Methods to Assess the Technical, Economic, and Financial Feasibility of ‘Solar Cities’

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1. Introduction

In a transition toward a low-carbon and sustainable economy, a solar city project can be a viable option for a city to consider. Indeed, the solar city concept has been gaining greater attention in response to "dual energy and climate change challenges" (Byrne et al., 2015a, p. 830). Dramatically declining PV system costs and rapidly growing PV penetration rates across the world have strengthened the economic feasibility of solar city projects. Moreover, it is increasingly being recognized that the abundant rooftop space of mega-cities can be utilized as a power station for producing a substantial amount of electricity from PV modules.

Under these circumstances, the research team from the Center for Energy and Environmental Policy (CEEP) explored the possibility of implementing a solar city project by proposing an infrastructure-scale deployment of PV systems across a city's rooftop space. Using Seoul as a case study, this report explains the detailed methods used to model the solar city project. Specifically, this report provides detailed methods for:

1. Collecting data for calculating the rooftop area of a city's buildings;
2. Calculating the technical potential of a large-scale PV project using the city's rooftop area;
3. Identifying and collecting PV system costs for the city;
4. Constructing a bond yield curve to calculate the cost of capital required to build the large-scale PV project in the city;
5. Calculating the dollar amount of available policy-driven incentives, which can be used as a source of revenue from the solar city project, and;
6. Conducting a cost-benefit analysis to assess the economic feasibility of a solar city project.

This report relies on key idea and methods presented in Byrne et al., 2015a. It also draws heavily from internal documents and conference presentations that the research team has developed. This report comprises four sections, including Introduction. The second chapter explains the detailed methods for modelling a solar city project using Seoul as a case study, and outlines possibilities for improving the business case for the Seoul solar city project. The third chapter presents information collected to date for the currently ongoing research on the solar city projects for six cities – Amsterdam, London, Munich, New York City, Seoul and Tokyo. Detailed methods for modelling these solar city projects will be available in near future.

2. Methods for Modeling a Solar City Project Using Seoul as a Case Study

This chapter explains the methods for modeling a solar city project using the city of Seoul as a case study to provide readers with a comprehensive understanding of the solar city modeling methods that the research team developed. The team's analysis results show that the Seoul solar city project becomes economically viable in 14 years. Options to make the Seoul solar city project viable in 10 years are also discussed.

2.1. Methods for Calculating Total Rooftop Area of Buildings

To calculate the solar technical potential for Seoul, the research team adopted a complete census methodology that focuses on computing the entire rooftop area in the region (Schallenberg-Rodriguez, 2013; Byrne et al. 2015a). This method draws mainly from existing statistical datasets that contain building-based information including floor area, number of floors, and total number of buildings.

The research team first attempted to obtain total rooftop area estimates for the city or technical potential estimates of PV installations that are calculated based on rooftop area from a local agency. While complete census methodology provides a more accurate means of calculating total rooftop area than single sample methodology or multivariate sampling-based methodology (Schallenberg-Rodriguez, 2013; Byrne et al. 2015a), its accuracy can still be influenced by the quality of available datasets. To obtain the most definitive data on the rooftop area of Seoul, the team approached Seoul Institute (SI), a municipal policy research agency established by the Seoul Metropolitan Government. SI provided the team with a document that estimated the electric potential of one-third of Seoul's total rooftop area to be 47.09 TWh (see Appendix 1).

In the absence of an official rooftop area estimate for Seoul's total rooftop space, the research team identified available datasets for buildings in Seoul from the Korea Statistical Information Service (KOSIS) which is operated and maintained by the Korean government. Although KOSIS does not provide specific data on rooftop area, it provides metropolitan-level data on buildings by area, ownership, use, and floor. The team used KOSIS datasets that sorted buildings by use (Table 1) and floor (Table 2) to calculate the total rooftop area for Seoul.

The two datasets (building data by use and by floor) allowed the team to estimate the number of total floors of all buildings, as shown in Table 3. To estimate the number of total floors of all buildings, we assumed that a median number for each floor category is a representative number for each category.

For example, '3 floors' was chosen for the 2-4 floors category and used to calculate the total rooftop area for the category. The total numbers of floors of each floor category was then utilized to calculate an average area per unit floor (m^2/floor) by dividing the number of floors by the total area of buildings (605,444,189 m^2) as follows: 605,444,189 / 2,039,850 = 289 m^2/floor. On the assumption that the rooftop area is the same as the average area per floor, the team multiplied the average area per unit floor (289 m^2/floor) by the number of all buildings (646,891) to obtain the total rooftop area in Seoul (187,050,838 m^2).

Table 1: Seoul building data by use provided by KOSIS

Category	Number of buildings	Total area of buildings (m^2)
Residential	494,704	277,017,527
Commercial	129,391	157,170,562
Industrial	3,117	9,457,290
Educational and Social	15,562	51,180,728
Other	4,117	110,618,082
Total	646,891	605,444,189

Note: The 'Other' category includes public and indoor agro-fishery markets, according to KOSIS. This dataset is available under 'Statistical Database', 'Construction/Housing/ Land', and 'Buildings Census.'

Table 2: Seoul building data by floor provided by KOSIS

Floor	Number of buildings
1 floor	143,924
2 – 4 floors	414,488
5 floor	50,039
6 – 10 floors	21,124
11 – 20 floors	13,390
21 – 30 floors	2,973
≥ 31 floors	242
Total	646,891

Note: The KOSIS website contains an additional 'Other' column that is not included in the table above. The number of 'Other' buildings is 730, which is 0.1 percent of the total buildings in Seoul. The research team did not include this number in our calculations because it is a very small number when compared to the total numbers of buildings by 'floor' and no explanation was provided for this category. Source: Korea Statistical Information Service (KOSIS).

Table 3: Median number and total number of floors by floor category

Floor category	Median number	Number of floors
1 floor	1	143,924
2 – 4 floors	3	1,243,464
5 floors	5	250,195
6 – 10 floors	8	168,992
11 – 20 floors	15	200,850
21 – 30 floors	25	74,325
≥ 31 floors	50	12,100
Sum	-	2,039,850

2.2. Methods of calculating the electric potential of a large-scale rooftop PV project in Seoul

To take into account shading and other limitations which can reduce the electricity generated from rooftop PV, the total rooftop area must be converted into one suitable for PV installment. The research team estimated this area, often called PV suitable rooftop area, by applying suitability or utilization factors for Seoul[1]. Based on our review of the literature, we applied a factor of 0.39 to residential buildings (Peng et al., 2013; Byrne et al., 2015a) and a factor of 0.6 to commercial, industrial, educational/social, and public/agro-fishery buildings (Denholm et al., 2008; Byrne et al., 2015a).

Table 4 shows the total rooftop area of each use category, which was calculated by multiplying the total rooftop area (187,050,838 m^2) by the proportion of each use category's buildings area to total building area (605,444,189 m^2). A 5% of set aside was subtracted from the total suitability area (94,267,854 m^2) to reflect a national local law[2]. Then, we deducted Ground Coverage Ratio (GCR) and Service Area (SA) to take into account "panel-to-panel shading effects and service and maintenance requirements" (Byrne et al., 2015a, p. 836). The team assumed that PV panels are installed at a 5 degree tilt, at which GCR and SA are assumed to be 80% and 17%, respectively (Byrne et al., 2015a).

[1] Suitability or utilization factors can vary depending on shading and other limitations, including the characteristics of a city, the types of buildings it contains, and the duration of insolation time. Byrne et al. (2015a) summarize utilization factors used in a selection of the literature (See Table 3 on page 834).

[2] Korean construction law requires "every building which is both higher than 11 stories and has a total floor area of all stories above the 11^{th} floor greater than 10,000 m^2 to have a heliport installed on the roof" (Byrne et al., 2015a, p. 836).

Table 4: Suitable rooftop area and available rooftop area of each use category at 5 degree tilt

Use category	Total area of buildings (m^2)	Total rooftop area (m^2)	Suitability factor (%)	Suitable area (m^2)	Available rooftop area (m^2)
Residential	277,017,527 (45.8%)	85,584,041	39%	33,377,776	19,927,754
Commercial	157,170,562 (26%)	48,557,548	60%	29,134,529	17,394,380
Industrial	9,457,290 (1.6%)	2,921,812	60%	1,753,087	1,046,657
Educational/ Social	51,180,728 (8.5%)	15,812,189	60%	9,487,314	5,664,273
Other	110,618,082 (18.3%)	34,175,247	60%	20,505,148	12,242,324
Total	605,444,189 (100%)	187,050,083	50%	94,267,854	56,275,388

Note: The values in the suitable area and available rooftop area columns are estimated areas when GCR is 80% and SA is 17%.

Finally, the team calculated the technical potential for PV installments using System Advisor Model (SAM) software developed by the National Renewable Energy Laboratory (NREL). Using the final suitable area, the installed capacities (MW_p) were calculated assuming a module efficiency of 20% and solar radiation of $1kW/m^2$. Power outputs per installed capacity (MWh/MW) at a 5 degree tilt were also calculated using SAM software based on a conversion parameter derived from Seoul meteorological data. The potential electricity generation (GWh) can also be calculated manually by multiplying the installed capacity (MW_p) at a 5 degree tilt by power output per installed capacity (MWh/MW_p) and dividing the result by 1,000. Our calculation results report that Seoul can install 11,255 MWp of PV, which can generate 14.26 TWh of electricity (Table 5). At a 5 degree tilt, power outputs per installed capacity is 1,267.31 MWh/MW_p (Byrne et al., 2015a, p. 839).

Table 5: Technical potential for PV deployment for each use category

Use category	Peak capacity (MW_p)	Generation (GWh)
Residential	3,986	5,011
Commercial	3,479	4,409
Industrial	209	265
Educational and Social	1,133	1,436
Other	2,448	3,103
Total	11,255	14,264

Box 1: Another way to calculate power output per installed capacity

According to Byrne et al. (2015a), using "software like PV Planner is the easiest and most accurate way to estimate electricity output per PV installed capacity. However, these estimates can be calculated by using the following PV output formula:

$$P(T) = P(25°C) \times [1 - \beta/100 \times (T - 25°C)]$$

where P(T) is electricity output at a PV cell temperature at a given PV cell temperature, P(25°C) is electricity output at standard test condition temperature (25°C), β is the max power temperature coefficient(%/°C) of PV module, and T is a cell temperature at a given atmosphere temperature."

The solar city project has great load shaving potentials for Seoul. The 14.26 TWh accounts for 30% of the city's total daily electricity use and 66% of its electricity use during daylight hours. The figures that follow illustrate the load shaving effects the solar city project could have for the city in spring. Figure 1 shows the load profile of Seoul during a typical day in May. This load profile was constructed based on the data provided from personal communication with KEPCO[3].

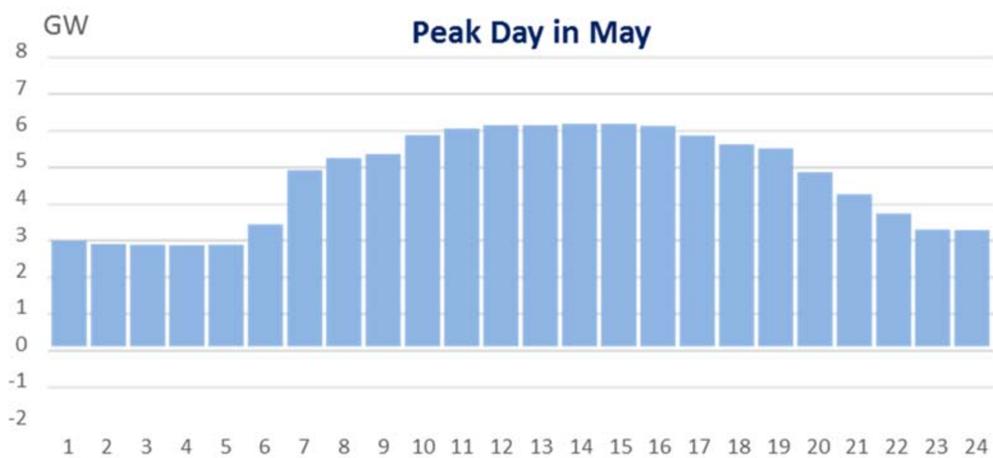

Figure 1. Electricity load profile of the city of Seoul during a typical day in May. Source: Byrne et al. 2015b.

[3] To assess contributions of the solar city concept, the research team calculated peak shaving potentials during daylight hours. Although monthly electricity demand data for the city of Seoul is publically available (Korea Electric Power Corporation, 2013, p. 138), hourly data, which is the most desirable level of data for evaluating peak shaving potentials, is not publicly available. The research team managed to obtain hourly data by directly requesting this information from KEPCO.

The research team assumed that Seoul has taken energy efficiency measures in the buildings across the city. Based on our review of the literature, we applied a 20% electricity savings from building energy efficiency measures to the load profile. The light blue areas in Figure 2 represent the electricity saved from the efficiency measures and the dark blue areas represent the remaining electricity that must be obtained from the grid.

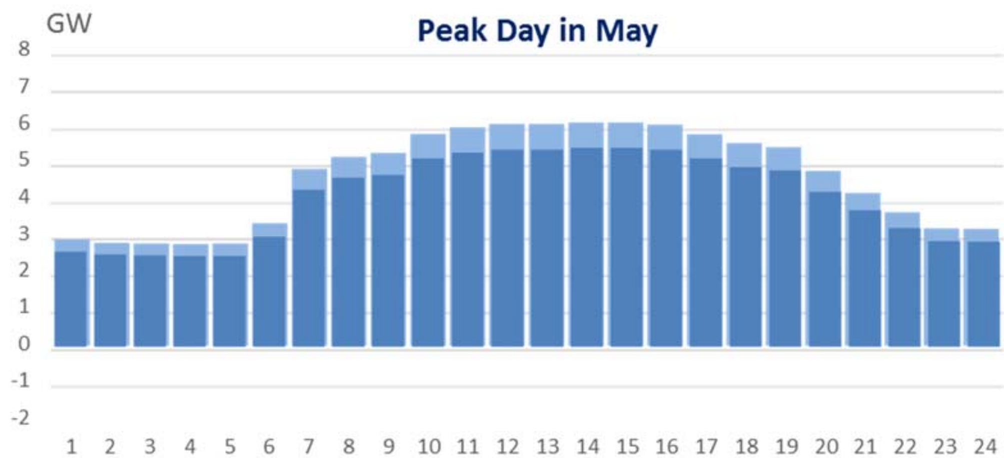

Figure 2. Electricity load profile (dark blue) after a 20% building efficiency improvement (light blue). Source: Byrne et al. 2015b.

A small portion of Seoul's rooftop area can provide a considerable amount of electricity. The dark green areas in Figure 3 represent the electricity which can be provided by installing PV on 32% of public buildings in Seoul.

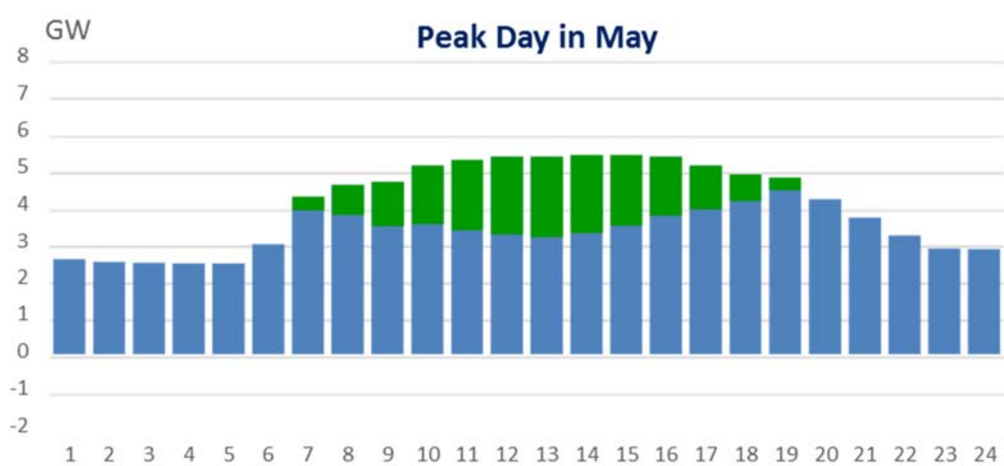

Figure 3. PV load shaving (green areas) resulting from the deployment of PV systems on 32% of the rooftop area of all public buildings. Source: Byrne et al. 2015b.

When 32% of Seoul's all building rooftop area is utilized for the deployment of PV systems, the solar city project is able to produce enough electricity to cover most of the daytime demand (light green) and can also produce extra electricity for five hours during the day (yellow), as shown in Figure 4. This extra electricity could either be fed into the grid or stored in batteries for later use.

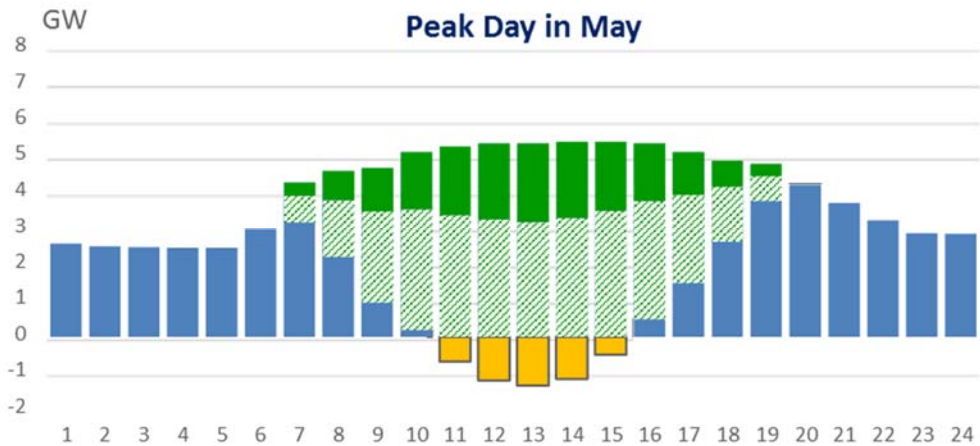

Figure 4. PV load shaving (dark green, light green and yellow areas) resulting from the deployment of PV systems to 32% of the rooftop area of all buildings. Source: Byrne et al. 2015b.

Similar load shaving effects can be found in August. The figures that follow illustrate peak shaving effects of the solar city project for Seoul in August when the city's electricity use is often the highest. Applying the same process used for the load profile analyses conducted for a typical day in May, the research team created the following four load profile graphs. Figure 5 shows the load profile for Seoul during a typical day in August. Although the load profile pattern is similar to that of May, electricity consumption during most of the day in August is greater, especially during the daylight hours.

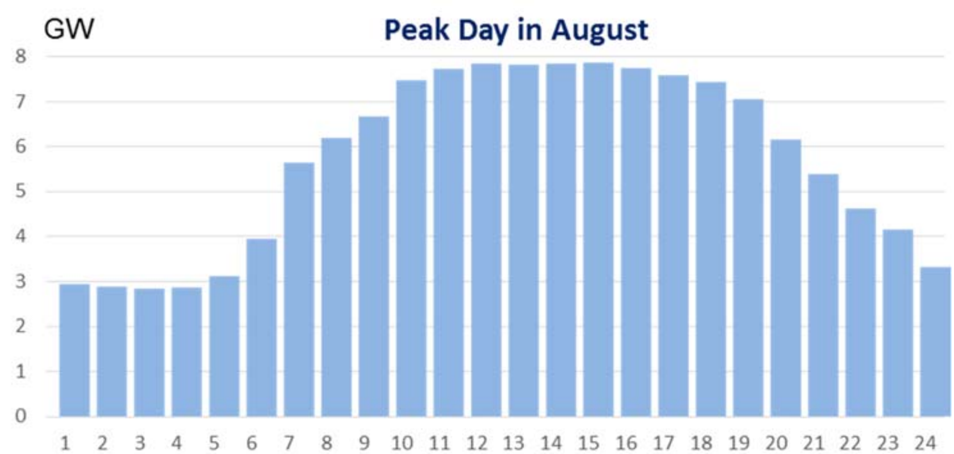

Figure 5. Electricity load profile of Seoul during a typical day in August. Source: Byrne et al. 2015b.

Like the peak shaving analyses for May, the research team assessed peak shaving effects of the deployment of PV systems across 32% of the rooftop area of all public buildings (green areas) and 32% of all buildings (light green areas)[4]. Figure 6 illustrates that the solar city project could supply a considerable amount of electricity to the city, and can provide more than half of the electricity consumed during daylight hours.

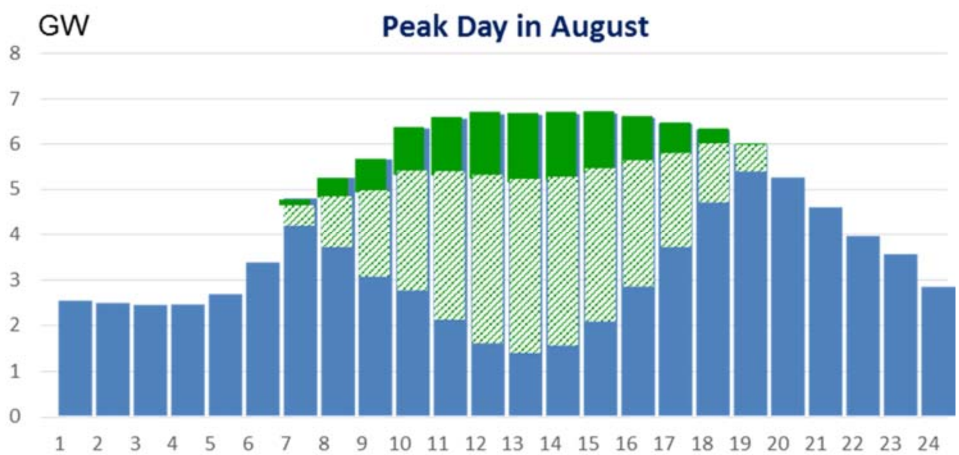

Figure 6. PV load shaving resulting from the deployment of PV systems on 32% of the rooftop area of all public buildings (dark green) and 32% of the rooftop area of all buildings (light green). Source: Byrne et al. 2015b.

2.3. Methods for collecting PV system costs and electricity retail rates

PV system costs and electricity retail rates are key inputs for the study's analysis, as this information allows for the computation of the essential financial metrics needed to gauge the feasibility of the various solar city strategies. Table 6 shows PV system costs and electricity retail rates used to analyze the feasibility of undertaking a solar city project in Seoul.

Table 6: PV system costs and Seoul electricity retail rates used for the study

Costs	Value (USD)
Turnkey installed system price ($/W)	2.30
System cost input ($/W)	2.45
Commercial electricity retail rate (cents/kWh)	11.6

The main source for installed PV system costs for Seoul ($2.30/W) was the 2014 International Energy Agency (IEA) PVPS trends report, which provides the costs of the PV systems (minus installation)

[4] Like the load shaving analyses for May, a 20% building efficiency reduction was also applied.

deployed in OECD countries, including South Korea. Being a major cost that impacts the cash flow of a PV project, the inverter replacement cost was also taken into account. The team assumed that inverters are covered under warranty for the project's entire lifetime although this is not normally the case (Feldman et al., 2014). The warranty cost was estimated as the current inverter cost of $0.223/W discounted at a rate of 3% for 13 years[5]. However, this estimate leaves out the potential negotiated benefits that are expected to be substantial at the discussed scale. In addition, the team used a rate of $20/kW per year to account for the operation and maintenance (O&M) costs of solar PV systems[6].

The commercial electricity retail rate is also a critical input, as a solar city project would involve substantial portions of the municipality being powered by PV. PV-generated electricity can result in electricity bill savings against an average commercial electricity retail price, creating a revenue stream equal to system output multiplied by the city's average commercial electricity retail price. To account for inflation, we assumed a 2% annual electricity escalation rate in Seoul based on the expectations outlined in the IEA World Energy Outlook and the EIA Annual Energy Outlook (International Energy Agency, 2014; U.S. Energy Information Administration, 2015). Data from KEPCO informed the rates for Seoul (Korea Electric Power Corporation, 2013, p. 144). Although the team uses a fixed annual electricity escalation rate of 2% for Seoul, city-specific annual electricity escalation rates can be estimated. For example, KEPCO provides nationwide historical average electricity prices for each sector in Korea, as shown in Table 7.

Table 7. Historical average electricity prices in South Korea (Unit: South Korean won/kWh)

Year	Residential	Public & Service	Educational	Industrial	Agricultural	Street Lighting	Mid-night	Total
2009	114.45	98.50	83.56	73.69	42.13	76.65	47.16	83.59
2010	119.85	98.93	87.23	76.63	42.54	81.13	50.49	86.12
2011	119.99	101.69	94.18	81.23	42.72	87.18	54.35	89.32
2012	123.69	112.50	108.84	92.83	42.90	98.89	58.65	99.10
2013	127.02	121.98	115.99	100.70	45.51	107.33	63.52	106.33

Source: Korea Electric Power Corporation (2014). Statistics of Electric Power in Korea. p. 144

5 A 3% discount rate was applied to overall cash flow calculations. Therefore, the research team also used 3% in the calculation of the warranty cost.

6 The research team identified a wide range of estimates for O&M costs but found that several sources seem to converge at a rate of around $20/kW per year.

Regarding PV installation configurations, the team assumed that all PV panels faced south and used optimized PV tilts of 22 degrees for Seoul as determined by SAM. We assumed a module efficiency of 20% and an inverter efficiency of 98.5%, as a large-scale application of a solar city strategy should be able to negotiate the purchase of state-of-the art equipment. PV module efficiencies in the market currently display even greater efficiencies. Furthermore, we applied a 90% power derate factor and a 0.5% degradation factor. Table 8 summarizes inputs for PV systems and installation configurations applied for Seoul.

Table 8: PV systems and installation configurations applied for Seoul

System configurations	Input	Source
PV module efficiency (%)	20	Assumption
PV array rated power (kWp)	100	Used for indicative purpose
PV module type	Mono-Crystalline	Assumption
Annual performance degradation (%)	0.5	Assumption
Slope of array (degree)	10	Tilt standardized across cities
Inverter efficiency (%)	98.5	Fraunhofer (2014)
Additional power derate factor (%)	90	Assumption
Direction of slope	South facing	Assumption

2.4. Methods for constructing a bond yield curve

An additional key input used in modeling solar city projects is financing costs data. Initiating an infrastructure-level strategy for municipal PV cannot proceed in the absence of a viable economic plan, and the cost of capital is a critical variable that affects the feasibility of solar city strategies. We considered the feasibility of various instruments that could finance infrastructure-scale solar PV projects in urban centers, as well as the availability of relevant data before ultimately opting to focus on bond financing. This decision was based largely on the benefits that bond financing has recently been demonstrating, and the difficulty of obtaining data for other financing instruments, e.g., loan interest data.

The research team estimated the cost of capital by establishing a bond yield curve for Seoul. As shown in Figure 7, the team constructed a bond yield curve to estimate the representative cost of capital for the city using a best fit polynomial curve. This curve reflects the borrowing rates by bond maturity. This allowed the team to establish borrowing costs of capital at each maturity. However, obtaining city-level bond data was difficult as the bond issuance volume proved too low to create a bond yield curve in Seoul. For example, the Seoul Metropolitan Government issued only one bond during the period of 2013-2014 (Korea Financial Investment Association Bond Information Service, 2015).

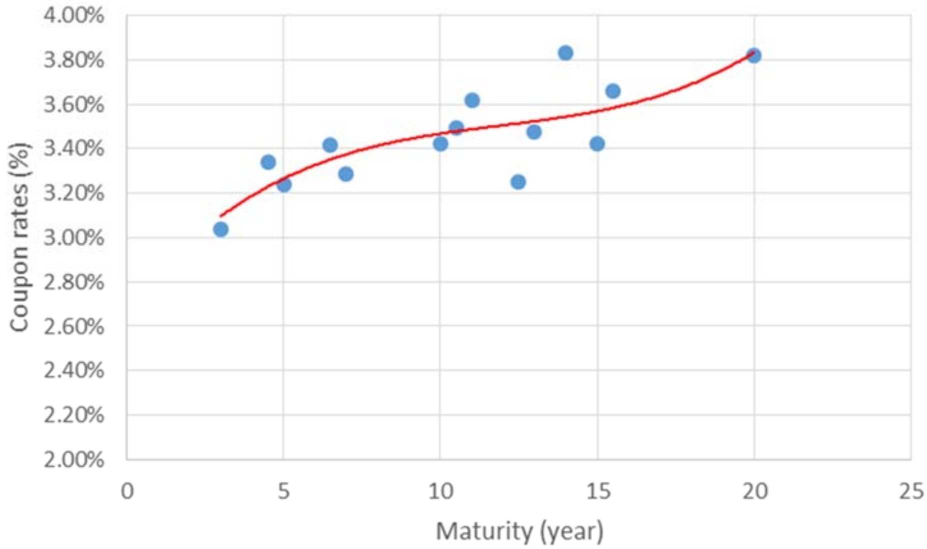

Figure 7: Revenue bonds issued by KEPCO and KOGAS during 2013-2014 and a bond yield curve using a best fit polynomial function.

Note: Each blue dot represents an interest rate and maturity for a revenue bond issued by KEPCO and KOGAS during 2013-2014.

Alternatively, bond data from KEPCO and the Korea Gas Corporation (KOGAS) were used to establish a bond yield curve for Seoul. KEPCO and KOGAS are publicly traded utilities, the largest shareholder of which is the Korean national government, which issue revenue bonds to finance large-scale energy projects. The research team identified 108 revenue bonds issued by the two utilities in 2013 and 2014 (Appendix 3 and Appendix 4). The maturities and coupon rates of these bonds range from 3 to 20 years and 2.73% and 3.97%, respectively. Weighted averages were applied to the coupon rates to reflect the issue sizes of these bonds. Table 9 shows the coupon rates by maturity after the weighted averages were applied. Using the polynomial functions established through polynomial curve fitting, the costs of capital can be calculated by maturity, as shown in Table 10.

Table 9. Weighted average bond coupon rates by maturity used to construct a bond yield curve for Seoul

No	Maturity (years)	Coupon rate (%)
1	3	3.04
2	4.5	3.34
3	5	3.24

4	6.5	3.42
5	7	3.29
6	10	3.42
7	10.5	3.49
8	11	3.62
9	12.5	3.25
10	13	3.48
11	14	3.83
12	15	3.42
13	15.5	3.66
14	20	3.82

Note: Original sources of the bond information in Table 9 are available in Appendix 3 and Appendix 4, which include issue dates, maturity dates, issue size, remaining times, coupon types, and coupon rates for the bonds issued by KEPCO and KOGAS. The list of bonds in the table above rearranged according to maturity of the two utilities. Source: Korea Financial Investment Association Bond Information Service portal

Table 10: Bond maturities and cost of capital for Seoul

Maturity (year)	Cost of capital (%)	Maturity (year)	Cost of capital (%)
1	2.74	11	3.50
2	2.96	12	3.53
3	3.09	13	3.56
4	3.18	14	3.58
5	3.25	15	3.60
6	3.31	16	3.62
7	3.36	17	3.64
8	3.40	18	3.66
9	3.44	19	3.68
10	3.47	20	3.70

2.5. Methods for calculating policy-driven incentives

Policy incentives comprise the final inputs used in our calculations. These were particularly critical inputs in light of our assumption that PV electricity can create city-wide electricity bill savings against average commercial electricity retail prices. In other words, the research team assumed that all electricity generated from city-wide PV installations is available for self-consumption. As a result, PV electricity generation in a city creates a revenue flow equal to a product of output and the city's commercial electricity retail price. Policy incentives were also assumed to be held in place for a ten-year period due partly to the rapid decline in PV system prices.

The research team identified the major policies that currently support PV electricity in Seoul and calculated the value of these policy incentives in $/kWh. Seoul relies primarily on nation-wide renewable portfolio standards (RPS) and a city-specific subsidy program of 10 cents/kWh to support small-scale solar PV. Therefore, both the national SREC market price of 12.6 cents/kWh and the local feed-in tariff (FIT) payment of 10 cents/kWh were used; however, it was also assumed that the local FIT is only available for the first 10 MWp of the installation and that the national SREC market prices will de-escalate at a rate of 3% per year (Table 11). We relied mainly on the SAM to calculate the dollar amount of incentives per unit of electricity. However, this also can be manually calculated by aggregating the dollar amount of incentives and dividing the result by the total amount of electricity generated during a system's lifetime.

Table 11: Inputs used to calculate policy benefits for PV electricity in Seoul

Variables	Inputs
Solar renewable electricity certificate price (cents/kWh)	12.6
De-escalation rate for SREC price (percent/year)	3
Feed-in tariff price (cents/kWh)	10

Note: The local FIT is only available for the first 10 MWp of the installation.

2.6. Measuring economic feasibility: cost-benefit analyses and results

The research team analyzed the economic feasibility of a large-scale PV deployment project for Seoul using various financial assessment tools, such as the payback period (PBP), the benefit-cost ratio (BCR), and the net present value (NPV) of the project. This report discusses a detailed step-by-step process for calculating the BCRs of the project. Table 12 presents these BCRs, which are the result of dividing cumulative revenues by cumulative costs from the start and end of the system year of the solar city project.

To evaluate the BCR of the entire project, we developed a formula for calculating cumulative revenues and cumulative costs as below:

$$\textit{Cumulative revenue at } Y_n = \textit{Cumulative revenue at } Y_{n-1} + \textit{Energy bill savings at } Y_n + \textit{Policy benefits at } Y_n$$

Energy bill savings at Y_n is the product of electricity generated at Y_n (kWh/year) and the retail electricity rate ($/kWh). The future value of the inflation rate and policy benefits at Y_n is equal to the sum of revenues from both the national SREC market and the local FIT payment[7] (Table 11). Electricity generated at Y_n (kWh/year) is the product of electricity generated at Y_{n-1} (kWh/year) and 99.5 percent (One minus the annual performance degradation rate). Electricity generated from the PV system during the first year is the product of the typical meteorological year for Seoul and PV system size. Table 13 summarizes these Seoul-specific and assumed inputs used to calculate the cumulative revenue from the solar city project.

Table 12: Benefit-cost ratios of the Seoul solar city project

System year	Cumulative costs ($)	Cumulative revenues ($)	Benefit-cost ratio
1	31,791	26,973	0.84
2	63,992	54,067	0.84
3	96,066	81,285	0.85
4	128,192	108,632	0.85
5	160,373	136,109	0.85
6	192,609	163,721	0.85
7	224,901	191,470	0.85
8	257,251	219,360	0.85
9	289,659	247,396	0.85
10	322,127	275,579	0.86
11	325,235	290,501	0.89
12	328,406	305,645	0.93
13	331,640	321,016	0.97
14	334,939	336,615	1.01
15	338,303	352,446	1.04

The formula to calculate cumulative costs is as follows:

$$\textit{Cumulative cost at } Y_n = \textit{Cumulative cost at } Y_{n-1} + \textit{Annual debt service} + \textit{Operation \& Maintenance cost at } Y_n$$

To calculate annual debt service, we used the interest rate for borrowing at 10 year maturity, which is equal to 3.47% (Table 13). Given this interest rate, the annual debt service to pay off capital costs ($245,000) is $29,421. To calculate O&M costs, we multiplied the product of the unit O&M cost ($25/kWp) and system size (100 kWp) by the inflation rate (2%).

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7 Revenue from selling electricity in the SREC market is the product of the annual average SREC price in 2013 ($0.126/kWh) and annual electricity generated. To calculate revenue from feeding electricity into the grid vis-à-vis the local FIT incentive scheme, we first divided the unit FIT price ($0.1/kWh) by the system size (100kWp) and multiplied the result by the annual electricity generated.

Table 13: Inputs used to calculate cumulative revenue from the Seoul solar city project.

Variables	Inputs
Retail electricity rate ($/kWh)	0.116
Inflation rate (%/year)	2
System size (kWp)	100
Annual system performance degradation rate (%/year)	0.5
TMY (kWh/m²)	1,109.54

Note: Seoul-specific policy incentive inputs are available in Table 11.

Table 14: Inputs used to calculate cumulative cost from the Seoul solar city project.

Variables	Inputs
Borrowing rate (%)	3.47
Annual debt service ($/year)	29,421
Capital costs ($)	245,000
System cost with warranty ($/Wp)	2.45
O&M cost ($/kWp)	25
Inflation rate (%)	2

Note: Capital costs are calculated by multiplying system size (100 kWp) and the unit system cost ($2,300/kWp) in Seoul. We assumed inverter replacement cost to be covered under warranty for the project's entire lifetime. This warranty cost was calculated by having the current inverter cost of 22.3 cents/Wp discounted against a 3% rate for 13 years. Therefore, the unit system cost for the Seoul solar project is $2.45/Wp with the warranty.

2.7. Options for Seoul to become a solar city in 10 years

As discussed in the previous section, the cumulative cost of the Seoul solar city project exceeds its cumulative benefit when the debt service of the project must be paid off in 10 years. The research team explored options that could make the Seoul solar city project economically viable in 10 years. These options have proven successful in financing large-scale sustainable energy projects and reducing the total upfront costs associated with installing PV systems. These options are illustrated in Figure 8 and explained as follows:

- Seoul can improve building energy efficiency by 20% and use the energy savings to support a solar city project. The energy savings potential from building energy efficiency improvements in Seoul could be significant. The building sector accounts for 56% of total energy consumption in Seoul. Of these, 420 large buildings are responsible for 14% of Seoul's total energy consumption (Seoul Metropolitan Government, 2015).

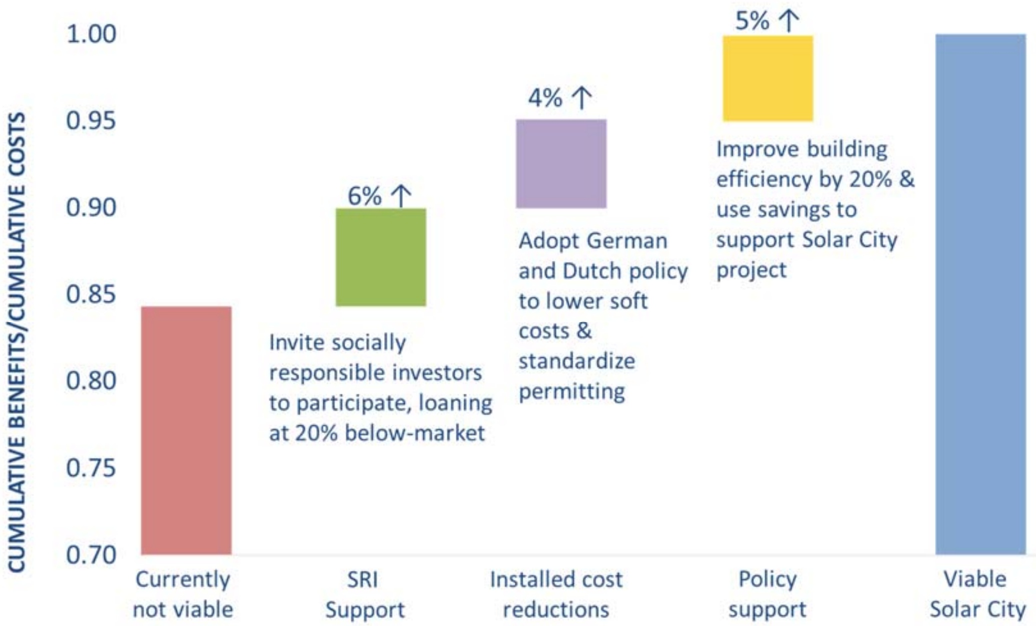

Figure 8: Options that make a Seoul solar city project economically feasible in 10 years. Source: Byrne et al. 2015b.

- Non-hardware or 'soft' costs[8] associated with PV installations generally account for nearly half of total installation costs. According to a 2014 report by the U.S. National Renewable Energy Laboratory which compares PV costs in Japan and the United States, the soft costs of installing small commercial PV systems in the United States and Japan accounted for 39% and 66% of the total costs, respectively (Friedman et al., 2014). The IEA's Photovoltaic Power Systems Programme has found that PV system prices, despite module price stagnation, went down in 2014 partly due to "a decrease in soft costs" (International Energy Agency Photovoltaic Power Systems Programme, 2015, p. 50). These results suggest that lowering soft costs has the potential to cut total upfront costs of PV installations, which in turn could help improve the economic viability of a solar city project.

- Finally, the Seoul solar city project could become more economically feasible by inviting socially responsible investors. While mainstream investors are primarily concerned with the financial performance of their investment, socially responsible investors also consider other

[8] Soft costs typically include costs associated with customer acquisition, PII (permitting, inspection and interconnection), installation labor, and financing. They also include profit and overhead, sometimes called 'other soft costs' (Ardani, et al., 2013). The majority of hardware costs comprises costs of modules and inverters.

factors, including the social and environmental impacts of investment assets. Globally, $21.4 trillion was invested by socially responsible investment (SRI) strategies at the start of 2014 (Global Sustainable Investment Alliance, 2015). In South Korea, SRI totaled $9 billion in 2014 (Kim et al., 2015). According to our estimate, the financial viability of a Seoul solar city project improves by 6 percent if SRI investors loan at a 20 percent below-market rate.

3. Methods for Modelling Solar City Projects for Six Case Cities

The previous section explained a step-by-step method for modelling a solar city project for Seoul, one of the six case cities. This section discusses the methods used to collect sets of data and, to some extent, model the solar city projects for the six case cities of Amsterdam, London, Munich, New York City, Seoul, and Tokyo. Detailed analysis of modelling the solar city projects for the six cities, including BCR analysis, will be available in near future.

3.1. Methods for calculating total rooftop area of buildings in six cities

As explained in Section 2, the first key factor for modelling solar city projects is the solar electric potential that could be expected if the solar city strategy were applied. To estimate solar electric potentials for each of the six cities, the research team attempted to find publicly available numbers on the electrical generation potentials when possible. As Table 15 shows, we were able to locate self-reported potentials for the cities of Amsterdam, London, and Munich. As we were unable to find relevant numbers for New York City and Tokyo, we calculated the potentials ourselves utilizing the methodology applied for Seoul (Byrne et al., 2015a). Based on the available area of each city, the research team calculated suitable space for various tilts after accounting for GCR and SA, as illustrated in Table 16.

Table 15: Calculation for available area and suitable area (unit: square meter)

City	Available area	Suitable area	Source
Amsterdam	-	11,000,000	Report from Amsterdam Municipality
London	74,897,816	34,872,423	Report from the Greater London Authority
Munich	40,200,000	18,700,000	Personal communication with Munich Environment and Municipal Services
New York	181,903,062	83,548,076	Database (New York City)
Seoul	187,050,083	89,544,961	Database (Seoul)
Tokyo	204,258,223	96,432,350	Report from Tokyo Metropolitan Gov't

Table 16: Suitable space after accounting for GCR and SA (unit: million square meter)

Tilt (degree)	0	5	10	15	20	25	30
Amsterdam	8.8	6.9	5.8	5.2	4.9	4.7	4.6
London	27.9	21.9	18.5	16.5	15.4	14.9	14.7
Munich	14.9	11.7	9.9	8.9	8.3	8.0	7.9
New York	66.8	52.5	44.3	39.6	36.9	35.6	35.3
Seoul	71.6	56.3	47.5	42.4	39.6	38.2	37.8
Tokyo	77.1	60.6	51.2	45.7	42.6	41.1	40.8

3.2. Methods for calculating electric potential of a large-scale rooftop PV project in the six cities

Using the final suitable area in Table 16, the research team calculated the installed capacities (GWp) assuming a module efficiency of 20% and solar radiation of 1kW/m^2 (Table 17).

Table 17: Calculation of installed capacity (MW)

Tilt (degree)	0	5	10	15	20	25	30
Amsterdam	1,760.0	1,382.6	1,167.7	1,042.6	972.5	938.6	929.8
London	5,579.6	4,383.2	3,702.0	3,305.4	3,083.0	2,975.4	2,947.8
Munich	2,992.0	2,350.4	1,985.1	1,772.5	1,653.3	1,595.5	1,580.7
New York	13,367.7	10,501.3	8,869.2	7,919.1	7,386.4	7,128.6	7,062.3
Seoul	14,327.2	11,255.1	9,505.9	8,487.6	7,916.6	7,640.2	7,569.2
Tokyo	15,429.2	12,120.8	10,237.0	9,140.4	8,525.5	8,227.9	8,151.4

Power outputs per installed capacity (MWh/MW) and expected total generation (TWh) were calculated using SAM software, as shown in Table 18 and Table 19, respectively.

Table 18: Calculation for MWh/MW

Tilt (degree)	0	5	10	15	20	25	30
Amsterdam	839.0	866.2	889.0	907.2	920.2	929.1	932.5
London	857.0	884.3	906.1	924.2	938.1	946.8	950.0
Munich	948.3	977.0	1,000.6	1,018.8	1,032.2	1,038.3	1,041.8
New York	1,172.2	1,215.2	1,251.4	1,280.6	1,301.8	1,313.6	1,320.6
Seoul	986.1	1,013.5	1,035.9	1,053.7	1,066.5	1,074.1	1,076.0
Tokyo	1,075.2	1,107.8	1,134.7	1,156.2	1,172.0	1,181.5	1,184.7

Table 19: Calculation of generation (TWh)

Tilt	0	5	10	15	20	25	30
Amsterdam	1.48	1.20	1.04	0.95	0.89	0.87	0.87
London	4.78	3.88	3.35	3.05	2.89	2.82	2.80
Munich	2.84	2.30	1.99	1.81	1.71	1,66	1.65
New York	15.57	12.76	11.10	10.14	9.62	9.36	9.33
Seoul	14.13	11.41	9.85	8.94	8.44	8.21	8.14
Tokyo	16.59	13.43	11.62	10.57	9.99	9.72	9.66

3.3. Methods for collecting PV system inputs and electricity retail rates

As explained in Section 2.3, PV system costs, configuration inputs, and electricity retail rates are major inputs for modelling solar city projects. Table 20 shows the city-specific system costs and commercial electricity retail rates that the team used for modelling solar city projects in the six cities.

Table 20: City PV system costs (based on national and international sources)

City	Turnkey installed system price ($/W)	Source
Amsterdam	1.99	2014 IEA PVPS
London	2.40	2014 IEA PV Technology Roadmap
Munich	1.90	2014 IEA PVPS
New York	3.57	2014 IEA PVPS
Seoul	2.30	2014 IEA PVPS
Tokyo	3.44	2014 IEA PVPS

Note: As explained in Section 2.3, inverter replacement cost ($/W) is a major cost component of PV installation. The team assumed that inverters are covered under warranty for the project's entire lifetime. Warranty costs were estimated as the current inverter costs discounted at a rate of 3% for 13 years, resulting in 15 cents/W.

The main source for installed PV system costs was the 2014 IEA PVPS trends report, which provides the costs of the PV systems (minus installation) deployed in Germany, Japan, South Korea, and the United States in 2013. Because the United Kingdom is not included in the 2014 IEA PVPS report, the IEA PV Technology Roadmap (2014) report was used to estimate PV system costs for London. Data from the Dutch PV monitoring agency was used for Amsterdam. Commercial electricity retail rates for the cities of Amsterdam, London, Munich, and Seoul are based on average national electricity prices. For New York City, ConEdison's commercial retail rate was extracted from EIA Form 861. Data from the Tokyo Electric Power Company (TEPCO) Factbook 2014 informed the rates for Tokyo.

Table 21: City electricity retail rates (based on national data)

City	Commercial electricity retail rate (cents/kWh)	Source
Amsterdam	14.8	Ministerie van Economische Zaken
London	16.8	Ministerie van Economische Zaken
Munich	23.3	Ministerie van Economische Zaken
New York	22.4	ConEdison
Seoul	11.6	Korea Electric Power Corporation
Tokyo	19.4	Tokyo Electric Power Company

The team assumed that all PV panels face south and used the optimized PV tilts as determined by SAM for Amsterdam (37 degrees), Greater London Authority (36 degrees), Munich (33 degrees), New York City (26 degrees), Tokyo (21 degrees), and Seoul (22 degrees). Other factors associated with PV systems that the team used are explained in detail in Section 2.2, which can be summarized as follows: module efficiency (20%), inverter efficiency (98.5%), PV rated power factor (100 kWp), annual performance degradation factor (0.5%), and PV module type (mono-crystalline).

To model inflation and discount effects, the team assumed electricity prices will increase from the published estimates by 2% for the cities of New York, Seoul, and Tokyo, and 3% for the Western European cities of Amsterdam, London, and Munich. The inflation rate for O&M was set at 2% per year, and an overall 3% discount rate was used in our cash flow calculations.

Additional price considerations were applied for Munich due to recent updates to the Renewable Energy Sources Act in Germany (EEG 2014), which established a 40% tax on the EEG surcharge for the self-consumption of generated electricity. The calculations used in this study reflect the Act's lowering the commercial electricity retail rate in Munich from 23.3 cents/kWh to 20.08 cents/kWh.

3.4. Methods for collecting financing costs data and constructing bond yield curves

As explained in Section 2.4, we estimated the cost of capital for the solar city project in Seoul by establishing a bond yield curve for the city. This gave us borrowing costs of capital and maturities. To establish bond yield curves for six case cities, we identified tax-exempt revenue bonds issued by either a municipal government or national government in 2013 and 2014. We only included bonds relevant to utility or infrastructure investments.

Like Seoul's case, obtaining city-level bond data was difficult as the bond issuance volume proved too low to create bond yield curves in some municipalities because bond issuance is not a common tool for financing large-scale projects. Table 22 summarizes the sources of bond data that the research team used and the level of the bond data, i.e., whether it is issued by a federal (or national) government or municipal (or subnational) government.

The research team referred to loan data from the Public Works Loan Board (PWLB) to establish a bond yield curve for London as local governments in the U.K. rely on the PWLB to finance large-scale projects. For Munich, the team used national-level bond issuance data to establish a proxy bond curve for the city.

Revenue bond data from KEPCO and KOGAS were used to establish a bond yield curve for Seoul, as explained in Section 2.4. Based on the six bond yield curves constructed from the bond data, the costs of capital used for each city can be calculated at certain maturities, as shown in Table 23.

Table 22: Sources and level of government of bond data for each city

City	Sources	Level of government
Amsterdam	Bank of Dutch Municipalities	Subnational
London	Public Works Loan Board (PWLB)	National
Munich	Germany Finance Agency / Stuttgart Stock Exchange	National
New York	Electronic Municipal Market Access (EMMA)	Subnational
Seoul	Korea Electric Power Corporation (KEPCO) and Korea Gas Corporation (KOGAS)	National
Tokyo	Tokyo Metropolitan Government	Subnational

Table 23: Bond maturities and cost of capital for each city

City	10 year	15 year	20 year
Amsterdam	1.82%	2.50%	2.87%
London	3.61%	4.07%	4.14%
Munich	1.49%	2.06%	2.43%
New York	3.05%	3.85%	4.22%
Seoul	3.46%	3.55%	3.87%
Tokyo	0.60%	1.05%	1.51%

3.5. Methods for collecting policy-driven incentives

As explained in Section 2.5, the research team identified major existing policies that support PV electricity and determined the value of policy incentives for each city in the dollar per kilowatt hour ($/kWh). Our investigation reveals distinctive differences in policy incentives among cities. For example, nation-wide FITs represent the major policy measure for the cities of Amsterdam, London, Munich, and Tokyo, while New York City relies primarily on Investment Tax Credits (ITS). As explained in Section 2.5, PV projects in Seoul receive both national and local incentives through the national renewable portfolio standard (RPS) and a local FIT of 10 cents/kWh, which supports small-scale solar PV.

Table 24: Existing policies in support of solar PV and quantified incentives for each city

City	Policy	Description	Input ($/kWh)
Amsterdam	FIT	Nationwide market-sensitive compensation; technology neutral	0.114
London	FIT	Nationwide incentives supporting small scale renewable energy installations (≤ 5 MW); comprises three financial benefits including generation tariff, export tariff for excess solar electricity, and electricity bill savings	0.16
Munich	FIT	Nationwide incentive supporting renewables; more than 10% of electricity from a commercial scale PV system must be self-consumed or sold at wholesale prices or spot prices; volume-responsive FIT support	0.14
New York	ITC	Nationwide incentive providing investors with a 30% tax credit against the capital costs of eligible renewable energy projects.	30%
	MW Block Initiative	A part of the New York Sun Initiative supporting PV in the state of New York; a block-by-block support system providing higher incentives for first blocks of installed MW	6%
Seoul	RPS	Nationwide support policy for renewables; its solar carve-out incentivizing the solar renewable energy credit (SREC) market; the RPS further supports PV by offering a credit multiplier of 1.5, i.e. 1 MWh of electricity yields 1.5 SREC	0.126
	Seoul FIT	FIT supported by the Seoul Metropolitan Government; it offers small-scale PV a FIT premium, 10 cents per kWh	0.10
Tokyo	FIT	Nationwide incentive supporting renewables; it mandates 10 electric utilities of Japan to purchase excess electricity from grid-connected renewable energy systems at fixed prices determined annually	0.27

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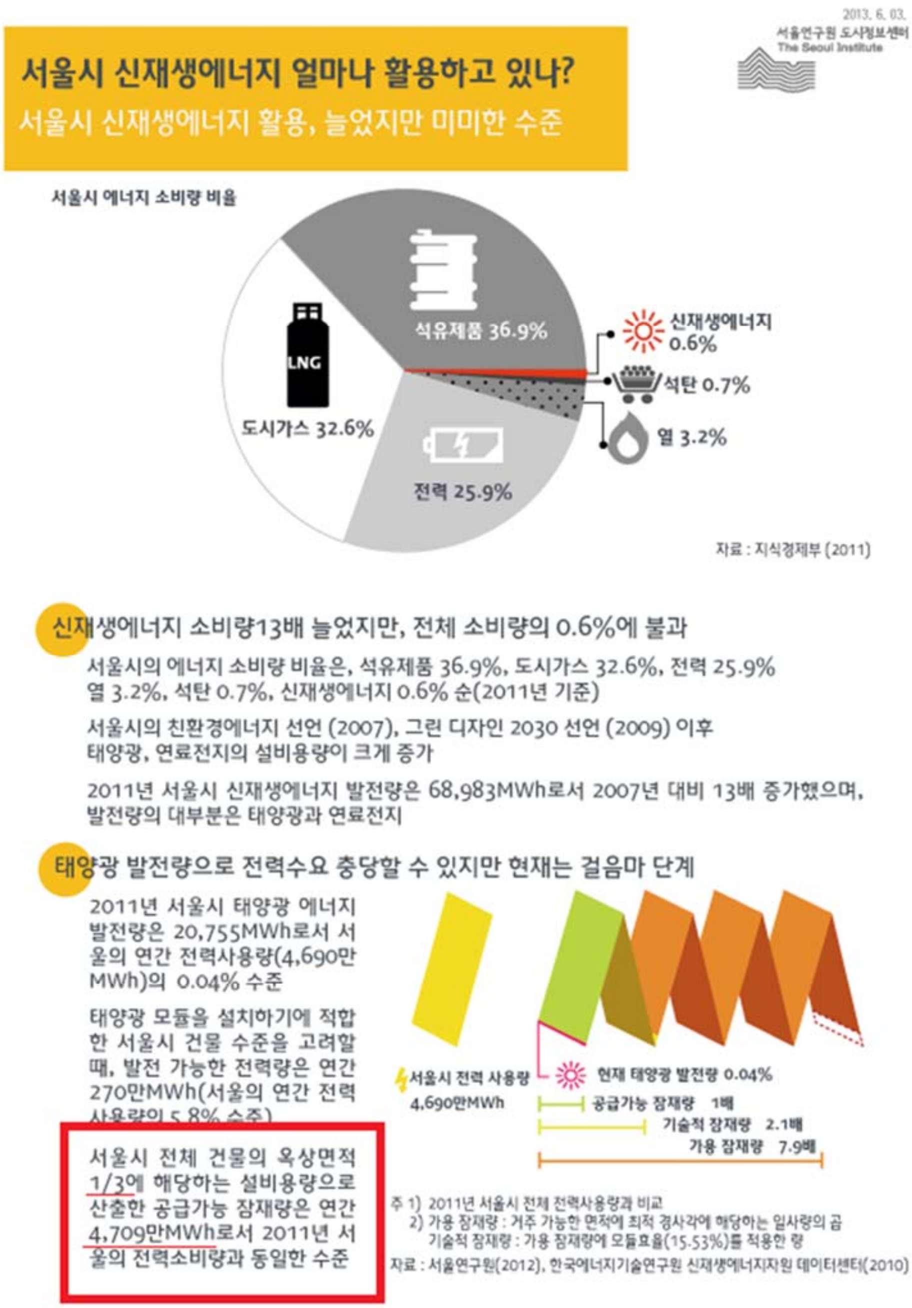
Appendix 1. The sheet of information received from Seoul Institute regarding the electric potential that could be supplied by PV installations on the rooftops in Seoul[9]



2013. 6. 03.
서울연구원 도시정보센터
The Seoul Institute

서울시 신재생에너지 얼마나 활용하고 있나?

서울시 신재생에너지 활용, 늘었지만 미미한 수준

자료 : 지식경제부 (2011)

신재생에너지 소비량13배 늘었지만, 전체 소비량의 0.6%에 불과

서울시의 에너지 소비량 비율은, 석유제품 36.9%, 도시가스 32.6%, 전력 25.9% 열 3.2%, 석탄 0.7%, 신재생에너지 0.6% 순(2011년 기준)

서울시의 친환경에너지 선언 (2007), 그린 디자인 2030 선언 (2009) 이후 태양광, 연료전지의 설비용량이 크게 증가

2011년 서울시 신재생에너지 발전량은 68,983MWh로서 2007년 대비 13배 증가했으며, 발전량의 대부분은 태양광과 연료전지

태양광 발전량으로 전력수요 충당할 수 있지만 현재는 걸음마 단계

2011년 서울시 태양광 에너지 발전량은 20,755MWh로서 서울의 연간 전력사용량(4,690만MWh)의 0.04% 수준

태양광 모듈을 설치하기에 적합한 서울시 건물 수준을 고려할 때, 발전 가능한 전력량은 연간 270만MWh(서울의 연간 전력 사용량의 5.8% 수준)

서울시 전체 건물의 옥상면적 1/3에 해당하는 설비용량으로 산출한 공급가능 잠재량은 연간 4,709만MWh로서 2011년 서울의 전력소비량과 동일한 수준

주 1) 2011년 서울시 전체 전력사용량과 비교
2) 가용 잠재량 : 거주 가능한 면적에 최적 경사각에 해당하는 일사량의 곱
기술적 잠재량 : 가용 잠재량에 모듈효율(15.53%)를 적용한 량

자료 : 서울연구원(2012), 한국에너지기술연구원 신재생에너지자원 데이터센터(2010)

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[9] The Korean character '만' in "4,709만MWh" signifies ten thousand.

Appendix 2. Electricity demand in Seoul in 2012 (Source: KEPCO)

Date (YMD)	9 am -6 pm	6 pm - 11 pm	11 pm - 9 am	Date(YMD)	9 am -6 pm	6 pm - 11 pm	11 pm - 9 am
20120101	46,980,338,831	22,584,214,112	45,486,997,191	20120702	65,966,790,318	24,968,996,336	48,081,265,831
20120102	72,316,012,822	26,957,541,807	53,827,540,722	20120703	65,198,379,651	25,346,061,903	49,369,572,566
20120103	72,615,161,979	27,613,963,116	55,531,806,342	20120704	68,222,375,804	26,087,748,296	50,787,818,328
20120104	74,391,937,696	28,080,552,894	56,949,406,914	20120705	66,671,222,468	25,307,757,922	51,454,021,454
20120105	73,036,583,211	27,606,218,333	57,119,492,269	20120706	62,318,638,447	23,982,616,794	49,937,388,433
20120106	70,662,834,260	26,985,487,754	55,721,684,353	20120707	56,062,954,251	23,226,336,303	45,625,065,696
20120107	60,095,903,286	24,485,973,312	52,034,771,296	20120708	52,321,942,651	22,881,015,106	43,920,019,768
20120108	52,042,129,068	23,513,455,295	47,828,914,380	20120709	71,109,430,066	27,624,179,692	50,071,612,427
20120109	71,360,670,877	26,800,166,929	53,654,284,230	20120710	71,143,785,914	26,616,928,602	53,133,811,788
20120110	70,529,439,946	26,954,215,561	55,163,161,667	20120711	68,664,904,091	25,859,101,308	51,581,437,545
20120111	72,726,836,244	27,761,980,050	55,934,518,172	20120712	67,579,144,894	26,976,347,796	50,716,997,198
20120112	72,467,793,624	27,052,914,019	56,823,377,932	20120713	71,696,044,621	27,755,970,739	52,883,819,532
20120113	69,326,328,528	26,674,748,743	54,946,328,086	20120714	56,473,416,356	22,941,820,484	48,752,519,598
20120114	58,780,919,647	24,044,890,134	51,214,777,988	20120715	47,109,290,403	21,326,823,190	42,732,992,609
20120115	51,420,856,414	23,409,156,557	47,186,866,453	20120716	61,625,179,908	24,820,017,533	47,096,963,281
20120116	69,078,579,301	26,197,556,335	53,741,369,856	20120717	67,485,962,973	26,510,230,247	49,548,408,011
20120117	66,265,346,181	25,863,656,335	53,277,640,551	20120718	70,896,041,869	27,944,074,898	52,293,959,989
20120118	66,479,068,048	25,864,396,090	53,281,793,537	20120719	68,022,184,805	26,031,287,160	52,511,085,643
20120119	64,537,845,367	25,016,237,746	52,360,913,042	20120720	70,579,149,609	27,205,502,110	51,657,236,417
20120120	61,568,014,628	23,862,401,985	51,007,428,029	20120721	62,534,855,266	26,136,065,134	49,725,268,113
20120121	50,524,987,457	21,983,800,015	46,061,271,663	20120722	56,024,511,349	25,557,438,060	47,698,242,791
20120122	46,567,528,483	20,955,892,324	44,846,300,049	20120723	76,099,329,890	29,234,275,956	54,667,948,724
20120123	39,618,114,754	19,776,802,684	43,647,270,846	20120724	77,763,203,330	29,785,749,146	56,642,848,188
20120124	48,083,751,373	22,706,944,945	45,147,494,677	20120725	77,714,799,011	29,890,058,010	56,698,235,144
20120125	73,908,554,192	27,715,432,342	54,858,955,432	20120726	77,956,929,404	29,982,844,992	57,223,014,452
20120126	72,864,651,444	27,147,310,273	56,490,408,552	20120727	78,116,658,419	29,762,255,613	57,610,598,550
20120127	70,598,181,470	26,517,964,592	55,291,271,007	20120728	66,558,894,708	27,912,994,686	53,903,619,406
20120128	59,207,363,340	24,212,343,877	51,165,530,997	20120729	61,838,245,709	27,453,056,151	52,106,301,086
20120129	51,140,964,436	23,630,434,934	47,429,059,922	20120730	71,649,439,585	26,938,024,193	56,777,924,436
20120130	73,755,605,212	27,700,172,067	55,372,131,174	20120731	79,967,666,110	31,019,893,754	59,599,792,272

Date (YMD)	9 am -6 pm	6 pm - 11 pm	11 pm - 9 am	Date(YMD)	9 am -6 pm	6 pm - 11 pm	11 pm - 9 am
20120131	73,771,614,185	27,595,902,541	56,877,923,979	20120801	82,594,518,029	32,488,068,793	60,147,005,368
20120201	77,469,693,135	29,386,216,894	58,818,814,387	20120802	80,989,602,297	32,463,549,207	60,013,317,470
20120202	79,344,584,691	29,552,207,242	60,443,401,991	20120803	80,572,977,995	32,218,619,185	61,750,880,527
20120203	77,204,660,033	28,278,861,707	60,212,191,711	20120804	69,906,628,099	30,311,631,579	58,544,767,477
20120204	60,922,731,018	24,974,346,436	53,542,779,792	20120805	67,181,321,905	30,260,941,384	57,821,544,929
20120205	51,386,660,807	23,420,347,163	48,382,162,569	20120806	86,080,201,660	34,172,366,830	64,397,742,853
20120206	70,159,092,182	26,441,220,317	54,573,719,510	20120807	83,632,629,657	32,835,454,972	63,587,531,644
20120207	75,186,731,021	28,772,863,082	57,088,669,115	20120808	81,845,131,833	32,521,982,882	61,977,030,339
20120208	75,275,685,837	28,265,780,592	58,952,406,222	20120809	83,325,817,540	32,276,701,473	63,168,474,330
20120209	72,405,514,924	27,516,099,735	57,653,863,666	20120810	77,354,575,876	28,987,463,279	61,903,051,709
20120210	70,637,004,446	27,038,995,499	56,513,097,655	20120811	64,930,227,447	27,299,955,897	54,314,999,916
20120211	59,570,977,650	24,462,504,237	52,516,921,873	20120812	55,864,879,667	24,369,036,146	50,187,048,842
20120212	50,182,555,290	23,016,062,770	47,485,096,978	20120813	74,762,832,168	28,270,460,411	52,374,128,176
20120213	67,389,145,238	25,718,005,516	52,772,783,862	20120814	74,383,796,380	28,132,440,196	53,911,113,528
20120214	64,180,163,183	25,369,535,453	52,839,472,997	20120815	57,413,809,833	24,016,375,464	49,694,287,044
20120215	66,332,617,969	26,211,074,080	53,330,658,913	20120816	71,349,787,914	27,527,658,988	51,953,852,450
20120216	67,199,423,623	26,749,039,155	54,300,590,464	20120817	75,815,274,562	29,271,906,896	54,523,368,205
20120217	71,023,797,699	27,443,224,057	55,684,216,352	20120818	64,456,620,091	26,847,601,999	52,811,221,453
20120218	60,814,312,299	24,913,726,204	52,781,993,687	20120819	58,743,831,014	26,134,025,772	49,694,163,406
20120219	51,283,956,516	23,547,492,853	48,827,248,447	20120820	74,367,159,332	28,120,137,517	55,217,883,609
20120220	68,967,244,473	26,215,168,148	53,902,460,695	20120821	73,176,579,972	28,228,226,261	55,051,726,923
20120221	66,920,949,149	25,697,066,114	53,298,692,603	20120822	64,709,924,034	25,201,548,570	52,476,845,674
20120222	62,489,267,235	24,569,952,340	52,352,577,956	20120823	62,911,371,943	24,863,911,332	49,511,403,277
20120223	61,710,519,274	24,745,788,607	50,523,145,139	20120824	63,370,200,829	25,138,384,885	48,683,174,737
20120224	56,401,101,104	24,258,156,211	50,807,234,999	20120825	58,362,664,773	24,620,865,040	46,954,417,077
20120225	54,170,564,182	23,078,535,781	47,440,049,061	20120826	55,410,480,042	25,433,455,012	45,933,531,925
20120226	48,547,460,594	22,611,897,444	45,609,134,579	20120827	76,356,730,382	28,705,032,449	53,119,982,808
20120227	65,997,283,329	25,775,405,461	52,067,812,527	20120828	70,277,021,082	25,914,082,406	54,297,281,192
20120228	64,356,084,919	25,084,226,749	52,392,448,783	20120829	71,315,629,493	27,455,902,392	51,817,376,687
20120229	60,566,702,606	24,192,829,203	51,147,672,225	20120830	64,560,695,597	24,165,848,149	52,378,941,791
20120301	48,005,336,095	21,972,452,407	45,102,508,916	20120831	65,765,756,975	26,158,251,699	48,993,057,920

Date (YMD)	9 am -6 pm	6 pm - 11 pm	11 pm - 9 am	Date(YMD)	9 am -6 pm	6 pm - 11 pm	11 pm - 9 am
20120302	60,360,217,686	23,903,813,462	48,362,335,287	20120901	58,174,318,294	23,981,882,933	47,575,465,980
20120303	50,095,061,852	21,614,007,974	45,672,132,184	20120902	51,618,216,194	23,193,115,745	44,013,553,649
20120304	45,223,024,692	21,252,057,230	42,547,694,457	20120903	69,409,899,971	26,592,842,599	50,305,989,807
20120305	62,481,490,521	24,502,629,235	48,509,322,892	20120904	63,537,467,239	24,723,734,697	51,082,657,120
20120306	64,632,381,165	24,924,007,714	50,198,500,891	20120905	62,754,653,024	23,796,101,080	49,030,331,831
20120307	61,242,039,551	24,651,550,275	50,593,825,874	20120906	60,263,809,415	23,958,406,181	46,615,713,859
20120308	62,073,781,007	25,080,474,854	50,584,781,966	20120907	61,041,798,921	24,207,550,631	47,001,240,556
20120309	61,485,762,237	24,306,835,156	51,129,894,209	20120908	50,233,648,374	21,130,378,902	44,344,827,926
20120310	51,750,610,230	22,489,372,883	46,499,143,761	20120909	45,457,540,719	20,974,175,075	40,438,859,959
20120311	48,520,573,419	22,739,378,608	44,609,387,468	20120910	61,164,108,072	24,125,732,549	45,654,595,699
20120312	66,679,564,251	25,925,154,069	52,168,507,666	20120911	61,053,286,220	24,241,475,625	46,759,577,306
20120313	63,320,697,112	25,232,531,377	52,264,094,145	20120912	59,846,277,224	23,878,418,114	47,116,346,243
20120314	64,561,105,400	24,926,159,298	50,941,688,253	20120913	59,021,259,800	23,374,129,322	47,367,806,028
20120315	59,934,304,499	24,195,938,570	50,968,502,947	20120914	55,826,158,038	22,585,034,946	45,932,421,898
20120316	59,140,875,012	23,685,084,920	49,184,109,473	20120915	49,276,011,309	21,280,965,355	42,598,944,526
20120317	48,739,551,731	21,257,970,458	45,206,740,123	20120916	43,898,659,826	20,287,613,896	40,017,189,642
20120318	43,419,830,180	21,025,732,133	41,764,185,098	20120917	54,982,199,966	22,308,646,744	43,765,267,100
20120319	59,805,274,219	24,368,670,058	48,316,776,300	20120918	56,280,234,897	23,059,499,927	45,173,650,804
20120320	59,683,288,844	24,454,662,499	49,871,984,486	20120919	56,420,267,333	22,885,600,510	45,577,179,809
20120321	58,661,305,866	24,177,391,404	49,673,789,509	20120920	56,327,258,432	23,090,742,163	45,224,460,836
20120322	58,114,582,363	23,583,064,147	48,826,420,647	20120921	56,265,000,371	22,732,259,179	45,672,140,396
20120323	61,796,039,823	24,093,092,704	48,480,596,605	20120922	49,227,219,264	21,205,303,950	42,774,414,004
20120324	52,181,976,698	22,384,106,141	46,133,453,852	20120923	45,019,773,777	20,573,971,984	40,494,974,911
20120325	45,496,041,570	21,582,087,022	43,206,149,117	20120924	57,436,522,812	23,196,837,922	44,258,024,481
20120326	60,450,424,089	24,436,272,194	48,873,943,106	20120925	57,739,884,979	23,467,190,826	45,589,953,573
20120327	59,489,773,583	23,876,795,588	49,151,065,185	20120926	57,246,778,910	23,417,909,487	45,844,828,614
20120328	55,594,671,371	23,100,121,035	48,175,151,164	20120927	55,909,850,844	22,899,213,610	46,028,460,282
20120329	54,520,353,093	22,803,782,622	47,101,836,774	20120928	53,946,915,525	21,324,509,353	45,234,518,488
20120330	56,100,119,226	23,004,561,300	46,787,390,385	20120929	40,065,883,409	17,952,375,985	39,209,768,096
20120331	48,387,655,469	21,455,995,987	44,236,352,671	20120930	33,859,747,195	16,648,695,827	35,947,269,022
20120401	43,292,069,598	20,865,704,736	41,773,753,899	20121001	37,986,646,474	18,367,922,397	36,076,726,883

Date (YMD)	9 am -6 pm	6 pm - 11 pm	11 pm - 9 am	Date(YMD)	9 am -6 pm	6 pm - 11 pm	11 pm - 9 am
20120402	58,491,094,758	23,390,799,774	46,549,783,588	20121002	47,674,202,645	20,515,531,030	40,241,800,263
20120403	61,076,165,339	24,182,703,703	48,213,028,919	20121003	44,443,690,021	20,421,538,322	39,435,066,995
20120404	56,056,460,421	23,400,919,526	48,130,866,542	20121004	53,990,300,471	22,277,337,617	43,249,956,288
20120405	55,897,717,523	23,508,246,116	47,421,956,371	20121005	53,858,160,145	22,254,708,633	44,454,309,143
20120406	57,253,615,469	23,541,218,383	47,770,541,304	20121006	47,668,951,714	20,389,576,944	42,122,865,921
20120407	48,516,302,352	21,159,472,306	44,791,607,387	20121007	42,948,954,181	19,966,895,115	39,422,098,711
20120408	42,037,123,103	20,236,292,793	41,108,722,056	20121008	52,513,108,754	21,892,833,891	42,886,019,228
20120409	52,476,945,815	22,209,734,396	44,866,930,757	20121009	52,012,631,351	21,905,723,722	43,280,882,203
20120410	53,717,629,117	22,311,878,756	44,925,288,680	20121010	52,545,992,040	21,804,104,406	43,841,866,980
20120411	47,026,520,140	21,241,210,114	42,575,435,900	20121011	50,999,228,912	21,658,319,195	43,288,908,202
20120412	53,594,208,371	22,665,090,439	44,976,695,015	20121012	51,355,255,073	21,594,555,931	43,231,604,613
20120413	53,136,548,045	22,267,019,941	45,326,907,180	20121013	45,541,273,950	19,951,135,236	41,276,741,886
20120414	45,726,216,361	20,401,256,300	42,658,908,579	20121014	41,356,415,845	19,387,215,191	38,932,735,629
20120415	40,891,768,305	19,719,385,204	39,734,931,595	20121015	50,923,245,284	21,633,262,600	42,090,703,331
20120416	51,616,060,540	21,950,141,038	43,372,339,777	20121016	51,424,623,724	21,819,628,775	43,261,733,834
20120417	51,244,140,561	22,035,062,250	44,396,235,236	20121017	51,154,271,278	21,734,052,799	44,041,600,709
20120418	51,170,933,190	21,920,721,796	44,202,611,513	20121018	50,702,879,064	21,683,417,658	43,493,825,962
20120419	51,294,656,436	21,949,224,883	44,122,952,060	20121019	50,970,160,105	21,528,173,673	43,567,857,463
20120420	51,589,847,742	21,890,551,650	43,967,912,923	20121020	45,825,274,035	20,122,611,236	41,437,536,007
20120421	47,799,346,218	20,569,667,524	41,907,725,732	20121021	42,075,894,175	19,801,636,481	39,421,171,319
20120422	43,395,594,145	20,045,903,468	39,846,729,190	20121022	53,255,053,039	21,940,767,368	43,386,295,105
20120423	52,370,882,859	22,117,374,544	43,732,488,110	20121023	51,711,949,089	21,826,031,179	44,052,683,602
20120424	51,911,288,797	22,327,749,219	44,291,507,760	20121024	51,744,277,289	21,788,216,583	43,815,152,324
20120425	53,277,319,900	22,249,788,379	44,574,113,539	20121025	51,328,575,027	21,825,564,346	44,005,647,199
20120426	50,950,877,481	21,949,038,372	44,393,830,955	20121026	51,287,577,531	21,529,913,721	44,043,617,250
20120427	51,050,204,791	21,620,926,107	43,972,708,514	20121027	47,871,214,668	20,323,787,854	41,976,985,174
20120428	45,302,137,462	20,127,105,841	41,569,683,779	20121028	41,266,124,618	19,637,248,054	39,560,627,037
20120429	41,911,226,584	19,984,160,854	39,246,621,227	20121029	51,488,245,265	21,850,555,416	42,790,524,494
20120430	54,035,717,812	22,688,806,465	43,329,607,031	20121030	51,930,201,921	22,097,218,040	44,108,670,240
20120501	49,528,932,852	22,148,015,808	42,888,809,801	20121031	53,436,924,035	22,332,843,762	44,948,817,690
20120502	58,028,088,256	23,598,115,931	45,008,283,620	20121101	54,806,030,788	22,820,497,250	45,513,248,159

Date (YMD)	9 am -6 pm	6 pm - 11 pm	11 pm - 9 am	Date(YMD)	9 am -6 pm	6 pm - 11 pm	11 pm - 9 am
20120503	56,180,647,330	22,935,135,864	45,476,903,478	20121102	54,544,405,529	22,411,623,524	46,028,018,595
20120504	56,526,263,711	22,436,644,702	45,132,534,416	20121103	46,886,456,446	20,456,278,499	43,020,166,276
20120505	44,856,037,488	19,826,212,611	41,178,235,782	20121104	42,902,900,854	20,005,832,607	40,058,534,263
20120506	42,011,646,146	19,614,450,582	38,859,133,180	20121105	56,747,733,980	22,673,532,638	44,410,133,413
20120507	53,805,967,857	22,037,777,741	42,742,507,242	20121106	57,443,879,523	22,945,977,283	45,857,222,509
20120508	54,477,486,451	22,234,422,694	43,592,395,865	20121107	55,527,951,064	22,638,603,539	46,277,664,606
20120509	56,015,091,617	23,051,968,106	44,139,717,867	20121108	55,768,478,662	22,581,561,647	46,039,675,909
20120510	56,277,050,822	22,890,571,130	44,945,043,926	20121109	54,578,423,529	22,238,483,620	46,385,881,465
20120511	52,974,514,732	21,976,947,639	44,303,224,366	20121110	46,835,924,058	20,391,317,607	42,948,583,316
20120512	46,467,385,151	20,361,819,905	41,489,254,168	20121111	44,267,786,837	20,417,374,266	40,636,710,257
20120513	42,606,488,882	20,010,529,719	39,088,377,451	20121112	57,869,398,954	22,977,688,962	45,837,440,336
20120514	53,056,399,165	22,129,304,757	43,242,789,245	20121113	57,951,168,128	23,562,370,842	47,021,045,891
20120515	53,294,643,845	21,990,090,597	44,022,453,013	20121114	59,920,571,900	23,868,626,329	48,467,811,095
20120516	52,933,762,421	22,094,444,828	43,728,916,930	20121115	59,234,383,413	23,606,875,042	48,771,291,387
20120517	52,069,793,768	21,967,163,162	43,778,449,228	20121116	60,476,873,136	23,330,525,079	48,615,646,883
20120518	53,416,038,957	21,945,821,226	43,633,216,623	20121117	50,421,436,345	21,507,436,412	44,698,160,973
20120519	47,167,198,681	20,423,718,315	41,625,481,367	20121118	44,915,532,027	20,935,731,678	42,209,369,943
20120520	43,746,560,251	20,425,274,458	39,377,776,024	20121119	61,870,594,140	24,486,408,449	47,598,302,059
20120521	56,827,814,542	23,310,171,764	43,811,315,637	20121120	62,090,391,984	24,272,313,735	49,931,093,156
20120522	58,600,423,415	23,495,392,295	45,697,700,461	20121121	61,400,531,262	23,992,148,048	49,565,650,148
20120523	58,671,149,672	23,296,956,879	45,958,768,507	20121122	59,495,796,000	23,477,534,714	48,987,430,263
20120524	56,282,491,635	22,689,360,670	45,689,320,311	20121123	60,577,800,777	23,869,692,358	48,817,960,915
20120525	57,594,214,997	22,570,786,500	45,297,260,201	20121124	52,027,320,255	21,904,549,879	46,191,222,441
20120526	48,050,729,703	20,354,645,345	42,154,231,821	20121125	46,252,766,409	21,069,298,156	42,902,997,008
20120527	42,679,194,493	19,436,208,453	39,472,321,691	20121126	63,898,600,248	24,981,377,577	48,394,277,516
20120528	46,163,085,346	20,933,805,259	39,800,089,082	20121127	63,319,822,391	24,535,419,201	50,926,174,224
20120529	56,404,094,180	22,894,899,622	44,323,916,082	20121128	62,010,181,386	24,251,142,121	49,675,493,536
20120530	55,433,339,569	22,729,142,033	45,186,200,372	20121129	63,506,844,173	24,759,737,377	50,607,028,305
20120531	57,253,508,054	23,082,503,130	45,149,568,504	20121130	62,727,107,368	24,560,357,647	50,710,106,254
20120601	57,148,386,543	23,012,126,652	45,497,961,016	20121201	55,411,583,546	22,665,214,450	48,064,308,844
20120602	51,085,714,795	21,559,645,275	43,271,305,209	20121202	47,206,521,727	21,675,730,353	43,772,917,189

Date (YMD)	9 am -6 pm	6 pm - 11 pm	11 pm - 9 am	Date(YMD)	9 am -6 pm	6 pm - 11 pm	11 pm - 9 am
20120603	46,177,552,433	20,938,241,722	40,744,280,453	20121203	66,325,410,373	24,812,983,906	49,838,302,979
20120604	60,727,391,437	23,789,473,568	45,336,567,864	20121204	67,421,978,220	25,731,025,864	52,364,161,525
20120605	61,567,198,563	23,930,822,014	47,167,023,116	20121205	70,213,219,757	26,303,091,816	53,121,261,311
20120606	50,760,370,060	22,103,047,798	43,617,721,677	20121206	71,243,448,931	26,742,020,083	55,363,488,662
20120607	62,734,985,582	24,550,688,933	46,644,116,904	20121207	71,890,537,931	26,507,217,992	55,034,186,244
20120608	62,379,342,015	24,011,280,885	47,848,138,420	20121208	61,611,839,466	25,365,711,712	51,932,317,718
20120609	54,469,778,828	22,837,793,318	45,019,239,392	20121209	55,457,339,915	24,748,959,122	50,306,867,955
20120610	48,237,458,289	21,607,073,298	42,465,689,591	20121210	77,426,400,475	28,552,141,509	57,554,773,614
20120611	62,645,195,211	24,363,621,398	47,197,587,013	20121211	74,856,909,786	28,115,641,503	58,430,316,889
20120612	63,988,495,277	23,897,181,816	48,221,743,001	20121212	73,529,998,500	27,542,316,577	57,812,447,880
20120613	62,205,257,226	24,695,991,515	47,129,563,147	20121213	71,223,535,299	26,704,738,801	56,956,407,206
20120614	63,892,571,239	25,474,702,601	48,017,702,065	20121214	70,790,832,563	25,589,430,261	54,787,380,313
20120615	62,803,592,371	24,603,961,417	48,287,050,231	20121215	55,261,921,187	22,810,892,970	48,923,933,865
20120616	54,892,440,228	22,567,990,153	45,577,234,962	20121216	49,680,221,697	22,419,520,623	45,537,610,741
20120617	48,717,017,087	21,732,426,137	42,239,201,875	20121217	69,009,505,689	26,502,948,310	52,344,682,871
20120618	66,016,729,754	25,219,394,968	47,611,821,343	20121218	72,955,096,698	27,352,697,077	56,388,562,878
20120619	68,044,762,138	25,529,633,006	49,601,417,878	20121219	62,542,209,689	25,864,479,013	52,806,870,016
20120620	68,106,357,674	25,732,524,294	49,801,945,022	20121220	72,975,597,664	26,974,585,608	56,657,272,149
20120621	68,664,329,257	26,527,177,634	50,197,292,580	20121221	71,973,335,666	26,381,513,650	55,351,758,631
20120622	66,721,856,460	25,715,663,043	50,817,229,049	20121222	59,941,756,732	24,396,068,275	51,096,007,469
20120623	58,709,620,515	24,490,160,200	47,526,621,363	20121223	54,211,342,677	24,459,845,064	49,218,667,884
20120624	53,204,741,427	23,925,467,213	45,434,995,243	20121224	76,366,592,569	26,994,999,533	57,447,373,414
20120625	70,066,361,053	26,220,722,602	49,726,106,083	20121225	57,181,509,990	25,383,773,812	51,593,542,775
20120626	67,115,083,126	25,131,937,665	49,649,892,166	20121226	79,605,849,256	28,955,356,933	58,896,991,550
20120627	67,285,148,776	25,755,292,279	48,893,554,167	20121227	75,954,383,361	27,677,246,236	59,247,680,914
20120628	67,303,222,413	26,140,088,267	50,165,429,609	20121228	72,817,143,408	26,275,392,240	56,598,981,454
20120629	70,941,071,602	26,743,089,635	51,579,472,178	20121229	60,162,059,313	24,027,799,482	50,828,325,760
20120630	56,018,816,027	22,608,958,341	48,453,215,439	20121230	54,083,937,830	24,319,681,910	49,265,272,127
20120701	47,875,805,254	21,837,585,665	42,921,173,895	20121231	70,330,487,586	26,341,700,916	54,724,571,633

Appendix 3. List of bonds issued by KEPCO from 2013 to 2014 (Source: Korea Financial Investment Association Bond Information Service)

Name	Issue date	Maturity date	Remaining life	Maturity (years)	Issue size (KRW 100mil)	Coupon		Coupon rate (%)
						Payment type	Term (month)	
KEPCO 894	2014-08-27	2029-08-27	13/10/22	15	1,100	Coupon	06	3.24
KEPCO 893	2014-06-27	2024-06-27	08/08/22	10	1,000	Coupon	06	3.28
KEPCO 892	2014-06-25	2017-06-23	01/08/18	3	1,000	Coupon	03	2.73
KEPCO 891	2014-06-25	2023-06-25	07/08/20	9	2,000	Coupon	06	3.24
KEPCO 890	2014-06-16	2019-06-16	03/08/11	5	1,000	Coupon	06	3.1
KEPCO 889	2014-06-10	2024-06-10	08/08/05	10	1,000	Coupon	06	3.47
KEPCO 888	2014-05-29	2024-05-29	08/07/24	10	1,000	Coupon	06	3.44
KEPCO 887	2014-05-23	2019-05-23	03/07/18	5	1,000	Coupon	06	3.22
KEPCO 886	2014-05-12	2021-05-12	05/07/07	7	800	Coupon	06	3.39
KEPCO 884	2014-04-29	2029-04-29	13/06/24	15	900	Coupon	06	3.72
KEPCO 883	2014-04-25	2021-04-25	05/06/20	7	1,100	Coupon	06	3.49
KEPCO 882	2014-04-23	2019-04-23	03/06/18	5	1,300	Coupon	06	3.35
KEPCO 881	2014-04-18	2024-04-18	08/06/13	10	700	Coupon	06	3.66
KEPCO 880	2014-04-14	2024-04-14	08/06/09	10	1,100	Coupon	06	3.66
KEPCO 879	2014-04-08	2019-04-08	03/06/03	5	900	Coupon	06	3.32
KEPCO 878	2013-12-24	2020-12-24	05/02/19	7	1,400	Coupon	06	3.67
KEPCO 876	2013-11-28	2020-11-28	05/01/23	7	700	Coupon	06	3.73
KEPCO 877	2013-11-28	2028-11-28	13/01/23	15	500	Coupon	06	3.88
KEPCO 874	2013-11-26	2020-11-26	05/01/21	7	600	Coupon	06	3.71
KEPCO 875	2013-11-26	2028-11-26	13/01/21	5	900	Coupon	06	3.9
KEPCO 872	2013-11-13	2020-11-13	05/01/08	7	900	Coupon	06	3.68
KEPCO 873	2013-11-13	2028-11-13	13/01/08	15	600	Coupon	06	3.82
KEPCO 871	2013-11-08	2020-11-08	05/01/03	7	1,100	Coupon	06	3.59
KEPCO 870	2013-11-05	2023-11-05	08/01/00	10	800	Coupon	06	3.69
KEPCO 869	2013-10-07	2023-10-07	08/00/02	10	600	Coupon	06	3.61
KEPCO 867	2013-09-16	2020-09-16	04/11/11	7	700	Coupon	06	3.55
KEPCO 868	2013-09-16	2028-09-16	12/11/11	15	500	Coupon	06	3.78
KEPCO 866	2013-09-10	2023-09-10	07/11/05	10	1,000	Coupon	06	3.75
KEPCO 865	2013-08-27	2028-08-27	12/10/22	15	1,000	Coupon	06	3.87
KEPCO 864	2013-08-26	2023-08-26	07/10/21	10	800	Coupon	06	3.81
KEPCO 863	2013-08-13	2023-08-13	07/10/08	10	1,300	Coupon	06	3.69
KEPCO 861	2013-08-06	2028-08-06	12/10/01	15	700	Coupon	06	3.74
KEPCO 862	2013-08-06	2033-08-06	17/10/01	20	1,000	Coupon	06	3.81
KEPCO 860	2013-08-05	2023-08-05	07/10/00	10	900	Coupon	06	3.69

Name	Issue date	Maturity date	Remaining life	Maturity (years)	Issue size (KRW 100 mil)	Coupon		Coupon rate (%)
						Payment type	Term (month)	
KEPCO 859	2013-07-30	2028-07-30	12/09/25	15	700	Coupon	06	3.69
KEPCO 858	2013-07-29	2018-07-29	02/09/24	5	1,100	Coupon	06	3.45
KEPCO 857	2013-07-25	2023-07-25	07/09/20	10	800	Coupon	06	3.66
KEPCO 856	2013-07-23	2020-07-23	04/09/18	7	500	Coupon	06	3.51
KEPCO 855	2013-07-17	2018-07-17	02/09/12	5	2,200	Coupon	06	3.45
KEPCO 854	2013-07-15	2023-07-15	07/09/10	10	1,400	Coupon	06	3.57
KEPCO 853	2013-07-09	2028-07-09	12/09/04	15	800	Coupon	06	3.86
KEPCO 852	2013-07-05	2023-07-05	07/09/00	10	1,100	Coupon	06	3.68
KEPCO 851	2013-06-28	2028-06-28	12/08/23	15	600	Coupon	06	3.66
KEPCO 850	2013-06-25	2018-06-25	02/08/20	5	1,500	Coupon	03	3
KEPCO 849	2013-06-17	2023-06-17	07/08/12	10	1,200	Coupon	06	3.3
KEPCO 848	2013-06-11	2018-06-11	02/08/06	5	2,000	Coupon	06	3.13
KEPCO 847	2013-05-30	2018-05-30	02/07/25	5	1,700	Coupon	06	3.03
KEPCO 845	2013-05-27	2020-05-27	04/07/22	7	1,400	Coupon	06	2.96
KEPCO 846	2013-05-27	2028-05-27	12/07/22	15	1,000	Coupon	06	3.14
KEPCO 844	2013-05-13	2023-05-13	07/07/08	10	800	Coupon	06	3.03
KEPCO 843	2013-05-13	2028-05-13	12/07/08	15	1,000	Coupon	06	3.08
KEPCO 842	2013-04-30	2028-04-30	12/06/25	15	1,000	Coupon	06	3.02
KEPCO 841	2013-04-29	2018-04-29	02/06/24	10	1,000	Coupon	06	2.77
KEPCO 839	2013-04-09	2020-04-09	04/06/04	7	1,000	Coupon	06	2.85
KEPCO 840	2013-04-09	2028-04-09	12/06/04	15	1,000	Coupon	06	3.03
KEPCO 838	2013-04-01	2018-04-01	02/05/27	5	800	Coupon	06	2.77
KEPCO 837	2013-04-01	2023-04-01	07/05/27	10	1,400	Coupon	06	2.93
KEPCO 836	2013-03-28	2020-03-28	04/05/23	7	2,400	Coupon	06	2.91
KEPCO 835	2013-02-28	2023-02-28	07/04/23	10	1,000	Coupon	06	3.08
KEPCO 834	2013-02-26	2020-02-26	04/04/21	7	1,600	Coupon	06	3.03
KEPCO 833	2013-02-15	2020-02-15	04/04/10	7	1,000	Coupon	06	3.09
KEPCO 832	2013-01-29	2020-01-29	04/03/24	7	1,100	Coupon	06	3.11
KEPCO 831	2013-01-08	2019-01-08	03/03/03	6	900	Coupon	06	3.1

Appendix 4. List of bonds issued by KOGAS from 2013 to 2014 (Source: Korea Financial Investment Association Bond Information Service)

Name	Issue date	Maturity date	Remaining life	Maturity (years)	Issue size (KRW 100mil)	Coupon		Coupon rate (%)
						Payment type	Term (month)	
KOGAS 370	2014-12-17	2025-06-17	09/08/12	10.5	1,000	Coupon	03	2.79
KOGAS 369	2014-11-26	2025-05-26	09/07/21	10.5	1,700	Coupon	03	2.75
KOGAS 368	2014-11-12	2029-11-12	14/01/07	15	800	Coupon	03	2.93
KOGAS 367	2014-10-22	2024-10-22	09/00/17	10	1,500	Coupon	03	2.85
KOGAS 366	2014-09-17	2021-09-17	05/11/12	7	1,400	Coupon	03	2.95
KOGAS 365	2014-08-26	2021-08-26	05/10/21	7	1,800	Coupon	03	3.07
KOGAS 363	2014-07-16	2024-07-16	08/09/11	10	1,500	Coupon	03	3.18
KOGAS 362	2014-06-17	2029-06-17	13/08/12	15	1,000	Coupon	03	3.5
KOGAS 361	2014-05-20	2029-05-20	13/07/15	15	1,200	Coupon	03	3.58
KOGAS 360	2014-04-29	2024-04-29	08/06/24	10	1,400	Coupon	03	3.65
KOGAS 359	2014-04-22	2034-04-22	18/06/17	20	600	Coupon	03	3.85
KOGAS 358	2014-03-18	2024-03-18	08/05/13	10	1,300	Coupon	03	3.67
KOGAS 357	2014-02-20	2034-02-20	18/04/15	20	900	Coupon	03	3.79
KOGAS 356	2014-01-23	2024-07-23	08/09/18	10.5	1,500	Coupon	03	3.83
KOGAS 355	2013-12-13	2029-06-13	13/08/08	15.5	1,500	Coupon	03	3.97
KOGAS 354	2013-12-05	2024-06-05	08/08/00	10.5	1,500	Coupon	03	3.93
KOGAS 353	2013-11-26	2024-05-26	08/07/21	10.5	1,000	Coupon	03	3.86
KOGAS 351	2013-11-22	2020-11-22	05/01/17	7	1,100	Coupon	03	3.74
KOGAS 350	2013-11-19	2024-05-19	08/07/14	10.5	1,000	Coupon	03	3.8
KOGAS 349	2013-11-15	2029-05-15	13/07/10	15.5	800	Coupon	03	3.87
KOGAS 348	2013-11-08	2024-05-08	08/07/03	10.5	1,700	Coupon	03	3.73
KOGAS 346	2013-11-05	2018-05-05	02/07/00	4.5	2,000	Coupon	03	3.34
KOGAS 347	2013-11-05	2033-11-05	18/01/00	20	800	Coupon	03	3.85
KOGAS 345	2013-10-30	2029-04-30	13/06/25	15.5	700	Coupon	03	3.71
KOGAS 343	2013-10-24	2020-04-24	04/06/19	6.5	300	Coupon	03	3.42
KOGAS 344	2013-10-24	2029-04-24	13/06/19	15.5	1,600	Coupon	03	3.66
KOGAS 342	2013-10-17	2020-10-17	05/00/12	7	1,300	Coupon	03	3.57
KOGAS 341	2013-10-15	2016-10-15	01/00/10	3	3,000	Coupon	03	3.14

Name	Issue date	Maturity date	Remaining life	Maturity (years)	Issue size (KRW 100mil)	Coupon		Coupon rate (%)
						Payment type	Term (month)	
KOGAS 340	2013-10-11	2023-10-11	08/00/06	10	1,100	Coupon	03	3.72
KOGAS 339	2013-10-02	2023-10-02	07/11/28	10	700	Coupon	03	3.66
KOGAS 338	2013-09-24	2026-09-24	10/11/19	13	500	Coupon	03	3.63
KOGAS 337	2013-09-13	2027-09-13	11/11/08	14	500	Coupon	03	3.78
KOGAS 336	2013-09-04	2027-09-04	11/10/30	14	900	Coupon	03	3.86
KOGAS 335	2013-08-28	2024-08-28	08/10/23	11	1,000	Coupon	03	3.79
KOGAS 334	2013-08-13	2026-08-13	10/10/08	13	1,200	Coupon	03	3.77
KOGAS 333	2013-07-26	2023-07-26	07/09/21	10	1,200	Coupon	03	3.67
KOGAS 332	2013-07-12	2023-07-12	07/09/07	10	1,500	Coupon	03	3.58
KOGAS 331	2013-06-18	2024-06-18	08/08/13	11	1,000	Coupon	03	3.45
KOGAS 330	2013-05-30	2026-05-30	10/07/25	13	1,600	Coupon	03	3.21
KOGAS 329	2013-04-30	2028-04-30	12/06/25	15	1,500	Coupon	03	3.06
KOGAS 328	2013-04-04	2023-04-04	07/05/30	10	1,300	Coupon	03	2.94
KOGAS 327	2013-02-21	2028-08-21	12/10/16	15.5	1,600	Coupon	03	3.24
KOGAS 326	2013-02-05	2025-08-05	09/10/00	12.5	1,600	Coupon	03	3.25
KOGAS 325	2013-02-01	2023-08-01	07/09/27	10.5	1,100	Coupon	03	3.24