

Green Campus Feasibility Study for Korea University

Hyun Wook Kim

Korea University

Yong Tack Oh

Korea University of Technology and Education

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Goal and Scope

- Goal
 - Estimation of the grid electricity cost for renewable energy penetration to college campuses
- Scope
 - HOMER simulation by estimated load profile
 - Selection of most effective renewable system configuration
 - Calculation of the portion of the renewables
 - Sensitivity analysis on Grid Electricity Price
 - Additionally, capital cost of the renewable sources

Campus Load Profile

- Available data: Real time measurement and display of the Campus

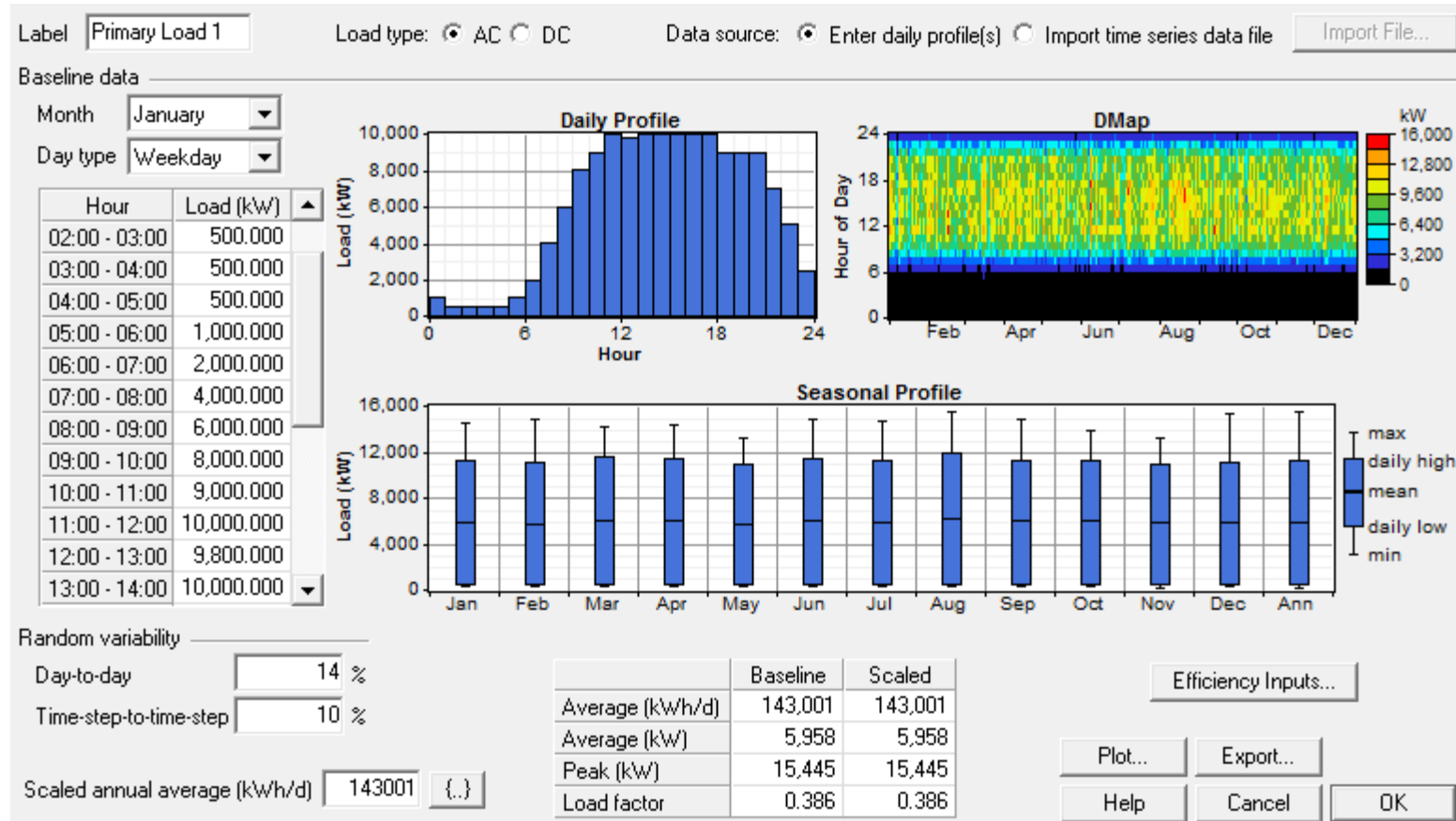


11:00 pm Jan 24, 2013

Ref) <http://kugc.korea.ac.kr/>

- Average Power Demand = 10,435 kW
- Peak Power Demand = 15,637 kW

Campus Load Profile



Site Information

□ Location:

Main campus of Korea
University (Seoul)

■ Latitude : 37.5846

■ Longitude : 127.02538

■ SWERA:

Solar & Wind data



HOMER Input for Solar Radiation

□ Solar data

Location

Latitude ° ' North South Time zone

Longitude ° ' East West

Data source: Enter monthly averages Import time series data file

Baseline data

Month	Clearness Index	Daily Radiation (kWh/m ² /d)
January	0.618	2.830
February	0.622	3.700
March	0.565	4.450
April	0.555	5.420
May	0.506	5.600
June	0.429	4.970
July	0.348	3.930
August	0.405	4.140
September	0.475	4.040
October	0.535	3.480
November	0.559	2.730
December	0.608	2.530
Average:	0.495	3.984

Scaled annual average (kWh/m²/d)

Global Horizontal Radiation

Daily Radiation (kWh/m²/d) Clearness Index

Plot... Export... Help Cancel OK

HOMER Input for Wind Speed

□ Wind data

Baseline data

Month	Wind Speed (m/s)
January	4.090
February	4.190
March	4.120
April	4.170
May	3.750
June	3.290
July	3.270
August	3.090
September	3.000
October	3.140
November	3.700
December	3.960
Annual average:	3.644

Wind Resource

Other parameters

Altitude (m above sea level)

Anemometer height (m)

Advanced parameters

Weibull k

Autocorrelation factor

Diurnal pattern strength

Hour of peak windspeed

Scaled annual average (m/s)

HOMER Input for Grid

- Grid power price : \$0.8/kWh
- Sellback rate : \$0.25/kWh

<별표 2-2> 태양광 전원의 용량 및 적용기간별 기준가격(원/kWh)

적용 시점	설치 장소	적용 기간	30kW 이하	30kW 초과 200kW 이하	200kW 초과 1MW 이하	1MW 초과 3MW 이하	3MW 초과
'11년	일반 부지	15년	484.52	462.69	436.50	414.68	349.20
		20년	439.56	419.76	396.00	376.20	316.80
	건축물 활용	15년	532.97	508.96	480.15	-	-
		20년	483.52	461.74	435.60	-	-

<별표 2-3> 연도별 기준가격 요금표(감소를 적용전원)

(단위 : 원/kWh)

차액지원개시일시점	풍력	연료전지	
		바이오가스 이용	기타연료 이용
2010년	103.04	214.05	257.87
2011년	100.98	207.63	250.13

Ref) 전기요금, 2013, 한국전력

Ref) 신재생에너지이용 발전전력의 기준가격 지침, 2010, 지식경제부

HOMER Input for Cost

□ Capital + O&M costs

- Photovoltaic \$5000 /kW
- Wind \$8000 /kW
- Battery \$400 /kW
- Fuel Cell (Electrolyzer + Hydrogen Tank) \$8000 /kW
- Converter \$0 /kW

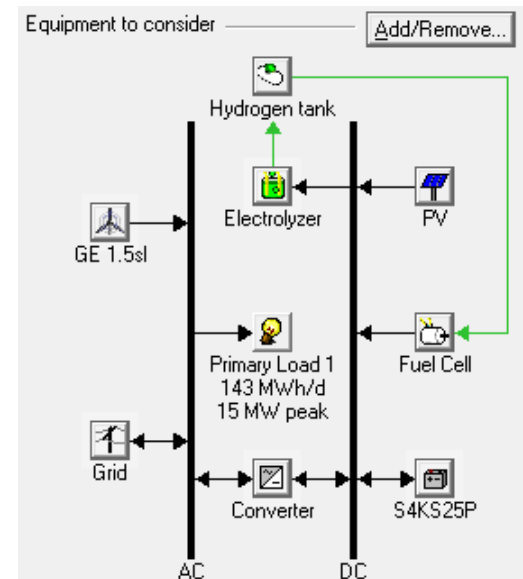
cf) Converter costs are included with the sources

□ Sensitivity Analysis values

- Grid power price : 0.4 0.8 1.0 2.0 3.0 4.0 5.0
[\$/kWh]

Optimal Configuration

- Grid alone is found to be the best
 - Under any and every condition



Sensitivity Results | Optimization Results

Double click on a system below for optimization results.

Rate W_2 Price (\$/kWh)	↑	↓	↕	↔	↔	PV (kW)	1.5sl	FC (kW)	S4KS25P	Conv. (kW)	Elec. (kW)	H2 tank (kg)	Grid (kW)	Initial Capital	Operating Cost (\$/yr)	Total NPC	COE (\$/kWh)	Ren. Frac.	Capacity Shorta...
0.040	↑	↓	↕	↔	↔								1000	\$ 1,000	318,930	\$ 3,659,096	0.040	0.00	0.95
0.500	↑	↓	↕	↔	↔								1000	\$ 1,000	3,986,619	\$ 45,727,204	0.500	0.00	0.95
1.000	↑	↓	↕	↔	↔								1000	\$ 1,000	7,973,238	\$ 91,453,408	1.000	0.00	0.95
2.000	↑	↓	↕	↔	↔								1000	\$ 1,000	15,946,475	\$ 182,905,...	2.000	0.00	0.95
3.000	↑	↓	↕	↔	↔								1000	\$ 1,000	23,919,712	\$ 274,358,...	3.000	0.00	0.95
4.000	↑	↓	↕	↔	↔								1000	\$ 1,000	31,892,950	\$ 365,810,...	4.000	0.00	0.95
5.000	↑	↓	↕	↔	↔								1000	\$ 1,000	39,866,184	\$ 457,263,...	5.000	0.00	0.95

Optimal Configuration

(optimization analysis)

Sensitivity Results Optimization Results

Sensitivity variables

Rate W_2 Power Price (\$/kWh) 0.04

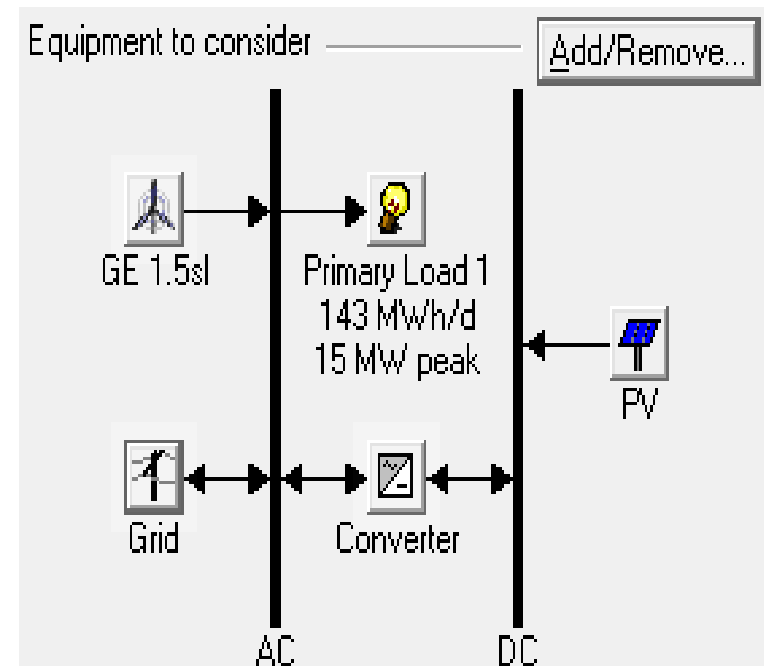
Double click on a system below for simulation results

	PV (kW)	1.5sl	FC (kW)	S4KS25P	Conv. (kW)	Elec. (kW)	H2 Tank (kg)	Grid (kW)	Initial Capital	Operating Cost (\$/yr)	Total NPC	COE (\$/kWh)	Ren. Frac.	Capacity Shorta...	FC (hrs)
								1000	\$ 1,000	318,930	\$ 3,659,096	0,040	0,00	0,95	
				36	30...			1000	\$ 577,000	368,255	\$ 4,800,859	0,052	0,00	0,95	
			200		30...	100		1000	\$ 40,001,...	310,027	\$ 43,556,988	0,476	0,00	0,95	0
			200	36	30...	100		1000	\$ 40,577...	359,353	\$ 44,698,752	0,488	0,00	0,95	0
	10...				30...			1000	\$ 50,001,...	2,809,364	\$ 82,224,184	0,351	0,64	0,71	
	10...			36	30...			1000	\$ 50,577,...	2,858,782	\$ 83,367,000	0,355	0,64	0,71	
		5						1000	\$ 60,001,...	3,384,223	\$ 98,817,768	0,759	0,34	0,88	
		5		36	30...			1000	\$ 60,577,...	3,434,068	\$ 99,965,488	0,767	0,34	0,88	
	10...		200		30...	100		1000	\$ 90,001,...	2,800,462	\$ 122,122,...	0,521	0,64	0,71	0
	10...		200	36	30...	100		1000	\$ 90,577,...	2,849,880	\$ 123,264,...	0,525	0,64	0,71	0
		5	200		30...	100		1000	\$ 100,001,...	3,375,320	\$ 138,715,...	1,065	0,34	0,88	0
		5	200	36	30...	100		1000	\$ 100,577,...	3,425,165	\$ 139,863,...	1,073	0,34	0,88	0
	10...	5			30...			1000	\$ 110,001,...	5,846,951	\$ 177,065,...	0,657	0,71	0,64	
	10...	5		36	30...			1000	\$ 110,577,...	5,896,991	\$ 178,215,...	0,661	0,71	0,64	
	10...	5	200		30...	100		1000	\$ 150,000,...	5,838,046	\$ 216,962,...	0,805	0,71	0,64	0
	10...	5	200	36	30...	100		1000	\$ 150,576,...	5,888,088	\$ 218,112,...	0,809	0,71	0,64	0

Renewable Portion

- Total load
 - About 15 MW peak
 - 143 MWh/day

- Generator
 - Wind $1.5\text{MW} * 5 = 7.5\text{MW}$
 - PV 10MW



Basic condition

□ Wind Turbine

- Capacity : $1.5\text{MW} * 5 = 7.5\text{MW}$
- Price : $\$8,000 / \text{kW} * 7.5\text{MW} = \$ 60,000,000$

Costs			
Quantity	Capital (\$)	Replacement (\$)	O&M (\$/yr)
5	60000000	6000000	25000

□ Photovoltaic

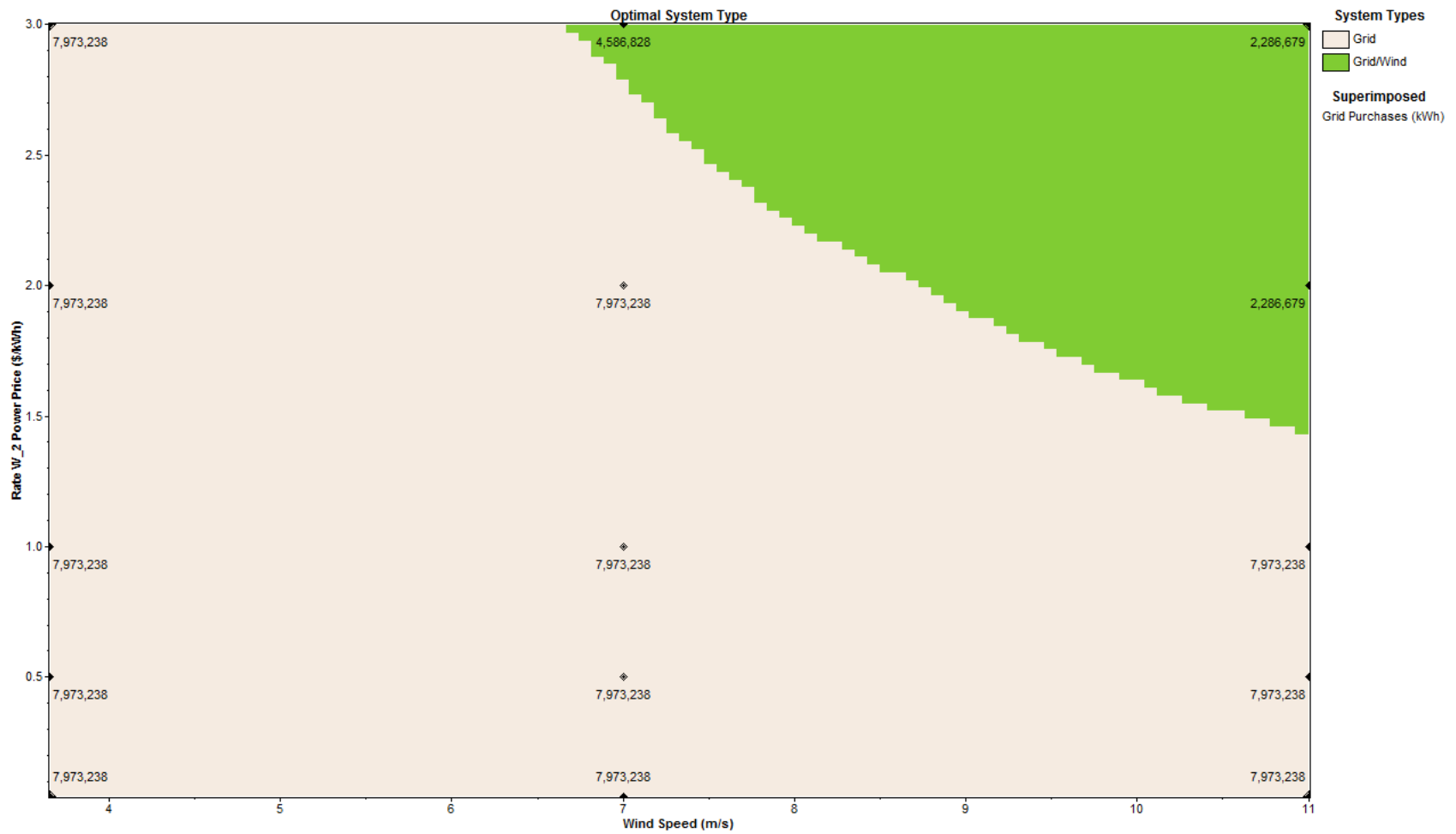
- Capacity : 10MW
- Price : $\$5,000 / \text{kW} * 10\text{MW} = \$ 50,000,000$

Costs			
Size (kW)	Capital (\$)	Replacement (\$)	O&M (\$/yr)
10000.000	50000000	5000000	50000

cf) Sensitivity Analysis

- Grid power cost 0.4 1 2 3 (\$/kWh)
- Wind speed 3.65 7.0 11.0 (m/s)

Basic condition – grid price



Condition 1

□ Wind Turbine

- Capacity : $1.5\text{MW} * 5 = 7.5\text{MW}$
- Price : $\$4,000 /\text{kW} * 7.5\text{MW} = \$ 30,000,000$

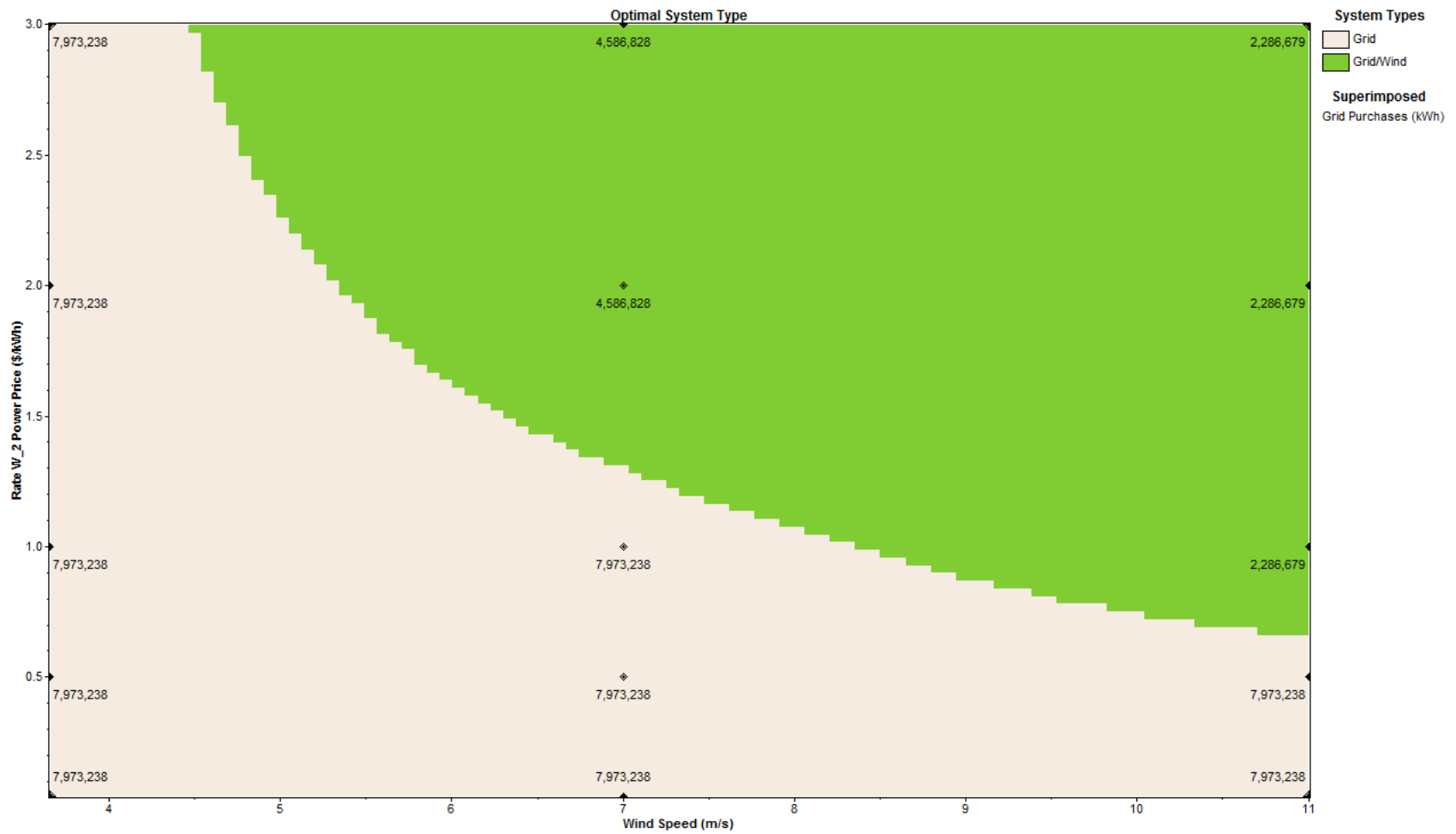
□ Photovoltaic

- Capacity : 10MW
- Price : $\$2,500 /\text{kW} * 10\text{MW} = \$ 25,000,000$

cf) Sensitivity Analysis

- Grid power cost 0.4 1 2 3 (\$/kWh)
- Wind speed 3.65 7.0 11.0 (m/s)

Condition 1



Condition 2

□ Wind Turbine

■ Capacity : $1.5\text{MW} * 5 = 7.5\text{MW}$

■ Price : $\$4,000 /\text{kW} * 7.5\text{MW} = \$ 30,000,000$

Quantity	Capital (\$)	Replacement (\$)	O&M (\$/yr)
5	30000000	600000	25000

□ Photovoltaic

■ Capacity : 10MW

■ Price : $\$1,000 /\text{kW} * 10\text{MW} = \$ 10,000,000$

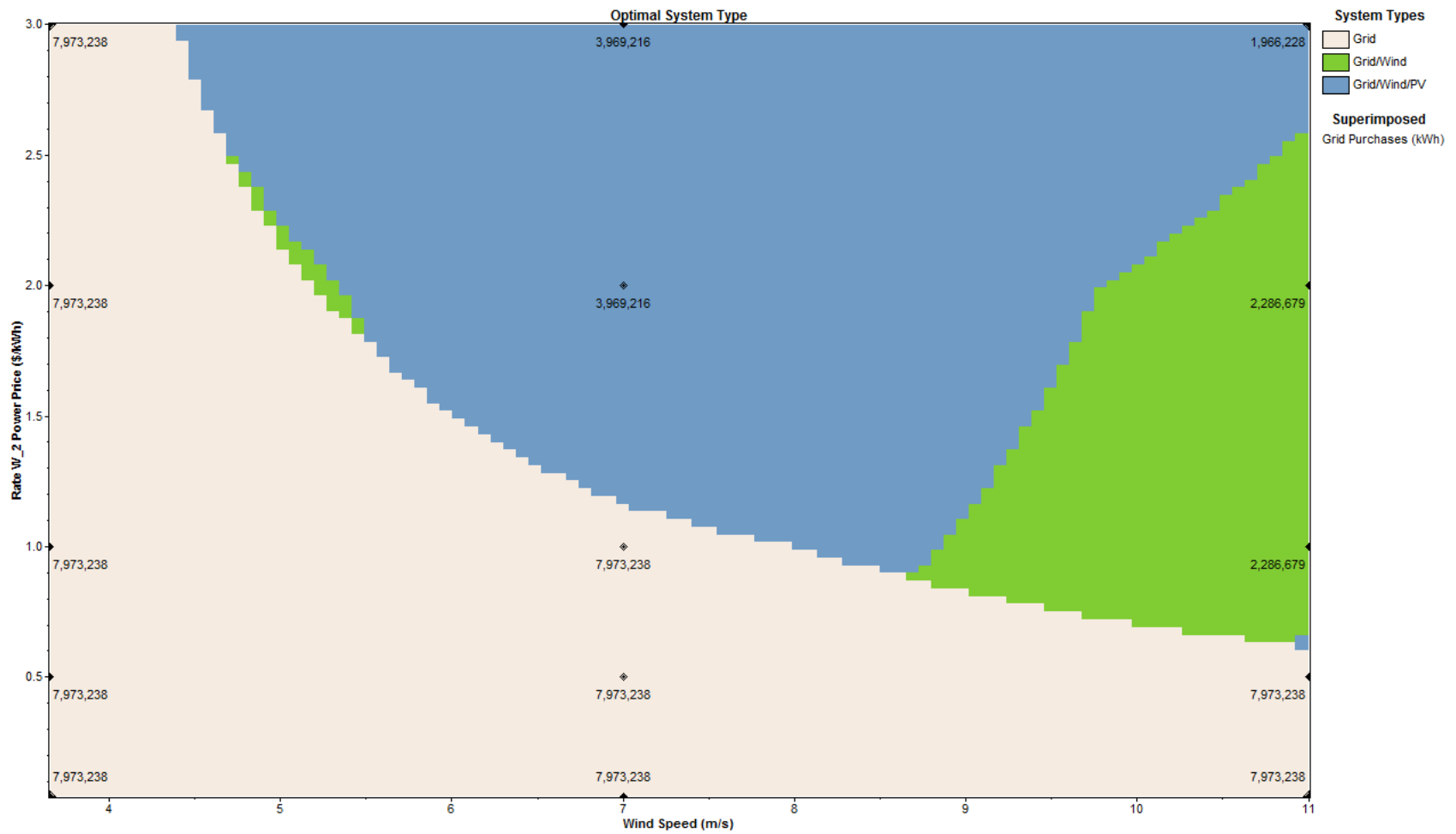
Size (kW)	Capital (\$)	Replacement (\$)	O&M (\$/yr)
10000.000	10000000	100000	50000

cf) Sensitivity Analysis

■ Grid power cost 0.4 1 2 3 (\$/kWh)

■ Wind speed 3.65 7.0 11.0 (m/s)

Condition 2



Condition 3 (dump case)

□ Wind Turbine

- Capacity : $1.5\text{MW} * 5 = 7.5\text{MW}$
- Price : $\$8,000 / \text{kW} * 7.5\text{MW} = \$ 60,000,000$

Quantity	Capital (\$)	Replacement (\$)	O&M (\$/yr)
5	60000000	6000000	25000

□ Photovoltaic

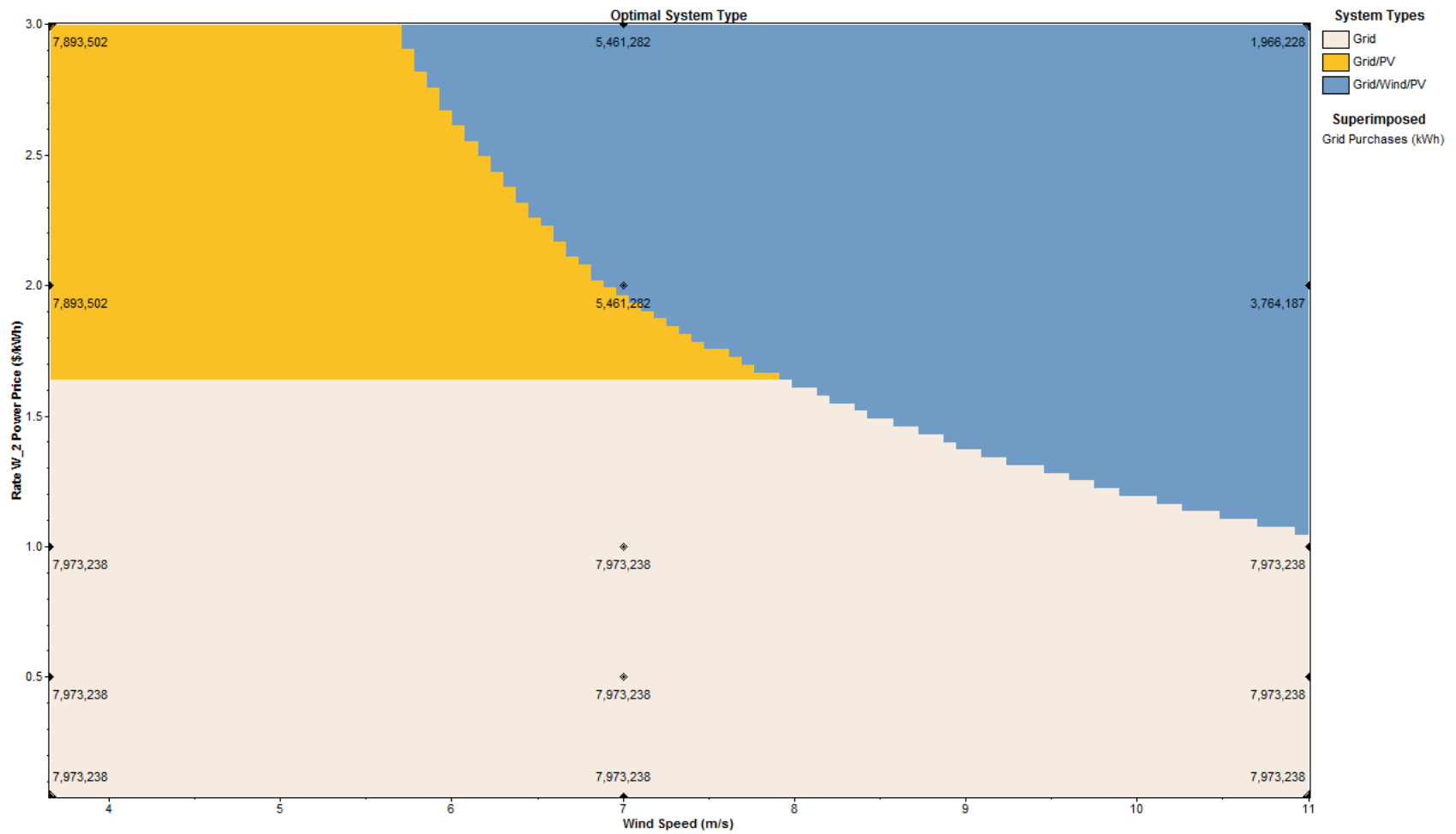
- Capacity : 10MW
- Price : $\$100 / \text{kW} * 10\text{MW} = \$ 1,000,000$

Size (kW)	Capital (\$)	Replacement (\$)	O&M (\$/yr)
10000.000	1000000	100000	50000

cf) Sensitivity Analysis

- Grid power cost 0.4 1 2 3 (\$/kWh)
- Wind speed 3.65 7.0 11.0 (m/s)

Condition 3 (dump case)



Conclusions

- ❑ Unless the grid electricity price is \$3.00/kWh, installation of renewable energy sources to Korea University is economically NOT viable (cf. the present price = \$0.4/kWh)
 - ❑ Government subsidy of renewable energy initial cost and of tax credits and other benefits would lower the barrier of renewable energy penetration to university campuses.
 - ❑ Carbon Emission Penalty and Tax policy would may further lower the barrier. (see the Conditions 1 and 2)
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THANK YOU.
