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Instructions on using the security-emissions software

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1 Introduction

This report presents instructions on using the software for explaining the energy security-greenhouse gas emissions graphs described in (Hughes and Sheth 2008). The graphs are created from application-specific data on energy supply,[1] infrastructure, price, greenhouse gas emission factors, and consumption. The application's energy sources are ranked using AHP (Analytic Hierarchy Process). The resulting security-emissions graphs allow the viewer to understand the state of the application's energy security, the level of greenhouse gas emissions, and the effort needed to improve energy security and reduce emissions.

The graph-generation software is written in VBA and uses Microsoft Excel to hold the tables and resulting graphs. The Excel file consists of five worksheets:

- Start, create a list of the energy sources and their associated emissions and consumption for the application.
- Criteria, rank the energy security criteria (supply, infrastructure, and price) to be applied to the energy sources.
- Alternatives, rank the different energy sources in terms of each criteria.
- Results, generate the energy security index for each energy source.
- Graph, produce the security-emissions graph for the application.

The VBA software can be examined by selecting the View tab and then Macros. The name of each subroutine corresponds to its worksheet.

The software is part of an Excel macro-enabled workbook. It requires the Microsoft Office 2007 version of Excel.

2 Start worksheet

The Start worksheet allows the user to enter the names of the different energy sources, their emissions factors, and the consumption associated with each energy source. This data is used by other worksheets. The worksheet is configured for data by typing control-s. When control-s is typed, the Start worksheet is opened.

2.1 Output

The software clears part of the worksheet and displays the following:

[1] An application can be any energy consuming entity; for example, an energy service, a company or organization, or jurisdiction. The software does not distinguish between types of application.

	A	B	C	D
1	Complete the following. After last entry in column A, type END			
2	Energy source	Emissions factor	Consumption	
3				- Row 3: Enter units for Emissions Factor (col 2) and Consumption (col 3)
4				- Row 4: Enter values for energy source (col 1), Emissions Factor (col 2) and Consumption (col 3)
5				- Repeat for each energy source. Enter END in col 1 as the last energy source

2.2 Input

The user is then expected to complete the worksheet. Row 3, column B is for the emissions factor units (for example, g/kWh), and row 3, column C is for the consumption units (for example, PJ or kWh). Row 4 is the start of the data, where column A is the name of the energy source, column B is the emissions factor associated with the energy source, and column C is the energy source's consumption. Each energy source is entered in the next available row. The end-of-data is indicated by entering the word "END" column A of the row following the last row of data. The software is not running when the data is being entered, all data checking is the responsibility of the user. Subsequent worksheets recognize a maximum of 15 energy sources.

The following is an example of a user's input to the Start worksheet (user input shown in *italics*):

	A	B	C
2	Energy source	Emissions factor	Consumption
3		*g/kWh*	*PJ*
4	*Oil*	*690*	*178.3*
5	*Domestic coal*	*940*	*10.3*
6	*Imported coal*	*940*	*69.1*
7	*Natural gas*	*460*	*2.3*
8	*Hydro*	*16*	*2.7*
9	*Renewables*	*30*	*16.6*
10	*END*		

3 Criteria worksheet

The Criteria worksheet allows the user to conduct a pair-wise comparison of the three criteria, supply, infrastructure, and price. The criteria software starts after control-c is typed, opening the Criteria worksheet and prompting the user for the first pair-wise comparison.

Input is entered via message-boxes. It can be stopped at any time by clicking the "Cancel" button in the message box.

3.1 Input

The software begins by clearing the Criteria worksheet and displaying the criteria matrix to be completed by the user:

	A	B	C	D
1		Supply	Infrastructure	Price
2	Supply	1.00		
3	Infrastructure		1.00	
4	Price			1.00

Next, the software requests the user to compare supply and infrastructure, supply and price, and infrastructure and price using values from Saaty's comparison table (see section 7). Values are entered into message boxes. For example, if supply was considered moderately or weakly more important than infrastructure, the user would enter the value 3. However, if infrastructure was considered moderately or weakly more important than infrastructure, the user would enter the value 1/3.

For example, if the user's comparison was supply-infrastructure (2), supply-price (4), and infrastructure-price (2), the software would complete the comparison matrix as follows:

	A	B	C	D
1		Supply	Infrastructure	Price
2	Supply	1.00	*2.00*	*4.00*
3	Infrastructure	0.50	1.00	*2.00*
4	Price	0.25	0.50	1.00

The lower-half of the diagonal comparing infrastructure and supply, price and supply, and price and infrastructure, is completed by the software.

3.2 Output

In addition to completing the comparison table, the software also displays the geometric mean values, the normalized geometric means, and the maximum eigenvalues. The resulting consistency index and consistency ratio are shown as well. The value of the random index is fixed at 0.58 for a 3-by-3 matrix. The values for the above matrix are as follows:

	A	B	C	D	E
11	Geometric Mean Value	Normalized Geometric Mean Value	Maximum Eigenvalues		
12	2.00	1.71	3.00	Consistency Index	0.00
13	1.00	0.86	3.00	Random Index	0.58
14	0.50	0.43	3.00	Consistency Ratio (%)	0.00
15	1.17	3.00	3.00		

Finally, the priority of each of the criteria is displayed:

	A	B
7	Priority of Supply	0.57
8	Priority of Infrastructure	0.29
9	Priority of Price	0.14

If the priority ranking is incorrect or needs to be revised, the software can be run again by typing control-c. The Criteria worksheet can be run before or after data is entered into the Alternatives worksheet. The priority results shown in the above table are used in the Results worksheet.

3.3 Errors

If the consistency index exceeds 10 percent, a diagnostic is displayed and the software clears the table and prompts for the first pair-wise comparison again.

4 Alternatives worksheet

The Alternatives worksheet allows the different energy sources to be compared, either qualitatively or quantitatively, with respect to each criterion (Supply, Infrastructure, or Price). The Alternatives software begins execution when control-a is typed, opening the Alternatives worksheet and prompting the user for one of a number of actions. Unlike the other worksheets, the Alternatives worksheet is not cleared when the software is activated because the priorities calculated by the software must remain on the worksheet for use by the Results worksheet.

4.1 Input

The first message box prompts for one of five actions:

0. Clear worksheet. The Alternatives worksheet is cleared. This will result in the loss of any priority values already calculated, meaning that they must be calculated again.
1. Supply. Enter the qualitative or quantitative comparison values of the energy sources for the Supply criterion.
2. Infrastructure. Enter the qualitative or quantitative comparison values of the energy sources for the Infrastructure criterion.
3. Price. Enter the qualitative or quantitative comparison values of the energy sources for the Price criterion.
4. All criteria. Prompt for all criteria (Supply, Infrastructure, and Price).

The values for the comparisons must be entered via the message-boxes; data entered directly to the worksheet is ignored and not included in the calculations. Input can be stopped at any time by clicking the “Cancel” button in the message-box.

The energy alternatives are compared either qualitatively or quantitatively. After a criterion is selected, the software prompts the user to specify how the comparison is to take place (0, Qualitative, or 1, Quantitative).

4.2 Qualitative comparison

Qualitative values are those obtained from a pair-wise comparison of the energy sources using Saaty's comparison table (see section 7). If the criterion comparison chosen is Qualitative, a message informs the user that the matrix is to be completed. Next, the user is prompted to compare one energy source with the remaining ones using Saaty's pair-wise comparison values. The software prompts for the values in the upper-half of the comparison matrix to the right of the diagonal only (the software completes the lower-half of the matrix).

The following is an example of a completed qualitative comparison table (user input is in *italics*):

	A	B	C	D	E	F	G
1	Criterion: Supply						
2		Oil	Domestic coal	Imported coal	Natural gas	Hydro	Renewables
3	Oil	1.00	*0.33*	*0.50*	*1.00*	*0.33*	*0.33*
4	Domestic coal	3.00	1.00	*2.00*	*2.00*	*1.00*	*2.00*
5	Imported coal	2.00	0.50	1.00	*2.00*	*0.33*	*0.50*
6	Natural gas	1.00	0.50	0.50	1.00	*0.33*	*0.50*
7	Hydro	3.00	1.00	3.00	3.00	1.00	*2.00*
8	Renewables	3.00	0.50	2.00	2.00	0.50	1.00

The software determines and applies a consistency ratio to the matrix; for example:

	A	B	C	D	E
19	Geometric Mean Value	Normalized Geometric Mean Value	Maximum Eigenvalues		
20	0.51	0.46	6.09	Consistency Index	0.03
21	1.70	1.50	6.14	Random index	1.24
22	0.83	0.74	6.17	Consistency Ratio (%)	2.18
23	0.59	0.52	6.14		
24	1.94	1.72	6.10		
25	1.20	1.06	6.17		
26	1.13	6.00	6.14		

4.3 Quantitative comparison

Comparisons can also take place quantitatively. In this case, the user is prompted to complete the quantitative comparison matrix by entering the quantitative value associated with each energy source; for example:

	A	B
1	Criterion: Supply	
2		
3	Oil	
4	Domestic coal	
5	Imported coal	
6	Natural gas	
7	Hydro	
8	Renewables	

The software determines the priorities from the quantitative values.

4.4 Output

As each comparison is completed, the software creates a priority table for each energy source and the criteria; for example:

	A	B	C	D
10		Supply	Infrastructure	Price
11	Priority of alternative Oil	0.08	0.17	0.09
12	Priority of alternative Domestic coal	0.25	0.12	0.20
13	Priority of alternative Imported coal	0.12	0.17	0.15
14	Priority of alternative Natural gas	0.09	0.09	0.10
15	Priority of alternative Hydro	0.29	0.28	0.32
16	Priority of alternative Renewables	0.18	0.17	0.13
17	Consistency ratio	2.18	1.73	

Qualitative values include their consistency ratio, whereas quantitative values have no consistency ratio.

The values in this table are used by the Results worksheet.

4.5 Errors

If the consistency index exceeds 10 percent, a diagnostic is displayed and the software clears the table and prompts for the first pair-wise comparison again. This applies to qualitative values only.

5 Results worksheet

The final step in the AHP process is the generation of the results, from the criteria and the alternatives, this takes place in the Results worksheet. When control-r is typed, the Results worksheet is opened and the results displayed. The Start, Criteria, and Alternatives worksheets should be completed before running the Results worksheet.

5.1 Output

Two sets of output are created. The first is a combination of the criteria vector (from the Criteria worksheet) and the alternatives array (from the Alternatives worksheet):

	A	B	C	D
1		Supply	Infrastructure	Price
2	Priority of criteria	0.57	0.29	0.14
3	Priority: Oil	0.08	0.17	0.09
4	Priority: Domestic coal	0.25	0.12	0.20
5	Priority: Imported coal	0.12	0.17	0.15
6	Priority: Natural gas	0.09	0.09	0.10
7	Priority: Hydro	0.29	0.28	0.32
8	Priority: Renewables	0.18	0.17	0.13

The second is the final priority list of the different energy sources generated using the AHP algorithm; this is the energy security index:

	A	B
11	Final priority: Oil	0.10
12	Final priority: Domestic coal	0.21
13	Final priority: Imported coal	0.14
14	Final priority: Natural gas	0.09
15	Final priority: Hydro	0.29
16	Final priority: Renewables	0.17

6 Graph worksheet

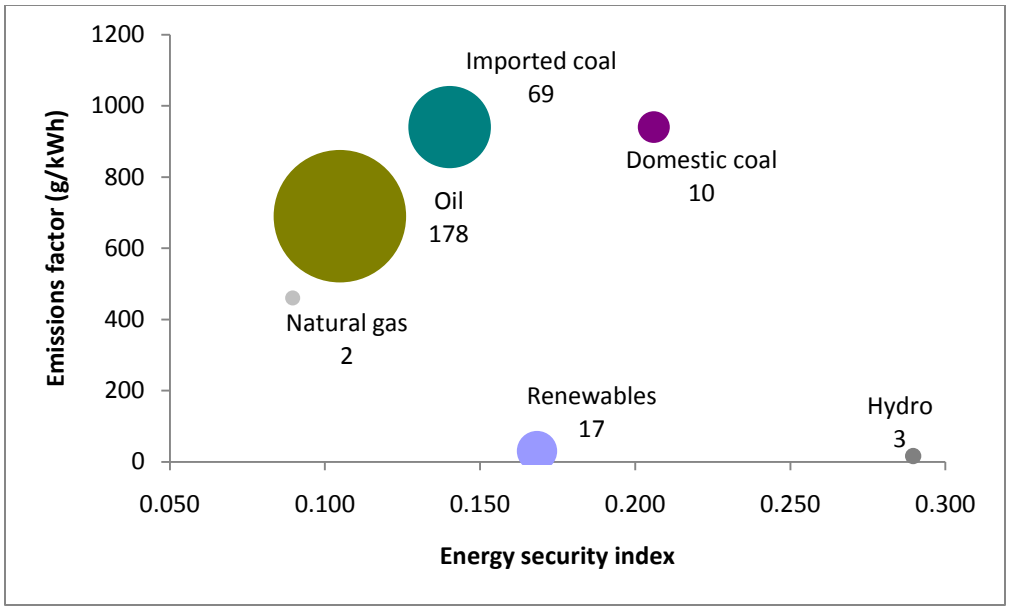
The final step is the production of the security-emissions graph from the security index results (Results worksheet), the emissions factors (Start worksheet), and the names of the energy sources (Start worksheet). The result is a bubble graph, with each energy source represented as a bubble showing its relative size in terms of the total energy it supplies; its x-position, the security index value; and its y-position, the emissions factor. The Graph worksheet is opened and the graph generated by typing control-g.

6.1 Output

The worksheet produces an array of the energy sources, their security indexes, and their emissions factors; for example:

	A	B	C	D
1	Energy source	Security index	Emissions factor	Consumption
2	Oil	0.105	690	178
3	Domestic coal	0.206	940	10
4	Imported coal	0.140	940	69
5	Natural gas	0.090	460	2
6	Hydro	0.290	16	3
7	Renewables	0.168	30	17

The associated graph is also produced:



The names of the energy sources can overlap the bubbles; if this occurs, any name can be moved by clicking on it and repositioning it. If the software is run more than once, previously generated graphs are not deleted and if data values change, the older graphs will change.

7 Saaty's pair-wise comparison table

Value	Meaning
1	A and B are of equal importance
3	A is moderately or weakly more important than B
5	A is strongly more important than B
7	A is demonstrably or very strongly more important than B
9	A is extremely or absolutely more important than B
2, 4, 6, 8	Intermediate values
Reciprocals	If activity *i* has one of the above numbers assigned to it when compared with activity *j*, then *j* has the reciprocal value when compared with *i*.
Fractions	Only occur when a reciprocal ratio is obtained.

References

Hughes, Larry, and Nikita Sheth. *A graphical technique for explaining the relationship between energy security and greenhouse gas emissions.* Halifax, Nova Scotia: Energy Research Group, Dalhousie University, 2008.