<응용기술논문 > **DOI http://dx.doi.org/10.3795/KSME-C.2016.4.1.011** ISSN 2288-3991(Online)

【특집섹션: ICT 와 지열에너지 융합】

Identifying, Prioritizing, Measuring and Verifying Clean Energy Solutions for Korea's Public Building Renewable Energy Obligation Policy

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(Received November 30, 2015 ; Revised January 5, 2016 ; Accepted February 3, 2016)

Key Words: RETScreen, Renewable Energy Obligation (REO), Energy Modelling, GSHP, Solar Thermal, Measurement and Verification, Monitoring Targeting and Reporting (MT&R)

Abstract: Under the Renewable Heat Obligation (RHO) public buildings in the Republic of Korea larger than 10,000 m^2 must achieve an 11% overall reduction to thermal energy consumption. Well intended solutions have been proposed. However, not all option is evaluated on the same basis, potentially resulting in incomplete or sub-optimal solutions. What's more once projects are implemented, there are inconsistencies in the methods used to measure and evaluate operating performance of the post-retrofit case. The RETScreen decision tools and methodology can be used by decision makers, policy developers, architects, engineers and community leaders to evaluate and select the most effective solutions for Korea's RHO needs.

1. Introduction

The Republic of Korea has implemented a Renewable Energy Obligation (REO) whereby public sector buildings larger than 1,000 m^2 must reduce their heating energy consumption by 15% in 2015 and at least 20% between by 2035. There are many commercially viable technologies and systems which may be suitable, however decision makers have questions like:

- Where do we start?
- How much will it cost?
- What's the best solution?
- Did the results meet expectations?
- How can we improve the results?

The RETScreen Clean Energy Project Analysis Software was developed by the Canadian Government, is freely available (www.retscreen.net), and is being used for clean energy project analysis in 222 countries. The software consists of two components:

1. RETScreen - which does pre-project analysis, and
2. RETScreen Plus – which does post-project analysis

Additionally, RETScreen Plus can be used by facility operators, managers and senior decision-makers to monitor, analyze, and report on key energy performance indicators in ground source heat pump(GSHP) systems. It can be used for Monitoring, Targeting & Reporting (MT&R), Measurement & Verification (M&V) and Energy tracking. The software has the ability to integrate near-real-time NASA satellite-derived weather data for all land points on the earth. This feature can be used to develop the energy performance baseline and also for adjustments to the baseline based on future weather factors.

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Fig. 1 ISO 50001 continuous improvement cycle

The RETScreen decision analysis software suite has evolved over 25 years of development by the Government of Canada. The underlying methodology conforms to continuous improvement best practices of the ISO 50001 Energy Efficiency Standard as illustrated in Fig 1.

The software suite includes:

- **RETScreen** – a clean energy planning and design tool, capable of assessing the energy impact, cost, financing options, greenhouse gas (GHG) impact and project risk for new and retrofit project situations.
- **RETScreen Plus** – an analytical tool to assess the performance of as-built projects (measurement and verification) or to improve their ongoing energy performance (monitoring and targeting).

While RETScreen can be used to Plan and Do a project, RETScreen Plus can be used to check the results and Act on making improvements. RETScreen is freely available[1], operates in 35 languages and is widely used for clean project analysis. RETScreen has been widely used for consistent evaluation of both renewable energy and energy efficiency project options. RETScreen includes robust energy model templates for almost all clean energy technologies, likely to be used for Korea's RHO including:

- Solar Thermal Heating (Air and Water),
- Ground Source Heat Pump,
- Air Source Heat Pump,
- Biomass
- Cogeneration and Trigeneration
- Energy Efficiency

2. Simulation Methodology

RETScreen has several steps to do renewable energy analysis as shown in Fig. 2 below:

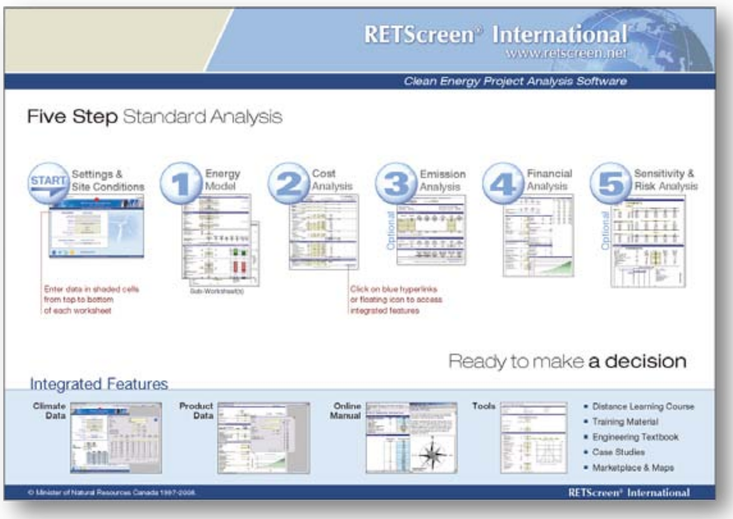

Fig. 2 RETScreen five step analysis

[1] Register and Download RETScreen from www.retscreen.net

RETScreen analysis starts by choosing the site or location where this project will be executed. RETScreen does the analysis based on the weather data that collected by NASA for the past 25 years all over the world. After that energy analysis can be performed followed by cost analysis, emission analysis and finally sensitivity & risk analysis.

On the other hand, as described before, RETScreen Plus does the post-project analysis with several of analysis types. RETScreen plus analysis helps user to monitor, analyze, and report key energy performance data to facility operators, managers and senior decision makers. Implementing an energy monitoring, targeting and reporting (MT&R) system can be a powerful way to better manage energy project investments as well as identify additional project opportunities. In addition, the measurement and verification (M&V) of actual savings (or production) achieved by a clean energy project is an important final step in the energy decision chain.

The practice of energy monitoring, targeting and reporting (MT&R) provides a systematic approach to gaining and maintaining control over energy consumption (or production) through measurement and analysis, followed by well-directed actions.

The key steps to effective MT&R are:

1. Measurement of energy consumption (or production) over time
2. Measurement of influencing factors (weather, production level, occupancy) over corresponding time intervals
3. Development of a relationship (a model) between energy and the influencing factors
4. Establishment of energy reduction (or production) targets
5. Frequent comparison of actual consumption (or production) with targets
6. Reporting of consumption (or production) and target variances
7. Initiation of actions to ensure targets are met

Energy cost savings (or energy production revenue) are the primary objective of MT&R systems. Other benefits include:

1. Improved budgeting and forecasting
2. Improved product/service costing
3. Tracking and verification of energy efficiency retrofits and energy production projects (e.g. photovoltaic electricity production)
4. Opportunity for improved operation and maintenance practices
5. Greenhouse gas (GHG) monitoring and verification
6. Waste avoidance

To help address this need on a global basis, RETScreen International, in collaboration with the Renewable Energy and Energy Efficiency Partnership (REEEP) and the NASA Langley Research Centre, has developed the RETScreen Performance Analysis Module. This energy management software tool, which integrates near real-time satellite-derived weather data from NASA for the entire surface of the planet, can be used worldwide to track a facility's actual energy performance versus predicted performance.

3. RETScreen Solution Analysis

The underlying energy models and calculation algorithms have been developed in collaboration with leading experts and institutes globally. RETScreen is regarded as an objective and unbiased tool and the model results have been accepted as mandated by organizations ranging from the World Bank[2], to the State of Texas, to the City of Toronto's Energy Office[3].

3.1 STEP 1 – PLAN

Selecting and planning for a renewable energy technology (RET) can be accomplished with RETScreen. For example, the selection of a GSHP design basis can be achieved with about 20 parameters using RETScreen. The user would enter information such as the project location, building dimensions, heating and cooling requirements, fuel rates, and cost factors for the GSHP and associated pipe and field as shown in Fig. 2.

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[2] World Bank reference

[3] City of Toronto Energy Efficiency Office

Heating project	Unit	
Base case heating system	Single building - space heating	
Heated floor area for building	m²	1,000
Fuel type		Natural gas - GJ
Seasonal efficiency	%	85%
Heating load calculation		
Heating load for building	W/m²	40.0
Domestic hot water heating base demand	%	10%
Total heating	MWh	82
Total peak heating load	kW	40.0
Fuel consumption - annual	GJ	349
Fuel rate	$/GJ	18.714
Fuel cost		$ 6,536
Proposed case energy efficiency measures		
End-use energy efficiency measures	%	0%
Net peak heating load	kW	40.0
Net heating	MWh	82

Fig. 2 Example of data entry for GSHP heating component

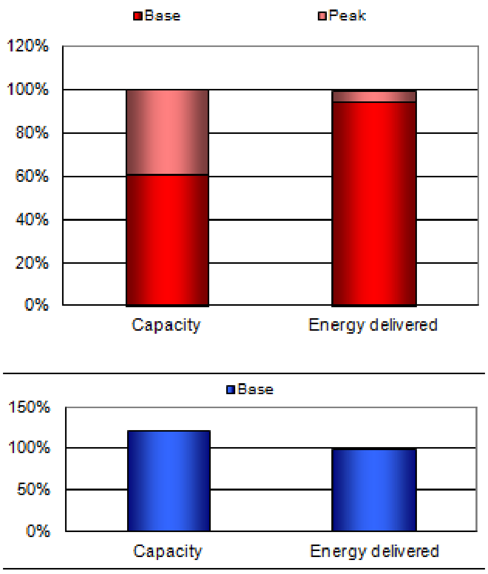


Fig. 3 Heating and cooling capacity and energy

With the heating and cooling requirements known, the GSHP component model of RETScreen is run. If additional capacity is required, the RETScreen model can be modified to include supplementary heating and cooling equipment. This model however uses an average value for COP. For the purpose of entering the COP value into the RETScreen software, it is preferable to determine the COP value best corresponding to the equipment part load ratio (PLR).

As the GSHP selection process is iterative in nature, RETScreen provides an estimate for the Peak Heating and Cooling Demand as well as the annual Heating and Cooling Energy requirements as shown in Fig. 3. The user can select different equipment makes and models using a built in library of operating parameters, or enter the required parameters in the appropriate part of the equipment specifications.

Once the optimal GSHP is selected to provide sufficient heating and cooling, supplementary equipment such as peak heating and cooling systems can also be selected. Cost components are entered using a standardized template consistent with best practices for cost estimation as shown in Fig. 4.

Initial costs (credits)	Unit	Quantity	Unit cost	Amount	Relative costs
Feasibility study					
Feasibility study	cost			$ -	
Subtotal:				$ -	0.0%
Development					
Development	cost			$ -	
Subtotal:				$ -	0.0%
Engineering					
Engineering	cost			$ -	
Subtotal:				$ -	0.0%
Heating system					
Base load - Heat pump	kW	24.3	$ 500	$ 12,150	
Peak load - Boiler	kW	16.0	$ 57	$ 914	
Energy efficiency measures	project			$ -	
				$ -	
				$ -	
Subtotal:				$ **13,064**	31.8%
Cooling system					
Base load - Heat pump	kW	30.5	$ 500	$ 15,250	
Energy efficiency measures	project			$ -	
User-defined	cost			$ -	
				$ -	
Subtotal:				$ **15,250**	37.2%
Balance of system & miscellaneous					
Spare parts	%			$ -	
Transportation	project			$ -	
Training & commissioning	p-d			$ -	
Ground Loop Installation	cost	1	$ 12,710	$ 12,710	
Contingencies	%		$ 41,024	$ -	
Interest during construction		6 month(s)	$ 41,024	$ -	
Subtotal:				$ **12,710**	31.0%
Total initial costs				$ **41,024**	100.0%

Fig. 4 Cost estimate screen from RETScreen

Financial viability		
Pre-tax IRR - equity	%	20.7%
Pre-tax IRR - assets	%	20.7%
After-tax IRR - equity	%	20.7%
After-tax IRR - assets	%	20.7%
Simple payback	yr	5.7
Equity payback	yr	5.2
Net Present Value (NPV)	$	49,896
Annual life cycle savings	$/yr	4,282
Benefit-Cost (B-C) ratio		2.22

Fig. 5 Financial output metrics from RETScreen

Next, the user would enter key project economic assumptions, financing characteristics and note any incentives or grants for the project. RETScreen would produce a comprehensive financial cash flow model and identify the key financial performance metrics like NPV, IRR, Benefit to Cost Ratio and Simple Payback as shown in Fig. 5.

Once the project is more or less finalized, RETScreen will compute the GHG impact of the project. This is done using standard CO2 emission factors for fossil fuels, or average annual emission factors for each country as published by the International Energy Agency (IEA). Alternatively the user can enter specific energy mix factors for a country to compute the average GHG emissions for electricity expressed in kg/kWh as shown in Fig.6.

Base case electricity system (Baseline) Fuel type	Fuel mix %	CO2 emission factor kg/GJ	CH4 emission factor kg/GJ	N2O emission factor kg/GJ
Natural gas	22.0%	49.4	0.0036	0.0009
Oil (#6)	3.0%	74.1	0.0029	0.0019
Coal	45.0%	92.7	0.0145	0.0029
Nuclear	29.0%	0.0	0.0000	0.0000
Hydro	1.0%	0.0	0.0000	0.0000
Biomass	0.0%	0.0	0.0299	0.0037
Wind	0.0%	0.0	0.0000	0.0000
Electricity mix	100.0%	153.5	0.0209	0.0044

Fig. 6 Average GHG emissions for electricity generated in Korea

Sensitivity analysis

Perform analysis on	After-tax IRR - equity
Sensitivity range	50%
Threshold	20 %

Fuel cost - base case		Initial costs				$
		20,512	30,768	41,024	51,280	61,536
$		-50%	-25%	0%	25%	50%
3,744	-50%	18.5%	7.5%	3.5%	1.1%	-0.6%
5,617	-25%	44.0%	20.2%	13.1%	9.4%	7.0%
7,489	0%	69.0%	31.3%	**20.7%**	15.5%	12.2%
9,361	25%	94.1%	42.1%	27.7%	20.9%	16.8%
11,233	50%	119.1%	52.8%	34.7%	26.1%	21.0%

Fuel cost - proposed case		Initial costs				$
		20,512	30,768	41,024	51,280	61,536
$		-50%	-25%	0%	25%	50%
1,275	-50%	86.1%	38.6%	25.5%	19.2%	15.4%
1,913	-25%	77.6%	34.9%	23.1%	17.4%	13.8%
2,550	0%	69.0%	31.3%	**20.7%**	15.5%	12.2%
3,188	25%	60.5%	27.6%	18.2%	13.5%	10.5%
3,825	50%	52.0%	23.8%	15.6%	11.4%	8.8%

Debt interest rate		Initial costs				$
		20,512	30,768	41,024	51,280	61,536
%		-50%	-25%	0%	25%	50%
0.00%	-50%	69.0%	31.3%	20.7%	15.5%	12.2%
0.00%	-25%	69.0%	31.3%	20.7%	15.5%	12.2%
0.00%	0%	69.0%	31.3%	**20.7%**	15.5%	12.2%
0.00%	25%	69.0%	31.3%	20.7%	15.5%	12.2%
0.00%	50%	69.0%	31.3%	20.7%	15.5%	12.2%

Fig. 7 Identifying risk elements with RETScreen

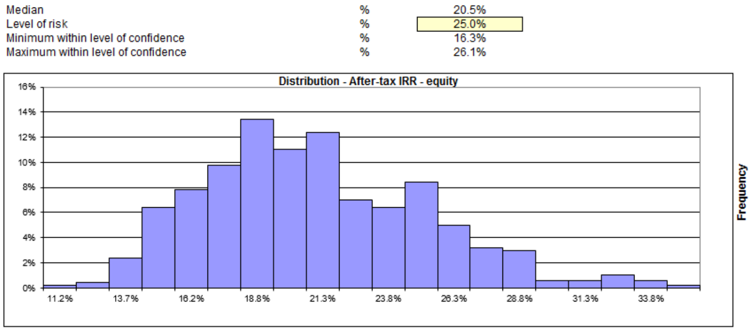


Fig. 8 Monte carlo simulation of risk

3.2 STEP 2 – DO

When a decision has been made to complete a more detailed feasibility study of a promising project, the RETScreen risk management tools can be used to identify and quantify the risk. As shown in Fig. 7, RETScreen produces various matrices quantifying the impact on a financial return parameter based on changes to an external factor such as fuel cost an interest rates.

The software can also develop a risk probability histogram to show best case, worst case and most likely case for the financial return metric. The underlying method uses Monte Carlo simulation for about 500 randomized "what-if" project scenarios as shown in Fig. 8.

3.3 STEP 3 – CHECK

Once the project is built and operating, daily, weekly or monthly data for energy performance should be recorded. Using RETScreen Plus, the near-real time historic weather information (air temperature, ground temperature, solar radiation, wind speed) can be automatically integrated from a NASA website link and incorporated into the baseline operating model which characterizes the behavior of the GSHP and external influences like outdoor temperature, building occupancy.

RETScreen Plus can be used to measure and verify (M&V) or to monitor and target (M&T) performance improvements. RETScreen Plus uses regression analysis in combination with statistical tools like Cumulative Sum of Variance (CUSUM) and Statistical Process Control (SPC) to identify changes and outliers to expected performance. The regression analysis is based on a cause and effect relationship between the energy consumption or production and the external influence. Fig. 9 illustrates the relationship between kW generated from solar PV and solar insolation.

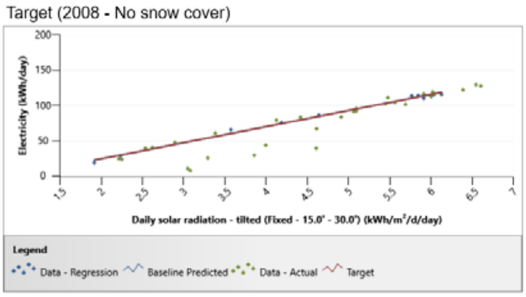
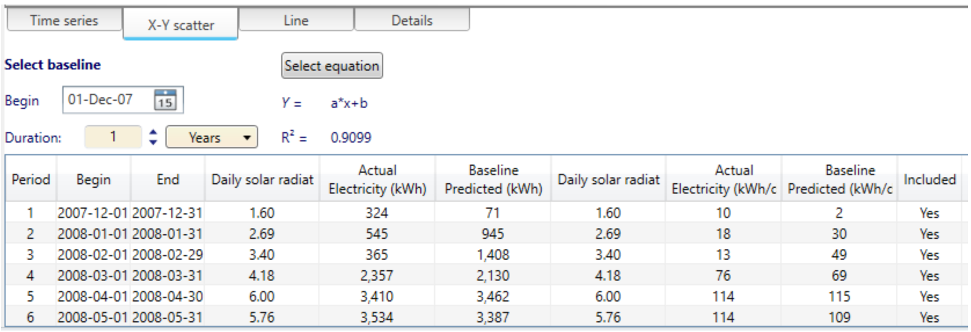


Fig. 9 Relationship between daily solar radiation and PV electricity production

Fig. 10 NASA weather data for Korea via RETScreen Plus



Period	Begin	End	Daily solar radiat	Actual Electricity (kWh)	Baseline Predicted (kWh)	Daily solar radiat	Actual Electricity (kWh/c	Baseline Predicted (kWh/c	Included
1	2007-12-01	2007-12-31	1.60	324	71	1.60	10	2	Yes
2	2008-01-01	2008-01-31	2.69	545	945	2.69	18	30	Yes
3	2008-02-01	2008-02-29	3.40	365	1,408	3.40	13	49	Yes
4	2008-03-01	2008-03-31	4.18	2,357	2,130	4.18	76	69	Yes
5	2008-04-01	2008-04-30	6.00	3,410	3,462	6.00	114	115	Yes
6	2008-05-01	2008-05-31	5.76	3,534	3,387	5.76	114	109	Yes

Fig.11 Example of regression analysis with RETScreen Plus

As solar insolation is dependent on the location, RETScreen Plus has a built in internet link to a NASA weather database with near real time daily weather parameters as shown in Fig. 10 for Korea.

Once the energy and weather data are entered, RETScreen Plus merges the files and proceeds to undertake a regression analysis. There are several regression functions built in from y=mx+b to several order polynomial equations as shown in Fig. 11.

The user can adjust for seasonality or spurious points and attempt to develop an equation with the most appropriate R^2 value.

3.4 STEP 4- ACT

The cumulative sum of the variance (CUSUM) is also generated by RETScreen. It shows the difference between

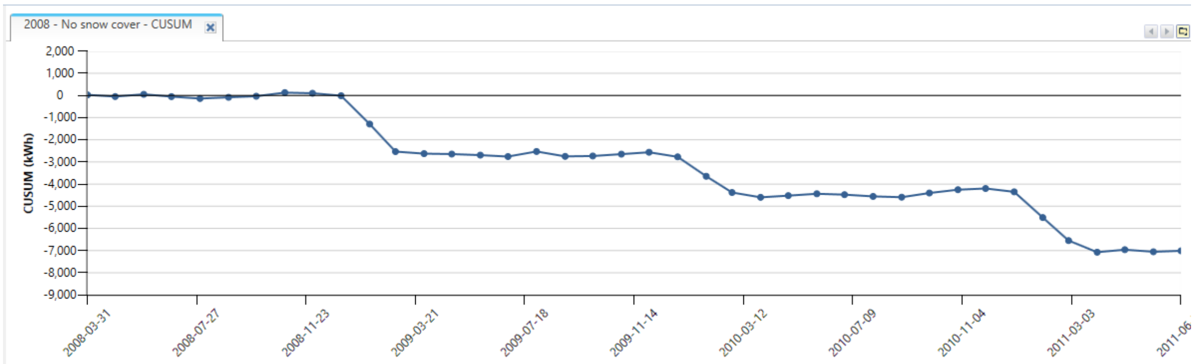


Figure 12 Quantification of lost production from snow cover on PV panels

the predicted or baseline energy consumption and the resultant energy consumption as a result of a change. The CUSUM line will slope downwards as energy efficiency improves, and slope upwards when energy efficiency decreases. A horizontal CUSUM line is one indicator that the system has been stabilized. Fig.12 is an example of the CUSUM line output from RETScreen.

Using curve-fitting and statistical methods like CUSUM the RETScreen Plus software can combine actual energy performance with near real time weather information from NASA. Figure 12 shows an example of using the CUSUM analysis to identify lost production on PV panels from snow cover. Using this methodology, the facility owner could decide if it would be cost effective to clean the panels after a snowfall.

4. Conclusion

The RETScreen and RETScreen Plus tools provide the ability to complete the Plan-Do-Act-Check cycle of best practices in the ISO 50001 standard. The software enables the user to access near real-time weather information which is a key component to the optimization process. It also provides powerful analytic tools for analysis and statistical validation of results using established M&V and Monitoring and Targeting techniques. The use of this methodology can assist Korea's public sector to achieve the national goal of using a higher amount of energy from renewable sources and also reducing the carbon emission impact.

Acknowledgement

This work was supported by the International Cooperation of the Korea Agency for Infrastructure Technology Advancement(KAIA)- and Korea Institute of energy Technology Evaluation and Planning(KETEP)- funded by the Korea Government Ministry of Knowledge Economy.(no.20133010111750)

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