

## Exploring low-carbon landscape design: focus on an urban waterfront area

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### Abstract

Sustainable designs like low-carbon landscapes are key to lowering the anthropogenic carbon footprint of our society and promoting harmony with natural ecosystems. We can design low-carbon landscapes for terrestrial (e.g. forests and urban farming areas) as well as aquatic (e.g. urban streams, ponds, and wetlands) urban spaces. Ecological interactions between water and soil in an urban ecosystem cause high carbon accumulation rates, especially in waterfront areas. Furthermore, heat absorption at waterfronts also significantly mitigates urban heat island effect. Therefore, urban open spaces with waterfronts are ecologically vital and may help us cope with climate change. However, the design and application of urban low-carbon landscapes are still in the conceptual phase and the creation a low carbon city remains as a preliminary draft. At present, there are very few studies measuring carbon emissions and carbon absorptions in the urban area. Moreover, studies that analyze low-carbon landscape components and their social effects are needed. In this study, we propose a novel conceptual definition of low-carbon landscape and investigate the research methods related to low-carbon landscape design. We have also listed numerous case studies of urban waterfronts scrutinizing the various components of a low-carbon landscape.

*Keywords: design elements, low-carbon society, carbon reduction, carbon sequestration.*

### 1 Introduction

Korea's high carbon footprint gained significant global and national notoriety after it became a signatory to the United Nations Framework Convention on



Climatic Change (UNFCCC). Moreover, significant amounts of greenhouse gases were being released due to urban economic activities. We are going to be tasked with reducing our CO<sub>2</sub> emissions based on the terms of the treaty (Lee and Lee [1]). Subsequently, the Korean government established and implemented policies like the “Five-year Plan for Green Growth” and “Urban Planning Guideline for the Development of Green City” (Park and Kim [2], Ko *et al.* [3]). Furthermore, legislations like “Framework Act on Low Carbon and Green Growth” were also introduced in 2010 to deal with global climate change (Yeo and Yoon [4]). Two critical elements that are often discussed while considering sustainable urban development as a response to systemic disruptions in Korea resulting from climate change are environmental sustainability and energy efficiency. Consequently, interest in introducing greenhouse gas reduction measures to urban areas grew (NGMS [5]). In order to address these problems and to achieve low carbon society, the concept of “low carbon landscape” was proposed. A low carbon landscape includes landscape elements composed of materials and facilities, which can reduce greenhouse gas emissions and minimize the overall carbon footprint (Zhang and Sui [6]). Since low carbon landscapes are one of the core elements that can reduce the greenhouse emissions (Hui-fang *et al.* [7]); these can be grouped along with other terrestrial (i.e. urban forests, parks, and urban agriculture spaces) and aquatic features (i.e. the waterfronts like rivers, ponds and wetlands). Waterfronts tend to have a high carbon accumulation rate due to systemic interaction between water and soil. Furthermore, waterfronts play a critical role (Lee [8], UNEP [9]), in mitigating urban heat island effect. However, fundamental research evaluating the design elements and criteria for low carbon landscape resources specific to urban waterfront is currently in the concept formulation phase. Using case studies, we have investigated low carbon landscape design elements for an urban waterfront. Moreover, we propose a novel conceptual definition of low-carbon landscape and state the criteria for low carbon landscape design.

## 2 Literature review

### 2.1 Related research trend

Interest in low carbon landscapes in Korea grew after the National Climate Change Adaptation Plan was established in 2008 to achieve the nation's vision of low carbon and green growth policy. In 2009, the Korea government declared it was planning an energy saving city utilizing new renewable energy sources along with Ministry of Land, Infrastructure and Transport (Kim [10], Park and Kim [2]). In order to do this, the elements of low carbon landscape needed to be actively utilized. Moreover, qualified evaluation of means and methods was needed before adopting new renewable energy sources. However, in Korea, assessment tools for planning and designing low carbon landscape are non-existent; making the detailed analysis of energy savings impossible (Lee and Lee [1]). Nevertheless, in order to compensate for this analytical difficulty, ecological and environment sectors have actively performed independent studies



that evaluate whether urban green space reduces the CO<sub>2</sub> concentrations (Ahn *et al.* [11]). These field studies were performed to ascertain the carbon reduction in the atmosphere based on tree carbon fixation calculations (Jo and Ahn [12], Park and Kang [13], Ahn *et al.* [11], Jo and Ahn [14]). However, such field studies are usually performed in metropolitan areas or forest ecosystems and focus on various technical aspects, often neglecting the hydro-ecosystem. The reason for the technical orientation of these studies is that Korean water resource development significantly affects irrigation planning of our rivers. Whereas, other countries had long recognized waterfronts like streams and wetlands as a method for greenhouse gas reduction and evaluated their carbon storage capacity and emissions from wetland soil. Furthermore, the use and management methods for waterfront design elements are also studied (Neue *et al.* [15], Persson [16], IPCC [17], Timothy and Paul [18]). Consequently, further research, which would provide insights into policy, design, planning, and management for low carbon landscape using technical data like absorption and evapotranspiration of CO<sub>2</sub>, is needed.

## 2.2 Definition of low-carbon landscape design

Low carbon landscapes were specifically proposed for incorporation into ‘low carbon cities,’ and were first used in many countries including Oceania, China, and Taiwan; which respond sensitively to climate change (Zhang and Sui [6], Beringer *et al.* [19], Huifang *et al.* [7], Zhou *et al.* [20]). Many studies define low carbon landscapes as spaces to assimilate nature in the process of landscape design and formation. Using landscape design model slow carbon landscapes have been shown to reduce the use of non-renewable energy by reducing energy consumption, pollution, and emissions while increasing carbon fixation rates (Huifang *et al.* [7]). However, very few case studies pertaining to design of low carbon landscapes exist since low carbon landscape design is still in its conceptual phase. This study establishes the concept of low carbon landscape by defining ‘low carbon’ and ‘landscape’ using peer-reviewed literature. “The Framework Act on Low Carbon, Green Growth” defines the usage of the term ‘low carbon’ as reducing the dependence on fossil fuels, increasing the use and supply of clean energy, and reducing the greenhouse gas concentration below the optimum level through research and development as well as increasing carbon absorption. Landscapes are a means of expressing the local environmental, visual and aesthetic characteristics composed by nature, artificial elements, and residential life style (Lee [21]). Therefore, ‘low carbon landscapes’ should be composed of elements necessary to reduce the greenhouse effect, cope with climate change, and make a low carbon city tangible. These elements can be predominantly classified as carbon reduction and carbon sequestration based on the CO<sub>2</sub> reduction method (table 1).



Table 1:        The classification standard for low carbon landscape.

Carbon reduction		Carbon sequestration	
Energy conservation	Installing high performance insulation and keeping buildings airtight	Complex greenery	Carbon park
	Considering solar and building orientation		Vegetable garden
	Bicycle activating system	3-dimensional planting	Roof planting
	Pedestrian road		Wall planting
	Transit transfer center	Green network	Greenway
	Public transportation and pedestrian mall		Ventilation path
	Carbon reduction public transportation		Carbon forest
	Green highway		Eco bridge
Renewable energy	Photovoltaic system	Water resource system	Brooklet
	Solar thermal system	Water circulation system	Detention ponds
	Passive solar system		Natural soil
	Small scale cogeneration system		Porous pavement
Recycling resources	Using natural resources	Waterfront	Wetland
	Recycling heavy water		Rain garden
	Storm water		Wildlife habitats
	Recycling storm water storage tank		Natural river

Data: Yoon [22]; Author Rewriting.

2.3 The classification standard for low carbon landscape

2.3.1 Carbon reduction

Carbon reduction can be achieved by introducing low carbon tourism and creating sustainable tourist allurements, the naturalism, and idealism (Costa and Soares [23]). Using renewable energy sources such as wind power should also be encouraged. Reducing the carbon footprint does not necessarily mean the carbon emission reductions. It may also be accomplished by offsetting carbon emissions using the dynamic carbon balance (ASQASKETS [24]). Various alternatives which use carbon reduction for accomplishing the balance of CO<sub>2</sub> are known (Ko *et al.* [3]). Urban traffic system with green transportation and virtuous circulation system that encourages walking and bicycling are vital for carbon reduction (Seo [25]). Furthermore, buildings retrofitted for small to medium wind power generation along with a passive solar power generation system are a norm in Korea (Rural Development Administration [26]).

2.3.2 Carbon sequestration

Carbon sequestration means to absorb the thermal energy using a green roof system and the insulation effect achieved by planting vegetation. Similarly, urban street trees, eco corridors, wetlands, village forest development, and rain gardens can be used to absorb CO<sub>2</sub> (Costa and Soares [23]).



### 3 Case study

#### 3.1 Outline of case study

This final phase study investigates low carbon landscape resources composed of typical waterfront areas of four new low carbon footprint towns. First, we analyzed the general details, the topographic characteristic, and the condition of water resources to understand the new town. Secondly, we investigated the low carbon landscape resources at the waterfront of the new town, and classified them as carbon sequestration or carbon emission (fig. 1).

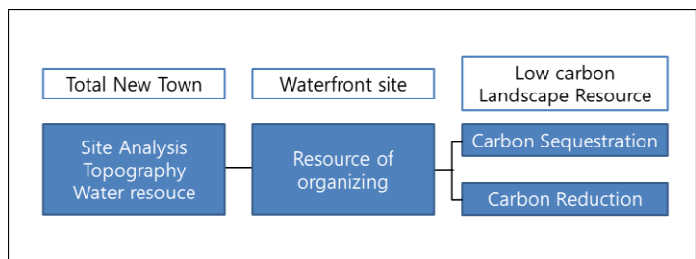


Figure 1: Outline of case study.

#### 3.2 Unjeong New Town

Unjeong New Town is located in Dongpae-ri, Mokdong-ri, Yadang-ri, Wadong-ri, Dangha-ri, Sangiiseok-ri, Dayul-ri, and Gyoha-ri in Paju-si, Gyeonggi-do (Korea Housing Corporation [27]). The New Towns are planned cities, which incorporate a water circulation system that will cope with climate change and create a sustainable urban environment improving the quality of life for urban residents. Topographically, the Unjeong New Town has an east to west slope. Gamaksan, Papyeongsan, and Gyemyeongsan are located to the eastern side of Unjeong New Town. Since about 80.2% (539.67 km<sup>2</sup>) land is under the altitude of 100 m large areas are available for development. The dimensional stability of Sori-stream was considered since both the Sori-stream as well as the river, overflowed in the 1996, 1998, and 1999 because of their flat topography. Furthermore, contamination of Sori-stream, which is used for drainage way, was common in the dry season. Consequently, river maintenance became essential and the Sori-stream implementation project was established in November 2006. The Sori-stream is the primary axis of the water circulation system of Unjeong New Town; while the brooklet, which circulates in the residential area, is the secondary axis. The space organization is composed of the water sports zone, the waterway zone, and the eco zone. The main contents are listed in table 2.

The carbon reduction and carbon sequestration components of waterfront area in the Unjeong New Town are listed in table 3.

Table 2: Unjeong New Town waterfront plan.

Zone	Contents
Water sports zone	<ul style="list-style-type: none"> <li>- The creation of the waterfront site based on natural landscape</li> <li>- Continuous rapids type drop structure</li> <li>- Provide the function of fish migration</li> </ul>
Waterway zone	<ul style="list-style-type: none"> <li>- The adjustment of river width accounting for flooding</li> <li>- Urban natural river planning</li> </ul>
Eco zone	<ul style="list-style-type: none"> <li>- Use of existing water system</li> <li>- The composition of eco friendly techniques</li> <li>- Rainwater harvesting, plant and wildlife habitat</li> <li>- Creating an eco pond</li> </ul>

Data: Korea Environment Institute [28].

Table 3: Unjeong New Town low carbon landscape resources.

Carbon reduction		Carbon sequestration	
Resource circulation	Storm water	3-dimensional Planting	Slope vegetation
		Water resource System	Brooklet
			Detention ponds
		Water circulation System	Porous pavement
		Waterfront	Wildlife habitats
			Natural river (Riffle, pond, natural-stone masonry)

### 3.3 Pangyo New Town

Sungnam-Si developed the Pangyo New Town in order to control the sprawling development after construction restrictions were cancelled and to establish sustainable urban planning (Korea Housing Corporation [29]). The development range of Pangyo New Town includes Pangyo-dong, Hasanun-dong, Unjung-dong, Sampyeong-dong, Baekhyeon-dong, Imae-dong, Yatap-dong, Seohyeon-dong and Sunae-dong in Bundang-gu, and Sujeong-gu, Sasong-dong, Geumto-dong in Sujeong-fu in Seongnam-si, Gyeonggi-do. The total development area is about 9,294m<sup>2</sup>. Topographically, Pangyo New Town is predominantly flat land. Subsequently, forests were created in the Meogeum Mountain near from the north side adjoining Seoul Ring Expressway, Geumto Mountain located at the center of site, and the Shinchon-park area of the south side. The Unjung and Geumto streams, which are the principal water resources in Pangyo run from west to east. The Hasan and Seongnaemi streams merge into the Unjung stream (Korea Housing Corporation [30]). The Pangyo New Town has a significant advantage for installing the water circulation system because of the artificial wetlands and agriculture waterways around the rural region of Unjung and Geumto stream. Table 4 lists the planning components of the water circulation system installed in the Pangyo New Town.

Table 4: Pangyo New Town water circulation system plan.

Plan	Contents
Using existing water system	- Arrangement of district site considering existing water system - Tandem operation of the water system with natural mountain flow system
Use of storm water	- Storm water was retained by the detention pond inside the park as well as the complex - Connecting private and public storm water drainage
Reusing groundwater	- The utilization of groundwater seepage during the construction of the subway and underground. - Reusing groundwater seepage from subways or underpass

Data: Korea Environment Institute [28].

The space organization is such that the brooklet is connected to the public space, neighborhood park, and the detention pond. The components of the waterfront in the complex and Water Restoration Center are listed in table 5.

Table 5: Pangyo New Town waterfront plan.

Zone	Components
Brooklet	- Water station - Observatory - Planting within the stream - Use of environmental materials - Habitat
Waterfront in complex	- Wetland
Water Restoration Center	- Treatment and discharge of residential sewage

Data: Korea Environment Institute [28]

The carbon reduction and carbon sequestration components of waterfront area in the Pangyo New Town are listed in table 6.

Table 6: Pangyo New Town low carbon landscape resources.

Carbon reduction		Carbon sequestration	
Energy conservation	Bicycle activating system	Complex greenery	Carbon park
	Pedestrian road		Vegetable garden
	Public transportation and pedestrian mall	3-dimensional planting	Roof planting
	Carbon reduction public transportation	Green network	Ventilation path
Resource recycling	Existing water system		Eco bridge
	Recycling heavy water	Water resource system	Brooklet
	Storm water		Detention ponds
	Recycling storm water storage tank	Waterfront	Wetland
-	Rain garden		
	Wildlife habitats		
	Natural river		



### 3.4 Gimpo Han River New Town

Gimpo Han River New Town was developed with the purpose of developing a green eco-city, solving housing shortages, and creating a comfortable environment in the metropolitan area (Korea Land Corporation [31]). The development range included Janggi-dong, Woonyang-dong and Yangchon-myeon of Gimpo-si and Korea Land. The Housing Corporation took over operational responsibilities after the development areas were designated as Housing Development district in 2006. The topography of Gimpo Han River New Town is both hilly as well as flat. The altitude around Unyusan is approximately 70 m, while Daemasan and Modansan are relatively flat (20m) and occupy about 70% of the total area. Most of the site is a plain area and the plow land occupies over 50% of the site. The shape of this site is long from east to west and has a valley. The Gamaji stream and the Gimpo waterway merge into the Han River in the business district. The Gamaji stream originates in the urban south side and flows into the Han River where it meets the Beopseongpo stream of the north side. The Gimpo waterway is also used for irrigation. It is feasible to develop it as a waterfront zone through reorganization and securing an additional water source. The Gimpo Han River New Town is divided into the complex business district, cultural exchange district, and ecological environment district. The waterfront area is composed of the eco canal zone, an ecological park for the wild birds zone, and the canal zone (table 7).

The carbon reduction and carbon sequestration components of the waterfront area in the Gimpo Han River New Town are listed in table 8.

Table 7: Gimpo Han River waterfront plan.

Zone	Components
Eco canal	<ul style="list-style-type: none"> <li>- Development of the ecological environment observation program</li> <li>- The selection of the waterfront site which connects with the eco-canal</li> <li>- The creation of the shore and gentle slopes</li> <li>- The installation of a pumping station and rainwater recycling facility</li> </ul>
Ecological park for wild birds	<ul style="list-style-type: none"> <li>- Wild bird's habitat composition</li> <li>- Build the eco center</li> </ul>
Culture	- Hydrologic and water pollution control facilities

Data: Korea Environment Institute [28].

Table 8: Gimpo Han River New Town low carbon landscape resources.

Carbon reduction		Carbon sequestration	
Energy Conservation	Mud cap house	Water resource system	Brooklet
	Pedestrian road		Detention ponds
	Public transportation and pedestrian mall	Waterfront	Wetland
	Green highway		Rain garden
Resource recycling	Recycling heavy water		Wildlife habitats
	Storm water		Natural river
	Recycling storm water storage tank		-





### 3.5 Gwanggyo New Town

Gwanggyo New Town is planned as metropolitan area and a southern central city. It was designed to be eco-friendly and incorporated education or research hubs, sport and leisure complexes. It is also a vital traffic node (Han [32]). The development range of Gwanggyo New Town includes Maetan-dong, Iui-dong, Woncheon-dong, Ha-dong, Uman-dong, and Yeonmu-dong in Suwon-si and Sanghyeon-dong and Yeongdeok-dong in Yongin-Si. The development area is 11,301,699 m<sup>2</sup>. Gwanggyo New Town is hilly. The hills are about 50–100 m high and occupy over 78.92%. The gentle slope with a 20° gradient and the hill occupy 91.8% of the whole area. The Woncheon and the Yeo streams, which are the primary water resources of Gwanggyo New Town; run from the north to the south and merge into the Hwangguji stream. The Suwon stream is to the west while the Tan, Mabuk and Osan streams are to the east. Seongbok and Dogmak streams are in the south. The water circulation system in Gwanggyo New Town is comprised of a brooklet and recycled storm water. The characteristics are listed in table 9.

Table 9: Gwanggyo New Town water circulation system plan.

Plan	Contents
Connecting the stream inside new town with the urban stream	The stream inside New Town and urban stream can be connected.
The plan for storage, penetration, and storm water recycle facility.	The plan to use storm water facility site plan is available to connect it to the water circulation system.
Creating an ecological storm water pond	Creating an eco pond with various functions like water detention and purification as well as habitat space.
Least destructive town layout for the water canal environment	Prevent the damage to the waterway due to road, parking lot, and other facilities in the housing estate.
Using renewable energy	The use of renewable energy including underground detention pond and photovoltaic system

The components of the Gwanggyo New Town waterfront are listed in table 10. The carbon reduction and carbon sequestration components of the waterfront area are listed in table 11.

Table 10: Gwanggyo New Town waterfront plan.

Zone	Components
Stream	<ul style="list-style-type: none"> <li>- Creating the retention and eco ponds</li> <li>- Habitat composition</li> <li>- Biotope</li> </ul>
Close-to-Nature River	<ul style="list-style-type: none"> <li>- Use of existing agricultural irrigation canal</li> <li>- Provide places for relaxation and leisure</li> <li>- Installation of water purification system</li> <li>- Constructing a water purification plant</li> </ul>

Data: Korea Environment Institute [28].



Table 11: Gwanggyo New Town low carbon landscape resources.

Carbon reduction		Carbon sequestration	
Energy conservation	Building layout considering the water resources	Green Network	Greenway
	Pedestrian road		Eco bridge
	Public transportation and pedestrian mall	Water Resource System	Brooklet
Renewable energy	Photovoltaic system		Detention ponds
	Solar thermal system	Waterfront	Wetland
Resource recycling	Recycling heavy water		Wildlife habitats
	Storm water		Natural river
	Recycling storm water storage tank		-

Data: Korea Environment Institute [28]

4 Results

This study explored the waterfront resources of four New Towns in order to assess their low carbon landscape resources for developing a low carbon city (table 12). The characteristics of water circulation system in each city's waterfront are as follows. Unjeong New Town constructed its water circulation system using water from the Sori-stream, which is a natural river. Many low-lying areas in the Sori-stream basin were prone to floods. To assess the flooding

Table 12: Low carbon landscape resources in urban waterfront.

Carbon reduction		Carbon sequestration	
Energy conservation	An adobe house	Complex greenery	Carbon park
	Building arrangement considered water resources		Vegetable garden
	Bicycle activating system	3-dimensional planting	Slope planting
	Pedestrian road		Roof planting
	Public transportation and pedestrian mall	Green network	Greenway
	Carbon reduction public transportation		Ventilation path
	Green highway		Eco bridge
Renewable energy	Photovoltaic system	Water resource system	Brooklet
	Solar thermal system		Detention ponds
Resource recycling	Using the natural resources	Water circulation system	Porous pavement
	Recycling heavy water	Waterfront	Wetland
	Storm water		Eco pond
	Recycling storm water storage tank		Rain garden
-			Wildlife habitats
			Natural river



problem, the river master plan developed by Korea Land and Housing Corporation was investigated and the planning of the water circulation system was analyzed. Unjung and Geumto streams were the main sources of water supply in Pangyo New Town. The water circulation system was constructed using an existing river. The Pangyo New Town has various characteristic waterfronts including an eco pond, a wetland, and a detention pond inside the complex, which the existing water system utilizes. Before the development in Gimpo Han River New Town, Gamaji stream and Gimpo waterway were used for irrigation. Nevertheless, there was potential for development of the waterfront zone through reorganization and securing an additional water source. Consequently, an eco canal in Gamaji stream and Gimpo waterway, was added to the existing water circulation system. Gwanggyo New Town has the most abundant water resources among the four New Towns. These resources are actively introduced to the water circulation system by applying storm water harvesting and connecting the streams between the housing estate and the urban area.

## 5 Conclusion

Low carbon city is slowly becoming a paradigm for urban development. In order to achieve a low carbon footprint for a city, urban planning using low-carbon landscape elements was introduced. Accordingly, in this study we have defined low carbon landscape and investigated related research trends and carbon landscape classification criteria. Low carbon landscapes are key to creating cities with reduced carbon footprint. Low carbon landscapes methods can be classified as carbon reduction or carbon sequestration and can be systematically analyzed. The results show that low carbon landscape resources were imparted to New Towns due to urban waterfront low carbon landscape design. Social and economic indicators like inherent to the waterfront can be used for further evaluation. However, since this study was limited to other objectives, criteria for selection of low carbon landscape resources have not been verified in terms of their validity and reliability. In future studies, it is necessary to develop an objective index for quantifying low carbon landscape resources and design elements.

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