EASiTool - User Manual -V4.0

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Introduction

Welcome to the third version of EASiTool (Enhanced Analytical Simulation Tool), developed for CO₂ storage-capacity estimation and uncertainty quantification.

This user manual will help you install and use EASiTool.

EASiTool is intended to help users achieve a fast, reliable, science-based estimate of storage capacity for any geologic formation containing brine. EASiTool, which provides strategies for optimizing a project's net present value (NPV), offers three major features:

- An advanced, closed-form analytical solution for pressure-buildup calculations used to estimate both injectivity and reservoir-scale pressure elevation, in both closed- and open-boundary aquifers (version 1.1)
- A simple geomechanical model coupled with a base model to evaluate and avoid the possibility of fracturing reservoir rocks by injecting cold, supercritical CO₂ into hot formations, which can cause rock deformation (version 2.0)
- An active reservoir-management system throughout the brine-extraction process (version 3.0).

Disclaimer

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Further Information

This software has been developed using MATLAB R2014b.

What's New?

Important changes in EASiTool V4.0:

• A new module was added to EASiTool which provide user with flexibility of placing the injectors and extractors on their own arbitrary locations. This new module can handle multiple reservoirs inside basin with arbitrary shapes.

Getting Started

This section has information on system requirements and installment of the EASiTool.

System Requirements

EASiTool is a Windows application. Windows Vista, Windows 7 (either 32-bit or 64-bit versions), Windows 8 or Windows 10 are the recommended operating systems. Windows XP (SP3) is also supported.

You must have administrative privileges on the system. You need a minimum of 700 MB disk space during the installation process. 16-bit color depth is required (32-bit recommended).

Installment

Once you download the install file from the EASiTool website, double-click it to start the installment. Click "Next" once you see the window below:



Determine the destination folder. If you don't want to change the location where the installation folder will be saved, click "Next":

CInstallation Options		_	×
Choose installation folder:			
C:\Program Files\EASiToolGUI		Browse	
	Restore Defa	ult Folder	
Add a shortcut to the desktop			
< Back Next >		Cancel	

MATLAB Compiler Runtime is required. Determine the destination folder. If you don't want to change the location where the installation folder will be saved, click "Next":

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MATLAB Compiler Runtime is required.			MATI AR [®]
Choose installation folder:			COMPILER RUNTIME R2014b
C:\Program Files\MATLAB\MATLAB Compiler Runtime		Browse	
	Restore De	efault Folder	
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Click "Install" to begin the installation:

Confirmation	—	×
EASiToolGUI will be installed in:		
C:\Program Files\EASiToolGUI		
EASiToolGUI requires MATLAB Compiler Runtime R2014b.		
MATLAB Compiler Runtime R2014b will be installed in:		
C:\Program Files\MATLAB\MATLAB Compiler Runtime\v84		
< Back Install >	Cancel	

Once the installation is completed (this may take a few minutes), you will see the window below. Click "Finish":



Now you are ready to use the EASiTool software by simply double clicking on the EASiTool icon.

Input Parameters

Section 1 has information on the input data required to run the program.

1. Reservoir Parameters

Necessary input for reservoir parameters includes in situ pressure (MPa), temperature (C), thickness (m), salinity of the formation brine (mol/kg), porosity (-), permeability (mD), rock compressibility (1/Pa), maximum injection pressure (MPa), reservoir area (km²), basin area (km²), and boundary condition, as shown in Section 1 at the top left-hand side of the input screen.

Note: EASiTool accepts only one set of fixed units; if the units differ from what is shown on the interface, they must be converted first.

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	GU	LF COAST	CARBON CENTER	C	BUREAU OF ECONOMIC GEOLOGY	
1-RESERVOIR PARAMETERS	-	(3-SIMULATION PARAMETERS	1	4-NPV	
General Geometry/Pattern			Uniform Injection/Extraction Rate		Injector Drilling Cost [\$M/well] 1	
Input File Name			Sensitivity Analysis (Slow)		Extractor Drilling Cost [SM/well]	
Pressure [MPa]	20		Simulation Time [year]	20		
Temperature [C]	65		Injection Well Radius [m]	0.1	Injector Operating Cost [Sk/weil/yr] 500	
Thickness [m]	100		Min Extraction Pressure [MPa]	29	Extractor Operating Cost [\$K/well/yr] 500	
Salinity [mol/Kg]	2		Injection Rate [ton/day/well]		Monitoring Cost [\$K/yr/km^2] 50	
Porosity [-]	0.2		Extraction Rate [m^3/day/well]		Tax Credit [\$/ton] 10	
Permeability [mD]	100		Max Number of Injectors	+00 -		
Rock Compressibility [1/Pa]	5e-10		Number of Extractors	-	Run	
Max Injection Pressure [MPa]	30		Estimate Max Injection Pressure II	nternally	Simulation Time [sec]= *****	
Reservoir Area [km^2]	100				5-RESULT CONTROLS	
Basin Area [km^2]	100		Density of Porous Media [Kg/m^3]		Number of Injection Wells	
Boundary Condition	Closed	•	Total Stress Ratio (H/V)		Estimated Max Inj Pressure [MPa]	
2-RELATIVE PERMEABILITY (Brooks-	Corey)	Biot Coefficient		Total Injected CO2 [Mton]	
Residual Water Saturation	0.5		Poisson's ratio		Total Extracted Brine [Mm^3]	
Residual Gas Saturation	0.1		Coefficient of Thermal Expansion [1/K]	1	Highest Bottomhole Pres. [MPa]	
m	3		Bottom Hole Temperature Drop [K]		Lowest Bottomhole Pres. [MPa]	
n	3		Young's Modulus [GPa]		Number of Failed Wells	
Kra0	1		Depth [m]			
Krg0	0.3				<u>visit our website.</u>	

Reservoir Area (km²): A reservoir is a part of the basin in which injectors are distributed. In the current version, we assume that reservoirs do not include detailed structures or dip angles. We also assume that reservoirs are square and placed at the center of the basins.

Basin Area (km²): A basin is the whole areal extent of the storage formation in which the reservoir of our interest is located. In the current version, we assume that basins do not include detailed structures or dip angles. We also assume that basins are square. The basin area should be bigger or equal to the reservoir area.

Boundary Condition: Using the drop-down menu, select either an "open" or a "closed" boundary condition (In the current version of EASiTool, the selected boundary condition will be enforced on all four sides of the basin.). A reservoir can be considered open as

long as the pressure change has not reached the boundaries. In an industrial-scale injection operation, the pressure effect is expected to reach the boundaries of the basin late in the injection process.

Note: EASiTool is designed to perform the calculations for multiple scenarios in which the number of wells increases from 1 to 400 in square numbers (1×1 , 2×2 , 3×3 , 4×4 , ..., 20×20). In each scenario, wells are equally spaced over the reservoir area. For example, well distribution for a 2×2 pattern is shown below:



The following table shows the range of parameters that are accepted by EASiTool:

Initial Pressure	≤ 60.0 MPa
Initial Temperature	≤ 300.0 °C
Thickness	≥ 0.1 m
Salinity	\geq 0.0 mol/kg and \leq 6.0 mol/kg
Porosity	≥ 0.0 and ≤ 0.9999
Permeability	≥ 0.0 mD
Rock Compressibility	≤ 1.0E-08 1/Pa
Max Injection Pressure	> Initial Pressure
Reservoir Area	≤ Basin Area

The following six figures show the range and frequency of some reservoir parameters based on two data sets prepared by the DOE and the USGS:













2. Relative Permeability Parameters

Section 2 allows the input of parameters for relative permeability, including residual water saturation (S_{ar}), critical gas saturation (S_{gc}), end-point relative permeability for aqueous phase (k_{ra0}), end-point relative permeability for gas phase (k_{rg0}), and power-law exponents for the aqueous and gas phases *m* and *n*. This section includes equations for relative permeability calculations from the Brooks-Corey model:

$$k_{ra} = \begin{cases} 0, & S_a < S_{ar} \\ k_{ra}^{\circ} \left(\frac{S_a - S_{ar}}{1 - S_{ar} - S_{gc}} \right)^m, & S_a > S_{ar} \end{cases}$$
$$k_{rg} = \begin{cases} 0, & S_g < S_{gc} \\ k_{rg}^{\circ} \left(\frac{S_g - S_{gc}}{1 - S_{ar} - S_{gc}} \right)^n, & S_g > S_{gc} \end{cases}$$

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	GULF COAST	CARBON CENTER		BUREAU OF ECONOMIC GEOLOGY	
1-RESERVOIR PARAMETERS	(3-SIMULATION PARAMETERS		4-NPV	
General Geometry/Pattern		Uniform Injection/Extraction Rate		Injector Drilling Cost [SM/well] 1	
Input File Name		Sensitivity Analysis (Slow)		Estructure Delitting Cont (EM/suppl)	
Pressure [MPa]	20	Simulation Time [year]	20	Extractor Drining Cost [SW/Wen]	
Temperature [C]	65	Injection Well Radius [m]	0.1	Injector Operating Cost [SK/well/yr] 500	
Thickness [m]	100	Min Extraction Pressure [MPa]	29	Extractor Operating Cost [\$K/well/yr] 500	
Salinity [mol/Kg]	2	Injection Rate [ton/day/well]		Monitoring Cost [\$K/yr/km^2] 50	
Porosity [-]	0.2	Extraction Rate [m^3/day/well]		Tax Credit [\$/ton] 10	
Permeability [mD]	100	Max Number of Injectors 4	•00 -		
Rock Compressibility [1/Pa]	5e-10	Number of Extractors 0	•	Run	
Max Injection Pressure [MPa]	30	Estimate Max Injection Pressure In	nternally	Simulation Time [sec]= *****	
Reservoir Area [km^2]	100	Density of Porous Media [Kg/m^3]		5-RESULT CONTROLS	
Boundary Condition	Closed V	Total Stress Ratio (H/V)		Estimated Max Inj Pressure [MPa]	
		Dist Occ#falact		Tatal Inicated CO2 (Miss)	
-2-RELATIVE PERMEABILITY (Brooks-Corey)	Bior coencient		Total injected 002 (mon)	
	0.0	Poisson's ratio		Total Extracted Brine [Mm^3]	
Residual Gas Saturation	0.1	Coefficient of Thermal Expansion [1/K]	1	Highest Bottomhole Pres. [MPa]	
m	3	Bottom Hole Temperature Drop [K]		Lowest Bottomhole Pres. [MPa]	
n	3	Young's Modulus [GPa]		Number of Failed Wells	
Krg0	0.3	Depth [m]		Visit our website,	

The following table shows the range of relative permeability parameters that are accepted by EASiTool:

Residual water saturation, Sar	≥ 0.0 and ≤ 0.9999
Residual gas saturation, S_{gr}	≥ 0.0 and ≤ 0.9999
Water relative permeability Corey exponent, m	≤ 1.0
Gas relative permeability Corey exponent, n	≤ 1.0
Water end-point relative permeability, Kra0	≥ 0.0 and ≤ 1.0
Gas end-point relative permeability, K_{rg0}	≥ 0.0 and ≤ 1.0

A typical range of relative permeability parameters based on data published in literature is listed in the table below:

Residual water saturation, Sar	0.2 - 0.6
Residual gas saturation, S_{gr}	0.1 – 0.35
Water relative permeability Corey exponent, m	1.5 – 4.0
Gas relative permeability Corey exponent, n	1.5 – 4.0
Water end-point relative permeability, K_{ra0}	1.0
Gas end-point relative permeability, K_{rg0}	0.1 – 0.6

3. Simulation Parameters

Section 3 has input parameters for simulation: simulation time (years), injection well radius (m), minimum extraction pressure (MPa), maximum number of injectors, and number of extractors.

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GCCC	GU	LF COAST	CARBON CENTER	BUREAU OF JACKSON
1-RESERVOIR PARAMETERS			3-SIMULATION PARAMETERS	4-NPV
General Geometry/Pattern			Uniform Injection/Extraction Rate	Injector Drilling Cost [\$M/well] 1
Input File Name			Sensitivity Analysis (Slow)	
			Simulation Time [year] 20	Extractor Drilling Cost [\$M/well]
Pressure [MPa]	20			Injector Operating Cost [\$K/well/yr] 500
Temperature [C]	65		Injection Well Radius [m] 0.1	Extractor Operating Cost (SK/well/wrl 500
Thickness [m]	100		Min Extraction Pressure [MPa] 29	Extractor operating cost [aroweniyi] 500
Salinity [mol/Kg]	2		Injection Rate [ton/day/well]	Monitoring Cost [\$K/yr/km^2] 50
Porosity [-]	0.2		Extraction Rate [m^3/day/well]	Tax Credit [\$/ton] 10
Permeability [mD]	100			
Rock Compressibility [1/Pa]	5e-10		Max Number of Injectors 400	Run
May Injection Processes (MPa)	20		Number of Extractors 0 -	Simulation Time [sec]= *****
Max Injection Pressure (MPaj	30		Estimate Max Injection Pressure Internally	Omitation Time [300]-
Reservoir Area [km^2]	100			5-RESULT CONTROLS
Basin Area [km^2]	100		Density of Porous Media [Kg/m^3]	Number of Injection Wells
Boundary Condition	Closed	•	Total Stress Ratio (H/V)	Estimated Max Inj Pressure [MPa]
2-RELATIVE PERMEABILITY (E	Brooks-	Corey)	Biot Coefficient	Total Injected CO2 [Mton]
Residual Water Saturation	0.5		Poisson's ratio	Total Extracted Brine (Mm^3)
Residual Gas Saturation	0.1		1 0133011 3 18110	Total Extenses onne (with of
~	2		Coefficient of Thermal Expansion [1/K]	Highest Bottomhole Pres. [MPa]
m	3		Bottom Hole Temperature Drop [K]	Lowest Bottomhole Pres. [MPa]
n	3		Youno's Modulus (GPa)	Number of Failed Wells
Kra0	1		rearing a monomos (or a)	Homeer Straned Wens
Krg0	0.3		Depth [m]	<u>Visit our website.</u>

The maximum acceptable injection well radius is 1.0 m. The minimum extraction pressure can be between 0 and 60 MPa and must be less than the maximum injection pressure. The maximum number of injectors can be set by the user on the basis of the size and properties of the aquifer. The maximum number of injectors can be varied between 1 and 400. This option gives the flexibility to avoid long simulation runs when a large number of injectors is not needed; for example, when the aquifers are small. The number of extractors can be fixed before running the simulation. The number of extractors can be 0, 4, 8, or 16.

Geomechanics Package

EASiTool can calculate the maximum allowable injection pressure internally from the reservoir properties. To include the geomechanics, check "Estimate Max Injection Pressure Internally." Next, in the new boxes, provide the following properties to estimate the maximum injection pressure:

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GCCC	GU	LF COAST	CARBON CENTER		BUREAU OF ECONOMIC CEOLOGY
1-RESERVOIR PARAMETERS		(3-SIMULATION PARAMETERS		4-NPV
General Geometry/Pattern			Uniform Injection/Extraction Rate		Injector Drilling Cost [SM/well] 1
Input File Name			Sensitivity Analysis (Slow)		
			Simulation Time [year]	20	Extractor Drilling Cost [SM/well]
Pressure [MPa]	20				Injector Operating Cost [\$K/well/yr] 500
Temperature [C]	65		Injection Well Radius [m]	0.1	Extractor Operating Cost (SK/well/vr) 500
Thickness [m]	100		Min Extraction Pressure [MPa]	29	
Salinity [mol/Kg]	2		Injection Rate [ton/day/well]		Monitoring Cost [\$K/yr/km^2] 50
Porosity [-]	0.2		Extraction Rate [m^3/day/well]		Tax Credit [\$/ton] 10
Permeability [mD]	100				
Rock Compressibility [1/Pa]	5e-10		Max Number of Injectors 4	• • •	Run
Max Injection Pressure (MPa)			Number of Extractors 0	•	Simulation Time [sec]= *****
			Stimate Max Injection Pressure In	ternally	
Reservoir Area [km^2]	100		Density of Porous Media (Ko/m^3)	2200	5-RESULT CONTROLS
Basin Area [km^2]	100				
Boundary Condition	Closed	•	Total Stress Ratio (H/V)	0.65	Estimated Max Inj Pressure [MPa]
2-RELATIVE PERMEABILITY	Brooks-	Corey)	Biot Coefficient	0.95	Total Injected CO2 [Mton]
Residual Water Saturation	0.5		Poisson's ratio	0.25	Total Extracted Brine [Mm^3]
Residual Gas Saturation	0.1				Ulabert Dettershele Des (MDa)
m	3		Coefficient of Thermal Expansion [1/K]	1e-5	Hignest Bottomnole Pres. [MPa]
	2		Bottom Hole Temperature Drop [K]	5	Lowest Bottomhole Pres. [MPa]
	-		Young's Modulus [GPa]	10	Number of Failed Wells
Kra0	1		Depth (m)	2200	
Krg0	0.3		Departing	2200	<u>Visit our website.</u>

Density of Porous Media (ρ **) [kg/m³]:** Density of porous media can be calculated as $\rho = \rho_d (1 - \phi) + \phi \rho_f$, where ϕ is porosity, ρ_f is fluid density, and ρ_d is dried density of the matrix.

Total Stress Ratio (H/V): The ratio of horizontal to vertical stress, K_h , is σ_h/σ_v .

Biot Coefficient (α **):** The effective-stress principle is of fundamental significance in soil and rock mechanics and is defined as $\sigma_{eff} = \sigma_c - \sigma_p$, where σ_c and σ_p are the total confining stress and fluid pore pressure, respectively. However, in fluid-saturated rocks, Terzaghi's principle of effective-stress may not be always valid. The Biot coefficient α (other than unity) was suggested to modify the effective-stress principle (Biot, 1941), which is given by $\sigma_{eff} = \sigma_c - \alpha \sigma_p$. The Biot coefficient α is a property of a solid constituent only. The existence of the Biot coefficient suggests that pore pressure modifies not only effective normal stresses but also effective shear stresses.

Note: $\phi \le \alpha \le 1$, where ϕ is porosity, α will be near its upper limit for soil-like materials.

Poisson's Ratio (v): An elastic constant that is a measure of the compressibility of material perpendicular to applied stress; that is, the ratio of latitudinal to longitudinal strain (0 < v < 0.5). Poisson's ratio can be expressed in terms of properties that can be measured in the field, including velocities of P-waves and S-waves. The Poisson's ratio for carbonate rocks is ~ 0.3, for sandstones, ~ 0.2; and for shale, above 0.3.

Coefficient of Thermal Expansion [1/K]: The coefficient of thermal expansion describes how the size of an object changes when the temperature changes. Specifically, it measures the fractional change in size per degree change in temperature at a constant pressure.

Bottom-Hole Temperature Drop [K]: The temperature difference between the formation and the injected fluid (CO₂) at the bottom of the wellbore. The fluid temperature is lower than the bottom-hole static temperature. The corresponding temperature difference causes thermal stresses in the formation and affects the maximum injection pressure.

Young's Modulus (E) [GPa]: Young's modulus, also known as the tensile modulus, modulus of elasticity, or elastic modulus, is defined as the ratio of the stress (force per unit area) along an axis to the strain (ratio of deformation over initial length) along that axis in the range of linear behavior of the material.

Depth [m]: Depth of the fluid injection (depth of perforation zone).

Estimated Max Injection Pressure [MPa]: Pressure above which the injection of fluids will cause the rock formation to fracture hydraulically. The reactivation of preexisting fracture planes via shear slip is likely to occur prior to other types of geomechanical failures in most cases. The Mohr-Coulomb shear failure criterion for the maximum pressure limit *P_{max}* is expressed as

$$\tau = c + (\sigma_n - \alpha P_{max})\mu$$

where τ is shear stress, σ_n is normal stress acting on a preexisting fracture plane, c is cohesion, and μ is the coefficient of friction.

Then, the P_{max} is

$$P_{max} = \frac{1}{\alpha} \left[\frac{1}{2} (\sigma_1 + \sigma_3) + \frac{1}{2} (\sigma_1 - \sigma_3) cos 2\theta - \frac{1}{2} (\sigma_1 - \sigma_3) \frac{sin 2\theta}{\mu} \right]$$

where σ_1 , σ_3 , and θ are major principal stress, minor principal stress, and angle with reference to minor principal stress, respectively.

The estimated maximum allowable injection pressure will be provided in the results section.

Uniform Constant-Injection/Extraction Rate

The default mode for calculation of well rates is "optimal constant-injection/extraction rate." EASiTool provides an option to calculate the final well pressures on the basis of user defined constant injection and constant extraction rates. To activate this option, check "Uniform Injection/Extraction Rate." Here, you can input the injection rate (ton/day/well) and extraction rate (m³/day/well).

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GCCCC	GU	LF COAST						
1-RESERVOIR PARAMETERS			3-SIMULATION PARAMETERS	4-NPV				
			✓ Uniform Injection/Extraction Rate	Injector Drilling Cost [\$M/well] 1				
Input File Name			Simulation Time [year] 20	Extractor Drilling Cost [SM/well]				
Pressure [MPa] Temperature [C]	20 65		Injection Well Radius [m] 0.1	Injector Operating Cost [\$K/well/yr] 500				
Thickness [m]	100		Min Extraction Pressure [MPa]	Extractor Operating Cost [SK/well/yr] 500				
Salinity [mol/Kg]	2		Injection Rate [ton/day/well] 100	Monitoring Cost [\$K/yr/km^2] 50				
Porosity [-]	0.2		Extraction Rate [m^3/day/well] 200	00 Tax Credit [\$/ton] 10				
Permeability [mD]	100 5e-10		Max Number of Injectors 400	Run				
Max Injection Pressure [MPa]	30		Number of Extractors 0	Simulation Time [sec]= *****				
Reservoir Area [km^2]	100		Estimate Max Injection Pressure Internally	ally 5-RESULT CONTROLS				
Basin Area [km^2]	100		Density of Porous Media [Kg/m^3]	Number of Injection Wells				
Boundary Condition C	losed	•	Total Stress Ratio (H/V)	Estimated Max Inj Pressure [MPa]				
2-RELATIVE PERMEABILITY (Br	ooks-	Corey)	Biot Coefficient	Total Injected CO2 [Mton]				
Residual Water Saturation	0.5		Poisson's ratio	Total Extracted Brine [Mm^3]				
m	U.1 3		Coefficient of Thermal Expansion [1/K]	Highest Bottomhole Pres. [MPa]				
n	3		Bottom Hole Temperature Drop [K]	Lowest Bottomhole Pres. [MPa]				
Kra0	1		Young's Modulus [GPa]	Number of Failed Wells				
Krg0	0.3		Deptn [m]	Visit our website.				

The injection rate should be between 0 and 10,000 ton/day/well. The extraction rate should be between 0 and 10,000 m³/day/well. The injection and extraction rates are only active for the "uniform injection/extraction rate" option.

Sensitivity Analysis

EASiTool can perform a sensitivity analysis on any combination of initial reservoir pressure, temperature, thickness, salinity, porosity, permeability, rock compressibility, maximum injection pressure, and relative permeability parameters. To include the sensitivity analysis of any of these parameters, check "Sensitivity Analysis (Slow)." Then, in the new boxes, provide the minimum and maximum of the parameters for sampling. This set of input for sensitivity analysis resembles the triangular probability distribution for parameters:



The one-parameter-at-a-time method is used for sampling in this version of EASiTool. In

this method, information about the effect of a parameter is gained by varying only one parameter at a time. Because this procedure is repeated in turn for all parameters to be studied, running sensitivity analysis simulations may take a few minutes to complete.

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1-RESERVOIR PARAMETERS				3-SIMULATION PARAMETERS	4-NPV
					Injector Drilling Cost [SM/well] 1
Input File Name				Sensitivity Analysis (Slow)	
Decement (140-1		Min	Max	Simulation Time [year] 20	Extractor brining cost [awwen]
Pressure (MPa)	20	18	22		Injector Operating Cost [SK/well/yr] 500
Temperature [C]	65	60	70	Injection Well Radius [m] 0.1	Evitantizy Operating Cost (SK/wall/w
Thickness [m]	100	75	125	Min Extraction Pressure [MPa] 29	Extractor operating cost (proversy)
Salinity [mol/Kg]	2	1	3	Injection Rate [ton/day/well]	Monitoring Cost (SK/yr/km*2) 50
Porosity [-]	0.2	0.18	0.22	Extraction Rate [m*3/day/well]	Tax Credit [Siton] 10
Permeability [mD]	100	10	200	Max Number of Injectors 400	Pup
Rock Compressibility [1/Pa]	5e-10	4e-10	6e-10	Number of Extractors	Kui
Max Injection Pressure [MPa]	30	29.5	32	v .	Simulation Time (sec)= *****
Reservoir Area [km^2]	100				5-RESULT CONTROLS
Basin Area [km^2]	100			Density of Porous Media [Kg/m^3]	Number of Injection Wells
Boundary Condition	Closed	•		Total Stress Ratio (H/V)	Estimated Max Inj Pressure [MPa]
2-RELATIVE PERMEABILITY (Brooks	Corey)	_	Biot Coefficient	Total Injected CO2 [Mton]
Residual Water Saturation	0.5	0.4	0.6	Poisson's ratio	Total Extracted Brine [Mm*3]
Residual Gas Saturation	0.1	0.08	0.12	Coefficient of Thermal Expansion [1/K]	Highest Bottomhole Pres. [MPa]
m	3	2	4	Detters Hale Terreneture Dese IV	Lauret Bettenhale Part (MBa)
n	3	2	4	bottom Hole Temperature Drop [K]	Contas dollarinore ries, (mr.a)
Kra0	1	0.95	1	Young's Modulus [GPa]	Number of Failed Wells
Krg0	0.3	0.25	0.35	Depth [m]	Wellow webster

The minimum and maximum of parameters should be in the ranges which were described in reservoir and relative permeability parameters.

4. NPV Analysis

Section 4 provides the option to conduct a very simple net present value (NPV) analysis along with the simulation. Here, you can input parameters such as injector drilling cost (\$M/well), extractor drilling cost (\$M/well), injector operating cost (\$K/well/year), extractor operating cost (\$K/well/year), monitoring cost (\$K/year/km²), and tax credit (\$/ton):

EASiToolGUI						
Main Interface						
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GCCC	GL	ILF COAST	CARBON CENTER	C	BUREAU OF ECONOMIC GEOLOGY	
-1-RESERVOIR PARAMETERS			3-SIMULATION PARAMETERS		4-NPV	
ARE SERVOIR PARAMETERS General Geometry/Pattern Input File Name Pressure [MPa] 20 Temperature [C] 65 Thickness [m] 100 Salinity [mol/Kg] 2 Porosity [-] 0.2		Uniform Injection/Extraction Rate	•	Injector Drilling Cost [\$M/well]	1	
Input File Name	lain Interface		Sensitivity Analysis (Slow)		Extractor Drilling Cost [\$M/well]	1
Pressure [MPa]	In Interface		Simulation Time [year]	20		
Temperature (C)			Injection Well Radius [m]	0.1	Injector Operating Cost [\$K/well/yr] 50	00
remperature [0]	65			0.1	Extractor Operating Cost [\$K/well/yr] 50	00
Thickness [m]	100		Min Extraction Pressure [MPa]	29		
Salinity [mol/Kg]	Salinity [mol/Kg] 2		Injection Rate [ton/day/well]		Monitoring Cost [SK/yr/km^2] 5	.0
Porosity [-] 0.2		Extraction Rate [m^3/day/well]	Tax Credit [\$/ton]	0		
Permeability [mD] 100		May Number of Intenters				
Rock Compressibility [1/Pa]	5e-10		max Number of Injectors	400 💌	Run	
Max Injection Pressure (MPa)	30		Number of Extractors	•	Simulation Time [sec]= *****	
max injection i resolre (mi aj	50		Estimate Max Injection Pressure I			
Reservoir Area [km ²]	100		Density of Density Martin (Kalento)		5-RESULT CONTROLS	-
Basin Area [km^2]	100		Density of Porous Media (Agrim-3)		Number of Injection Wells	
Boundary Condition	Closed	•	Total Stress Ratio (H/V)		Estimated Max Inj Pressure [MPa]	
2-RELATIVE PERMEABILITY	(Brooks-	-Corey)	Biot Coefficient		Total Injected CO2 [Mton]	
Residual Water Saturation	0.5		Poisson's ratio		Total Extracted Brine [Mm^3]	
Residual Gas Saturation	0.1		1 0130113 12110			
	3		Coefficient of Thermal Expansion [1/K	1	Highest Bottomhole Pres. [MPa]	
			Bottom Hole Temperature Drop [K]		Lowest Bottomhole Pres. [MPa]	
n	3		Young's Modulus [GPa]		Number of Failed Wells	
Kra0	1		D. # 4 3			
Krg0	0.3		Depth [m]		Visit our website.	

The following table shows the range of NPV parameters that are accepted by EASiTool:

Drilling Cost	≥ 0.0001 million \$/well
Operation Cost	≥ 0.0001 thousand \$/well/year
Monitoring Cost	≥ 0.0001 thousand \$/year/km ²
Tax Credit	≥ 0.0 \$/ton
Drilling Cost of Extractors	≥ 0.0001 million \$/well
Operation Cost of Extractors	≥ 0.0001 thousand \$/well/year

Running the Simulation

To run the simulation, click "Run" in the EASiTool interface. A message box pops up, showing the progress in calculations:

EASiToolGUI								
Main Interface								
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GCCCC GUL	.F COAST C	ARBON CENTER	BUREAU OF ECONOMIC GEOLOGY					
1-RESERVOIR PARAMETERS	3	3-SIMULATION PARAMETERS	4-NPV					
General Geometry/Pattern		Uniform Injection/Extraction Rate	Injector Drilling Cost [\$M/well]					
Input File Name		Sensitivity Analysis (Slow)	Extractor Drilling Cost (SM/well)					
Pressure [MPa] 20	5	Simulation Time [year] 20						
Temperature [C]			Injector Operating Cost [SK/well/yr] 50	D				
EASiTo	ol		Extractor Operating Cost [\$K/well/yr] 50	D				
I nickness [m]	P	Please wait	Monitoring Cost [\$K/yr/km^2]					
Salinity [mol/Kg]								
Porosity [-]		Cancel	Tax Credit [\$/ton]					
Permeability (mD) 100		Max Number of Injectors						
Rock Compressibility [1/Pa] 5e-10			Run					
Max Injection Pressure [MPa] 30	'	Number of Extractors 4	Simulation Time [sec]= *****					
Receptoir Area (km/2) 100	[Estimate Max Injection Pressure Internally	5-RESULT CONTROLS					
		Density of Porous Media [Kg/m^3]	Number of Injection Wells	-				
Basin Area [km^2] 100	_ .	Tatal Otara Datia (100						
Boundary Condition Closed	•	Total Stress Ratio (H/V)	Estimated Max Inj Pressure [MPa]					
2-RELATIVE PERMEABILITY (Brooks-Co	orey)	Biot Coefficient	Total Injected CO2 [Mton]					
Residual Water Saturation 0.5	,	Poisson's ratio	Total Extracted Brine [Mm^3]					
Residual Gas Saturation 0.1		Conflicted of Thermal Excession (4.8/2	Highest Bottombole Pres (MPc)					
m 3		Coefficient of Thermal Expansion [1/K]	ingnesi bottomnole ries, (MrB)					
n 3	1	Bottom Hole Temperature Drop [K]	Lowest Bottomhole Pres. [MPa]					
	,	Young's Modulus [GPa]	Number of Failed Wells					
		Depth [m]	Visit our website					
Krg0 0.3			MISIC COLLWED SILE,					

The simulation results will appear on the right side of the controller window to inform you that the simulation is complete:

Main Interface			
	ST CARBON CENTER	BUREAU OF ECONOMIC GEOLOGY	
1-RESERVOIR PARAMETERS	3-SIMULATION PARAMETERS	4-NPV	
General Geometry/Pattern	Uniform Injection/Extraction Rate	Injector Drilling Cost [SM/well] 1	
Input File Name	Sensitivity Analysis (Slow)		Z 30 9 CZ -500 ℃
Pressure [MPa] 20	Simulation Time [year] 20	Extractor Drilling Cost [\$M/well]	
Temperature [C] 65	Injection Well Radius [m] 0.1	Injector Operating Cost [SK/well/yr] 500	0 20 0 -1000 -1000 0 50 100 0 50 100 0 50 100
Thickness [m] 100	Min Extraction Pressure [MPa] 29	Extractor Operating Cost [\$K/well/yr] 500	CO2 Diverse Extension Wells Well Pate (top/day)
Salinity [mol/Kg] 2	Injection Rate [ton/day/well]	Monitoring Cost [\$K/yr/km^2] 50	
Porosity [-] 0.2	Extraction Rate [m^3/day/well]	Tax Credit [\$/ton]	8 8
Permeability [mD] 100	Max Number of Injectors 100 💌	Pun	<u>ب</u> و
Rock Compressibility [1/Pa] 5e-10	Number of Extractors 4	Simulation Time [sec]= 7.1	\succ 4 \succ 4
Reservoir Area [km^2] 100	Estimate Max Injection Pressure Internally	5-RESULT CONTROLS	2
Basin Area [km^2] 100	Density of Porous Media [Kg/m^3]	Number of Injection Wells	
Boundary Condition Closed -	Total Stress Ratio (H/V)	Estimated Max Inj Pressure [MPa]	X, km X, km
2-RELATIVE PERMEABILITY (Brooks-Corey)	Biot Coefficient	Total Injected CO2 [Mton]	
Residual Water Saturation 0.5	Poisson's ratio	Total Extracted Brine [Mm^3]	
Residual Gas Saturation 0.1	Coefficient of Thermal Expansion [1/K]	Highest Bottomhole Pres. [MPa]	
m 3	Bottom Hole Temperature Drop [K]	Lowest Bottomhole Pres. [MPa]	
Kra0 1	Young's Modulus [GPa]	Number of Failed Wells	
Krg0 0.3	Depth [m]	Visit our website.	

Outputs

This section provides information on how to evaluate the outputs of EASiTool.

1. Optimal Constant-Injection/Extraction Rate

Optimal constant-injection/extraction rate: This procedure guarantees that nonidentical constant-injection/extraction rates are calculated optimally at each well to meet the maximum pressure limit for the injectors and the minimum user-defined pressure limit for the extractors at the end of simulation time. For example, if the pressure limit of injectors is selected to be 30 MPa and the minimum pressure of extractors is selected to be 29 MPa for a 20-year simulation, then the program will calculate injection and extraction rates for all wells so that the bottom-hole pressure of the injectors and extraction rates exceed 2,000 ton/day and 2,000 m³/day, respectively, a warning message box will appear.

After completing a simulation using the default "optimal constant-injection/extraction rate" option, you can see the results on the right-hand side of the window:



The results include the "Storage Capacity (Mtons of CO₂)," "NPV (\$M)," "CO₂ Plume Extension" (graphical map view of the CO₂ plumes and the location of extractors), and "Well Rate (ton/day)" for injectors and extractors.

The output text file will be saved where the installation folder was installed.

Note: Make sure that the installation folder is writable. Otherwise, the output file will not be saved.



To look at the values, press the "Data Cursor" icon in the upper tab:

Then, click on the "Well Rate" plot to see the value and coordinates of each well:

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Main Interface						۲
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GCCC	GU	LF COAST	CARBON CENTER	6	BUREAU OF JACKSON	8 45 500 · · · · · · · · · · · · · · · · ·
				6 4		5 ⁴⁰
1-RESERVOIR PARAMETERS			3-SIMULATION PARAMETERS		4-NPV	
Ceneral Geometry/r attent			Constituity Analysis (Slow)		Injector brining cost (awiwen)	
Input File Name			aerisiuvity Analysis (alow)		Extractor Drilling Cost [\$M/well] 1	
Pressure [MPa]	20		Simulation Time [year] 2	20		
Temperature [C]	65		Injection Well Radius [m] 0	0.1	Injector Operating Cost [\$K/weil/yr] 500	0 50 100 0 50 100
					Extractor Operating Cost [\$K/well/yr] 500	Number of Injection Wells Number of Injection Wells
Thickness [m]	100		Min Extraction Pressure [MPa] 2	29	Monitoring Cost (SK/vr/km^2)	CO2 Plume Extension Well Rate (ton/day)
Salinity [mol/Kg]	2		Injection Rate [ton/day/well]		50	
Porosity [-]	0.2		Extraction Rate [m^3/dav/well]		Tax Credit [\$/ton] 10	8
Permeability [mD]	100					
			Max Number of Injectors 100	•	Run	<u><u> </u></u>
Rock Compressibility [1/Pa]	5e-10		Number of Extractors 4	-		\succ 4 \times 4 \times 1.5 Y: 1.5
Max Injection Pressure [MPa]	30		_		Simulation Time [sec]= 7.1	2 • • • • • • • • • • • 2 • • Z: 38.7
Reservoir Area [km^2]	100		Estimate Max Injection Pressure Intern	nally	5-RESULT CONTROLS	
Basin Area [km^2]	100		Density of Porous Media [Kg/m^3]		Number of Injection Wells	0 5 10 0 5 10
Boundary Condition	Closed	•	Total Stress Ratio (H/V)		Estimated Max Inj Pressure [MPa]	X, km X, km
2-RELATIVE PERMEABILITY (Brooks-	Corey)	Biot Coefficient		Total Injected CO2 [Mton]	
Residual Water Saturation	0.5		Poisson's ratio		Total Extracted Brine [Mm^3]	
Residual Gas Saturation	0.1				History Detterrisely Des. (MD-1	
m	3		Coefficient of Thermal Expansion [1/K]		righest bottomilore Pites. [MP8]	
	2		Bottom Hole Temperature Drop [K]		Lowest Bottomhole Pres. [MPa]	
	3		Young's Modulus [GPa]		Number of Failed Wells	
Kraŭ	1		Depth (m)			
Krg0	0.3				Visit our website.	

The number of injection wells can be changed by clicking on the drop-down menu for "Number of Injection Wells":

C EASIToolGUI			
Main Interface			¥
	COAST CARBON CENTER	BUREAU OF ECONOMIC GEOLOGY	
1-RESERVOIR PARAMETERS	3-SIMULATION PARAMETERS	4-NPV	
General Geometry/Pattern	Uniform Injection/Extraction Rate	Injector Drilling Cost [SM/well] 1	
Input File Name	Sensitivity Analysis (Slow)	Extractor Drilling Cost [SM/well]	[≤ 30 P A; = 20 P
Pressure [MPa] 20	Simulation Time [year] 20	Injector Operating Cost [SK/well/yr] 500	
Temperature [C] 65	Injection Well Radius [m] 0.1	Extractor Operating Cost (SK/well/yr) 500	0 50 100 0 50 100 Number of Injection Wells Number of Injection Wells
Thickness [m] 100	Min Extraction Pressure [MPa] 29		
Salinity [mol/Kg] 2	Injection Rate [ton/day/well]	Monitoring Cost [\$K/yr/km^2] 50	10 CO2 Plume Extension Well Rate (ton/day)
Porosity [-] 0.2	Extraction Rate [m^3/day/well]	Tax Credit [\$/ton] 10	
Permeability [mD] 100	Max Number of Injectors 100 👻		
Rock Compressibility [1/Pa] 5e-10	Number of Extractors	Run	× 4 × 4
Max Injection Pressure [MPa] 30	4	Simulation Time [sec]= 7.1	
Reservoir Area [km^2] 100	Estimate Max Injection Pressure Internally	5-RESULT CONTROLS	
Basin Area [km^2] 100	Density of Porous Media [Kg/m^3]	Number of Injection Wells	
Boundary Condition Closed 💌	Total Stress Ratio (H/V)	Estimated Max Inj Pressure (MF a 4	X, km X, km
2-RELATIVE PERMEABILITY (Brooks-Core	v) Biot Coefficient	Total Injected CO2 [Mton] 16	
Residual Water Saturation 0.5		25	
Residual Gas Saturation 0.1	Poisson's ratio	1 otai Extracted Brine [Mim*3] 36 49	
	Coefficient of Thermal Expansion [1/K]	Highest Bottomhole Pres. [MPa 64	
m <u>3</u>	Bottom Hole Temperature Drop [K]	Lowest Bottomhole Pres. [MPa] 100	
n <u>3</u>	Young's Modulus [GPa]	Number of Failed Wells	
Kra0 1	Depth [m]	Visit our website	
Krg0 0.3		wish our website.	

The total CO₂ storage capacity and NPV of the simulated scenario based on the number of injection wells can be viewed by clicking on the circles of the "Capacity" and "NPV" plots.

The "Zoom In" and "Zoom Out" options can be used to focus on the output figures.

The units of CO₂ injection and brine extraction rates are ton/day in the "Well Rate" figure. The brine extraction rate unit can be converted from ton/day to sm³/day (standard cubic meter per day) using the following table:

Salinity (mol/kg)	Brine Density (kg/m ³)	
0	999.0	
1	1038.4	
2	1081.4	
3	1127.2	
4	1175.5	
5	1226.6	
6	1280.2	

2. Uniform Constant-Injection/Extraction Rate

Uniform constant-injection/extraction rate: This procedure applies identical constantinjection/extraction rates at each well. The program will calculate the final pressures of all injectors and extractors. The calculated final injection pressures will be compared with the user-defined or estimated maximum injection pressure at the end of simulations. Also, the calculated final extraction pressures will be compared with 50% of the initial pressure. If the calculated pressures fall outside the acceptable range, a warning message box will appear.

After completing a simulation using the "uniform constant-injection/extraction rate" option, you can see the results on the right-hand side of the window:



3. Sensitivity Analysis

After completing a simulation with sensitivity analysis, you can see the results on the right-hand side of the window:



The tornado chart on the lower right shows the impact of each parameter on the total capacity. In this chart, the parameters are listed downward from the highest direct impact to the highest inverse impact.

General Geometry/Pattern

This module provides users with flexibility of selecting well locations and constraints as well as reservoir and basin shape. In reality, multiple reservoirs with arbitrary shapes might be under storage operations. Also, various well constraints and patterns might be used in different reservoirs. In this module, user will be capable of including an Excel input file containing several arbitrary-shaped reservoirs with various well patterns and constraints. To activate this option, check "General Geometry/Pattern." Here, you can include the input file name and define the length and width of the basin as well as the other parameters defined in the input parameters section:

EASiToolGUI					
Main Interface					
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GCCC	GU	LF COAST	CARBON CENTER		BUREAU OF JACKSON
			2 SIMULATION DADAMETERS		
General Geometry/Pattern			3-SINULATION PARAMETERS		Injector Drilling Cost [SM/well]
Input File Name	EASITO	ol_Case01.xlsx			
Pressure (MPa)	20		Simulation Time [year]	20	Extractor Drilling Cost [\$M/well]
Temperature [C]	20		Injection Well Radius [m]	0.1	Injector Operating Cost [\$K/well/yr]
Thickness [m]	100		Min Extraction Pressure (MPa)		Extractor Operating Cost [\$K/well/yr]
Salinity [mol/Kg]	2		laisatian Data Maadaadaa IV		Monitoring Cost [\$K/yr/km^2]
Porosity [-]	0.2		Injection Rate [ton/day/weil]		Tax Credit [\$/ton]
Permenhility (mD)	100		Extraction Rate [m^3/day/well]		<u></u>
Pack Comprossibility [1/Pa]	50.10		Max Number of Injectors		Run
Max Injection Pressure (MPa)	5e-10		Number of Extractors		Simulation Time [sec]= *****
max injection i residire (nin a)					
Reservoir Area [km^2]		X [km] Y [km]	Density of Porous Media [Kg/m^3]		Number of Injection Wells
Basin Area [km^2]	Oliverat	20 10	Total Stress Ratio (H/V)		Estimated Max Inj Pressure [MPa]
Boundary Condition	Closed		Rist Coofficient		Total Injected CO2 [Miton]
-2-RELATIVE PERMEABILITY Residual Water Saturation	Brooks- 0.5	Corey)	bior openicient		
Residual Gas Saturation	0.1		Poisson's ratio		Total Extracted Brine [Mm^3]
m	3		Coefficient of Thermal Expansion [1/K]		Highest Bottomhole Pres. [MPa]
n	3		Bottom Hole Temperature Drop [K]		Lowest Bottomhole Pres. [MPa]
Kra0	1		Young's Modulus [GPa]		Number of Failed Wells
Krg0	0.3		Depth [m]		Visit our website.

The basin can be a rectangle with a maximum length-to-width ratio of 10.

User has been provided with an example Excel input file named

"EASiTool_Case01.xlsx." This Excel input file can be found where the installation folder was installed. The first sheet of the example file includes the well number, well location in X (m) and Y (m) directions, injection rate (ton/day), extraction rate (m³/day), maximum allowable pressure (MPa), minimum allowable pressure (MPa), and well type. The origin of the coordinate system for all wells is the left lower edge of the basin. Injectors and extractors are assigned by 0 and 1 indicators, respectively. All extractors must be listed after injectors. There is no upper limit for the number of wells. The rest of reservoir, relative permeability, and simulation parameters can be entered through the interface as before. Here, you can see a screen shot of the example first sheet:

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-	: X v	fx					
٨	R	C	D	E	E	G	Ц
Well Number	Well X (m)	Well Y (m)	Injection Rate (Ton/day)	Extraction Rate (m^3/day)	Max Injection Pressure (Mpa)	Min Extraction Pressure (Mpa)	Well Type (0 for Injector/1 for Extract
1	2973.7965	6768.2927	500	0	35	20	0
2	3290.6764	6743.9024	134	0	35	20	0
3	2717.855	6439.0244	378	0	35	20	0
4	3095.6734	6439.0244	174	0	35	20	0
5	3534.4302	6426.8293	367	0	35	20	0
7	2644.7288	6085.3659	446	0	35	20	0
8	3375 9902	6073 1707	138	0	35	20	0
9	3765.9963	6073,1707	405	0	35	20	0
10	3839.1225	5731.7073	432	0	35	20	0
11	3436.9287	5719.5122	421	0	35	20	0
12	2985.9842	5719.5122	159	0	35	20	0
13	2571.6027	5731.7073	157	0	35	20	0
14	2254.7227	5365.8537	276	0	35	20	0
15	2608.1658	5353.6585	274	0	35	20	0
10	2949.4211	5341.4634	453	0	35	20	0
19	2914 7471	5329.2085	267	0	35	20	0
19	3802 5594	4963 4146	215	0	35	20	0
20	3400.3656	4963,4146	455	0	35	20	0
21	2985.9842	4951.2195	301	0	35	20	0
22	2583.7904	4939.0244	166	0	35	20	0
23	2181.5966	4963.4146	455	0	35	20	0
24	2071.9074	4536.5854	427	0	35	20	0
25	2437.5381	4512.1951	224	0	35	20	0
26	2864.1073	4475.6098	344	0	35	20	0
27	3302.8641	4475.6098	239	0	35	20	0
28	3/41.621	4487.8049	2/3	0	35	20	0
30	3607 5564	4121.9912	274	0	35	20	0
31	2998.1718	4109.7561	396	0	35	20	0
32	2535.0396	4109.7561	349	0	35	20	0
33	2035.3443	4109.7561	158	0	35	20	0
34	1950.0305	3707.3171	196	0	35	20	0
35	2327.8489	3695.122	459	0	35	20	0
36	2827.5442	3658.5366	351	0	35	20	0
37	3315.0518	3646.3415	152	0	35	20	0
38	3839.1225	3658.5366	310	0	35	20	0
39	4302.2547	3658.5366	368	0	35	20	0
40	5191,9561	3621.9512	148	0	35	20	0
42	1901.2797	3341.4634	431	0	35	20	0
43	2364.4119	3292.6829	286	0	35	20	0
44	2851.9196	3256.0976	245	0	35	20	0
45	3412.5533	3207.3171	351	0	35	20	0
46	3900.0609	3207.3171	274	0	35	20	0
47	4326.6301	3219.5122	455	0	35	20	0
48	4789.7623	3195.122	449	0	35	20	0
49	5301.6453	31/0./317	162	0	35	20	0
50	2193./843	2829.2683	338	0	35	20	0
52	3180 9872	2029.2000	282	0	35	20	0
53	3644.1194	2817.0732	305	0	35	20	0
54	4192.5655	2768.2927	227	0	35	20	0
55	4655.6977	2756.0976	337	0	35	20	0
56	2449.7258	2439.0244	288	0	35	20	0
57	2925.0457	2426.8293	403	0	35	20	0

The reservoir boundaries can be sketched point by point using the second sheet of Excel file:

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																						- 1
A 0 C D E F G H I J K L M N 0 P Q R 5 T 2 13799 1198.207 1027.217 1023.398 1023.298 </td <td>V1</td> <td></td> <td>-</td> <td>XV</td> <td>fx</td> <td></td> <td>v</td>	V1		-	XV	fx																	v
••••••••••••••••••••••••••••••••••••		^	p	C	D	E	E	G		т		V		М	N	0	D	0	P	c	т	
2 373 103434 100243 101234 101234 101234 101234 4 54534 201344 101234<	1	ResX1 (m) ResY1 (m)	ResX2 (m)	ResY2 (m)	ResX3 (m)	ResY3 (m)	ResX4 (m)	ResY4 (m)	ResX5 (m)	ResY5 (m)	ResX6 (m)	ResY6 (m)	ResX7 (m)	ResY7 (m)	ResX8 (m)	F ResY8 (m)	ResX9 (m)	ResY9 (m)	3 ResX10 (m)	ResY10 (n	n) –
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20 4008.75 4708.293 11810.18 8414.844 Interview 21 4008.75 5036.585 1122.46 8500 Interview Interview 23 4008.75 5036.585 1122.46 8500 Interview Interview Interview 24 4034.126 5170.732 1122.46 8500 Interview	25	4009.7	5 4646.341	16806.83	5439.024	11334.55	8304.878															
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45 3424.741 7000 18025.59 6963.415 9043.266 8500 46 3339.427 7060.976 18001.22 7060.976 18021.52 1060.976 1289.1389 8451.22 47 3217.55 7073.171 17964.66 7158.537 8762.949 8402.439 1	44	3522.24	6951 22	18062 16	6817 073	9177 331	8524.39															-
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After completing the simulation for the example, you can see the results on the right-hand side of the window. The upper figure show the pressure contours at the end of two years. The red circles and blue triangles on the lower figures show the CO_2 plume extensions and the location of extractors, respectively. A third potential storage reservoir is located in the same basin. A monitoring point at coordinates of (10km, 6.75km) is used to track the pressure buildup in the third reservoir. The result section shows the total injected CO_2 , total extracted brine, highest bottomhole pressure, lowest bottomhole pressure, and the number of wells whose bottomhole pressure fail to fall within the minimum and maximum allowable pressure.



User will be provided with an Excel output file including the final bottomhole pressure of each well. The final pressure of each well will be checked with the maximum and minimum allowable pressure of each well. The results of the pressure check will be shown by 'P' or 'F' for pass or fail in the pressure criteria column of the output file.

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)	P	0	N	м	L	К	J	I	Н	G	F	E	D	С	В	А	
										Prssure_Criteria	Prssure_MPa	tRate_CubicMeterPerDay	InjRate_TonPerDay	WellY_m	WellX_m	INumber	1 Wel
-										P	30.65217429	0	500	6768.293	2973.796	1	2
1										P	30,45757767	0	378	6439 024	2717 855	2	4
										P	30.78613615	0	174	6439.024	3095.673	4	5
										P	30.86491759	0	367	6426.829	3534.43	5	6
										P	31.08422224	0	446	6085.366	2644.729	6	7
										P	31.22936263	0	429	6073.171	2985.984	7	8
										P	31.05575854	0	138	6072 171	33/5.99	8	10
										P	31.30746263	0	403	5731 707	3839 122	10	11
										P	31.4633056	0	421	5719.512	3436.929	11	12
										P	31.27608434	0	159	5719.512	2985.984	12	13
										P	31.06606011	0	157	5731.707	2571.603	13	14
										P	31.09665821	0	276	5365.854	2254.723	14	15
										P	31.3701904	0	274	5353.659	2608.166	15	16
										P	31 57789674	0	433	5329.268	3363 803	10	18
										Р	31.45369052	0	353	5317.073	3814.747	18	19
										P	31.47622766	0	215	4963.415	3802.559	19	20
										P	31.78697902	0	455	4963.415	3400.366	20	21
										P	31.67789724	0	301	4951.22	2985.984	21	22
										P	31.42635227	0	166	4939.024	2583.79	22	23
										P	31.31466752	0	455	4963.415	2181.597	23	24
										P	31 45942569	0	224	4512 195	2437 538	24	25
										P	31.74676546	0	344	4475.61	2864.107	26	27
										P	31.72650021	0	239	4475.61	3302.864	27	28
_										P	31.64203264	0	273	4487.805	3741.621	28	29
-										P	31.64999964	0	411	4121.951	4046.313	29	30
-										P	31.72085702	0	274	4134.146	3607.556	30	31
1										P	31,61572978	0	349	4109.756	2535.04	32	33
1										P	31.09598254	0	158	4109.756	2035.344	33	34
1										P	31.01634517	0	196	3707.317	1950.03	34	35
										P	31.51119005	0	459	3695.122	2327.849	35	36
-										P	31.68368921	0	351	3658.537	2827.544	36	37
-										P	31.61978514	0	152	3646.341	3315.052	37	38
-										P	31.6/66644	0	310	3658.537	3839.122	38	39 40
1										P	31.31492177	0	481	3634.146	4777.575	40	41
1										P	30.75716396	0	148	3621.951	5191.956	41	42
										P	31.03002435	0	431	3341.463	1901.28	42	43
										P	31.30705955	0	286	3292.683	2364.412	43	44
-										P	31.50509346	0	245	3256.098	2851.92	44	45
-										P	31.65199452	0	351	3207.317	3412.553	45	40
										P	31.53397978	0	274	3219 512	4326.63	46	48
1										P	31.23940503	0	449	3195.122	4789.762	48	49
										P	30.61736114	0	162	3170.732	5301.645	49	50
1										P	30.98455724	0	338	2829.268	2193.784	50	51
4										P	31.37613199	0	440	2829.268	2681.292	51	52
-										P	31.4106062	0	282	2792.683	3180.987	52	53
-										P	31.45438758	0	305	2817.073	3644.119	53	55
										P	31.24505787	0	227	2756.098	4655 698	54	56
1										P	30.8825732	0	288	2439.024	2449.726	56	57
										D	21 105 02575		200	2426.020	0005.046		

READY

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Warning and Error Dialogs

Several warning and error dialogs have been designed to help users with the simulation process. The warning and error dialogs may pop up before, during and after simulations.

Presimulation Errors

The range of acceptable input parameters were listed in the "Input Parameters" section. If one or more entered parameter is out of the acceptable range, an error will pop up at the beginning of the simulation and the simulation will not proceed. For example, if the entered initial pressure is 100 MPa, the following error will pop up:

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Main Interface					۲ ۲
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GCCCC GULF COAST	CARBON CENTER		BUREAU OF ECONOMIC GEOLOGY		
1-RESERVOIR PARAMETERS	3-SIMULATION PARAMETERS	1	4-NPV		
General Geometry/Pattern	Uniform Injection/Extraction Rate	.	Injector Drilling Cost [SM/well] 1		
Input File Name	Sensitivity Analysis (Slow)				
Pressure [MPa] 100	Simulation Time [year]	20	Extractor Drilling Cost [SM/well]		
Temperature [C] 65	Injection Well Radius [m]	0.1	Injector Operating Cost [SK/well/yr] 500		
Thickness [m] 100	Min Extraction Pressure [MPa]	29	Extractor Operating Cost [\$K/weil/yr] 500		
Salinity [mol/Kg] 2	Injection Rate [ton/day/well]		Monitoring Cost [\$K/yr/km^2] 50		
Parosity [-] 0.2	Extraction Rate [m^3/day/well]		Tax Credit [\$/ton] 10	Error Dialog	
Permeability [mD] 100	Max Number of Injectors	400 👻	Bun	Error: Initial pressure should be less than 60 MPa.	
Rock Compressibility [1/Pa] 5e-10	Number of Extractors 0		Kun	ОК	
Max Injection Pressure [MPa] 30	Estimate Max Injection Pressure In	Internally	5.RESULT CONTROLS		
Basin Area [km^2] 100	Density of Porous Media [Kg/m^3]		Number of Injection Wells		
Boundary Condition Closed 🔻	Total Stress Ratio (H/V)		Estimated Max Inj Pressure [MPa]		
2 DELATIVE DEDMEABILITY (Brooks Corev)	Biot Coefficient		Total Injected CO2 [Mton]		
Residual Water Saturation 0.5	Poisson's ratio		Total Extracted Brine [Mm^3]		
Residual Gas Saturation 0.1	Coefficient of Thermal Expansion [1/K]	9	Highest Bottomhole Pres. [MPa]		
m 3	Bottom Hole Temperature Drop [K]		Lowest Bottomhole Pres. [MPa]		
n <u>3</u>	Young's Modulus [GPa]		Number of Failed Wells		
Kra0 1	Depth [m]		Visit our website		
Krg0 0.3					

Midsimulation Errors

When the simulation cannot reach the convergence the simulation will fail. The main reasons for convergence failure are the following:

- The total rate of extraction is much higher than total rate of injection, which results in over-depletion of reservoir.
- The total rate of injection is much higher than total rate of extraction, which results in over-pressurization of reservoir.

In the following example, the total extraction rate using eight extractors is much higher than the total injection rate using nine injectors. Therefore, the reservoir pressure becomes unrealistic and the convergence fails.

EASiToolGUI						
Main Interface						3
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	GU	LF COAST	CARBON CENTER		BUREAU OF ECONOMIC GEOLOGY	
1-RESERVOIR PARAMETERS			3-SIMULATION PARAMETERS	-	4-NPV	
			Uniform Injection/Extraction Rate		Injector Drilling Cost [SM/well] 1	
Input File Name					Extractor Drilling Cost [SM/well] 1	
Pressure [MPa]	20		Simulation Time [year]	20		
Temperature [C]	65		Injection Well Radius [m]	0.1	Injector Operating Cost [\$K/well/yr] 500	
Thickness [m]	100		Min Extraction Pressure [MPa]		Extractor Operating Cost [\$K/well/yr] 500	
Salinity [mol/Kg]	2		Injustice Pate (tex/day/well)	100	Monitoring Cost [\$K/yr/km^2] 50	
Porosity [4]	0.2		injection kate (tonday/wenj	100	Tax Credit [S/ton]	Error Dialog
			Extraction Rate [m^3/day/well]	2000		Fron Convergence did not achieved
Permeability [mD]	100		Max Number of Injectors 100	•	Run	It the control generation and the calculated pressures are too low or too high.
Rock Compressibility [1/Pa]	5e-10		Number of Extractors 8	-		ОК
Max Injection Pressure [MPa]	30		Estimate Max Injection Pressure Inte	mally	Simulation Time [sec]= *****	
Reservoir Area [km^2]	100				5-RESULT CONTROLS	
Basin Area [km^2]	100		Density of Porous Media [Kg/m^3]		Number of Injection Wells	
Boundary Condition	Closed	•	Total Stress Ratio (H/V)		Estimated Max Inj Pressure [MPa]	
2-RELATIVE PERMEABILITY	Brooks-	Corey)	Biot Coefficient		Total Injected CO2 [Mton]	
Residual Water Saturation	0.5		Poisson's ratio		Total Extracted Brine [Mm^3]	
Residual Gas Saturation	0.1		Coefficient of Thermal Expansion [1/K]		Highest Bottomhole Pres. [MPa]	
m	3					
n	3		Bottom Hole Temperature Drop [K]		Lowest bottomhole Pres. [MPa]	
Kra0	1		Young's Modulus [GPa]		Number of Failed Wells	
Krg0	0.3		Depth [m]		Visit our website.	
	-					

Postsimulation Warnings

When the simulation is finished, the results will be compared with the monitoring constraints. The monitoring constraints are the following:

- Uniform Injection/Extraction Rate: "Max Injection Pressure" for injectors and 50% of the initial pressure for the extractors.
- Optimal Injection/Extraction Rate: 2,000 ton/day for injectors and 2,000 m³/day for extractors.

In the "Uniform Injection/Extraction Rate" case, if the calculated pressures violate the monitoring constraints, a warning will pop up at the end of the simulation and the following will be suggested: adjust the operating constraints ("Injection Rate" and/or "Extraction Rate"). In the following example, the bottom-hole pressure of some injectors in well patterns of 49 and 64 injectors increases above the "Max Injection Pressure." The well patterns which have out of the range pressures will be marked by a red "X."



In the "Optimal Injection/Extraction Rate" case, if the calculated rates violate the monitoring constraints, a warning will pop up at the end of the simulation, and the following will be suggested: adjust the operating constraints ("Max Injection Pressure" and/or "Minimum Extraction Pressure"). In the following example, the extraction rate of some extractors in well patterns of 49 and 64 injectors is above 2,000 m³/day. The well patterns which have out of the range rates will be marked by a red "X."



At the end of the simulations, the plume extensions will be checked to make sure the CO_2 plumes do not overlap or cross the reservoir boundaries. If the CO_2 plumes overlap or cross the reservoir boundaries, a warning message will pop up and the well patterns with oversized plumes will be marked by a green "+". In the following example, some of the CO_2 plumes overlap or cross the boundaries for well pattern of 36 injectors.

C EASiToolGUI				
Main Interface				لا لا
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GCCCC G	ULF COAST	CARBON CENTER	BUREAU OF ECONOMIC GEOLOGY	
1-RESERVOIR PARAMETERS	(3-SIMULATION PARAMETERS	4-NPV	° ≤ 40 · ≥ 50 · · ·
		Uniform Injection/Extraction Rate	Injector Drilling Cost [\$M/well]	
Input File Name		Simulation Time (year)	Extractor Drilling Cost [\$M/well]	
Pressure [MPa] 20			Injector Operating Cost [SK/well/yr] 500	
Temperature [C] 65	5	Injection Well Radius [m] 0.	Extractor Operating Cost [\$K/well/yr] 500	0 10 20 30 40 0 10 20 30 40 Number of Injection Wells Number of Injection Wells
Thickness [m] 100	0	Min Extraction Pressure [MPa]		CO2 Plume Extension Well Pressure (MPa)
Salinity [mol/Kg] 2		Injection Rate [ton/day/well] 20	Monitoring Cost [SKlyrikm*2] 50	
Porosity [-]	2	Extraction Rate [m^3/day/well] 10	Tax Credit [\$/ton] 10	2.5
Permeability [mD] 100	0	Max Number of Injectors 36		
Rock Compressibility [1/Pa] 5e-1	10	Number of Extractors	Run	
Max Injection Pressure [MPa] 30		4	Simulation Time [sec]= 2.6	
Reservoir Area [km^2] 10		Estimate Max Injection Pressure Interna	5-RESULT CONTROLS	
Basin Area [km^2] 10		Density of Porous Media [Kg/m^3]	Number of Injection Wells 36 -	
Boundary Condition Oper	n 💌	Total Stress Ratio (H/V)	Estimated Max Inj Pressure [MPa]	X , km X , km
2-RELATIVE PERMEABILITY (Brook	ks-Corey)	Biot Coefficient	Total Injected CO2 [Mton]	EASiTool
Residual Water Saturation 0.5	5	Poisson's ratio	Total Extracted Brine [Mm^3]	Design Considerations:
Residual Gas Saturation 0.1	1	Coofficient of Thormal Expansion (1%)	Highest Bottomhole Pres [MPa]	 CO2 plume of at least one injector crosses the reservoir boundary or overlaps another plume in the well patterns marked by +.
m 3		Coencient of Therman Expansion [1/k]		Consider adjusting these parameters:
n 3		Bottom Hole Temperature Drop [K]	Lowest Bottomnole Pres. [MPa]	- Maximum injection pressure - Minimum extraction pressure - Injection rate - Extraction rate.
Kra0 1		Young's Modulus [GPa]	Number of Failed Wells	ОК
Krg0 0.3	3	Depth [m]	Visit our website.	

Examples and Verifications

Table 1 summarizes the input for the EASiTool template. The aquifer is located at a depth of 1,000 m. In this study, the problem was solved for closed and open boundary conditions. The basin area is the same as the reservoir area for the case of the closed boundary condition. The basin area is 10,000 km² for the case of the open boundary condition. The maximum allowable injection pressure is assumed to be 20 MPa.

Table 1: Reservoir Parameters	
Initial pressure, MPa	10
Initial temperature, °C	40
Thickness, m	100
Salinity, kg/mol	0
Porosity	0.2
Permeability, mD	100
Rock compressibility, 1/Pa	5.0E-10
Maximum injection pressure, MPa	20
Reservoir area, km ²	100
Basin area, km ²	100 or 10,000
Boundary Condition	Closed or Open

Table 2 summarizes the relative permeability parameters used in the Brooks-Corey model for a two-phase flow of gas and aqueous phases.

 Table 2: Relative Permeability Parameters for Brooks-Corey Model

Residual water saturation, S _{wr}	0.5
Residual gas saturation, Sgr	0.1
Water exponent, m	3.0
Gas exponent, ⁿ	3.0
Water end-point relative permeability, k_{rw}^{*}	1.0
Gas end-point relative permeability, k_{rg}	0.3

Table 3 shows the simulation parameters.

Table 3: Simulation Parameters		
Simulation time, year	20	
Injection well radius, m	0.1	
Minimum extraction pressure, MPa	19	
Maximum number of injectors	16	
Number of extractors	0	

The basin models were prepared for numerical simulation using GEM by CMG (Computer Modeling Group) for both boundary conditions. The injection rates calculated by EASiTool were used in numerical simulation to compare the analytical and numerical results. Figure 1 shows the pressure distributions throughout the reservoir and bottomhole pressures of all wells after 20 years of injection using 1, 4, 9, and 16 injectors. The injection rates were calculated using the closed boundary condition of EASiTool. The color legend shows the range of pressure throughout the reservoir at the end of 20 years. It is observed that the maximum pressure in the reservoir is very close to the target pressure of 20 MPa. The pressure distribution is more uniform by using more injectors. The bottom-hole pressure of all wells is very similar throughout the injection period.



Figure 1: Pressure distributions and bottom-hole pressures for the closed boundary condition after 20 years of constant injection at a depth of 1000 m.

Figure 2 shows the pressure distributions and bottom-hole pressures after 20 years of injection using the open boundary condition. A 100-km² reservoir is located at the center of a 10,000-km² basin. The final pressure from simulations differs slightly from the final pressure of 20 MPa used for calculating the rates by EASiTool. This difference decreases when more injectors are used. In addition, the simulation results show that the effect of pressure reaches the boundaries of the basin at the end of the injection process. The implication is that the open boundary condition is not accurate for a 20-year process.





Figure 2: Pressure distributions and bottom-hole pressures for open boundary condition after 20 years of constant injection at a depth of 1000 m.

Figures 3 and 4 show the maximum capacity for closed and open boundary problems versus the number of injectors. The open boundary reservoirs have a much larger storage capacity. The storage capacity of reservoirs remains constant after a specific number of injectors is reached.



Figure 3: CO_2 capacity for 20 years of injection versus number of injectors using closed boundary condition at a depth of 1000 m.



Figure 4: CO_2 capacity for 20 years of injection versus number of injectors using open boundary condition at a depth of 1000 m.

The same comparative study was performed for a reservoir at a depth of 3,000 m. The initial temperature and pressure in this study were 90 °C and 30 MPa, respectively. It was assumed that the maximum pressure in the reservoir would be 40 MPa after 20 years of injection. Figures 5 and 6 show the final pressure distribution obtained by simulation. Again, the results of the closed boundary case are closer to the results of EASiTool than are the results of the open boundary case.



Figure 5: Pressure distribution for closed boundary condition after 20 years of constant injection at a depth of 3,000 m.



Figure 6: Pressure distribution for open boundary condition after 20 years of constant injection at a depth of 3,000 m.

Figures 7 and 8 show the maximum capacity for closed and open boundary problems versus the number of injectors. It is observed that the open boundary reservoirs have a much larger storage capacity.



Figure 7: CO_2 capacity for 20 years of injection versus number of injectors using closed boundary condition at a depth of 3,000 m.



Figure 8: CO_2 capacity for 20 years of injection versus number of injectors using open boundary condition at a depth of 3,000 m.

EASiTool assumes that the reservoir is square, flat, and horizontal. The effect of reservoir shape and structure on the EASiTool estimations was studied. An anticline model was used for reservoir simulation with the average properties of the reservoir used as input for EASiTool. Estimated injection rates by EASiTool were also used as input for reservoir

simulation. Tables 4 and 5 show the average properties of the anticline reservoir and the simulation parameters. Figure 9 shows the pressure distribution in the reservoir after 10 years of injection using 16 injectors. The simulation predicts the maximum pressure of 24.07 MPa, which is very close to the target pressure of 25 MPa.

Table 4: Properties of Anticline Reservoir	
Reference pressure, MPa	16.55
Reference depth, m	1750
Initial temperature, °C	40
Average thickness, m	24.39
Salinity, kg/mol	0
Porosity	0.2
Permeability, mD	100
Rock compressibility, 1/Pa	5.0E-10
Reservoir area, km ²	42.87
Basin area, km ²	42.87
Boundary condition	Closed

Table 5: Simulation Parameters		
Simulation time, year	20	
Injection well radius, m	0.1	
Maximum injection pressure, MPa	25	



Figure 9: Pressure distribution after 20 years of injection using 16 injectors.

EASiTool assumes that the reservoir is homogeneous. The effect of reservoir heterogeneity on the EASiTool estimations was studied. The same anticline in Figure 9 was used for reservoir simulation using the average properties and simulation parameters of Tables 4 and 5. Two realizations for permeability distribution were prepared with Petrel software. Figures 10 and 11 show the histograms of the two realizations. The second model is more heterogeneous than the first.



Figure 10: Histogram of permeability for first realization.



Figure 11: Histogram of permeability for second realization.

Figures 12 and 13 show the permeability distributions of the respective models. The estimated injection rates by EASiTool were used as input for reservoir simulation for both models.



Figure 12: Permeability distribution for first realization.



Figure 13: Permeability distribution for second realization.

Figures 14 and 15 show the pressure distribution in the reservoir after 20 years of injection using 16 injectors. The simulation predicts the maximum pressure of 25.07 and 25.51 MPa, respectively, which are very close to the target pressure of 25 MPa.



Figure 14: Pressure distribution for first realization.



Figure 15: Pressure distribution for second realization.

Figures 16 shows the results of simulation using nine injectors and four extractors. The initial pressure is 20.0 MPa. The final target bottom-hole pressures are 25.0 and 20.0 MPa for the injectors and extractors, respectively. Figure 16 shows the distribution of reservoir pressure after 20 years. In addition, Figure 17 shows the bottom-hole pressure of one injector and one extractor. The final reservoir pressures are 25.1 and 20.1 MPa which are very close to the target pressures of 25.0 and 20.0 MPa.



Figure 16: Pressure distribution throughout the aquifer after 20 years using nine injectors and four extractors.



Figure 17: Bottom-hole pressure of injector #5 and extractor #1 versus time.

Figures 18 and 19 show the results of simulation for 16 injectors and 4 extractors. The initial pressure is 20.0 MPa and the target bottom-hole pressure of injectors and extractors are 25.0 and 20.0 MPa, respectively. The predicted bottom-hole pressures after 20 years using numerical simulations are very close to the target pressures.



Figure 18: Pressure distribution throughout the aquifer after 20 years using 16 injectors and 4 extractors.



Figure 19: Bottom-hole pressure of injector #10 and extractor #1 versus time.

Table 6 summarizes the reservoir parameters for a general example with 30 injectors and 8 extractors.

Table 6: Reservoir Parameters	
Initial pressure, MPa	20
Initial temperature, °C	65
Thickness, m	100
Salinity, kg/mol	0
Porosity	0.2
Permeability, mD	100
Rock compressibility, 1/Pa	5.0E-10
Basin X, km	12
Basin Y, km	8
Boundary Condition	Closed

The relative permeability parameters for this problem is the same as the ones presented in Table 2. Table 7 summarizes the simulations parameters.

Table 7: Simulation Parameters	
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Table 7. Simulation Parameters	
Simulation time, year	10
Injection well radius, m	0.1

Table 8 summarizes the well locations and operating constraints for all injectors and extractors.

Well	Well X	Well Y	Injection Rate	Extraction Rate	Max Injection	Min Extraction	Well Type (0 for
Number	(m)	(m)	(Ton/day)	(m^3/day)	Pressure (Mpa)	Pressure (Mpa)	Injector/1 for Extractor)
1	1790	5390	250	0	35	20	0
2	2090	5070	200	0	35	20	0
3	1650	4870	200	0	35	20	0
4	2110	4530	150	0	35	20	0
5	1510	4310	150	0	35	20	0
6	2090	3990	250	0	35	20	0
7	1450	3710	200	0	35	20	0
8	2070	3450	250	0	35	20	0
9	1350	3150	200	0	35	20	0
10	2790	2990	100	0	35	20	0
11	1390	2590	300	0	35	20	0
12	2910	2450	200	0	35	20	0
13	2630	1890	350	0	35	20	0
14	2030	1410	500	0	35	20	0
15	1630	1930	150	0	35	20	0
16	1850	3010	200	0	35	20	0
17	2430	2630	250	0	35	20	0
18	2090	2130	300	0	35	20	0
19	9050	3010	350	0	35	20	0
20	8770	3450	150	0	35	20	0
21	9310	3470	200	0	35	20	0
22	8690	3910	250	0	35	20	0
23	9530	3890	100	0	35	20	0
24	8730	4410	100	0	35	20	0
25	9150	4790	150	0	35	20	0
26	9830	4650	200	0	35	20	0
27	10450	4630	150	0	35	20	0
28	10190	5150	200	0	35	20	0
29	10590	5390	150	0	35	20	0
30	9210	4250	300	0	35	20	0
31	2170	1810	0	200	35	20	1
32	1890	2530	0	200	35	20	1
33	2330	3030	0	200	35	20	1
34	1770	3870	0	200	35	20	1
35	1770	4590	0	200	35	20	1
36	9030	3730	0	200	35	20	1
37	9390	4570	0	200	35	20	1
38	10190	4790	0	200	35	20	1

Table 8: Well Locations and Operating Constraints

Table 9 summarizes the output file for the above example.

WellNumber	WellX_m	WellY_m	InjRate_TonPerDay	ExtRate_CubicMeterPerDay	Prssure_MPa	Prssure_Criteria
1	1790	5390	250	0	33.43482	Р
2	2090	5070	200	0	33.45416	Р
3	1650	4870	200	0	33.45067	Р
4	2110	4530	150	0	33.46696	Р
5	1510	4310	150	0	33.45002	Р
6	2090	3990	250	0	33.57468	Р
7	1450	3710	200	0	33.52467	Р
8	2070	3450	250	0	33.61311	Р
9	1350	3150	200	0	33.54522	Р
10	2790	2990	100	0	33.49868	Р
11	1390	2590	300	0	33.60333	Р
12	2910	2450	200	0	33.56705	Р
13	2630	1890	350	0	33.65188	Р
14	2030	1410	500	0	33.68509	Р
15	1630	1930	150	0	33.49465	Р
16	1850	3010	200	0	33.59129	Р
17	2430	2630	250	0	33.62914	Р
18	2090	2130	300	0	33.64285	Р
19	9050	3010	350	0	33.41074	Р
20	8770	3450	150	0	33.31918	Р
21	9310	3470	200	0	33.32449	Р
22	8690	3910	250	0	33.38588	Р
23	9530	3890	100	0	33.24537	Р
24	8730	4410	100	0	33.2718	Р
25	9150	4790	150	0	33.25464	Р
26	9830	4650	200	0	33.24743	Р
27	10450	4630	150	0	33.14206	Р
28	10190	5150	200	0	33.18715	Р
29	10590	5390	150	0	33.09748	Р
30	9210	4250	300	0	33.39318	Р
31	2170	1810	0	200	33.3133	Р
32	1890	2530	0	200	33.33027	Р
33	2330	3030	0	200	33.33242	Р
34	1770	3870	0	200	33.29281	Р
35	1770	4590	0	200	33.23397	Р
36	9030	3730	0	200	33.09923	Р
37	9390	4570	0	200	33.0445	Р
38	10190	4790	0	200	32.95544	Р

Table 9: Excel Output File

Figures 20 and 21 shows the final pressure contour and CO₂ plume extensions.



Figure 20: Pressure contour after 10 years of injection and extraction.



Figure 21: CO₂ plume extensions after 10 years of injection and extraction.

Figures 22 and 23 show the numerical simulation results for this general case. The results show that the predicted pressure and plume extension by EASiTool is very close the predictions by numerical simulation.



Figure 22: Pressure contour by numerical simulation.



Figure 23: Gas saturation by numerical simulation.

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