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Prepared for the U.S. Department of Energy
under Contract DE-AC05-76RL01830

TRL Computer System User's Guide

DW Engel
AC Dalton

January 2014



Pacific Northwest
NATIONAL LABORATORY

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Pacific Northwest National Laboratory
Richland, Washington 99352

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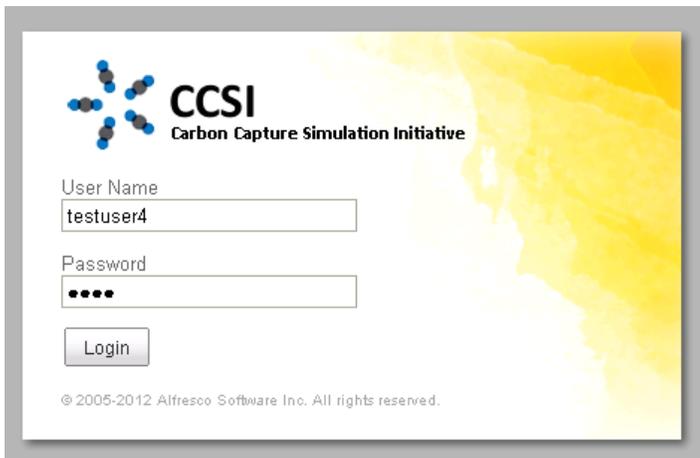
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I. Request and Create a New User Account

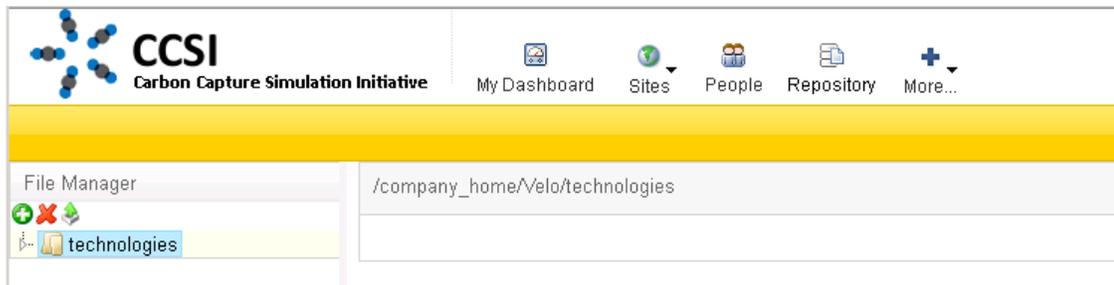
The user should contact the system administrator to open an account for the TRL system. The system administrator will login into the Alfresco web interface (not the share interface) as Admin and create an account for a new user. The Admin will then email the user the account information and the URL.

The user can now use the user name and password to log in (example login screen shown below).



II. TRL Questionnaire

When using the system for the first time, a user needs to define the technologies and processes that he/she plans to analyze. This is done through the **File Manager**. To create a technology, click on the “technologies” folder to highlight it, and then click on the add button (⊕), as shown in the following screen capture.



Clicking on the add button will bring up the “Create” window. Under the Create option, select **Technology** from the dropdown list, and give it a name (e.g. Technology A). Note, a set of default questions is provided in the TRL questionnaire for all technologies and processes upon the installation of the TRL system. To create a questionnaire with the default questions, click on “Create”. A small confirmation window pops up, stating “Created Technology A”, click “OK” to save the technology in the File Manager directory.

Create
✕

Create: Technology

Name: Technology A
Spaces are not allowed and will be removed.

Optional csv template: Browse... **No file selected.**
No spaces or special characters - #, <, >, [,], |, {, and } - are allowed in file names.

Create
Cancel

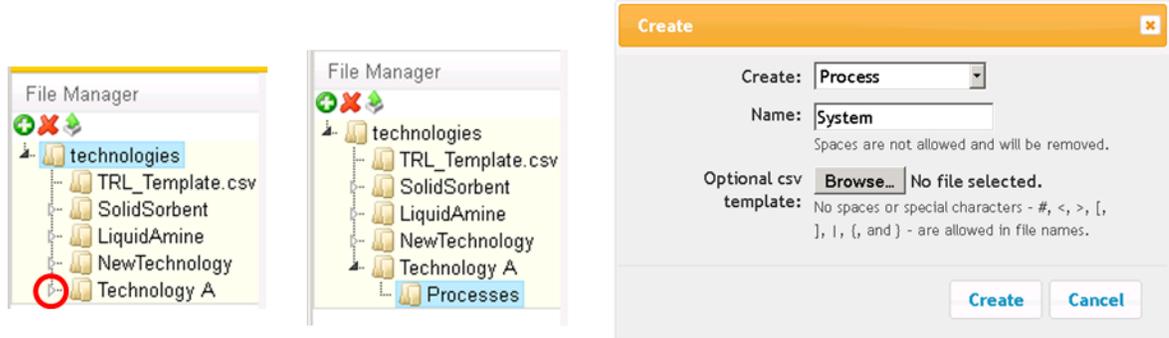
However, if the user wishes to use different TRL questions, the system allows the user to upload a questionnaire as long as it is an Excel spreadsheet in comma separated variable (CSV) format. A partial sample questionnaire (csv) file is shown below. To upload a csv questionnaire, bring up the Create pop-up window, select “Technology” from the dropdown list, name the technology, and click on the Browse button in the Create window. The user will be asked to locate and upload the csv file through a file-upload window. Once done, the newly added technology can be found under the “Technologies” folder.

#	A	
1	#Definition	
2	Commercial operation in relevant environment	
3	Commercial demonstration, full scale deployment in final form	
4	System prototype in an operational environment	
5	Fully integrated pilot (prototype) tested in a relevant environment	
6	Component validation in relevant environment (coal plant)	
7	Component validation tests in laboratory environment	
8	Analytical and experimental critical function proof-of-concept	
9	Formulation of application	
10	Basic principles	
11	#Definition	
12		
13	#TRL 1: Have basic principles been observed and reported?	This is the lowest level of technology readiness. At this level, scientific research begins to be translated in
14	Has a reasonable process concept been proposed?	
15	Do basic principles (physical and chemical) support the concept?	
16	Have scientific observations been reported?	
17	Have mathematical formulations of concepts been developed?	
18	Do rough calculations support the concept?	
19		
20	#TRL 2: Has a concept or application been formulated?	At this level, practical applications of the characteristics based on the basic scientific principles observed a
21	Have functional requirements been determined?	Functional requirements: describe the functionality that the system is to execute. Functional requirement
22	Have results of analytical studies been reported in peer-reviewed papers?	
23	Have potential design solutions been identified?	
24	Have the basic components of the technology been identified and partially characterized?	
25	Have performance predictions been documented for each component?	
26	Have paper studies (studies done without laboratory work) confirmed the feasibility of simple process simulations?	
27	Does preliminary analysis confirm basic scientific principles?	
28	Have experiments validating the concept been designed with synthetic data?	Synthetic data definition:
29	Has preliminary qualitative risk analysis been documented?	
30		
31	#TRL 3: Has analytical and experimental proof-of-concept been demonstrated in a laboratory environment?	TRL 3 focuses on active research and development. This level includes both analytical studies to set the te
32	Have experiments validated the predicted capability of technology components?	
33	Have analytical studies verified performance predictions and produced algorithms?	
34	Are the technology or system performance metrics established?	
35	Can science relevant to developing the technology be modeled or simulated?	
36	Have technology or system performance characteristics been confirmed and documented with representative data sets?	
37	Do experiments or modeling and simulation (M&S) validate performance predictions of technology capability?	

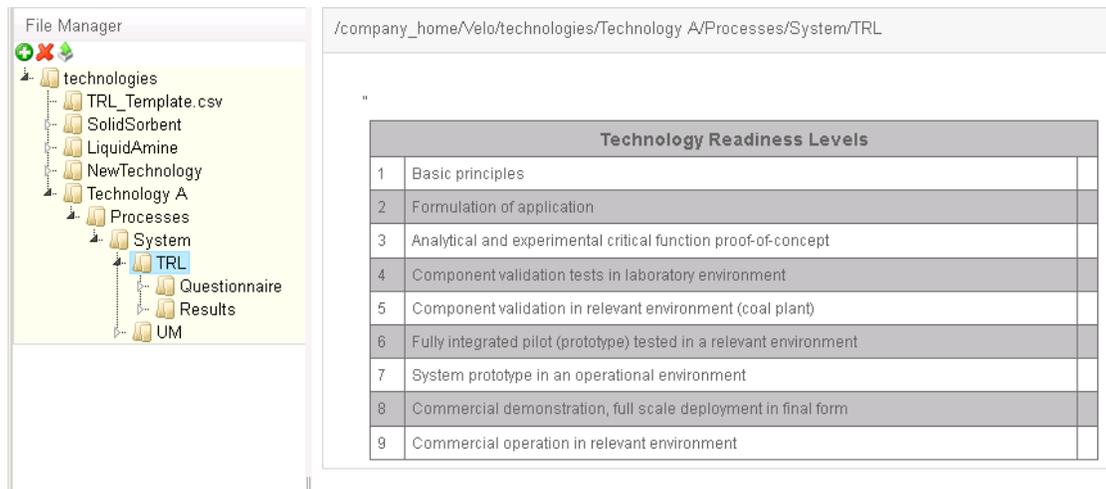
To delete a technology, locate the technologies tab under the **File Manager**. Then click on the delete icon ✕ and select the item to be deleted in a pop-up Delete window.

Now that a technology has been created, the user can create a process under the newly created technology. A process is a subsystem within a technology. The user is required to create at least one

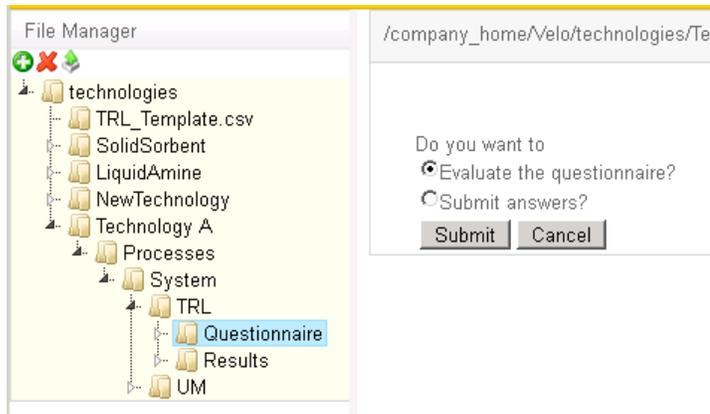
process under each technology. To do so, select the “technologies” folder to open the file directory, highlight the Processes tab, and then click on the add button (+). To navigate down the directory, click on the triangle next to the chosen technology, as shown in the figure below. A Process is created by using the same process for creating a technology.



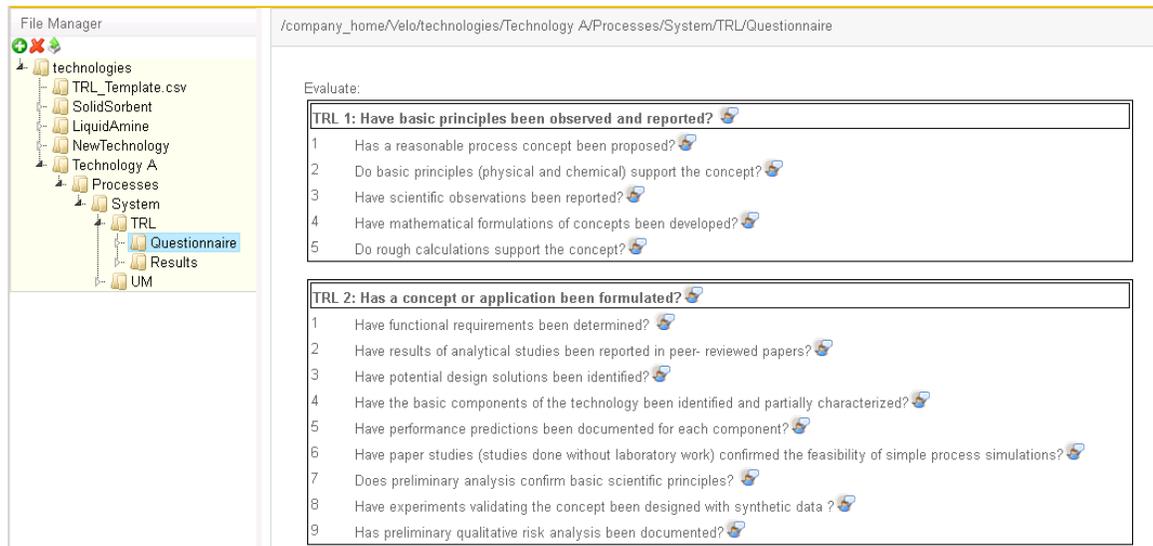
With at least one technology and at least one process in the system, the TRL questionnaire and analysis tools now become available. To get to the questionnaire, use the **File Manager** to locate the **TRL** tab (as shown below). The nine levels of the TRL are shown.



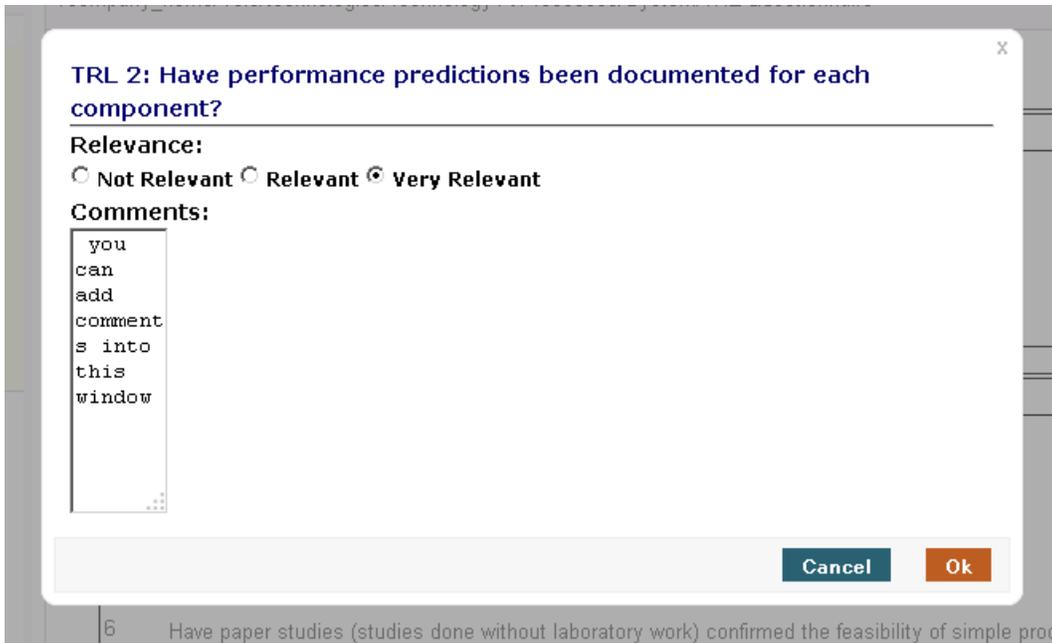
Next, click on the **Questionnaire** tab and two operational options are shown. The first option is an Evaluation mode. This mode gives the user a chance to review and comment on the TRL questions rather than eliciting answers to these questions. To choose this option, select the **Evaluate the questionnaire ?** circle and click on **Submit**.



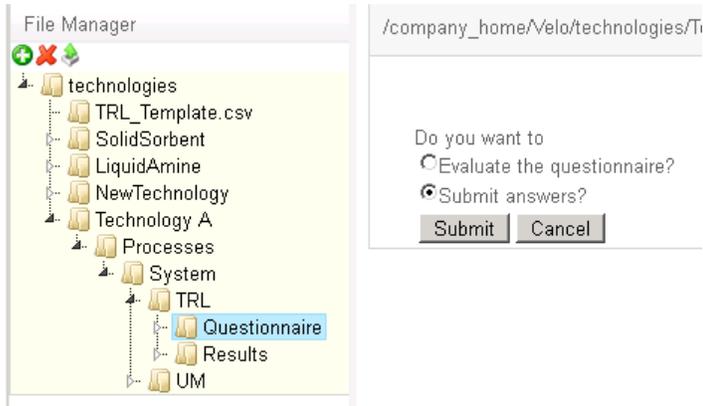
The following window shows what the evaluation mode looks like. This mode contains all of the nine levels as shown on Page 4 as well as the questions for each level. The user can evaluate each one of these levels and/or questions by selecting the icon next to each line. 🖱️



When the evaluate icon is selected, the evaluation window pops up, as illustrated below. The user will provide input as needed. All of the information from the evaluation is sent to the system admin. This information could be very useful in modifying the questionnaire to capture the feedback from subject matter experts (SMEs).



To exit the evaluation mode, click on the **Questionnaire** tab on the File Manager. This will bring the user back to the options window. If the user wishes to answer the questionnaire, select the **Submit answers? Mode** and click on **Submit**.



This brings up the questionnaire window, as shown below. By default, the answers to all the questions are set as **“No”**. The user will go through the questionnaire and click on a **Yes** or **No** radio button to respond to each question.

File Manager

- technologies
 - TRL_Template.csv
 - SolidSorbent
 - LiquidAmine
 - NewTechnology
 - Technology A
 - Processes
 - System
 - TRL
 - Questionnaire
 - Results
 - UM

/company_home/Velo/technologies/Technology A/Processes/System/TRL/Questionnaire

TRL 1: Have basic principles been observed and reported?

1	Has a reasonable process concept been proposed?	<input type="radio"/> Yes <input checked="" type="radio"/> No
2	Do basic principles (physical and chemical) support the concept?	<input type="radio"/> Yes <input checked="" type="radio"/> No
3	Have scientific observations been reported?	<input type="radio"/> Yes <input checked="" type="radio"/> No
4	Have mathematical formulations of concepts been developed?	<input type="radio"/> Yes <input checked="" type="radio"/> No
5	Do rough calculations support the concept?	<input type="radio"/> Yes <input checked="" type="radio"/> No

TRL 2: Has a concept or application been formulated?

1	Have functional requirements been determined?	<input type="radio"/> Yes <input checked="" type="radio"/> No
2	Have results of analytical studies been reported in peer- reviewed papers?	<input type="radio"/> Yes <input checked="" type="radio"/> No
3	Have potential design solutions been identified?	<input type="radio"/> Yes <input checked="" type="radio"/> No
4	Have the basic components of the technology been identified and partially characterized?	<input type="radio"/> Yes <input checked="" type="radio"/> No
5	Have performance predictions been documented for each component?	<input type="radio"/> Yes <input checked="" type="radio"/> No
6	Have paper studies (studies done without laboratory work) confirmed the feasibility of simple process simulations?	<input type="radio"/> Yes <input checked="" type="radio"/> No
7	Does preliminary analysis confirm basic scientific principles?	<input type="radio"/> Yes <input checked="" type="radio"/> No
8	Have experiments validating the concept been designed with synthetic data?	<input type="radio"/> Yes <input checked="" type="radio"/> No
9	Has preliminary qualitative risk analysis been documented?	<input type="radio"/> Yes <input checked="" type="radio"/> No

If having any questions about the TRLs or the questions, the user can hover the mouse over one of the documented icons. This built-in tutorial capability helps the user understand the definition of each maturity level and the terminology used in the questions. The content of these definitions and terminology clarification is by default part of the questionnaire csv file, as illustrated in an earlier section.

TRL 1: Have basic principles been observed and reported?

1	Has a reasonable process concept been proposed?	<input checked="" type="radio"/> Yes <input type="radio"/> No
2	Do basic principles (physical and chemical) support the concept?	<input checked="" type="radio"/> Yes <input type="radio"/> No
3	Have scientific observations been reported?	<input checked="" type="radio"/> Yes <input type="radio"/> No
4	Have mathematical formulations of concepts been developed?	<input checked="" type="radio"/> Yes <input type="radio"/> No
5	Do rough calculations support the concept?	<input checked="" type="radio"/> Yes <input type="radio"/> No

TRL 2: Has a concept or application been formulated?

1	Have functional requirements been determined?	<input checked="" type="radio"/> Yes <input type="radio"/> No
2	Have results of analytical studies been reported in peer- reviewed papers?	<input checked="" type="radio"/> Yes <input type="radio"/> No
3	Have potential design solutions been identified?	<input checked="" type="radio"/> Yes <input type="radio"/> No
4	Have the basic components of the technology been identified and partially characterized?	<input checked="" type="radio"/> Yes <input type="radio"/> No
5	Have performance predictions been documented for each component?	<input checked="" type="radio"/> Yes <input type="radio"/> No
6	Have paper studies (studies done without laboratory work) confirmed the feasibility of simple process simulations?	<input checked="" type="radio"/> Yes <input type="radio"/> No
7	Does preliminary analysis confirm basic scientific principles?	<input checked="" type="radio"/> Yes <input type="radio"/> No
8	Have experiments validating the concept been designed with synthetic data?	<input checked="" type="radio"/> Yes <input type="radio"/> No
9	Has preliminary qualitative risk analysis been documented?	<input checked="" type="radio"/> Yes <input type="radio"/> No

Synthetic data definition:
Any production data applicable to a given situation that are not obtained by direct measurement. Synthetic data are generated to meet specific needs or certain conditions that may not be found in the original, real data. (Wikipedia).

TRL 3: Has analytical and experimental proof-of-concept been demonstrated in a laboratory environment?

Once the questionnaire is completed, click on the Submit button at the bottom of the page.

TRL 9: Has the actual unit successfully operated in the full operational environment (hot operations)? 650 MW

1	Does technology/system function as defined in Operational Concept document?	<input type="radio"/> Yes <input checked="" type="radio"/> No
2	Has technology/system been deployed in intended operational environment?	<input type="radio"/> Yes <input checked="" type="radio"/> No
3	Has technology/system been fully demonstrated?	<input type="radio"/> Yes <input checked="" type="radio"/> No
4	Has Operational Test and Evaluation (OT&E) been successfully completed and documented?	<input type="radio"/> Yes <input checked="" type="radio"/> No
5	Have design to cost (DTC) goals been met?	<input type="radio"/> Yes <input checked="" type="radio"/> No
6	Have safety/adverse effects issues been identified and mitigated?	<input type="radio"/> Yes <input checked="" type="radio"/> No
7	Has all programmatic documentation been completed?	<input type="radio"/> Yes <input checked="" type="radio"/> No

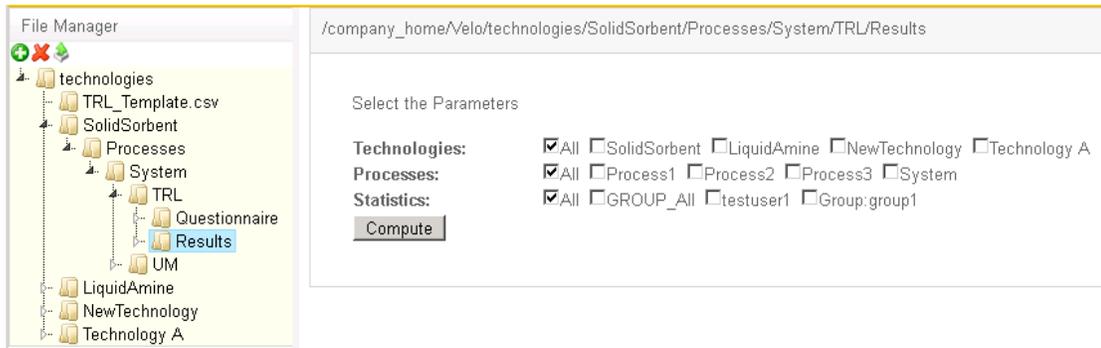
Submit Cancel

III. TRL Results

3.1 TRL-Likelihood Model

The TRL system can perform two types of analyses. The first is the likelihood model (TRL-LM), which converts the discrete results from the questionnaire into a probabilistic estimate of the maturity level. The second type is uncertainty model (TRL-UM), used to estimate an uncertainty factor based on the estimated TRL.

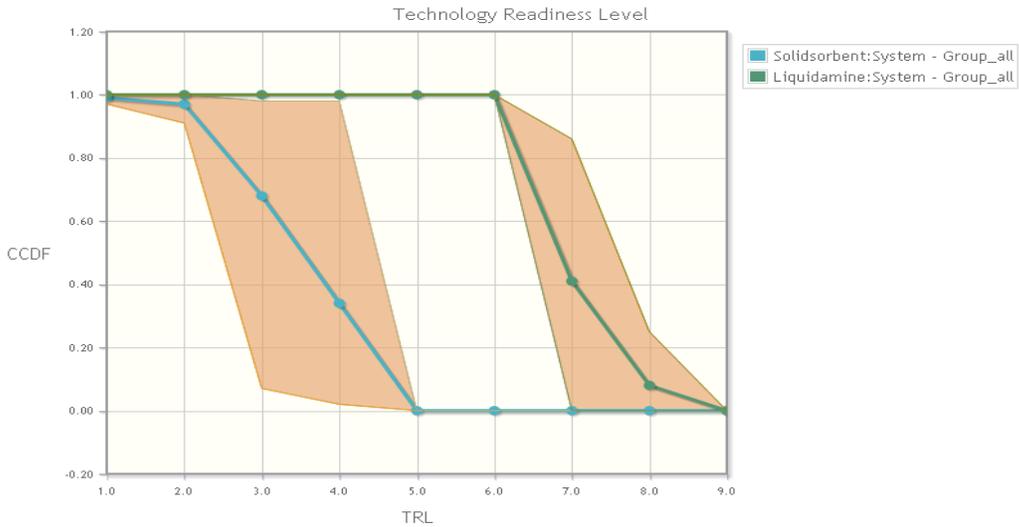
To access the TRL-LM, click on the **Results** tab underneath the **TRL** tab. By clicking on **Results**, the following window is displayed.



At this point, the user can select different combinations of technologies, processes, and users as parameters for statistical analyses. As an example, the following window shows the results of comparing the TRLs for two technologies. Note the parameters chosen are: two technologies (solid sorbent and liquid amine), one process (system), and all users within a group (`GROUP_ALL`). Groups are developed by the system Admin to allow comparisons between different sets of users.

Select the Parameters

Technologies: All SolidSorbent LiquidAmine NewTechnology Technology A
Processes: All Process1 Process2 Process3 System
Statistics: All GROUP_All testuser1 Group.group1



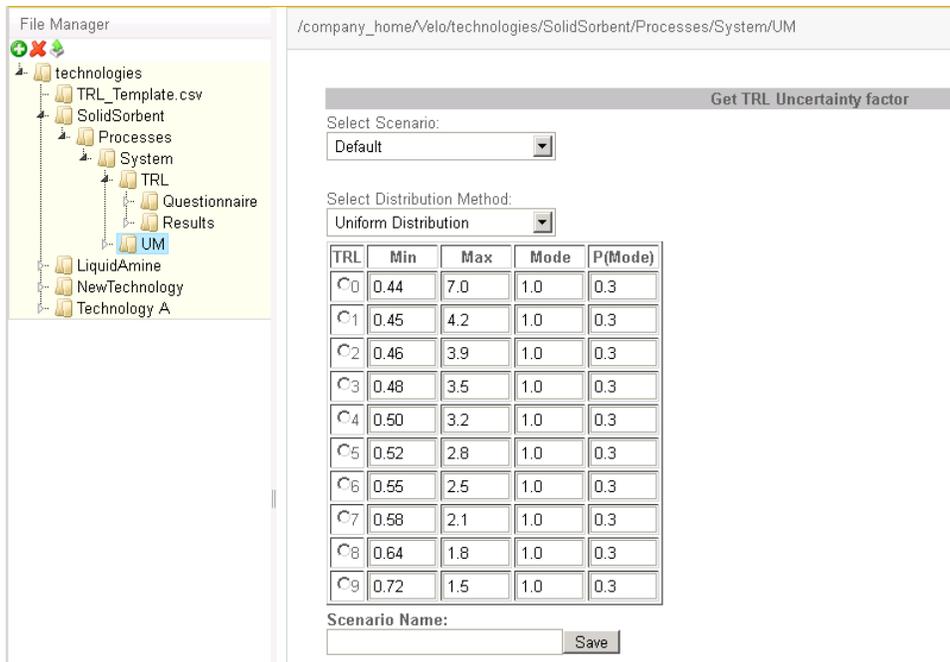
Download results as +CSV file

Technology	Process	Statistics	TRL1	TRL2	TRL3	TRL4	TRL5	TRL6	TRL7	TRL8	TRL9
SolidSorbent	System	GROUP_All	0.99	0.97	0.68	0.34	0.00	0.00	0.00	0.00	0.00
SolidSorbent	System	Min	0.97	0.91	0.07	0.02	0.00	0.00	0.00	0.00	0.00
SolidSorbent	System	Max	1.00	1.00	0.98	0.98	0.00	0.00	0.00	0.00	0.00
LiquidAmine	System	GROUP_All	1.00	1.00	1.00	1.00	1.00	1.00	0.41	0.08	0.00
LiquidAmine	System	Min	1.00	1.00	1.00	1.00	1.00	1.00	0.00	0.00	0.00
LiquidAmine	System	Max	1.00	1.00	1.00	1.00	1.00	1.00	0.86	0.25	0.00

The plot shows the range of the complimentary cumulative distribution functions (CCDF) for the two different technologies, based on input from different SMEs. The CCDF indicates the probability of being at least in or beyond a certain TRL (i.e., cumulate all probabilities of the lesser levels). For instance, these results mean that the average probability of the LiquidAmine being at least in TRL-7 is 0.41 (minimum is 0.0 and the maximum 0.86).

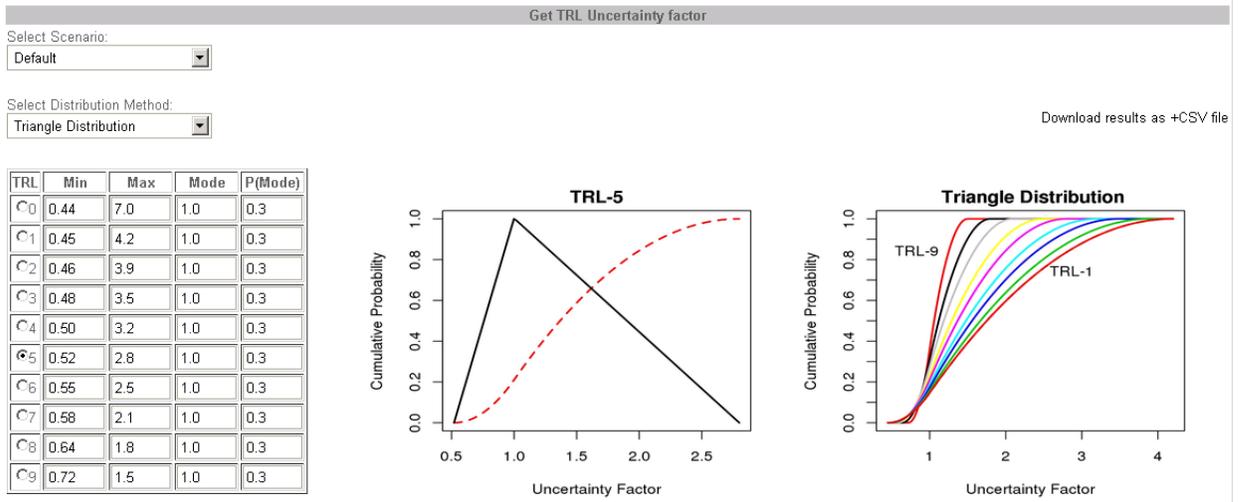
3.2 TRL-UM

The TRL-LM estimates the maturity level of a specific technology being developed. The TRL-UM uses the maturity level and industry specific uncertainty estimates to quantify the uncertainty due to the lack of technology maturity. To access the TRL-UM, click on the **UM** tab under the specific process of interest (see the following **File Manager**). The following window is then displayed.

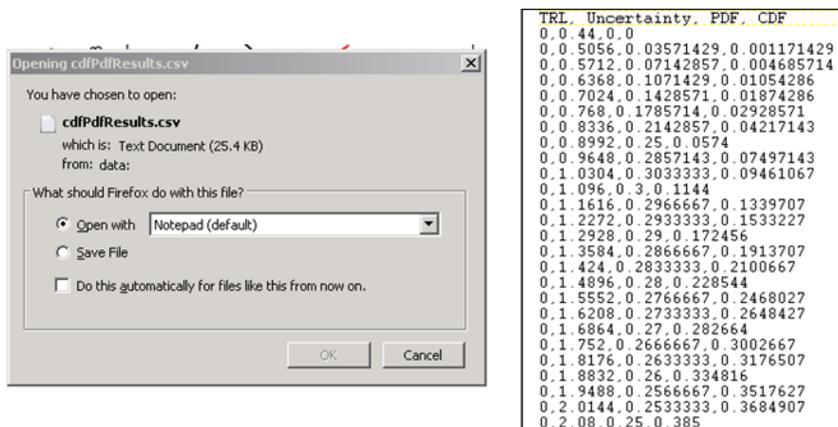


The TRL-UM window displays a table containing uncertainty information for each maturity level. To model uncertainty for each level, a range (min and max), a mode (highest probability point) and a cumulative probability at the mode is input for each level. The user can specify a distribution type to model the probabilities at each maturity level. In the current version of the TRL system, three distributions have been implemented: uniform, triangle, and log-normal. The last column in the table, cumulative probability at the mode **P(Mode)**, is only used when the uniform distribution is selected.

The values within the uncertainty table can be modified, saved, and retrieved for further analysis. To save any modifications, use the **Scenario Name:** window located under the table. To preview the distribution at a specific maturity level, select the level of interest. Once the level is selected, the individual probability distribution is displayed, along with the cumulative distributions for all of the maturity levels, as illustrated in the following window.



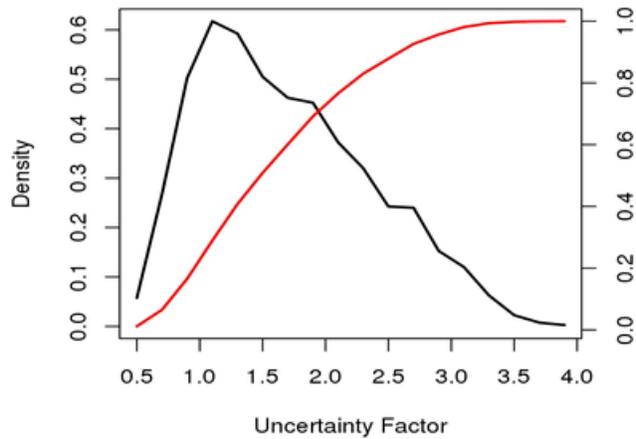
These results can be saved and used for other analyses by clicking on the **Download results as +CSV file** button (marked with a red rectangle in the above screen capture). By doing this, a pop-up window appears which allows the user to save the results to a file. A partial sample file is also shown in the window below.



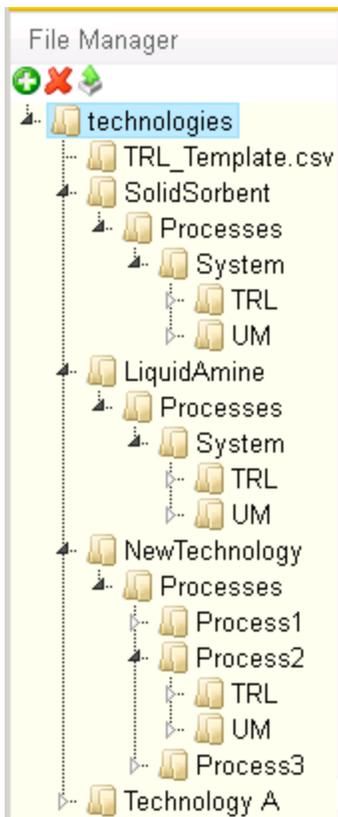
With the information about the uncertainties for each TRL in hand, the user can perform an uncertainty analysis. First, select from the dropdown list under **Select_Statistic** a group of users that will be used for modeling the TRL-LM. Next input the number of simulation runs (2000 in the case shown below). Finally, click on the **Run** button to simulate the uncertainties (also shown in the following window). The TRL-UM results can be saved for further analysis by clicking on the **Download results as CSV file** button to save the distribution of the simulated uncertainty factors (PDF and CDF) or by clicking on the **Download generated uncertainty factors** to save the actual simulated uncertainty factors (2000 of them for this example).

Simulate Uncertainty factor distribution

Select Statistic: Number of Runs:



Utilizing these capabilities, the user can now evaluate the maturity level and uncertainties for all kinds of technologies. Using the File Manager, the user can switch between the different technologies and processes.





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