameters as follows:

peakparameters.xls (used with Unrecov.m):

- Resource lifetime lambda.
- Total length of the simulation.
- Time resource peak occurs in the simulation.
- Resource capital cost
- Discount rate.
- Total number of years the resource was actually deployed in the simulation.

Peakparameters2.xls (used with Unrecov2.m):

- Resource lifetime lambda.
- Total length of the simulation.
- Time step where unrecovered cost analysis should start.
- Time step where unrecovered cost analysis should end.
- Resource capital cost.
- Discount rate.
- Total number of years the resource was actually deployed in the simulation.

Peakparameters3.xls (used with Unrecov3.m):

- Resource lifetime lambda.
- Total length of the simulation.
- Time resource peak occurs in the simulation.
- Resource capital cost
- Discount rate.
- Total number of years the resource was actually deployed in the simulation.

Peakparameters4.xls (used with Unrecov4.m):

- Resource lifetime lambda.
- Total length of the simulation.
- Time resource peak occurs in the simulation.
- Resource capital cost
- Discount rate.
- Total number of years the resource was actually deployed in the simulation.

The unrecovered cost analysis outputs two EXCEL .xls files. The first is labeled unrecovcost.xls. It shows the unrecovered costs at each time step. The second file is labeled unrecovpu.xls. This file outputs the unrecovered cost per unit of the resource deployed in the

particular simulation. This value should then be entered into the value of the parameter `adjxx` for the particular resource in the `ConstantsXX.m` file (`xx` stands for the particular identifier code for the resource as defined in `Constants.XX.m`).

The CEAGOM model can call for tree planting on its own; however, due to the delay in the full effect of the tree planting due to the logistic function, the user may wish to manually force a specified amount of tree planting at desired point in the simulation. The user can do this by added a simple if-then statement in the `ToyOptXX.m` file right after the code reads in the results from the `fmincon` subroutine (i.e. after the statement `OptResult(t) = fval;`. For example, to have 500 million hectares of trees planted at year 50, the user would insert the following code right after the `OptResult(t) = fval` statement:

```
if t == 50
    x(15) = 500;
end
```

`x(15)` is the variable for tree planting in the CEAGOM code.