American International University- Bangladesh
Department of Electrical and Electronic Engineering
EEE: Renewable Energy Technology Laboratory

Title: Familiarization with RETScreen Software for Renewable Energy Sources (RES) Based System Design

Abstract:

The purpose of this experiment is to be familiarized with RETScreen Software for Renewable Energy Sources (RES) Based System Design. Firstly the students will investigate a case study of an existing RES (In this case, Photovoltaic) based system. Then they will design and analyze a system based on an upcoming Photovoltaic project in the perspective of Bangladesh.

Introduction:

RETScreen is a Clean Energy Management Software system for energy efficiency, renewable energy and cogeneration project feasibility analysis as well as ongoing energy performance analysis. RETScreen 4 is an Excel-based clean energy project analysis software tool that helps decision makers quickly and inexpensively determine the technical and financial viability of potential renewable energy, energy efficiency and cogeneration projects. RETScreen Plus is a Windows-based energy management software tool that allows project owners to easily verify the ongoing energy performance of their facilities.

System Requirements:

- Microsoft® Excel 2003 | 2007 | 2010 | 2013
- Microsoft® Windows XP | Windows Vista | Windows 7 | Windows 8
- Microsoft® .NET Framework 4 or higher. Note that the Full Profile version must be installed, not just the Microsoft® .NET Framework 4 Client Profile version.

The primary objectives of the lab experiment are-

1. To be familiarized with RETScreen Software
2. To investigate an existing case study
3. To design a RES based system and analyze its feasibility

Theory and Methodology:

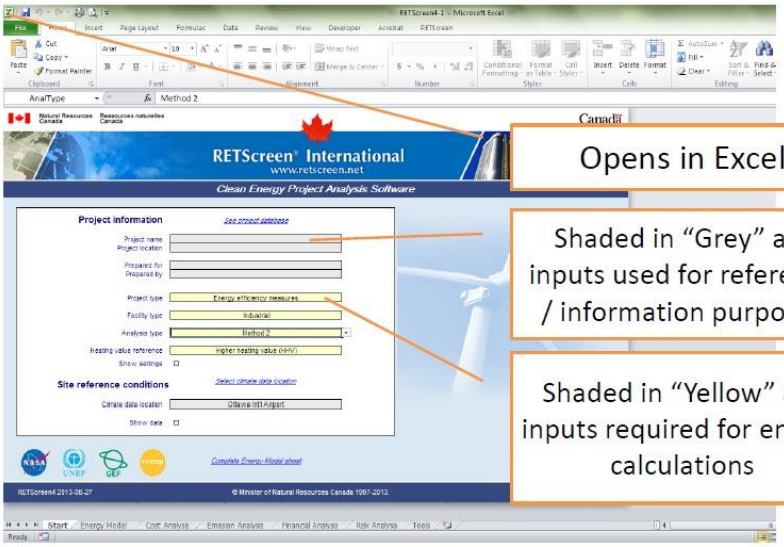
Why do we use RETScreen?

- "Pre-feasibility" study for renewable energy, energy efficiency projects.
- Gives us an idea on whether a project proposals is worth looking into further
- Inexpensive first step to project planning (software is free to download)

Where can we get RETScreen Software?

- Go to www.retscreen.net
- Download RETScreen Suite
- Save or Run RETScreenSuite.exe
- Run the .exe file and it will download to your computer.

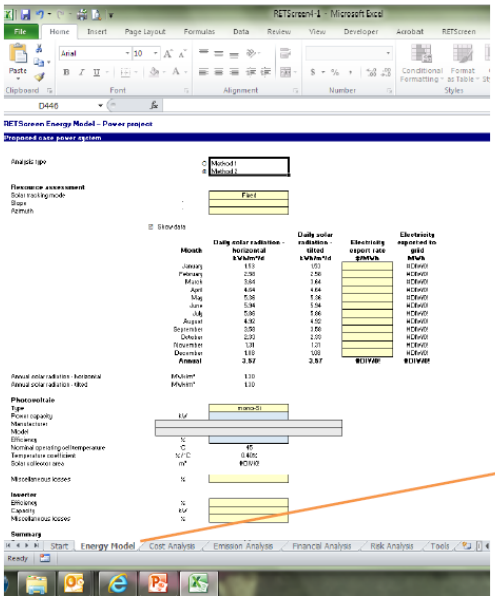
"RETScreen 4" is current version.



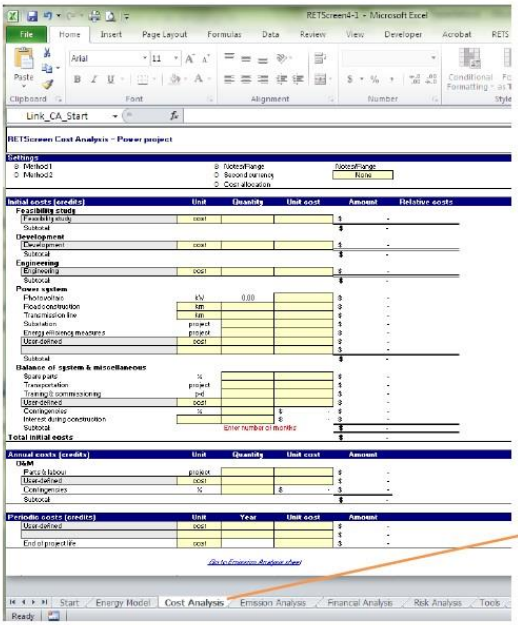
Opens in Excel

Shaded in "Grey" are inputs used for reference / information purposes

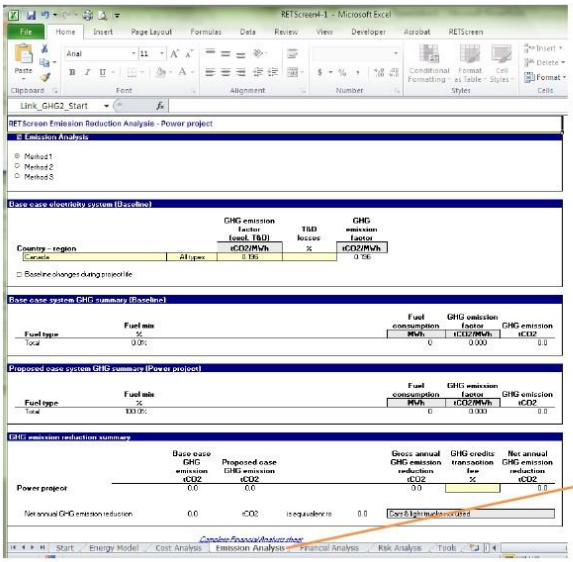
Shaded in "Yellow" are inputs required for energy calculations



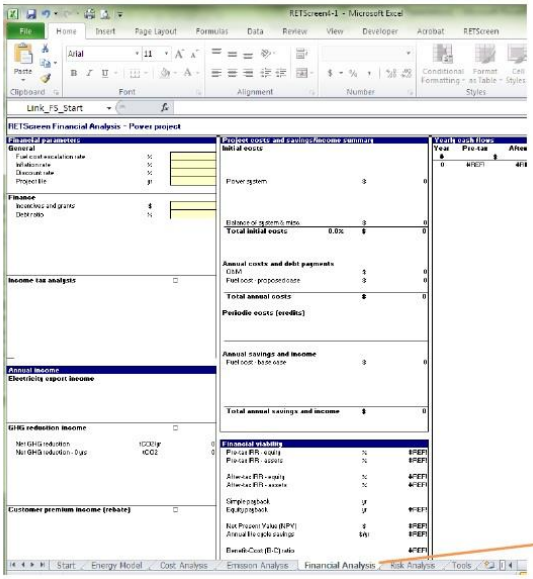
"ENERGY MODEL" worksheet collects data on renewable energy technology and the costs of energy offset.



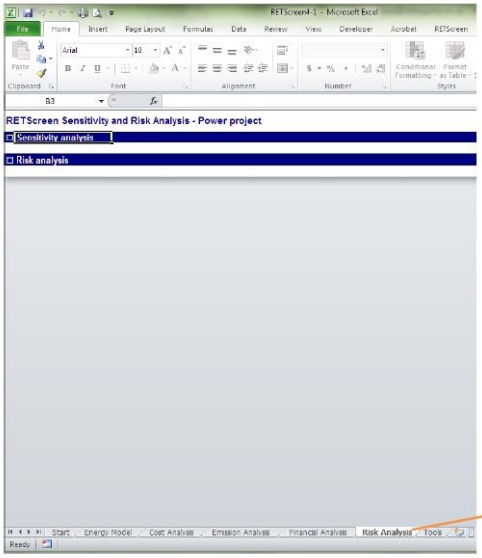
"COST ANALYSIS " worksheet collects data on CAPITAL and O&M Costs



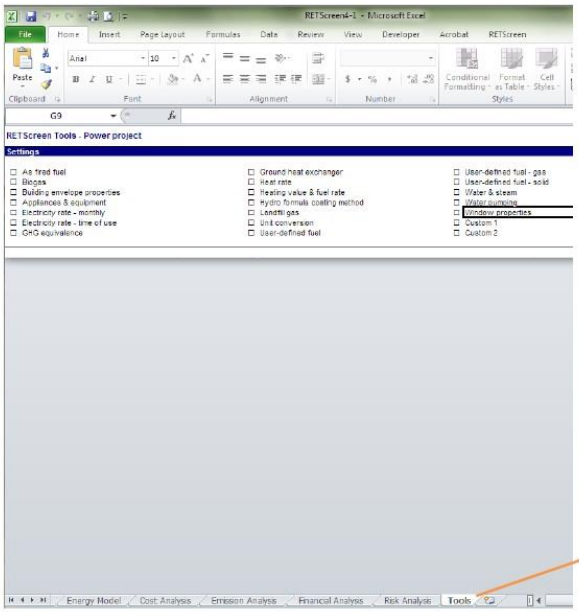
"EMISSION ANALYSIS" estimates the reduction in Greenhouse Gases (GHG)



"FINANCIAL ANALYSIS" summarizes overall costs, cost of energy offset, interprets fuel savings, calculates payback period and annual costs savings



"RISK ANALYSIS" allows for sensitivity and risk analysis on key financial parameters. These are optional and inputs on this worksheet to not impact the others



"TOOLS" allows users to input further details and calculations. This worksheet is optional.

Pre-Lab Homework:

Study about clean energy project analysis mechanisms. Install RETScreen 4 software and investigate existing case studies from the database.

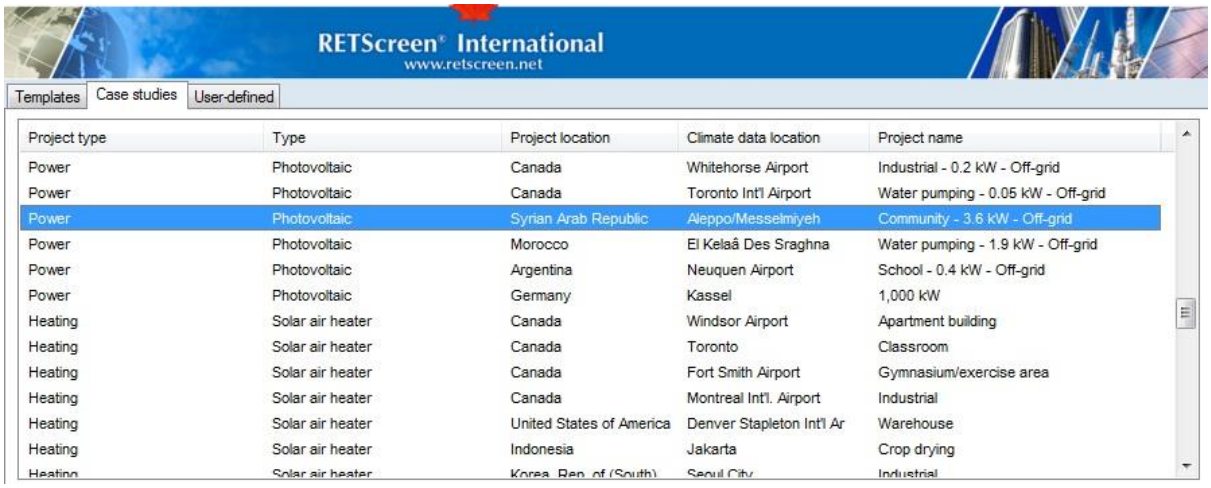
Apparatus:

Computer installed with RETScreen4 Software and necessary system requirements.

Experimental Procedure:

Part 1: Investigation of a Case Study: 3.6 KW Photovoltaic Power System in Syria

1. Run RETScreen 4 from your computer
2. Click on *See Project Database*
3. Under the Case studies tab select the case of Syrian Arab Republic - Community-3.6 kw-offgrid System



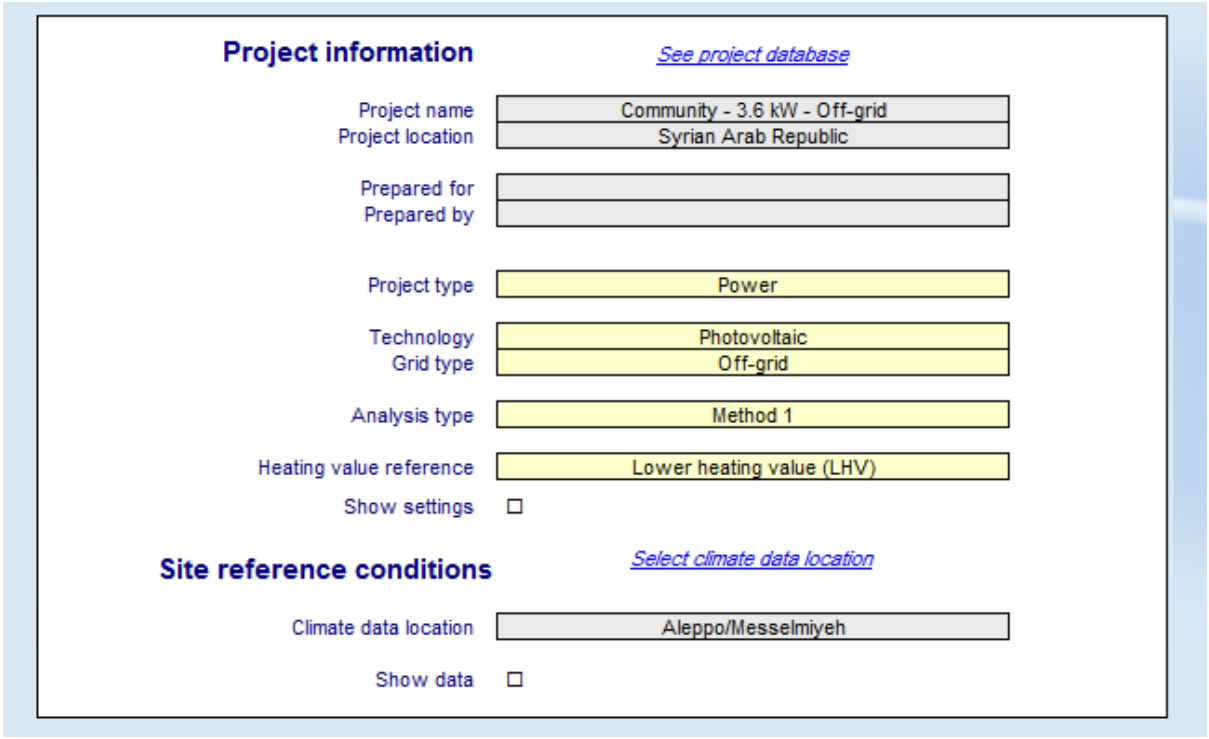
Project type	Type	Project location	Climate data location	Project name
Power	Photovoltaic	Canada	Whitehorse Airport	Industrial - 0.2 kW - Off-grid
Power	Photovoltaic	Canada	Toronto Int'l Airport	Water pumping - 0.05 kW - Off-grid
Power	Photovoltaic	Syrian Arab Republic	Aleppo/Messelmiyeh	Community - 3.6 kW - Off-grid
Power	Photovoltaic	Morocco	El Kelaâ Des Sraghna	Water pumping - 1.9 kW - Off-grid
Power	Photovoltaic	Argentina	Neuquen Airport	School - 0.4 kW - Off-grid
Power	Photovoltaic	Germany	Kassel	1,000 kW
Heating	Solar air heater	Canada	Windsor Airport	Apartment building
Heating	Solar air heater	Canada	Toronto	Classroom
Heating	Solar air heater	Canada	Fort Smith Airport	Gymnasium/exercise area
Heating	Solar air heater	Canada	Montreal Int'l. Airport	Industrial
Heating	Solar air heater	United States of America	Denver Stapleton Int'l Ar	Warehouse
Heating	Solar air heater	Indonesia	Jakarta	Crop drying
Heating	Solar air heater	Korea, Rep. of (South)	Seoul City	Industrial

4. Here is a small Summary of the Project-

- 3.6 KW Photovoltaic Power System
- 6 Households
- Syrian Arab Republic
- Peak load 2.4 KW
- Average daily load 8.4 kwh
- Installed cost of PV: US$ 6000 per kWp for array plus US$ 17000 for other equipment and installation
- Competing genset: US$ 1000 but consumes 13,400 L Diesel per year

Photo credit: Binu Parthan, IT Power India Ltd.

5. **START** Sheet: If you click the yellow tabs, you will find that there are different options in the drop down menu.

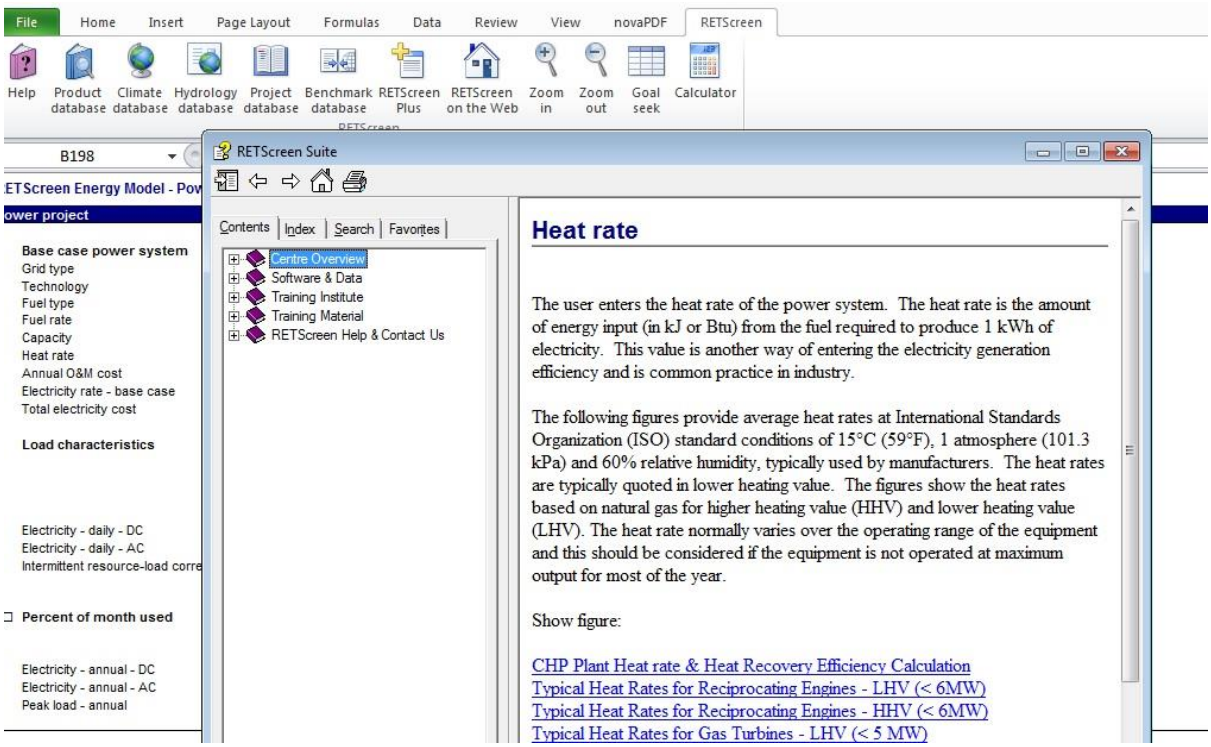


For Analysis type, Method 1 indicates 1 step analysis where Method 2 gives the scope for a detailed 5 steps analysis. First we will investigate the case using Method 1. The Project Information and Site reference conditions indicate different features of the project.

6. **Energy Model** Sheet: In the Energy Model sheet, firstly we can see that the following parameters are defined for the base case power system.

Base case power system			
Grid type		Off-grid	
Technology	Reciprocating engine		
Fuel type	Diesel (#2 oil) - L		
Fuel rate	$/L	0.150	
Capacity	kW	3.00	
Heat rate	kJ/kWh	167,716	
Annual O&M cost	$	0	
Electricity rate - base case	$/kWh	0.693	
Total electricity cost	$	2,126	

Here you can see that *Technology, Fuel type, Fuel rate, Heat rate and Annual O&M cost* are the variables. RETScreen provides very useful databases for the user. For example, if you do not know the definition of Heat Rate, you can just click on the term and then click on Help. The following window will appear.



The following figure indicates the Load characteristics. The user selects the intermittent resource-load correlation. The three options from the drop-down list are: "Negative," "Zero" and "Positive." "Negative" (i.e. negative correlation) corresponds to cases where the load is very irregular or occurs mostly when the resource is not available (e.g. at night in the case of a PV system). In this case, the model considers that the load is always met from the battery. A light used exclusively at night, for the PV system example, falls into this category. "Zero" (i.e. zero correlation) corresponds to steady loads. The model considers that the load is constant throughout the day and is met partly from the battery, partly directly by the power system without going through the battery. A cathodic protection system would fall into this category. "Positive" (i.e. positive correlation) corresponds to loads that are turned on only when there is enough electricity produced by the resource to power them directly. In this case, the model then considers that the load is met directly by the power system and the battery does not play a role.

Load characteristics

◉ Method 1
○ Method 2

	Unit	Base case	Proposed case
Electricity - daily - DC	kWh	0.000	0.000
Electricity - daily - AC	kWh	8.400	8.400
Intermittent resource-load correlation			Negative

The following window indicates the annual dc/ac load and peak load.

Percent of month used					
		Base case	Proposed case	Energy saved	Incremental initial costs
Electricity - annual - DC	MWh	0.000	0.000		$ -
Electricity - annual - AC	MWh	3.066	3.066	0%	$ -
Peak load - annual	kW		2.40		

Now under the proposed case, firstly parameters of different equipment are put in.

				Incremental initial costs
Inverter				
Capacity	kW	2.4	Peak load - annual - AC	$ -
Efficiency	%	90%		
Miscellaneous losses	%	0%		
Battery				
Days of autonomy	d	4.0		
Voltage	V	48.0		
Efficiency	%	85%		
Maximum depth of discharge	%	80%		
Charge controller efficiency	%	95%		
Temperature control method		Ambient		
Average battery temperature derating	%	2.9%		
Capacity	Ah	1,101	1,046	
Battery	kWh	53		$ -
Technology		Photovoltaic		

Then the solar PV positions are put in according to the geographic location.

Resource assessment		
Solar tracking mode		Fixed
Slope	°	45.0
Azimuth	°	0.0

You can also see the solar radiation data according to the location you have selected earlier.

Month	Daily solar radiation - horizontal kWh/m²/d	Daily solar radiation - tilted kWh/m²/d	Electricity delivered to load MWh
January	2.34	3.37	0.28
February	3.13	3.99	0.26
March	4.47	4.97	0.29
April	5.42	5.15	0.28
May	7.22	6.02	0.29
June	7.94	6.16	0.28
July	7.75	6.20	0.29
August	6.97	6.30	0.29
September	5.72	6.10	0.28
October	4.23	5.39	0.29
November	2.82	4.09	0.28
December	2.19	3.32	0.28
Annual	**5.03**	**5.09**	**3.39**

Annual solar radiation - horizontal	MWh/m²	1.83
Annual solar radiation - tilted	MWh/m²	1.86

The next section allows you to select the Photovoltaic Technology and its different features. You can also check the product database to select your particular panel.

Photovoltaic					
Type		mono-Si			
Power capacity	kW	3.60	150.0%		$ 30,327
Manufacturer		BP Solar			
Model		mono-Si - BP 250F		72 unit(s)	
Efficiency	%	11.4%			
Nominal operating cell temperature	°C	45			
Temperature coefficient	% / °C	0.40%			
Solar collector area	m²	31.5			
Control method		Maximum power point tracker			
Miscellaneous losses	%	0.0%			

And then you can see the summary of the proposed case-

Summary			
Capacity factor	%	19.9%	
Electricity delivered to load	MWh	3.39	110.6%
Peak load power system			
Technology		Not required	

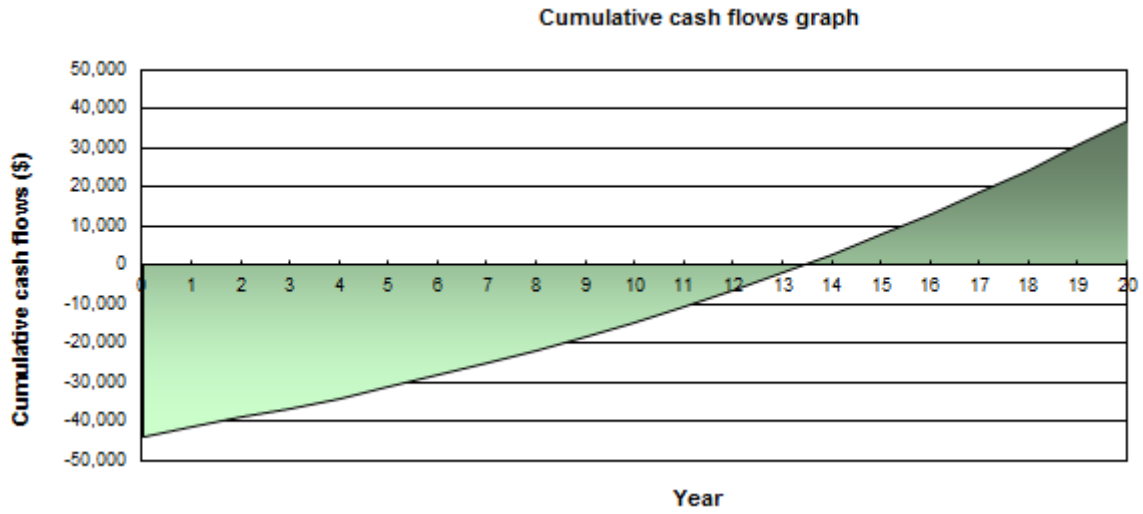
The next section shows the emission analysis. Here you can see that the net annual GHG emission reduction is equivalent to 7 cars and light trucks not used. It can also be compared with other examples from the dropdown menu.

GHG emission					
Base case	tCO2	38.0			
Proposed case	tCO2	0.0			
Gross annual GHG emission reduction	tCO2	38.0			
GHG credits transaction fee	%	0.0%			
Net annual GHG emission reduction	tCO2	38.0	is equivalent to	7.0	Cars & light trucks not used
GHG reduction income					
GHG reduction credit rate	$/tCO2	0.00			

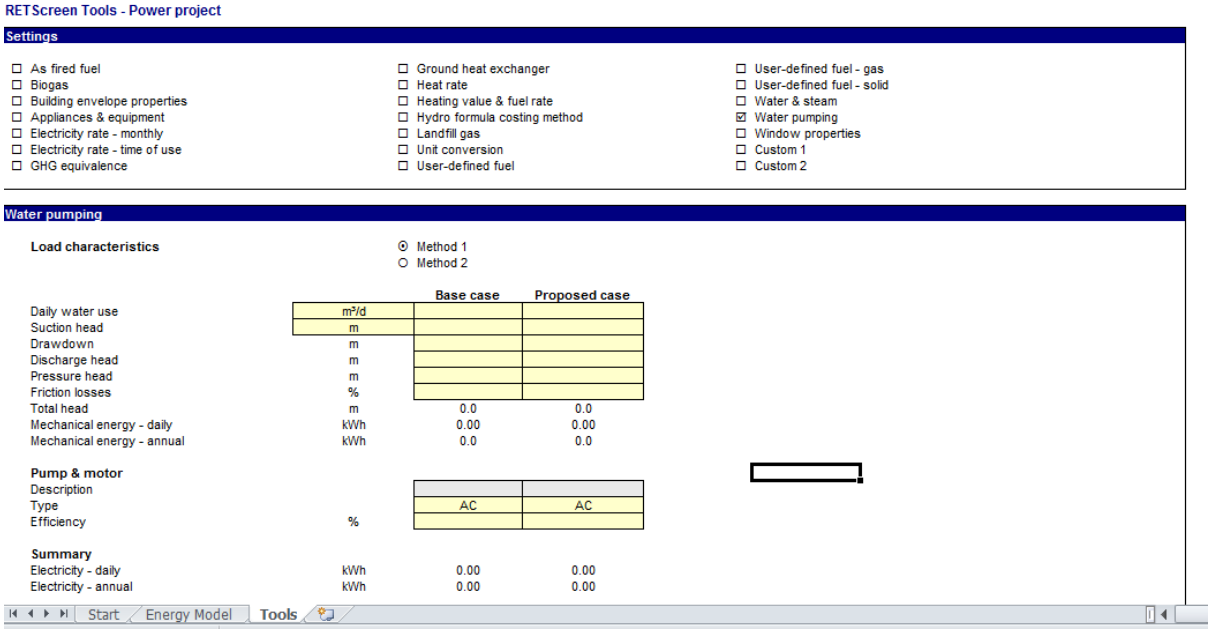
The financial section lets you put different financial parameters, costs, incentives etc. of the project.

Financial parameters		
Inflation rate	%	6.0%
Project life	yr	20
Debt ratio	%	0%
Initial costs		
Power system	$	30,327
Other	$	13,308
Total initial costs	$	43,635
Incentives and grants	$	
Annual costs and debt payments		
O&M (savings) costs	$	50
Fuel cost - proposed case	$	0
Other	$	
Total annual costs	$	50
Annual savings and income		
Fuel cost - base case	$	2,126
Other	$	
Total annual savings and income	$	2,126
Financial viability		
Pre-tax IRR - assets	%	5.5%
Simple payback	yr	21.0
Equity payback	yr	13.4

Here you can find that, the internal rate of return is 5.5% before tax, the simple payback period is 21 years and the equity payback (year number and the cumulative after-tax cash flows are considered) is 13.4 years. If the financial parameter inputs are changed, the financial viability will change accordingly. The following figure shows the cumulative cash flow graph for this case. It shows that the cash flow goes from negative to positive in 13.4 years.



7. **TOOLS** Sheet: It gives you the choice of putting any further inputs relevant to the project. For example, you can select water pumping and put the inputs of Load characteristics, machine specifications etc.



8. Now let's go back to the Start Sheet for Method 2 Analysis. You can find there are 5 sheets now for a detailed analysis. The **Energy Model** remains the same. In the **Cost Analysis** section, there are now different sections for Initial Costs, Annual Costs, Annual Savings and Periodic Costs. There are subsections like Feasibility, Development, Engineering etc. to give you the scope of a more elaborate cost analysis. In the **Emission Analysis** section you can now choose from three different methods to calculate the GHG emission. The **Financial Analysis** section now lets you have the scope of investigating the yearly cash flows and costs and savings income summary etc. In the **Risk Analysis** section you can perform the sensitivity analysis which shows what happens to the selected financial indicator (e.g. After-tax IRR - equity) when two key parameters (e.g. Initial costs and O&M) are varied by the indicated percentages. The risk analysis is performed using a Monte Carlo simulation that includes 500 possible combinations of input variables resulting in 500 values of after-tax IRR - equity, after-tax IRR - assets, equity payback or Net Present Value

(NPV). The risk analysis allows the user to assess if the variability of the financial indicator is acceptable, or not, by looking at the distribution of the possible outcomes.

Part 2: Design of a RES based system in the context of Bangladesh

Now we will design a Solar Plant in the context of Bangladesh. The system is based on an upcoming project of BPDB. The summary of the plan is given below-

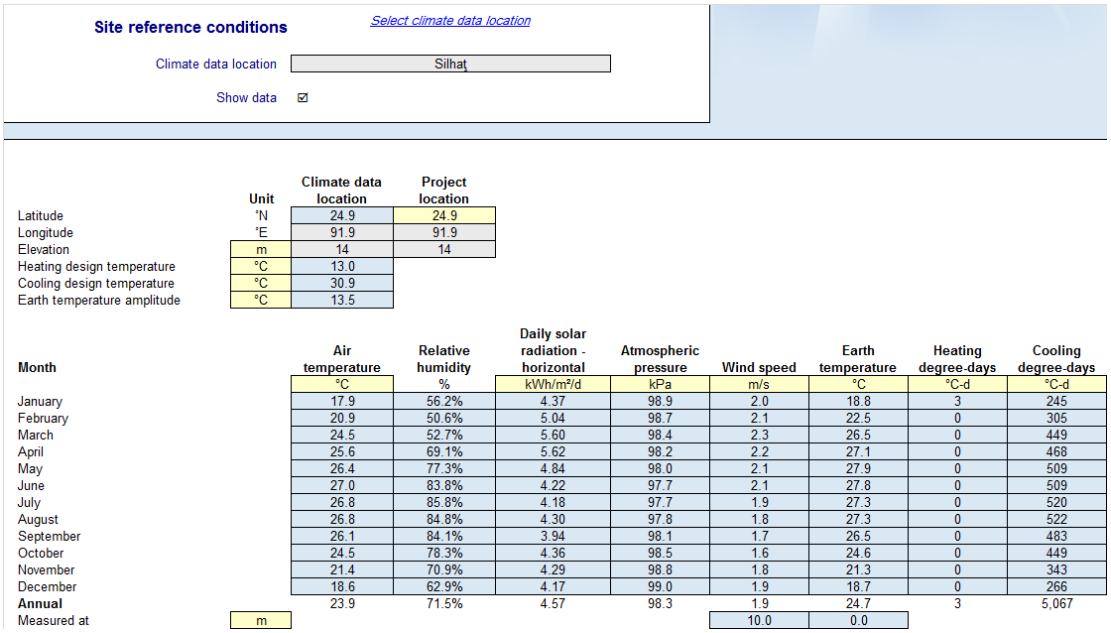
"The government will install the biggest solar power plant of the country at the haor areas of Sunamganj to provide electricity to about 900 families. The plant with a ***650 kilowatt peak*** *(kwp) capacity will be set up at Sulla upazila of the north-eastern district. Bangladesh Power Development Board (BPDB) inked a deal last week with Rahimafrooz Renewable Energy Ltd to construct the plant and associated distribution line at a cost of* ***Tk 24.5 crore****. The plant is expected to generate* ***400 kW load per day****, sufficient to meet a significant portion of the electricity demand of Aguai village of Habibpur union parishad in Sunamganj. The system will consist of* ***2,300 panels*** *of* ***280 watts****. A six-kilometre distribution line will be built to provide electricity connection to the area. The plant's per unit production cost is expected to be* ***Tk 30****, but customers will pay* ***Tk 4-8*** *depending on the amount they will consume as the government will provide subsidies on it. Rahimafrooz will maintain the first year operation of the plant, with BPDB to take over from then. The plant is expected to last about* ***20-25 years.****"* **[1]**

For simplicity we will consider Method 1 only. The Project Information is given below.

Project information *See project database*

Project name	Solar Micro Grid Power Plant
Project location	Sunamganj
Prepared for	AIUB EEE Department
Prepared by	Md. Nasimul Islam Maruf
Project type	Power
Technology	Photovoltaic
Grid type	Central-grid
Analysis type	Method 1
Heating value reference	Higher heating value (HHV)
Show settings	☑
Language - Langue	English - Anglais
User manual	English - Anglais
Currency	Bangladesh
Units	Metric units

The climate data location is Sylhet.



Site reference conditions *Select climate data location*

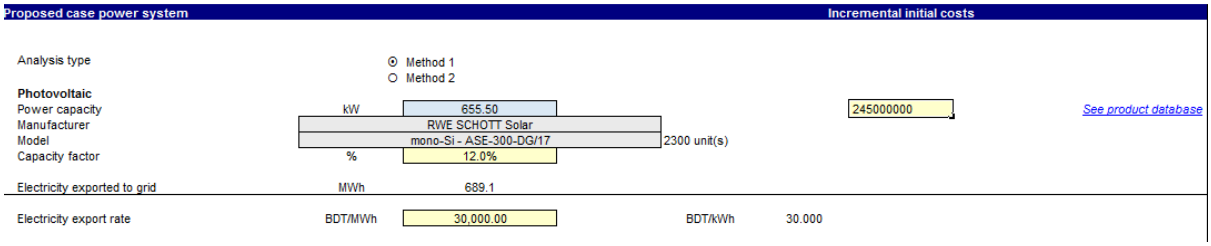
Climate data location: Silhat

Show data ☑

	Unit	Climate data location	Project location
Latitude	°N	24.9	24.9
Longitude	°E	91.9	91.9
Elevation	m	14	14
Heating design temperature	°C	13.0	
Cooling design temperature	°C	30.9	
Earth temperature amplitude	°C	13.5	

Month	Air temperature	Relative humidity	Daily solar radiation - horizontal	Atmospheric pressure	Wind speed	Earth temperature	Heating degree-days	Cooling degree-days
	°C	%	kWh/m²/d	kPa	m/s	°C	°C-d	°C-d
January	17.9	56.2%	4.37	98.9	2.0	18.8	3	245
February	20.9	50.6%	5.04	98.7	2.1	22.5	0	305
March	24.5	52.7%	5.60	98.4	2.3	26.5	0	449
April	25.6	69.1%	5.62	98.2	2.2	27.1	0	468
May	26.4	77.3%	4.84	98.0	2.1	27.9	0	509
June	27.0	83.8%	4.22	97.7	2.1	27.8	0	509
July	26.8	85.8%	4.18	97.7	1.9	27.3	0	520
August	26.8	84.8%	4.30	97.8	1.8	27.3	0	522
September	26.1	84.1%	3.94	98.1	1.7	26.5	0	483
October	24.5	78.3%	4.36	98.5	1.6	24.6	0	449
November	21.4	70.9%	4.29	98.8	1.8	21.3	0	343
December	18.6	62.9%	4.17	99.0	1.9	18.7	0	266
Annual	23.9	71.5%	4.57	98.3	1.9	24.7	3	5,067
Measured at	m				10.0	0.0		

Here in the proposed case power system, you can see that the initial cost is 2.45 crore. An approximately close PV panel has been selected from the product database (655.5 kW, 2300 units, with capacity factor of 12%.The capacity factor can be calculated through a more detailed analysis using method 2. Other parameters can also be analyzed using method 2). The electricity export rate is 30 BDT/kWh. 689.1 MWh electricity can be exported to the grid.



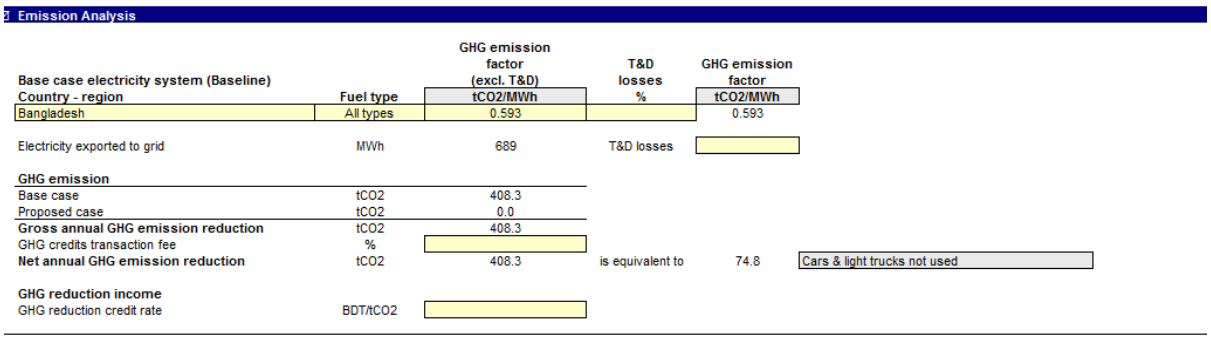
Proposed case power system — **Incremental initial costs**

Analysis type: ◉ Method 1 ○ Method 2

Photovoltaic

Power capacity	kW	655.50		245000000	*See product database*
Manufacturer		RWE SCHOTT Solar			
Model		mono-Si - ASE-300-DG/17	2300 unit(s)		
Capacity factor	%	12.0%			
Electricity exported to grid	MWh	689.1			
Electricity export rate	BDT/MWh	30,000.00	BDT/kWh	30.000	

In the emission analysis, you can select Bangladesh, and for all types of fuel the GHG emission factor is 0.593 by default. The calculation shows that GHG gas reduction is 408.3 tCO_2 from the plant, which is equivalent to 74.8 cars and light trucks not used.



Emission Analysis

Base case electricity system (Baseline) Country - region	Fuel type	GHG emission factor (excl. T&D) tCO2/MWh	T&D losses %	GHG emission factor tCO2/MWh
Bangladesh	All types	0.593		0.593
Electricity exported to grid	MWh	689	T&D losses	

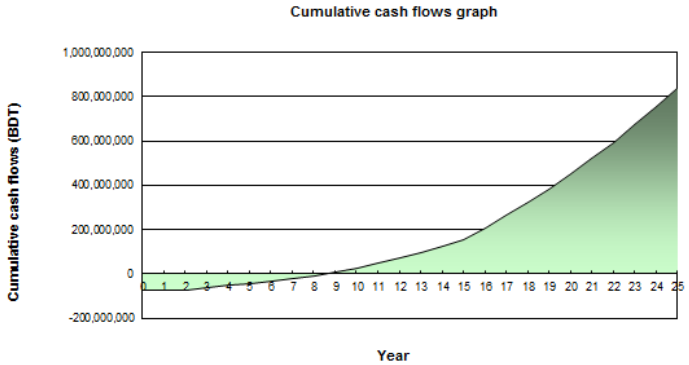
GHG emission					
Base case	tCO2	408.3			
Proposed case	tCO2	0.0			
Gross annual GHG emission reduction	tCO2	408.3			
GHG credits transaction fee	%				
Net annual GHG emission reduction	tCO2	408.3	is equivalent to	74.8	Cars & light trucks not used
GHG reduction income					
GHG reduction credit rate	BDT/tCO2				

In the financial analysis, the inflation rate has been considered to be 6%, project life is 25 years, debt ratio is 70% (ratio of debt over the sum of the debt and the equity of a project), debt interest rate is 7% for the term of 15 years.

From these calculations it is seen that the Internal rate of return is 18.1% for equity and 8.1% for assets. The simple payback period is 11.9 years and equity payback is 8.5 years. From these findings it can be said that the project is viable. Changing the inputs result in different rates of return and payback periods.

Financial Analysis

Financial parameters		
Inflation rate	%	6.0%
Project life	yr	25
Debt ratio	%	70%
Debt interest rate	%	7.00%
Debt term	yr	15
Initial costs		
Power system	BDT	245,000,000
Other	BDT	
Total initial costs	BDT	245,000,000
Incentives and grants	BDT	
Annual costs and debt payments		
O&M (savings) costs	BDT	
Fuel cost - proposed case	BDT	0
Debt payments - 15 yrs	BDT	18,829,778
	BDT	
Total annual costs	BDT	18,829,778
Annual savings and income		
Fuel cost - base case	BDT	0
Electricity export income	BDT	20,671,848
	BDT	
Total annual savings and income	BDT	20,671,848
Financial viability		
Pre-tax IRR - equity	%	18.1%
Pre-tax IRR - assets	%	8.1%
Simple payback	yr	11.9
Equity payback	yr	8.5



Conclusion: The RETScreen Software can be used to evaluate industrial, commercial, institutional, community, residential and utility applications for Wind, Small Hydro, PV, Biomass heating, Solar Heating (Air, Water and Passive), Heat pump and CHP project models. The students are advised to investigate at least one example of the existing case studies of different technologies available.

Report writing:

Design and Analyze a 5MW Grid-Connected Solar PV System in Kaptai, Rangamati, Bangladesh. At a module capacity of 220 Wp Kaptai plant will have a total of 22,728 modules which makes up an aggregate capacity of 5000 kWp. Five central inverters of 1000kW each would be required for the Kaptai site and a maintenance stock of spare parts can be kept on site. Total cost for the project is US$ 32.77 million. For other references please use the example stated in the Lab Manual.

Discussion and Conclusion:

Discuss your designed system for different financial scenarios. Also discuss the limitations of RETScreen software.

References:

[1] http://www.thedailystar.net/news/sunamganjs-haor-area-to-get-the-biggest-solar-power-plant

[2] http://www.nrcan.gc.ca/energy/software-tools/7465

[3] Introduction to RETScreen, Presentation at the 2014 NOFNEC, By: Chris Price, Bimose Tribal Council & Laura Sayers, Shibogama FNC, September 30, 2014