# DC-E-WISE (Data Center Energy and Water Information Simulator and Evaluator) User Manual

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#### 1. General Information

The DC-E-WISE is an excel-based tool that we developed to facilitate the comparison of nine cooling systems based on five main criteria: *Energy Use, Onsite Water Use, Total Cooling Water Use, Reliability,* and *Maintenance*.

The nine studied cooling systems are: *Air-cooled chiller*, *Air-cooled chiller* + *Air-side economizer* (*ASE*), *Pre-cooled-air-cooled chiller*, *Pre-cooled-air-cooled chiller* + *ASE*, *Water-cooled chiller*, *Water-cooled chiller* + *Water-side economizer* (*WSE*), *Water-cooled chiller* + *ASE* + *WSE*, and *Evaporative cooling system* + *ASE*.

The *DC-E-WISE* tool employs the technique for order preference by similarity to ideal solution (*TOPSIS*) method to rank the modeled cooling systems. The tool then presents a tabulated list of the ranked cooling systems, which includes energy and water use data, as the result. By utilizing the *TOPSIS* method, the tool provides a systematic and objective way of comparing and ranking the cooling systems, enabling users to make informed decisions when selecting and optimizing cooling systems, allowing users to quickly identify the most efficient and effective options for their specific needs.

#### 1.1. Modeled Energy and Water Use Data for Cooling System

This tool utilizes modeling data for cooling energy, water use (onsite cooling and humidification), and total cooling water use in DCs located in the greater Phoenix area. The power and water use data, which are model outputs, are normalized based on the modeled IT load (in MW) at the uninterrupted power supply (UPS) output. Therefore, the tool can calculate the total energy and onsite and total cooling water use for a given IT load as entered by the user. Along with overall DC power and water use, the tool provides estimates for key DC metrics such as *PUE* (Eq. 1), *WUE*<sub>Onsite</sub> (Eq. 2), and *WUE*<sub>Source</sub> (Eq. 3a and Eq. 3b). These metrics are defined as follows:

$$PUE = \frac{\text{Total Facility Energy}}{\text{IT equipment Energy}} Eq. 1$$

$$WUE_{Onsite} \left(\frac{gal}{kWh}\right) = \frac{Onsite Water Usage (gal)}{IT equipment Energy (kWh)} Eq. 2$$

$$WUE_{Source} \left(\frac{gal}{kWh}\right) = \frac{Onsite Water Usage (gal) + Source Water Use for Energy Generation(gal)}{IT equipment Energy (kWh)} Eq. 3a$$

Source Water Energy Usage (gal) =  $EWIF(\frac{gal}{kWh}) \times (Total Facility Energy(kWh))$  Eq. 3b

### 1.2. Reliability and Maintenance

#### 1.2.1. Reliability

The cooling system's reliability criteria is determined by considering five main factors: *Annual Availability, Fluctuation of IT Room Air Supply Affected by Outdoor Condition, Lifetime, IT Room Air Contamination,* and *Complexity.* These factors, except for *Annual Availability,* are assigned a weight ranging from 0 (lowest) to 10 (highest). The Annual Availability factor is given a weight that is five times greater than the other criteria, ranging from 0 (lowest) to 50 (highest). To determine the *overall Reliability* value, a scaling process is applied, resulting in a scale of 0 to 100. For more detailed information regarding the default values for *Reliability*, please refer to the *Reliability Default Values sheet* available in

the *DC-E-WISE* excel file. By considering these factors, the cooling system's reliability can be accurately evaluated, and necessary improvements can be made to ensure its continued effectiveness and efficiency.

### 1.2.2. Maintenance

The maintenance actions are categorized as *Annual, Semi-Annual, Monthly, Weekly,* and *Daily,* and *Water Treatment Requirement,* with each assigned a weight that corresponds to the severity of the action. The weight assigned to an action is determined by its degree of difficulty, which increases as the frequency of the action decreases. For instance, an annual action has a higher weight than a semi-annual action. Among all maintenance actions, *water treatment requirement* has the highest weight because of the complexity of the water treatment processes. The number of each maintenance action is specified for all cooling systems, and an *overall maintenance* value for each cooling system is determined using Eq. 4. This quantification process enables effective management and monitoring of the maintenance needs of cooling systems, ensuring their continued operation and longevity.

```
Overall Maintenance Value = \sum (number of action × action weight) Eq. 4
```

**Note:** The higher maintenance value means higher negative effect on the rank of cooling system in *DC-E-WISE*.

### 2. DC-E-WISE

### 2.1. How to Use *DC-E-WISE for DCs*:

1- Open DC-E-WISE excel file.

"This file type is not supported in protected View." You can click *Ok* or skip the message (Figure 1).



**Figure 1.** Opening the main file (Section 2.1, Step 1)

Upon opening the file, a window prompt appears asking the user if they wish to remove previous results. The user is given the option to select *Yes* to keep the previous run results, or *No* to delete them (as shown in Figure 2). By providing this option, users have the flexibility to choose whether to retain or remove previous results, enabling them to manage their data more efficiently.

Note: If the user selects No option, the old results will be overwritten by the new results.



Figure 2. Message for keeping or deleting the previous results (Section 2.1, Step 1)

- 2- Go to the *File* menu and select *Save As*. Choose the *Excel Macro-Enabled Workbook* format and specify the desired file name and location using the *Save As* icon. The file name should follow the format *filename.xlsm*.
- 3- Once the file is saved, open it and navigate to the *User-Interaction* sheet to begin using the DC-E-WISE tool (Figure 3).



Figure 3. User-Interaction sheet (Section 2.1, Step 3)

- 4- To initiate DC-E-WISE the user should fill the User Input Form.
- 5- Click the *User Input Form* button (Figure 4) in the *User-Interaction* sheet to open the *User Input Form* (Figure 5).

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|     |             | Us       | er Input Form |               |            | 1              | Eva        | porative Co  | oling +ASE    |            | 69             | 0,265     |
|     | Þ           |          |               |               |            | 2              | Watar      | ter-Cooled ( | Uniller+ASE   | CE.        | 10             | 1,831     |
|     |             |          |               |               |            | 3              | water-v    | Cooled Chi   | iller+ ASE    | ASE        | 10             | 4 000     |
|     |             | +-       |               |               |            | 5              | Pre-Cool   | led-Air-Coo  | led Chiller - | ASE        | 17             | 4.425     |
|     |             | ×÷ Ru    | n Calculation |               |            | 6              | Wat        | er-Cooled O  | Chiller+WSH   | 3          | 14             | 0,798     |
|     |             |          |               |               |            | 7              | 1          | Water-Cook   | ed Chiller    |            | 14             | 5,267     |
|     |             |          |               |               |            | 8              |            | Air-Cooled   | Chiller       |            | 33             | 7,282     |
|     | 1           |          |               |               |            | 9              | Pre-C      | Cooled-Air-O | Cooled Chill  | er         | 31             | 4,689     |
|     |             |          | Show Results  |               |            | Note: Tot      | al Cooling | Water Use    | data include  | e both Ons | site Water Use | and the V |
|     |             | <b>=</b> | to PDF        |               |            |                |            |              |               |            |                |           |
|     |             |          |               |               |            |                |            | 2.0          | ) [           |            | ∎P             | UE O      |
| >   |             | Tool De  | scription     | er_Intera     | tion       | Cooling        | Systems    | s Graphs     | Coolir        | ng Syster  | m Scher 🚥      | +         |

Figure 4. The User Input Form button in the User-Interaction sheet (Section 2.1, Step 5)

**Note:** When opening the file or when run *User Input Form*, the user may receive a message similar to the one shown in Figure 5, stating that macros are disabled. In order to use the *DC-E-WISE* tool, they must enable macros in Excel. To do so, click *OK* on the message prompt and close the file without saving any changes. Then, follow the steps 1 through 4 to save the file in Excel Macro-Enabled Workbook format and open the *User-Interaction* sheet.

- 1. Open Excel
- 2. Go to file > options > Trust Center > Trust Center Settings...
- 3. Enable the options as shown in Figure 6, then click OK.
- 4. Close the excel and open *DC-E-WISE* excel file again.

|          |                               |                                   |             |  |   | ,                                |             |                          |
|----------|-------------------------------|-----------------------------------|-------------|--|---|----------------------------------|-------------|--------------------------|
| 📴 Macros | ⊙ Unhide Sheets               | $\equiv$ Insert TOC $\Rightarrow$ |             |  |   |                                  |             |                          |
| • :      | $	imes \checkmark f_x$ Rankin | g                                 |             |  |   |                                  |             |                          |
| В        | С                             | D                                 | E           | F  | G   | н                                |             | I.                       |
|          |                               |                                   |             |  |   |                                  |             |                          |
|          |                               |                                   | Please fit  | nd the ranking results in the following  | g Table.                                  |                                  |             |                          |
|          | •                             | Microsoft Even                    |             |  |   |                                  |             | ling Water Use (acre-ft) |
|          | User Input Form               | WICLOSOTT EXCEL                   |             |  |   |                                  | ^           | 418                      |
|          |                               |                                   |             |  |   |                                  |             | 1,118                    |
| -        |                               | Cannot run                        | the macro " | MCDST for Data Centers.xlsm'!Show_Inpt_F | orm'. The macro may not be available in t | his workbook or all macros may b | e disabled. | 1,118                    |
|          |                               |                                   |             | - • -                                    | ,   | ,                                |             | 440                      |
| t-       | Run Calculation               |                                   |             |  | OK  |                                  |             | 838                      |
|          |                               |                                   |             |  | OK  |                                  |             | 2,115                    |
|          |                               |                                   | 7           | Water-Cooled Chiller                     | 145,267                                   | 1,943                            |             | 2,133                    |
|          | 1                             |                                   | 8           | Air-Cooled Chiller                       | 337,282                                   | 0.43                             |             | 443                      |
|          |                               |                                   | 9           | Pre-Cooled-Air-Cooled Chiller            | 314 689                                   | 527                              |             | 940                      |

Figure 5. Potential error message after running the *User Input Form* when the macros are disabled in excel (Section 2.1, Step 5, Note)



Figure 6. Enable macros in excel to run the tool (Section 2.1, step 5, Note-step 3)

6. Once the user has entered their desired inputs and made their choices in the *User Input Form* (Figure 7), they should click the *Save* button in order to ensure that any changes are saved.

## Notes

- The *User Input Form*, contains four tabs, each with its own unique set of required inputs and selections that are explained in Section 2.2 of the *User Input Form*.
- If the user fails to meet the input requirements in any of the tabs and clicks the *Save* button (or Alt+S), they may encounter different pop-up messages, which will be explained in Section 2.2 of this manual.
- To start with a blank user form, the user can click the *Leave* button (or Alt+L) to close the form. However, during the data entry process in the *User Input Form*, clicking the Save button will overwrite any previous input values and selected options with new inputs.

7. The *User Input Form* automatically closes when the data entry is completed in the last tab and the *Save* button is clicked.

8. After the user has entered all the required data in the *User Input Form*, they should go to the *User\_Interaction* sheet and click on the *Run Calculation* button (Figure 8) to initiate the *DC-E-WISE* calculation process. Once the calculation is complete, a message will appear saying "The calculation is done!" (Figure 9) and the user will need to confirm to continue. Then, another message will appear prompting the user to click on the *Show Results* button (Figure 10) to view the results.



Figure 7. User Input Form (Section 2.1, Step 6 and 7)



Figure 8. The message shown after clicking Run Calculation button (Section 2.1, Step 8)

### Notes

 Please note that the calculation in the *DC-E-WISE* tool is performed automatically and the user does not need to perform any manual calculations. The tool is designed to be user-friendly and does not require any advanced technical skills. The user only needs to enter the required inputs in the User Input Form, run the calculation, and view the results. The calculation steps are performed in the background and are not visible to the user. The *DC-E-WISE* spreadsheets are protected to ensure that only the inputs given in the User Input Form can alter the values shown in each spreadsheet for different airflow management strategies.



Figure 9. The message shown after clicking *Run Calculation* button in the *User-Interaction* sheet (Section 2.1, Step 8)

| ank<br>Co<br>Evap     | Microsoft Excel            |                                  | × | 1) | 0 |
|-----------------------|----------------------------|----------------------------------|---|----|---|
| Vate<br>er-C<br>Air-( | Please click the 'Show Res | ults' button to see the results. |   |    |   |
| oole<br>Vate:<br>W    |                            | ОК                               |   |    |   |
| A                     | ir-Cooled Chiller          | 337,282                          |   |    |   |



9. In the *Use-Interaction* sheet click the *Show Results* button to see the tabulated results of the ranked cooling systems (Figure 11). In addition, a graph is presented in this sheet showing the *PUE*, *WUE*<sub>Onsite</sub>, and *WUE*<sub>Source</sub> for the ranked cooling systems.

Then a message is shown to remind the user to export the results to a PDF file (Figure 12).



Figure 11. Click the *Show Results* button in the *User\_Interaction* sheet to see the results (Section 2.1, Step 9)



Figure 12. Message to remind the user to export the results (Section 2.1, Step 9)

10. In the *User-Interaction* sheet, click on the *Print Results to PDF* button to save the results shown in the *User\_Interaction* sheet as a PDF file (Figure 13). After clicking the button, the user will be prompted to enter a file name and location to save the PDF file (Figure 14).



Figure 13. Click the *Print Results to PDF* button in the *User\_Interaction* sheet to export the results to a PDF file (Section 2.1, Step 10)

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|---|--|----------------------|
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| ↓ Downloads   | MCDSTforDataCenters-LK_xlsm_27032023_1206  | 3/27/2023 12:06 PM   |
| Documents   | User_Interaction_20230227_1917   | 2/27/2023 4:17 PM    |
| Pictures  | User_Interaction_20230220_1611   | 2/20/2023 1:11 PM    |
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Figure 14. Message asking the user to define the results' PDF file name and saving location (Section 2.1, Step 10)

# 2.2. User Input Form

The User Input Form is divided into four main tabs, each requiring different sets of inputs and selections. The tabs are Input Data, Weights and Parameter Importance Comparison Values, Reliability Values, and Maintenance Values. Detailed instructions for data entry and selection are provided in Section 2.2 of the User Input Form.

## 2.2.1. Input Data tab

- 1. In the *Input Data* tab (Figure 15) in the *User Input Form*, locate the *Annual IT Load (MW)* data entry field (Figure 16) and enter the expected annual IT power load in megawatts.
- 2. In the *Input Data* tab, enter the UPS efficiency for the *UPS Efficiency* data entry (Figure 16). You can either enter a customized value or use the recommended value of 0.9.
- 3. In the *Input Data* tab, enter either a customized, or the recommended value (0.01) for the *Lighting Power Use to IT Load Ratio* (Figure 16).
- 4. In the *Input Data* tab, enter either a customized, or the recommended value (0.02) for the *Percentage of Power Loss in Power Transformation and Distribution System* (Figure 16).
- 5. In the *Input Data* tab, enter either a customized, or the recommended value (0.427 for Salt River Project territory in AZ) for the *Energy-Water Intensity Factor (EWIF)* (Figure 16).

**Note:** If the user does not enter any of the required inputs as explained in steps 1-5, or if a negative value is entered, an error message will appear asking the user to correct the values (Figure 17).

6. The user should select one of the four desired airflow management strategies by clicking on the *Airflow Management Strategies* dropdown box (Figure 18) in the *Input Data* tab of the *User Input Form*.

# Note

- The four air flow management strategies are as follows:
  - 1. No aisle containment on server rows;
  - 2. Cold aisle containment (CAC) on server rows;
  - 3. Hot aisle containment (HAC) or Vertical Exhaust Duct (VED) on server rows. Both HAC and VED are types of hot aisle containment methods and have similar advantages. For more information please review the referred paper [1];
  - 4. CACs or VEDs/HACs on all server rows.

| User Input For | m                 |   |                        |   |
|----------------|-------------------|---|------------------------|---|
| Input Data We  | eights and Parame | ter Importance Comparison Values        | Reliability Values     | Maintenance Values                          |
| Please ent     | er the values fo  | r the following parameters.             |                        |   |
| Annual<br>(M   | IT Load<br>W)     | UPS Efficiency (Recommended value: 0.9) | Lighting Pov<br>(Recom | ver Use to IT Load R<br>nended value: 0.01) |
|                |                   |   |                        |   |
|                |                   |   |                        |   |
|                |                   |   |                        |   |
| Please cho     | oose the Air Flov | v Management Startegies?                |                        |   |
|                |                   |   | - ¥                    | Please press 'Save' I<br>change             |
|                |                   |   |                        |   |
|                |                   |   |                        |   |

Figure 15. Input Data tab in the User Input Form (Section 2.2.1, Step 1).

| User Input Form             |  |   |  |   |
|-----------------------------|--|---|--|---|
|                             |  |   |  |   |
|                             |  |   |  |   |
| Input Data Weights and Para | meter Importance Comparison Values   F | Reliability Values   Maintenance Values |  |   |
|                             |  |   |  |   |
|                             |  |   |  |   |
| Please enter the values     | for the following parameters.          |   |  |   |
| Annual IT Load              | UPS Efficiency (Recommended            | Lighting Power Use to IT Load Ratio     | Percentage of Power Loss in Power Transformation and Distribution System | Energy-Water Intensity Factor (EWIF;    |
| (MW)                        | value: 0.9)                            | (Recommended value: 0.01)               | (Recommended value: 0.02)  | Recommended value in AZ: 0.427 gal/kWh) |
|                             |  |   |  |   |
|                             |  |   |  |   |
|                             |  |   |  |   |

Figure 16. Required inputs in the Input Data tab (Section 2.2.1, steps 1 to 5)

| tance Comparis                | son Values   Re               | liability Values   Maintenance Values                            |                     |   |
|-------------------------------|-------------------------------|--|---------------------|---|
| lowing param                  | eters.                        |  |                     |   |
| iciency (Recom<br>value: 0.9) | mended                        | Lighting Power Use to IT Load Ratio<br>(Recommended value: 0.01) | Percentage of Power | Loss in Power Transformation and Distribution (Recommended value: 0.02) |
| ).9                           |                               | -0.2   |                     | 0.02  |
| ement Starte                  | Microsoft Exe<br>Please input | cel<br>a valid lighting to IT energy ratio for the               | ×<br>e Data Center. |   |
|                               |                               |  | ОК                  |   |

Figure 17. An error message shown because the user entered a negative value for the *Lighting Power Use* to IT Load Ratio (Section 2.2.1, Note to Steps 1 to 5).

| User Input | Form   |
|------------|--|
|            |  |
| Input Data | Weights and Parameter Importance Comparison Values   Reliability Values   Maintenance Values |
|            |  |
| Please e   | enter the IT load (MW).  |
| An         | inual IT Load (MW)   |
| Г          |  |
|            |  |
| Please c   | hoose the air flow management startegies?  |
| Trease e   | Diasce press 'Caue' butten to apply  |
|            | changes.   |
| Choose     | No Aisle Containment' for air flow managemnet  |
| Choose     | P HAC or VED on server rows' for air flow managemnet   |
| Choose     | CACs or VEDs/HACs on all rows' for air flow managemnet                                       |
|            |  |

Figure 18. Air flow management strategies choices (Section 2.2.1, Step 6).

### 2.2.2. Weights and Parameter Importance Comparison Values tab

1. In the *Weights and Parameter Importance Comparison Values* tab of the *User Input Form* (Figure 19), the user needs to choose the preferred method to enter the weight percentage values of operating parameters. This can be done by selecting an option from the *Which way would you prefer to enter the operating parameters weight percentage values?* dropdown box (Figure 20), which offers two choices:

**a.** *Input the Weight Percentage data my way:* This approach allows the user to determine the relative importance of each criterion in the comparison of cooling systems. The user assigns weight percentages, ranging from 0 to 100, to each criterion to reflect its importance (Figure 21).

As previously discussed in Section 1, the decision-making criteria have been classified into five groups.

- I. Energy Use
- II. Onsite Water Use
- III. *Total Cooling Water Use* (The Total Cooling Water Use criterion comprises both onsite cooling water use and the water used in power plants to generate cooling power utilized in the data center).
- IV. *Reliability*
- V. Maintenance

#### Examples

- If the user prioritizes cooling system energy use as the most important criterion, with a preference for a system that consumes the least amount of energy, it is recommended to assign a large weight percentage to the *Energy Use* criterion (Figure 21).
- In the case where the user places greater emphasis on the onsite water use of the cooling system, it is suggested to assign a large weight percentage to both the *Onsite Water Use* and *Total Cooling Water Use* criteria (Figure 21).
- **b.** *Calculate the Weight Percentage based on paired parameters' importance comparison values:* his approach involves the user comparing the importance of criteria in pairs, and the program automatically calculates the weight percentage for each parameter after the user completes the necessary data entry in the subsequent step, as explained in Part 2 of Section 2.2.2.

#### Note

When the user chooses a weight percentage entry method and clicks the *Save* button, the remaining input boxes that correspond to the other method on the tab are disabled. If the user wishes to switch to the other weight percentage calculation method, they must select the method from the *Which way would you prefer to enter the operating parameters weight percentage values?* dropdown box and click the *Save* button to activate the relevant boxes and deactivate the irrelevant data entry boxes.

| way would you prefer to enter  | the paramter w   | reight percentage values?            | Please press 'Save' button to apply ch   | nanges.   |                                |
|--|--|--------------------------------------|--|---|--------------------------------|
| enter the weight of each facto<br>nergy Use Onsite Water U   | r in percentage<br>se Total Coolir   | your way.<br>ngwater Use Reliability | Maintenance  |   |                                |
|  |  |                                      |  |   |                                |
| aired paramters' importance o  | omparison value  | es would you prefer to use?          | 2  |   |                                |
| paired paramters' importance o   | omparison value  | es would you prefer to use?          | Please press 'Save' button to apply changes.   |   |                                |
| paired paramters' importance o<br>enter the parameters' importa  | omparison value  | es would you prefer to use?          | Please press 'Save' button to apply changes.   |   |                                |
| paired paramters' importance o<br>enter the parameters' importa  | omparison value<br>ince comparison<br>Default values<br>out of 10                            | es would you prefer to use?          | Please press 'Save' button to apply changes.   | Default values<br>out of 10                           | Customized values<br>out of 10 |
| oaired paramters' importance o<br>enter the parameters' importa<br>Onsite Water Use vs. Energy USe   | omparison value<br>ince comparison<br>Default values<br>out of 10                            | es would you prefer to use?          | Please press 'Save' button to apply changes.   | Default values<br>out of 10                           | Customized values<br>out of 10 |
| enter the parameters' importance o<br>enter the parameters' importa<br>Onsite Water Use vs. Energy USe<br>Total Water Use vs. Energy Use   | omparison value<br>ince comparison<br>Default values<br>out of 10<br>1<br>2                  | es would you prefer to use?          | Please press 'Save' button to apply changes.<br>Total Water Use vs. Onsite Water USe<br>Reliability vs. Onsite Water Use   | Default values<br>out of 10                           | Customized values<br>out of 10 |
| enter the parameters' importance o<br>enter the parameters' importa<br>Onsite Water Use vs. Energy USe<br>Total Water Use vs. Energy Use<br>Reliability vs. Energy Use   | omparison value<br>nnce comparison<br>Default values<br>out of 10<br>1<br>2<br>4             | es would you prefer to use?          | Please press 'Save' button to apply changes.<br>Total Water Use vs. Onsite Water USe<br>Reliability vs. Onsite Water Use<br>Maintenance vs. Onsite Water Use   | Default values<br>out of 10<br>1<br>4<br>0.3          | Customized values<br>out of 10 |
| enter the parameters' importance o<br>enter the parameters' importa<br>Onsite Water Use vs. Energy USe<br>Total Water Use vs. Energy Use<br>Reliability vs. Energy Use<br>Maintenane vs. Energy Use                                    | omparison value<br>ince comparison<br>Default values<br>out of 10<br>1<br>2<br>4<br>0.3      | es would you prefer to use?          | Please press 'Save' button to apply changes.<br>Total Water Use vs. Onsite Water USe<br>Reliability vs. Onsite Water Use<br>Maintenance vs. Onsite Water Use<br>Maintenance vs. Total Water Use                                | Default values<br>out of 10<br>1<br>4<br>0.3<br>0.3   | Customized values<br>out of 10 |
| enter the parameters' importance o<br>enter the parameters' importa<br>Onsite Water Use vs. Energy USe<br>Total Water Use vs. Energy Use<br>Reliability vs. Energy Use<br>Maintenane vs. Energy Use<br>Reliability vs. Total Water Use | omparison value<br>ince comparison<br>Default values<br>out of 10<br>1<br>2<br>4<br>0.3<br>4 | es would you prefer to use?          | Please press 'Save' button to apply changes.<br>Total Water Use vs. Onsite Water USe<br>Reliability vs. Onsite Water Use<br>Maintenance vs. Onsite Water Use<br>Maintenance vs. Total Water Use<br>Maintenance vs. Reliability | Default values<br>out of 10<br>4<br>0.3<br>0.3<br>0.1 | Customized values<br>out of 10 |

Figure 19. Weights and Parameter Importance Comparison Values tab in the User Input Form (Section 2.2.2, Step 1).

| Input Data             | Weights and Parameter Im                                 | portance Comparison Values              | Reliability Values | Maintenance Values |
|------------------------|--|---|--------------------|--------------------|
| Which way              | y would you prefer to en                                 | ter the paramter Weight P               | Percentage values  | ?                  |
|                        |  |   |                    |                    |
| Input the<br>Calculate | e Weight Percentage data r<br>e the Weight Percentage ba | ny way<br>ased on paired parameters' ir | nportance comparis | son values         |
| Figure                 | <b>20.</b> Choosing the weig                             | ht percentage entry meth                | hod (Section 2.2   | .2, Step 1)        |
|                        |  |   |                    |                    |
| ase enter the          | weight of each factor in                                 | percentage your way.                    |                    |                    |
| Energy Use             | Onsite Water Use   | Total Cooling Water Use                 | Reliability        | Maintenance        |

Figure 21. Required weight percentage for five criteria when the user selects *Input the Weight Percentage* data my way in step 1 (Section 2.2.2, Step 1a).

1. If the user selects the second method of weight percentage calculation, which is *Calculate the Weight Percentage based on paired parameters' importance comparison values* in step 1,'the second dropdown box will become active. The user must then choose either *Default paired parameters' importance comparison values* or *Customized Default paired parameters' importance comparison values* (Figure 22). If the user selects the *Choose default paired parameters' importance comparison values* option, they do not need to enter any data. However, if the user selects the *Choose customized paired parameters' importance comparison values* option, they must manually enter the customized values (Figure 23).

| What paired paramters' importance comparison values would you prefer to use? |   |  |
|--|---|--|
| •  | Ĵ | Please press 'Save' button to apply changes. |
| Choose default paired parameteters' importance comparison values             | _ |  |
| Choose customized paired parameteters'importance comparison values           |   |  |

**Figure 22.** Choosing either default, or customized values for *Paired parameters' importance comparison values*, when the user selects *Calculate the Weight Percentage based on paired parameters' importance comparison values* method in step 1 (Section 2.2.2, Step 2).

| Please enter the parameters' importa | Please enter the parameters' importance comparison for the following pairs: |                                |                                      |                             |                                |  |  |  |  |  |
|--------------------------------------|---|--------------------------------|--------------------------------------|-----------------------------|--------------------------------|--|--|--|--|--|
|                                      | Default values<br>out of 10   | Customized values<br>out of 10 |                                      | Default values<br>out of 10 | Customized values<br>out of 10 |  |  |  |  |  |
| Energy Use vs. Onsite Water Use      | 3   |                                | Onsite Water Use vs. Total Water Use | 1                           |                                |  |  |  |  |  |
| Energy Use vs. Total Water Use       | 2   |                                | Onsite Water Use vs. Reliability     | 0.5                         |                                |  |  |  |  |  |
| Energy Use vs. Reliability           | 0.8   |                                | Onsite Water Use vs. Maintenance     | 2                           |                                |  |  |  |  |  |
| Energy Use vs. Maintenane            | 5   |                                | Total Water Use vs. Maintenance      | 1.5                         |                                |  |  |  |  |  |
| Total Water Use vs. Reliability      | 0.4   |                                | Reliability vs. Maintenance          | 6                           |                                |  |  |  |  |  |

Figure 23. Parameters' importance comparison values data entry when the user selects the Customized paired parameters' importance comparison values in step 2 (Section 2.2.2, Step 2).

### 1.2.3. Reliability Values tab

In the *User Input Form*'s *Reliability Values* tab (Figure 24), the user can choose between two methods of calculating the reliability values by clicking on the *What Reliability values would you prefer to use?* dropdown box (Figure 25).

a. **Default** *Reliability* **values:** The values are pre-calculated based on the defined parameters and can be found in the *Reliability Default Values* sheet within the *DC-E-WISE* Excel file. **Customized** *Reliability* **values:** This option enables the user to manually input customized values ranging (0 to 50) for *Annual Availability* and (0 to 10) for other reliability factors that are *IT Room Air Fluctuation Due to Outdoor Condition, Lifetime, IT Room Air Contamination,* and *Complexity* for all types of cooling systems in the *Reliability Values* tab of the user form. By doing so, the program will automatically calculate the *Overall Reliability* (%) values for all cooling systems, removing the need for manual calculations (Figure 26).

#### Note

If any of the customized values entered for the reliability factors, *Annual Availability, IT Room Air Fluctuation Due to Outdoor Condition, Lifetime, IT Room Air Contamination,* and *Complexity*, are not within the defined range or are missing, the program will show an error message and prompt the user to fix the error before proceeding to the next tab. The cursor will then move to the first box (*Annual Availability*) of any cooling system for which the customized values were not entered correctly. The user should review the customized reliability parameters' values for that specific cooling system and make any necessary corrections to ensure accurate data entry (Figure 27).



Figure 24. Reliability Values tab in the User Input Form (Section 2.2.3).

| Input Data   Weights and Parameter Importance Comparison Values                           | Reliability Values   Maintenance Values  |
|---|--|
| What Reliability values would you prefer to use?  | Air-Cooled Chiller   |
| Choose defualt reliability values<br>Choose customized reliability values<br>Availability | Default value Customized<br>out of 10 values out of 10<br>10 Annual Availability |

Figure 25. Choosing one of two options, either using default, or customized *Reliability values* (Section 2.2.3).

| User Input Form   |   |                             |   |   |   |  |   |  |
|---|---|-----------------------------|---|---|---|--|---|--|
|   |   |                             |   |   |   |  |   | Minimize   |
| Input Data Weights and Parameter Importance                   | Comparison Values Relia                             | bility Values   Maintenance | e Values  |   |   |  |   |  |
| What Reliability values would you prefer                      | r to use?   | Air-Cooled Chiller          |   | Air-Cooled Chiller+AS                         | E P   | re-Cooled Air-Cooled Chill                     | er Pre-Cooled                                   | Air-Cooled Chiller +ASE                                |
| Choose customized reliability values                          | ▼ De  | fault value Customized      |   | Default value Customize                       | ed D  | Default value Customized                       | Def   | ault value Customized                                  |
| Please press 'Save' button to apply changes.                  | Annual Availability                                 |                             | nnual Availability                                  | 10 10 Values out 0                            | Annual Availability                               |  | Annual Availability                             | 10 Values out of 10                                    |
|   | IT Room Air Fluctuation                             |                             | Room Air Fluctuation                                | 8.5   | IT Room Air Fluctuation                           |  | T Room Air Fluctuation                          | 8.5  |
|   | Lifetime  | 9                           | fetime  | 8.75  | Lifetime  | 9 L  | ifetime   | 8.75   |
| Please enter the customized<br>reliability parameters values. | IT Room Air<br>Contamination                        | 10 II Co                    | Room Air<br>ontamination                            | 8   | IT Room Air<br>Contamination                      | 10   | T Room Air<br>Contamination                     | 8  |
|   | Complexity  | 10 00                       | omplexity   | 8   | Complexity  | 9  | Complexity                                      | 7  |
|   | Overall Reliability(%)                              | 08 0                        | verall Reliability(%)                               | 86.5  | Overall Reliability(%)                            | 95   | Overall Reliability(%) [                        | 84.5   |
|   |   | 90                          |   | 1 00.5  |   | 90   |   | 04.5   |
| Water-Cooled Chiller  |   | ator-Cooled Chiller + ACE   |   | Nator-Cooled Chiller+WC                       | E Wa  | tor Cooled Chiller + ACE +1                    | MCE   | Europorative Cooling + ACE                             |
| water-cooled Chiller  | v   | Alei-Cooled Chiller +ASE    | . *   | Vater-Cooled Chiller + W3                     |   | ter-cooled chiller +A3E +1                     | WJL   | Evaporative Cooling +ASE                               |
| Default value Customi<br>out of 10 values out                 | zed<br>of 10  | out of 10 values out of     | ed<br>of 10   | Default value Customi<br>out of 10 values out | zed<br>of 10                                      | Default value Customiz<br>out of 10 values out | zed<br>of 10                                    | Default value Customized<br>out of 10 values out of 10 |
| Annual Availability 10  | Annual Availability                                 | 10                          | Annual Availability                                 | 10  | Annual Availability                               | 10   | Annual Availability                             | 9  |
| IT Room Air Fluctuation<br>Due to Outdoor Condition           | IT Room Air Fluctuation<br>Due to Outdoor Condition | 8.5                         | IT Room Air Fluctuation<br>Due to Outdoor Condition | n 9   | IT Room Air Fluctuation<br>Due to Outdoor Conditi | on 7.5   | IT Room Air Fluctuatio<br>Due to Outdoor Condit | n 8.5  |
| Lifetime 10   | Lifetime  | 9.75                        | Lifetime  | 9.75  | Lifetime  | 9.5  | Lifetime  | 9.25   |
| IT Room Air<br>Contamination                                  | IT Room Air<br>Contamination                        | 8                           | IT Room Air<br>Contamination                        | 10  | IT Room Air<br>Contamination                      | 8  | IT Room Air<br>Contamination                    | 8  |
| Complexity 8.5  | Complexity  | 6.5                         | Complexity  | 7.5   | Complexity  | 5.5  | Complexity                                      | 8  |
| Overall Reliability(%) 97                                     | Overall Reliability(%)                              | 85.5                        | Overall Reliability(%                               | <b>6)</b> 92.5                                | Overall Reliability(%                             | b) 81  | Overall Reliability(%                           | <b>6)</b> 85.5   |

Figure 26. Data entry for the customized *Reliability values* (Section 2.2.3).

|                | Air-Cooled Ch                                    | niller               |   | Air-Cooled Chiller+ASE        |                          |   |  |  |  |
|----------------|--|----------------------|---|-------------------------------|--------------------------|---|--|--|--|
| D              | efault value <b>C</b> u<br>out of 10 <b>valu</b> | ustomize<br>es out o | ed<br>f 10  | Default value<br>out of 10    | Customiz<br>values out o | ed<br>of 10                                 |  |  |  |
|                | 10   | 4                    | Annual Availability                                     | 10                            | a                        | Annual Availability                         |  |  |  |
| tion<br>dition | 10   | 5                    | IT Room Air Fluctuation<br>Due to Outdoor Conditior     | 8.5                           | 15                       | IT Room Air Fluctuat<br>Due to Outdoor Cond |  |  |  |
|                | 9  | 5                    | Lifetime  | 8.75                          | 5                        | Lifetime                                    |  |  |  |
|                | 10   | 5                    | IT Room Air<br>Contamination                            | 8                             | 2                        | IT Room Air<br>Contamination                |  |  |  |
|                | 10   | 5                    | Complexity  | 8                             | 10                       | Complexity                                  |  |  |  |
| (%)            | 98   | Mic                  | rosoft Excel Reason                                     | ns for show                   | n error r                | nessage X                                   |  |  |  |
| v              | Vater-Cooled Ch                                  | Ple<br>reli          | ase enter the numeric va<br>ability paramters for Air-0 | lues between<br>Cooled Chille | 0 and 10 f<br>r + ASE.   | for customized                              |  |  |  |
|                | Default value<br>out of 10                       | (<br>vali<br>3       |   |                               |                          | ОК  |  |  |  |

Figure 27. Error message shown because of errors in customized reliability factors values for Air-Cooled Chiller + ASE cooling system (Section 2.2.3, Note)

## 2.2.4 Maintenance Values tab

In the *Maintenance Values* tab (Figure 28) in the *User Input* Form, the user can choose between two methods of calculating the maintenance values by selecting one of the options in the *What Maintenance values would you prefer to use?* dropdown box (Figure 29):

- a. **Default** *Maintenance* values: These values are pre-calculated based on the defined *Action Weight* and *Action Frequency*, as described in Section 1.2.2. The *Maintenance Default Values* sheet in the *DC-E-WISE* Excel file provides more details on this calculation.
- b. **Customized** *Maintenance* values: If the user selects *Customized Maintenance* values in the *Maintenance* Values tab, they need to manually enter the *Customized Maintenance Action Weight* and *Customized Maintenance Action Frequency* for each maintenance action of all cooling systems. The program then automatically calculates the *Overall Maintenance* values for all cooling systems based on user-assigned weights and action frequencies, removing the need for manual calculations (Figure 30).

### Note

- **1.** If any of the *Customized Weight* or *Customized Frequency* values are missing, non-numerical, or less than zero, the program will display an error message and prompt the user to fix the error before proceeding (Figure 31 and 32).
- 2. If any of the *Customized Weight* or *Customized Frequency* values are missing or are non-numerical, or a value less than zero is entered, an error message is displayed by the program. The cursor will then move to the first box of *Customized Weight* or *Customized Frequency* of the affected cooling system. The user should then check the values entered for that specific cooling system and correct any errors in data entry before proceeding.

| User Input Form           |             |                |                          |                |             |                     |              |                  |            |
|---------------------------|-------------|----------------|--------------------------|----------------|-------------|---------------------|--------------|------------------|------------|
|                           |             |                |                          |                |             |                     |              |                  |            |
| Input Data Weights an     | d Parameter | Importance Co  | omparison Values   Relia | ability Values | Maintenance | Values              |              |                  |            |
| What Maintenance          | values wo   | uld you prefer | to use?                  |                |             | Ple                 | ase enter th | ne customizer    | 1 mainten: |
|                           |             | •              | Please press 'Sa         | we' button to  | apply       | rie.                | Noto: O      | vorall Maintonar | So-Sum(A   |
| 1                         |             |                | Cha                      | anges.         |             |                     | Note: Of     |                  | A)muc–sum  |
|                           |             |                |                          | Air-Coole      | d Chiller   |                     | Air-Coolec   | I Chiller+ASE    |            |
| Mainte                    | nance Act   | ion weight     |                          | Default        | Customized  |                     | Default      | Customized       |            |
|                           | Default     | Customized     |                          | Frequency      | Frequency   |                     | Frequency    | Frequency        |            |
|                           | Weight      | Weight         | Annual                   | 10             |             | Annual              | 11           |                  | Annual     |
| Annual Action             | 5           |                | Semi-Annual              | 4              |             | Semi-Annual         | 7            |                  | Semi-Anr   |
| Semi-Annual Action        | 4           |                | Monthly                  | 0              |             | Monthly             | 0            |                  | Monthly    |
| Monthly Action            | 3           |                | Weekly                   | 6              |             | Weekly              | 8            |                  | Weekly     |
| Weekly Action             | 2           |                | Daily                    | 3              |             | Daily               | 3            |                  | Daily      |
| Daily Action              | 1           |                | Water treatment          |                |             | Water treatment     |              |                  | Water tre  |
| Water Treatment<br>Action | 10          |                | Overall Maintenanc       | e 81           |             | Overall Maintenance | e 102        |                  | Overall    |
|                           |             |                |                          |                |             |                     |              |                  |            |



Figure 28. Maintenance Values tab in the User Input Form (Section 2.2.3).

Figure 29. Choosing one of two options, either default, or customized *Maintenance values* (Section

2.2.4).

| Determine the set of th | Input Data Weights an   | Input Data Weights and Parameter Importance Comparison Values Reliability Values Maintenance Values |                      |                     |                      |               |  |  |             |                    |                      |            |                   |                 |             |
|---|---|---|----------------------|---------------------|----------------------|---------------|--|--|-------------|--------------------|----------------------|------------|-------------------|-----------------|-------------|
| Plane       Plane       Same Same Subtituition tegraphy       Determine       Same Same Subtituition tegraphy       Determine       Same Same Subtituition tegraphy       Determine       Same Same Same Same Same Same Same Same   | What Maintenance values would you prefer to use? Please enter the customized maintenance action weight and frequency. |   |                      |                     |                      |               |  |  |             |                    |                      |            |                   |                 |             |
| Droce defailt       Der Coded Chiller       Der Co  | Please press 'Save' button to apply changes.  |   |                      |                     |                      |               | Note: Overall Maintenance=Sum(Action Degree of Difficulty *Action Frequency) |  |             |                    |                      |            |                   |                 |             |
| Balante Action         Default         Customized         Prequency   | Choose default mai<br>Choose customized   | Choose default maintenance values Choose customized maintenance values Air-Cooled Chiller           |                      |                     |                      |               |  | Air-Cooled Chiller+ASE Pre-Cooled Air-Cooled Chiller |             |                    |                      | iller Pi   | re-Cooled Air-Coo | ed Chiller +ASE |             |
| Default         Customized<br>Weight         Frequency<br>Annual         Frequency<br>1         Frequency<br>1 <th>Mainte</th> <th>nance Acti</th> <th>on weight</th> <th></th> <th>Default</th> <th>Customized</th> <th></th> <th>Default</th> <th>Customized</th> <th></th> <th>Default</th> <th>Customized</th> <th>I.</th> <th>Default</th> <th>Customized</th>  | Mainte  | nance Acti  | on weight            |                     | Default              | Customized    |  | Default  | Customized  |                    | Default              | Customized | I.                | Default         | Customized  |
| Annual Action       5       Semi-Annual       4       Semi-Annual       1       Annual       11       Annual       11       Annual       12       Image       <   |   | Default<br>Weight   | Customized<br>Weight | Annual              | Frequency            | Frequency     | Annual   | Frequency  | Frequency   | Annual             | Frequency            | Frequency  | Annual            | Frequency       | Frequency   |
| Semi-Annual Action       4       Monthly       0       Monthly       1       Monthly       3       Daily       Annual       Annual       A  | Annual Action   | 5   |                      | Semi-Annual         |                      | <u> </u>      | Semi-Annual  | 11   |             | Semi-Annual        |                      | -          | Semi-Annual       | 12              |             |
| Monthly Action       3       Weekly       6       Weekly       8       Weekly       1       Monthly       1       Monthly <th>Semi-Annual Action</th> <th>4</th> <th></th> <th>Monthly</th> <th></th> <th><u> </u></th> <th>Monthly</th> <th></th> <th>-</th> <th>Monthly</th> <th>4</th> <th><u></u></th> <th>Monthly</th> <th></th> <th><u> </u></th>   | Semi-Annual Action  | 4   |                      | Monthly             |                      | <u> </u>      | Monthly  |  | -           | Monthly            | 4                    | <u></u>    | Monthly           |                 | <u> </u>    |
| Weekly Action       2       Daily       3       Daily       4       Daily       Annual       10       Overail Maintenance       102       Overail Maintenance       124       Daily       Annual       12       Annual       12       Annual       124       Daily       Annual       12       Annual       12       Annual       12       Annual       12  | Monthly Action  | 3   |                      | Weekly              | 6                    |               | Weekly   | 8  |             | Weekly             | 9                    |            | Weekly            | 10              |             |
| Daily Action       1       Water treatment       0       Wa   | Weekly Action   | 2   |                      | Daily               | 3                    | <u> </u>      | Daily  | 3  | <u> </u>    | Daily              | 3                    | <u> </u>   | Daily             | 3               | <u> </u>    |
| Water Treatment       10       Overall Maintenance       81       Overall Maintenance       102       Overall Maintenance       103       Overall Maintenance       124         Water Cooled Chiller       Water Cooled Chiller + ASE       Water Cooled Chiller + ASE       Water Cooled Chiller + ASE + WSE       Eveporative Cooling + ASE         Maintenance       Prequency       Pr  | Daily Action  | 1   |                      | Water treatment     |                      |               | Water treatment  | 0  |             | Water treatment    | 1                    | <u> </u>   | Water treatment   | 1               |             |
| Wate-Cold Chiller     Wate-Cold Chiller +ASE     Wate-Cold Chiller +ASE     Wate-Cold Chiller +ASE +MSE     Expositive Chiller +ASE +MSE  | Water Treatment<br>Action   | 10  |                      | Overall Maintenance | 81                   |               | Overall Maintenance  | 102  |             | Overall Maintenanc | e 103                |            | Overall Mainter   | nance 124       |             |
| Default<br>Frequency     Outsonized<br>Frequency     Default<br>Frequency     Default   |   | Water-C   | ooled Chiller        |                     | Water-Coo            | ed Chiller +A | SE V   | Vater-Cooled   | Chiller+WSE | Water              | -Cooled Chill        | er +ASE +W | SE                | Evaporative (   | ooling +ASE |
| Default     Customized     Default     Customized     Default     Customized     Default     Customized     Default     Customized     Default     Customized       Annual     13     Annual     14     Annual     14     Annual     15     Annual     2       Semi-Annual     4     Semi-Annual     14     Annual     15     Annual     2       Semi-Annual     4     Semi-Annual     4     Semi-Annual     7     Semi-Annual     4       Monthly     4     Monthly     4     Monthly     4     Monthly     4     Monthly     1       Weekly     13     Weekly     15     Weekly     11     Weekly     13     Weekly     0       Oally     6     Daily     6     Daily     0     Daily     0     0       Vater treatment     2     Water treatment     2     Water treatment     2     Water treatment     2     Water treatment     2     0   |   |   |                      |                     |                      |               |  |  |             |                    |                      |            |                   |                 |             |
| Annual       13       Annual       14       Annual       15       Annual       2         Semi-Annual       4       Semi-Annual       7       Semi-Annual       4       Semi-Annual       7       Semi-Annual       4       Monthly  |   | Default<br>Frequency  | Frequency            |                     | Default<br>Frequency | Frequency     |  | Frequency  | Erequency   |                    | Default<br>Frequency | Frequency  |                   | Frequence       | Frequency   |
| Semi-Annual         4         Semi-Annual         7         Semi-Annual         7         Semi-Annual         4         Semi-Annual         7         Semi-Annual         4         Monthly         1         Monthly         4         Monthly   | Annual  | 13  |                      | Annual              | 14                   |               | Annual   | 14   |             | Annual             | 15                   |            | Annual            | 2               |             |
| Monthly       4       Monthly       4       Monthly       4       Monthly       1       1         Weekly       13       Weekly       15       Weekly       11       Weekly       13       Weekly       3         Daily       6       Daily       6       Daily       6       Daily       6       Daily       0         Water treatment       2       Water treatment       2       Water treatment       2       Water treatment       2       Overall Maintenance       16       Overall Maintenance <td< th=""><th>Semi-Annual</th><th>4</th><th></th><th>Semi-Annual</th><th>7</th><th></th><th>Semi-Annual</th><th>4</th><th></th><th>Semi-Annual</th><th>7</th><th></th><th>Semi-Annual</th><th>4</th><th></th></td<>   | Semi-Annual   | 4   |                      | Semi-Annual         | 7                    |               | Semi-Annual  | 4  |             | Semi-Annual        | 7                    |            | Semi-Annual       | 4               |             |
| Weekly     13     Weekly     15     Weekly     11     Weekly     13     Weekly     3       Daily     6     Daily     6     Daily     6     Daily     0     0       Water treatment     2     0       Overall Maintenance     145     Overall Maintenance     166     Overall Maintenance     167     Overall Maintenance     55   | Monthly   | 4   |                      | Monthly             | 4                    |               | Monthly  | 4  |             | Monthly            | 4                    |            | Monthly           | 1               |             |
| Daily     6     Daily     6     Daily     6     Daily     0       Water treatment     2   | Weekly  | 13  |                      | Weekly              | 15                   |               | Weekly   | 11   |             | Weekly             | 13                   |            | Weekly            | 3               |             |
| Water treatment     2     Water treatment     2     Water treatment     2     Water treatment     2       Overall Maintenance     145     Overall Maintenance     146     Overall Maintenance     167     Overall Maintenance     55  | Daily   | 6   |                      | Daily               | 6                    |               | Daily  | 6  |             | Daily              | 6                    |            | Daily             | 0               |             |
| Overall Maintenance         145         Overall Maintenance         146         Overall Maintenance         167         Overall Maintenance         55  | Water treatment   | 2   |                      | Water treatment     | 2                    |               | Water treatment  | 2  |             | Water treatment    | 2                    |            | Water treatment   | 2               |             |
| Stop Lang   | Overall Maintenance   | 145   |                      | Overall Maintenance | 166                  |               | Overall Maintenance  | 146  |             | Overall Maintenanc | e 167                |            | Overall Maint     | enance 55       |             |
| Tote Feate  |   |   |                      |                     |                      |               |  |  | Sa          | we                 | L.                   | eave       |                   |                 |             |

Figure 30. Data entry for the customized *Maintenance Action Weights and Maintenance Action Frequency values* (Section 2.2.4).

| Input Data Weights and  | d Paramete        | r Importance Co      | omparison Values | Reliability Values   | Maintenance Values      |                      |  |  |  |
|---|-------------------|----------------------|------------------|----------------------|-------------------------|----------------------|--|--|--|
| What Maintenance values would you prefer to use?       Please press 'Save' button to apply changes.       Please enter the please press 'Save' button to apply changes. |                   |                      |                  |                      |                         |                      |  |  |  |
| Air-Cooled Chiller Air-Co<br>Maintenance Action Weight  |                   |                      |                  |                      |                         |                      |  |  |  |
|   | Default<br>Weight | Customized<br>Weight | Annual           | Default<br>Frequency | Customized<br>Frequency | Default<br>Frequency |  |  |  |
| Annual Action   | 5                 | a                    | Microsoft Excel  |                      | 10                      | ×                    |  |  |  |
| Semi-Annual Action  | 4                 | 5                    |                  | Reason for show      | vn error message        |                      |  |  |  |
| Monthly Action  | 3                 |                      | Please enter the | numerical values     | equal or greater that   | n 0 for customized   |  |  |  |
| Weekly Action   | 2                 | 4                    | Maintenance A    | tion Weight.         | equal of greater that   | -                    |  |  |  |
| Daily Action  | 1                 | 3                    |                  |                      |                         | -                    |  |  |  |
| Water Treatment<br>Action   | 10                | 10                   |                  |                      |                         | ОК                   |  |  |  |
|   | Wator-            | Cooled Chiller       |                  | Water-Cool           | lad Chillor + ASE       | Water-Coole          |  |  |  |

Figure 31. Error message shown because of errors in customized *Maintenance Action Weight* values (Section 2.2.4, Note)

|                         | Please enter the customized maintenance action weight and frequency. |                      |                         |  |  |  |  |  |  |  |  |
|-------------------------|--|----------------------|-------------------------|--|--|--|--|--|--|--|--|
| apply                   | Note: Overall Maintenance=Sum(Action Dec                             | gree of Difficulty ' | *Action Freque          |  |  |  |  |  |  |  |  |
| ed Chiller              | Air-Cooled Chiller+ASE   | Pre-Cooled A         | ir-Cooled Chill         |  |  |  |  |  |  |  |  |
| Customized<br>Frequency | Default Customized<br>Frequency Frequency                            | Default<br>Frequency | Customized<br>Frequency |  |  |  |  |  |  |  |  |
| Microsoft Excel         | Reason for shown error message                                       | 11                   | 10                      |  |  |  |  |  |  |  |  |
|                         | Reason for shown error message                                       | 4                    | 10                      |  |  |  |  |  |  |  |  |
| Please enter the nume   | erical values equal or greater than 0 for customized                 | 1                    |                         |  |  |  |  |  |  |  |  |
| Maintenance Action F    | -requency for Pre-Cooled Air-Cooled Chiller.                         | 8                    | 101                     |  |  |  |  |  |  |  |  |
|                         |  | 3                    | 10                      |  |  |  |  |  |  |  |  |
|                         | ОК   | 1                    | 10                      |  |  |  |  |  |  |  |  |
|                         |  | 103 ICE              |                         |  |  |  |  |  |  |  |  |
|                         |  |                      |                         |  |  |  |  |  |  |  |  |

Figure 32. Error message shown because of errors in *customized Maintenance Action Frequency* values for Air-Cooled Chiller + ASE cooling system (Section 2.2.4, Note)

# 3. Notes

- 1. The *Cooling System Schematics* sheet in the DC-E-WISE excel file allows the user to review the schematics of the nine discussed cooling systems.
- 2. The *Cooling System Graphs* sheet in the DC-E-WISE excel file displays plotted normalized values for *Energy, Onsite Water Use*, and *Total Cooling Water Use*, based on IT load, for four different airflow management strategies.
- 3. The *No Airflow Containment, CAC Airflow, HAC-VED Airflow, and CAC* and *HAC-VED Airflow* sheets in DC-E-WISE excel file, containing modeled data for four airflow management strategies are all protected to prevent manual changes. However, they become writable when the *User Input Form* is active to allow for data entry.
- 4. Although *DC-E-WISE* is compatible with MAC systems, it is recommended that users run it on a Windows operating system to access all features. VBA codes tend to work better in Windows operating systems.
- 5. The *User\_Interaction* sheet in the DC-E-WISE excel file displays the results of each run and saves them for later review if the user saves changes before closing the file.

# 4. Reference

 S. K. Shrivastava, A. R. Calder, and M. Ibrahim, "Quantitative Comparison of Air Containment Systems," in 13th InterSociety Conference on Thermal and Thermomechanical Phenomena in Electronic Systems, San Diego, CA, 2012, 2012, pp. 68-77, doi: 10.1109/ITHERM.2012.6231415.