

Optimal renewable power generation systems for Busan metropolitan city in South Korea



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ABSTRACT

The metropolitan cities of developed countries comprise more than 50% of the global population and consume over 60% of the world's energy. Many governments plan to enhance their energy infrastructure and the electricity supply–demand reliability of their energy sources. Among them, South Korea's government has developed electricity generation facilities, most of which use renewable resources such as photovoltaic and wind energy. This study determines the optimal renewable electricity generation configuration for one of the largest metropolitan cities in South Korea, Busan metropolitan city. A simulation using 2013 Busan electricity demand data produces this optimal configuration, which includes photovoltaic panels, wind facilities, converters, and batteries with \$0.399 of COE (Cost of Electricity) and 100% of renewable fractions. Both the study's practical limitations and implications are discussed.

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1. Introduction

Following several energy crises, including the global oil crisis and the Fukushima accident, both sustainability and green growth are considered key concepts for public and industrial growth. Within this trend, many industrialized nations have made energy security their most important policy planning consideration [15]. Moreover, as these nations' metropolitan cities, containing about 50% of the global population, represent about two thirds of global energy consumption [24], most of them aim to strengthen their energy infrastructure and security by diversifying their energy and electricity sources [42].

For this reason, many governments have enacted policies and programs (e.g., feed-in-tariffs, quota obligations, subsidies and tax

incentives) to encourage the use of renewable energy [5,21,31,41]. Many local US governments have adopted renewable portfolio guidelines with various tax incentives to encourage green growth [46,10,11,47,48]. For example, Portland introduced a residential energy policy to provide incentives (a 25% support fund per house and a 35% corporate tax deduction for using renewable energy), and Los Angeles constructed a 120 MW wind farm and a 687 GWh solar farm through the Pine Tree Wind and Solar Path projects to supply green energy to their metropolitan cities [7]. In Europe, the German government has promoted various renewable energy policy models. In Freiburg, the local government provides a subsidy for PV utilization and purchased a residual quantity of electricity, while Aachen lets local communities share the expenses and benefits of using renewable energy [7]. In addition, BedZED in England, Hammarby in Sweden, and many islands in Spain provide examples of successful renewable energy cities [30]. Table 1 presents several examples in the world.

Many urban renewals of metropolitan cities are occurring in Asian countries as well. China, the world's largest greenhouse gas (GHG) emitter, is being pressured by its high energy dependency on

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Table 1
Representative Green cities all over the world.

City	Country/location	Policy and program
Riem	Germany/Munich	• 50% of developing area is designated as green zone.
Vauban	Germany/Freiburg	• Green growth policy plan called “finger plan” for wind power generation” is operated • Tram in the middle of the city • Citizens’ ‘no car agreement’
BedZed	England/Sutton	• Afforestation of roof, recycling of natural materials. • “City car club” car pool adoption
Hammarby	Sweden	• 100% of electricity supplied by renewable energy (biogas, wind, PV generation) • 80% of transportation replaced by green transportation (electric car, bio-fuel car)
Masdar	UAE/Abu Dhabi	• PV, wind turbine, geothermal generation for city • Personalized Electric Transport System, Personal Rapid System
Dockside	Canada/Victoria	• Biomass generation and PV street lamp • Water recycling system
Jeju	South Korea	• PV, wind turbine generation for city • Electric car support policy

Source: [18,25,30].

oil and gas to explore green growth [13,34,36,58]. Beijing plans to triple its renewable energy use between 2005 and 2010 [6]. Moreover, China's twelfth five-year plan commits to obtain 30% of its electricity without fossil fuels and to reduce its energy consumption per unit of GDP by 16% and its CO emissions per unit of GDP by 17% by 2015 [34,54].

South Korea, a rapidly industrializing country that lacks natural resources, has attempted to minimize its heavy reliance on fossil fuels by using renewable electricity facilities and operating related-policies for promoting renewable energy plan and green growth [29]. The Korean government introduced a new policy for reducing 70% of the nation's greenhouse gas emissions (GHGs) by 2020 [27], and plans to implement the Greenhouse Gas Emission Trading Scheme in 2015 [22,23,28,32].

Although there is research on the potential for sustainable energy for business [14] and the need to use renewable energy in metropolitan cities [52], few studies have examined the feasibility of using hybrid systems for renewable energy, an option with significant practical and research implications that should be explored through empirical data.

Therefore, this study investigates an optimized renewable power generation system for Busan metropolitan city, South Korea's second-largest city, by using its electricity consumption data. This study employs the hybrid optimization of multiple energy

resources (HOMER) to suggest a renewable power generation system for Busan metropolitan city along with the relevant economic parameters, the cost of electricity (COE), and the net present cost (NPC).

2. Busan metropolitan city

2.1. Population and location

Busan metropolitan city is one of South Korea's largest cities. Its deep harbor and slow ocean currents helped Busan metropolitan city grow into one of Asia's major container distribution ports. The center of the city is 34° 37' of latitude and 128° 31' of longitude. The city has approximately 3.5 million residents and is about 768.41 km², about 1% of the Korean Peninsula (Fig. 1).

2.2. Energy status and policy

Busan has the highest dependency on nuclear energy of any South Korea city. It also has the highest rate of electricity self-sufficiency (at 43.9%, compared to Seoul's 7.6%, Daegu's 16.4%, Incheon's 18.2%, and Ulsan's 29.7%; Table 2). However, 98% of its electricity production was supplied by a nuclear power plant, and only 1.68% of its electricity consumption was provided by

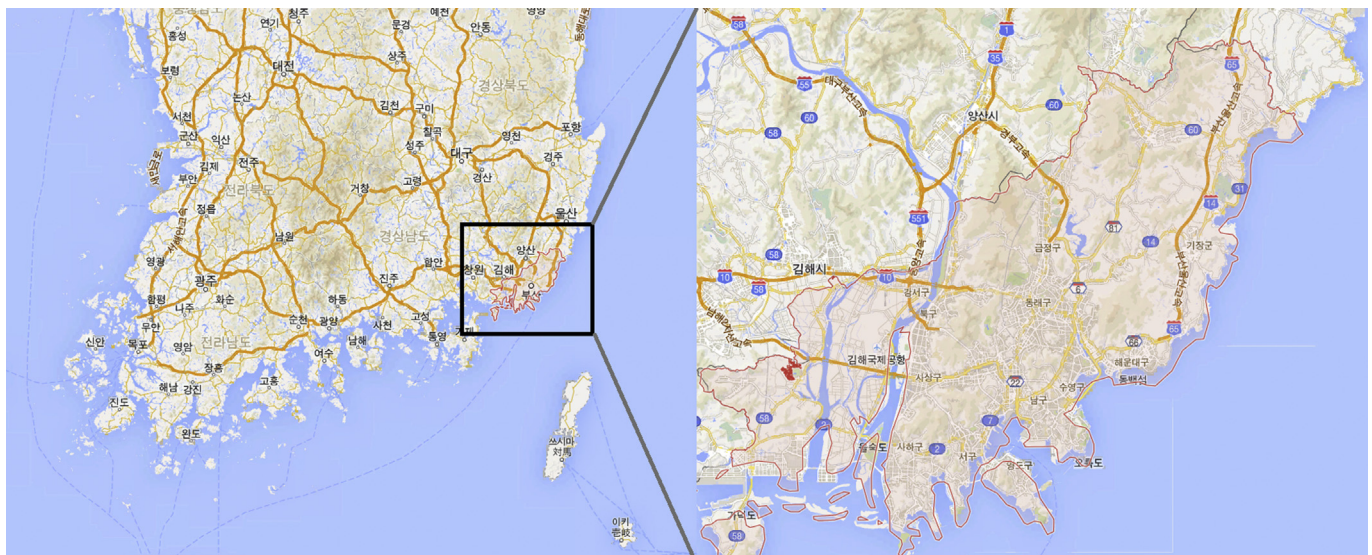


Fig. 1. A map of Busan metropolitan city.

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