# Study on the Business Strategy and Model for River-water Hydrothermal Energy

By

**YOO, Sung Jae**

**CAPSTONE PROJECT**

Submitted to

KDI School of Public Policy and Management

In Partial Fulfillment of the Requirements

For the Degree of

**MASTER OF PUBLIC MANAGEMENT**

**2024**

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Committee in charge:

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# Abstract

**Study on the Business Strategy and Model for River-water Hydrothermal Energy**

**- Focusing on dam, river water's hydrothermal energy business plan and evaluation**

By

**Yoo, Sung-Jae**

This study delves into the business models and strategies pertaining to the utilization of hydrothermal energy extracted from deep dam water and river water in South Korea. The research undertakes an assessment of potential capacities, devise model strategies and designs, and evaluates their economic viability.

Key findings indicate that deep dam water holds suitability for national-scale projects targeting energy-intensive clusters, necessitating accurate post-project conception calculations of actual potential. The study proposes strategic indicators and hierarchical weighting analysis for comprehensive evaluation. In the context of river water, the research identifies its viability for heating and cooling large urban buildings, albeit requiring meticulous return on investment evaluation due to high initial costs. Continuous updates on the Coefficient of Performance (COP) of heat pumps based on project-specific factors are deemed essential. The study underscores the critical importance of precise Return On Investment calculations and potential improvement measures in implementation design, advocating for diversified evaluation methods that encompass policy considerations, operational data collection, and international case studies.

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# 1. Introduction

## *1.1 Problem statement*

The world's serious response to climate change can be traced back to the Kyoto Protocol. As a concrete implementation plan for the international agreement on regulating and mitigating global warming known as the Climate Change Convention, it established greenhouse gas reduction targets for developed countries. This occurred during the Third session of the Conference of the Parties (COP3) meeting of the UN Climate Change Convention held in December 1997. With the expiration of the Kyoto Protocol in 2020, the climate agreement to be in effect from 2021 is the Paris Agreement, declared at the twenty first of the Countries of Paris Agreement (COP21) United Nations Climate Change Conference.

The Paris Agreement encourages the participation of more countries and calls for each nation to voluntarily submit their Nationally Determined Contributions (NDCs) to set greenhouse gas reduction targets. Ministry of Environment, Republic of Korea (2021), The United States has committed to a 26-28% absolute reduction by 2030 in its NDC, while the European Union aims for a 40% absolute reduction by 2030. China has pledged to reduce its emissions by 60-65% relative to its Gross Domestic Product (GDP) by 2030, and South Korea has set a target of reducing emissions by 37% by 2030 compared to its Business-As-Usual (BAU) projections.

## *1.2 Research questions*

To address climate change, South Korea has been formulating its Basic Plan for Power Supply and Demand every five years since 2002. Under the overarching goal of greenhouse gas reduction, the plan also focuses on achieving the NDCs in accordance with the Paris Agreement while ensuring a stable energy supply. In this process, South Korea aims to increase the share of nuclear power generation to enhance supply stability and provides stronger demand management goals to curb power consumption. The key focus of the 10th Basic Plan for Power Supply and Demand is to achieve a target of 45.3%

renewable energy by 2036, marking a significant step towards South Korea's transition to a carbon-neutral future by 2050.

## 2. Research methods

### *2.1 Data collection*

The purpose of this study is to approach the solutions for Ministry of Environment, Republic of Korea (2020). The quantitative targets of this plan are set at 0.25 GW by 2025, 0.50 GW by 2030, and 1.00 GW by 2040, with an annual reduction goal of 2,138 GWh and 54.7 thousand tons of CO2 emissions by 2040. This plan encompasses three strategies and seven implementation challenges, with major projects including dam deep-water hydrothermal projects and river water source hydrothermal projects, aiming to establish optimized models for achieving reduction targets.

Therefore, in this study, a case study, which is a qualitative research for two business models, is conducted. This aims at to propose project strategies based on the existing models of dam and river water source hydrothermal energy projects to achieve the goals of activating hydrothermal energy in South Korea. Additionally, through this, the study investigates project model development and evaluation methods to explore the scalability and direction of hydrothermal energy projects.

### *2.2 Data analysis*

This study focuses on two project models as part of or Ministry of Environment, Republic of Korea (2020), namely, the dam-based and river water-based projects. The model for dam deep-water hydrothermal energy draws upon the ongoing Gangwon Province Hydrothermal Complex Cluster Project. In the case of river water, the study investigates project models tailored for urban areas or locations near urban centers, considering large facilities and buildings as potential demand sources.

Both models initially calculate the hydrothermal energy's potential capacity. They provide foundational research methods for identifying and supplying hydrothermal energy by estimating not only the theoretical potential capacity but also the practical, usable potential capacity.

Furthermore, the study conducts strategic research for both project models, presenting project concepts. For dam deep-water hydrothermal energy, being a large-scale energy project that requires national planning, a project strategy is formulated in the form of a public project development plan. For river water-based projects, the focus lies on the economic viability of the projects, and the strategy is devised based on the economic feasibility considering the willingness of potential energy users.

Consequently, different evaluation methods are proposed for these two project models. dam deep-water hydrothermal energy, following a public project model, undergoes Analytic Hierarchy Process (Saatry&vargas, 2001), a hierarchical weight analysis, to create key indicators, calculate weights, and facilitate evaluation, guiding the strategy and direction for project implementation. In contrast, for river water projects, an analysis based on the payback period of the investment cost is conducted to assess the project's economic feasibility. This analysis broadly calculates Return On Investment (George & Franklin, 1996) and sets criteria for basic data, initial investment costs, and annual operating expenses to evaluate the projects, especially for potential users who have not been confirmed yet.

## 3. Descriptive Analysis_Dam Deep-Seated Hydrothermal Energy Model Study

### *3.1 Estimation of Potential Capacity*

The potential capacity of energy in dam deep-water hydrothermal sources can be defined in various ways based on their utilization method. In this study, the potential capacity is defined based on the utilization of hydrothermal energy using heat pumps. It is calculated using the following equation and applied to 20 multipurpose dams in South Korea:

*Target: 20 multipurpose dams

(Chungju Dam, Soyanggang Dam, Heongseong Dam, Andong Dam, Imha Dam, Gunwi Dam, Kimcheon-Buhang Dam, Bohyeonsan Dam, Seongdeok Dam, Miryang Dam, Hapcheon Dam, Namgang Dam, Yeongju Dam, Daecheong Dam, Yongdam Dam, Juam Dam, Seomjingang Dam, Boryeong Dam, Buan Dam, Jangheung Dam)

Heat Calculation Formula : $Q = mC\Delta T$

### *3.1.1 Theoretical Potential Capacity*

To calculate the theoretical potential capacity, according to the Practical Handbook of Water (Korea Water Resource Corporation, 2022) the total discharge flow of the dam is considered because dam deep-water hydrothermal energy is utilized from the dam's discharge flow. The formula assumes that Q represents the total discharge flow of the dam, c represents the specific heat of water, and ΔT represents the average temperature difference (5°C) as the heat source for the heat pump. The calculated theoretical potential capacity using this formula is represented in Joules (J), as it signifies the amount of energy. Since most values are based on annual statistics, it is often expressed in TJ/year. However, the unit of Watt, typically used to represent energy per hour, is also included in MW units. When converting 1 year into 365 days, the calculation becomes as follows:

1 TJ/year = 106 MJ / (365 * 24 * 3600) sec = 0.031710 MW

Furthermore, units related to heating and cooling energy are often expressed in RT (Refrigeration Tons). The commonly used USRT (referred to as RT) typically has the following value:

1 RT = 3.5168 kW

Therefore, the theoretical potential capacity for the 20 multipurpose dams was calculated based on recent 5-year (‘17~‘21) and recent 10-year (’12~‘21) average and minimum discharge flow values. Among these, considering recent rapid climate changes and local precipitation patterns in South Korea, the study predominantly utilized the average discharge flow of the past 5 years to estimate the hydrothermal potential capacity. As a result, the theoretical potential capacity for the 20 multipurpose dams is calculated as 10,011 MW (2,846,470 RT). Furthermore, among the top 5 dams with the highest theoretical potential capacity, namely Chungju, Soyanggang, Daecheong, Namgang, and Andong, they collectively contribute to approximately 74% of the overall potential capacity in Table 1.

**Table 1.** Theoretical Potential Capacity of 20 Multipurpose Dams

| Dam | ’17~‘21yr Ave 5yr MW(RT) | ’17~‘21yr Min 5yr MW(RT) | ‘12~’21yr Ave 10yr MW(RT) | ‘12~’21 Min 10yr MW(RT) | Remarks |
|---|---|---|---|---|---|
| Chungju | 2,660 (756,420) | 1,857 (528,024) | 2,465 (701,017) | 1,004 (285,495) | |
| Soyanggang | 1,316 (374,064) | 880 (250,255) | 1,182 (336,187) | 534 (151,510) | |
| Daecheong | 1,518 (431,540) | 879 (249,879) | 1,382 (392,909) | 879 (249,879) | |
| Namgang | 1,328 (377,645) | 473 (134,550) | 1,321 (375,760) | 473 (134,550) | |
| Andong | 551 (156,598) | 396 (112,502) | 516 (146,611) | 358 (101,761) | |
| Yongdam | 494 (140,580) | 269 (76,509) | 454 (129,085) | 269 (76,509) | |
| Imha | 376 (107,037) | 254 (72,175) | 330 (93,846) | 208 (59,172) | |
| Hapcheon | 410 (116,648) | 190 (54,084) | 391 (111,183) | 190 (54,084) | |
| Seomjingang | 364 (103,457) | 225 (64,072) | 361 (102,514) | 225 (64,072) | |
| Juam | 445 (126,635) | 213 (60,680) | 425 (120,794) | 213 (60,680) | |
| Yeongju | 121 (34,486) | 30 (8,480) | 106 (30,151) | 30 (8,480) | ‘15yr~ Operation |
| Heongseong | 78 (22,048) | 48 (13,568) | 76 (21,483) | 30 (8,669) | |
| Jangheung | 93 (26,571) | 52 (14,699) | 93 (26,571) | 52 (14,699) | |
| Boryeong | 80 (22,614) | 53 (15,076) | 72 (20,541) | 53 (15,076) | |
| Miryang | 63 (17,902) | 38 (10,741) | 56 (16,018) | 38 (10,741) | |
| Kimcheon -Buhang | 38 (10,930) | 23 (6,596) | 34 (9,799) | 23 (6,407) | ‘15yr~ Operation |
| Buan | 27 (7,538) | 16 (4523) | 25 (6,973) | 16 (4,523) | |
| Gunwi | 25 | 15 | 23 | 15 | |

| | | | | | |
|---|---|---|---|---|---|
| | (6,973) | (4,334) | (6,407) | (4,334) | |
| Seongdeok | 15<br>(4,334) | 9<br>(2,638) | 13<br>(3,769) | 5<br>(1,508) | ‘16yr~<br>Operation |
| Bohyeonsan | 9<br>(2450) | 7<br>(1,885) | 7<br>(2,073) | 2<br>(565) | ‘16yr~<br>Operation |
| Total | 10011<br>(2,846,470) | 5,927<br>(1,685,268) | 9333<br>(2,653,690) | 4617<br>(1,312,712) | |

### *3.1.2 Practical Potential Capacity*

The theoretical potential capacity based on the discharge flow of multipurpose dams is abundant. However, the areas around the reservoirs are predominantly designated as restricted zones for water conservation purposes, with limited nearby facilities or buildings that could accommodate large-scale heat loads. Consequently, the actual potential capacity is relatively minimal.

This study does not consider the reservoir volume of dams as potential hydrothermal energy. The reason is that utilizing the reservoir volume would necessitate using it as a source for hydrothermal energy, which requires re-releasing it into the dam after utilization. Utilizing the reservoir volume for hydrothermal energy through long-distance pipelines is anticipated to have significant initial investment costs due to construction expenses, as well as high operational costs for pumps, leading to unfavorable economic viability. Therefore, considering these practical factors, the actual potential capacity of the dam's reservoir volume is considered nearly non-existent.

Similarly, in the case of dam discharge water, most large dams are situated in mountainous areas, which pose hydrographically disadvantageous settings for accommodating large-scale residential or industrial facilities that could consume significant amounts of hydrothermal energy. However, the ongoing creation of the Gangwon Province Hydrothermal Complex Cluster Project demonstrates the potential for utilizing dam discharge water, prompting an inference of the actual potential capacity based on this premise.

*Gangwon Province Hydrothermal Complex Cluster Project Dam Discharge Water Utilization Model:*

*- Alleviates hydrographical and environmental disadvantages using existing pipelines for development.*

*- Aims to enhance operational economic viability by targeting large consumers (Naver Data Center).*

*- Creates stable conditions for project execution as a national environmental project model.*

The Table 2. presents the designed hydrothermal energy generation based on the 2014 Soyanggang intake water information in the Gangwon Province Hydrothermal Complex Cluster Project. The thermal energy is calculated utilizing the Soyanggang intake volume(m) for the Soyang Water Purification Plant, considering precise specific heat values of water at different temperatures. To calculate this, the variations in monthly intake temperatures at the Soyanggang water purification plant and the distance(4km) are divided to derive the temperature change per kilometer, factoring in the intake temperature at the project facility (2.7km). The average temperature difference used as the heat source for the heat pump is 5°C. As a result, the current Gangwon Province Hydrothermal Complex Cluster Project plans to supply 58MW (16,500RT) of hydrothermal energy using the discharge water from the Soyanggang Dam.

**Table 2.** Soyanggang Intake Water Data in 2014

| Month | Flow [㎥] | Inlet Temp [°C] | Temperature Difference [°C] | Potential Capacity[GWh] | | "Naver" Load [GWh] |
|---|---|---|---|---|---|---|
| | | | | 100% Usage | 50% Usage | |
| 1 | 2,086,090 | 5.81 | 5.0 | 12.13 | 6.06 | 4.76 |
| 2 | 1,907,020 | 5.18 | 5.0 | 11.09 | 5.54 | 4.30 |
| 3 | 2,189,400 | 5.95 | 5.0 | 12.73 | 6.36 | 4.76 |
| 4 | 2,130,010 | 6.59 | 5.0 | 12.38 | 6.19 | 4.61 |
| 5 | 2,154,500 | 8.07 | 5.0 | 12.53 | 6.26 | 4.76 |
| 6 | 2,121,190 | 9.20 | 5.0 | 12.33 | 6.17 | 4.61 |
| 7 | 2,190,350 | 11.07 | 5.0 | 12.73 | 6.37 | 4.76 |
| 8 | 2,176,950 | 13.90 | 5.0 | 12.66 | 6.33 | 4.76 |
| 9 | 2,113,660 | 14.38 | 5.0 | 12.29 | 6.14 | 4.61 |
| 10 | 2,196,560 | 13.62 | 5.0 | 12.77 | 6.39 | 4.76 |
| 11 | 2,099,080 | 12.02 | 5.0 | 12.20 | 6.10 | 4.61 |
| 12 | 2,152,110 | 6.62 | 5.0 | 12.51 | 6.26 | 4.76 |
| Ave | 2,126,410 | 9.37 | 5.0 | **12.36** | **6.18** | **4.67** |
| Sum | 25,516,920 | - | - | 148.35 | **74.18** | **56.06 (16,000 RT)** |

Based on the recent 5-year data (‘17~‘21), the average theoretical hydrothermal energy potential capacity of the Soyanggang Dam, calculated using discharge water, is approximately 1,316 MW (374,064 RT). Therefore, it can be inferred from this simple calculation that the Gangwon Province Hydrothermal Complex Cluster Project utilizes about 4.4% of the hydrothermal energy inherent in the discharge water from the Soyanggang Dam. If similar hydrothermal clusters were established around major multipurpose dams nationwide, it could be assumed that around 4.4% of the discharge water could be utilized.

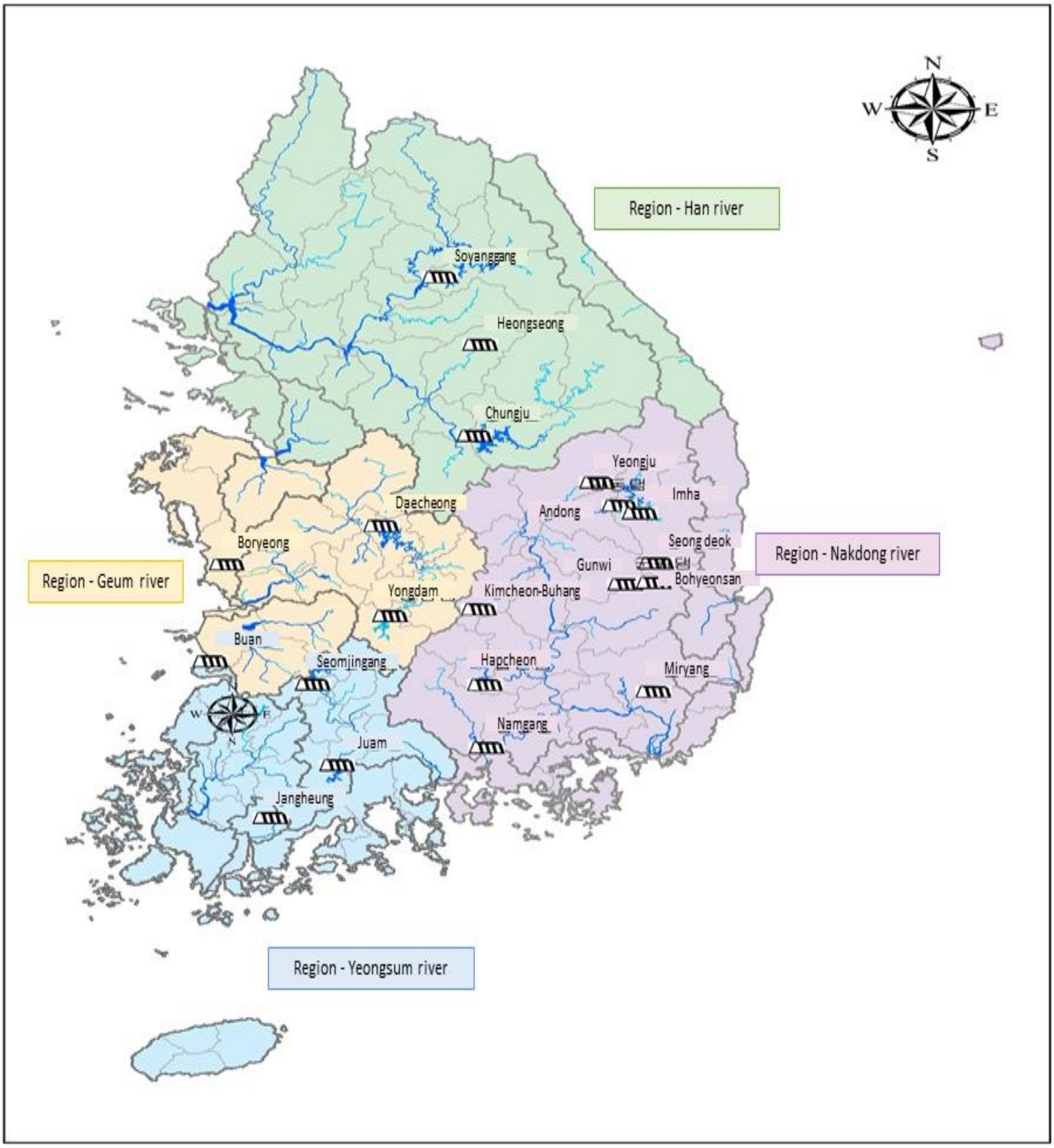
With this assumption, considering the recent 5-year (‘17~‘21) data, an annual average theoretical potential capacity of 440MW (1,254,466 RT), which is 4.4% of the average potential capacity for the 20 major multipurpose dams based on their discharge flow, could represent the practical achievable potential capacity of multipurpose dams based on their discharge flow.

**Table 3**. Theoretical and Practical Potential Capacity of 20 Multipurpose Dams

| Dam | Theoretical Potential MW(RT) | Practical Potential MW(RT) | Contribution Rate(%) |
|---|---|---|---|
| Chungju | 2,660(756,420) | 117(3,328,249) | 26.57 |
| Soyanggang | 1,316(374,064) | 57(1,645,883) | 13.14 |
| Daecheong | 1,518(431,540) | 66(1,898,777) | 15.16 |
| Namgang | 1,328(377,645) | 58(1,661,637) | 13.27 |
| Andong | 551(156,598) | 24(689,032) | 5.50 |
| Yongdam | 494(140,580) | 21(618,553) | 4.94 |
| Imha | 376(107,037) | 16(470,963) | 3.76 |
| Hapcheon | 410(116,648) | 18(513,250) | 4.10 |
| Seomjingang | 364(103,457) | 16(455,209) | 3.63 |
| Juam | 445(126,635) | 19(557,195) | 4.45 |
| Yeongju | 121(34,486) | 5(151,736) | 1.21 |
| Heongseong | 78(22,048) | 3(97,011) | 0.77 |
| Jangheung | 93(26,571) | 4(116,911) | 0.93 |
| Boryeong | 80(22,614) | 3(99,499) | 0.79 |
| Miryang | 63(17,902) | 2(78,770) | 0.63 |
| Kimcheon-Buhang | 38(10,930) | 1(48,091) | 0.38 |

| | | | |
|---|---|---|---|
| Buan | 27(7,538) | 1(30,166) | 0.26 |
| Gunwi | 25(6,973) | 1(30,678) | 0.24 |
| Seongdeok | 15(4,334) | 0(19,070) | 0.15 |
| Bohyeonsan | 9(2,450) | 0(10,779) | 0.09 |
| ToTal | 10,011(2,846,470) | 440(12,524,466) | 100 |

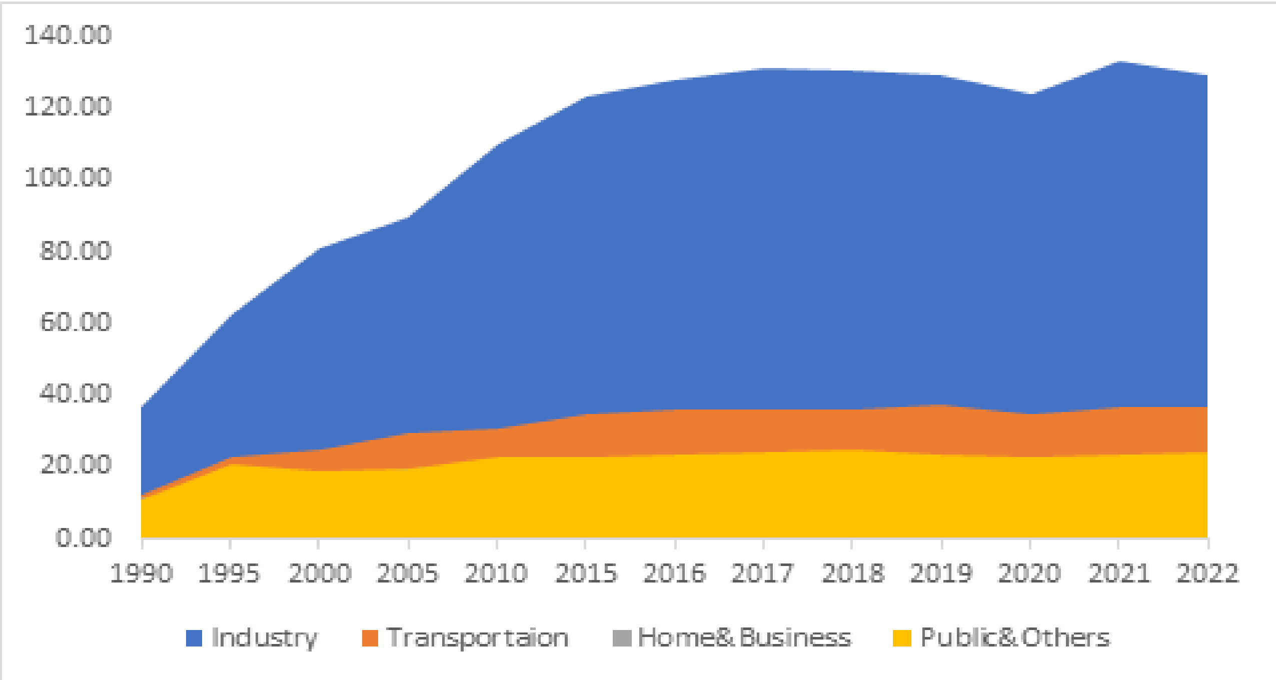
**Figure 1.** Multipurpose dams and River Regions by K-water




### *3.2 Model Strategy*

According to the Energy Economics Institute (2023), the energy consumption of industrial facilities is continuously increasing as shown in Figure 1. In consideration of this situation and balanced regional development, a hydrothermal energy complex business model is being promoted as a way to activate hydrothermal energy. Therefore, this model follows the Gangwon Province Hydrothermal Complex Cluster Project and the core is the circulation of hydrothermal energy and the creation of regional and corporate specialized complexes, which are energy-intensive buildings such as data centers and smart farms and the development of eco-friendly hydrothermal energy specialized complexes.

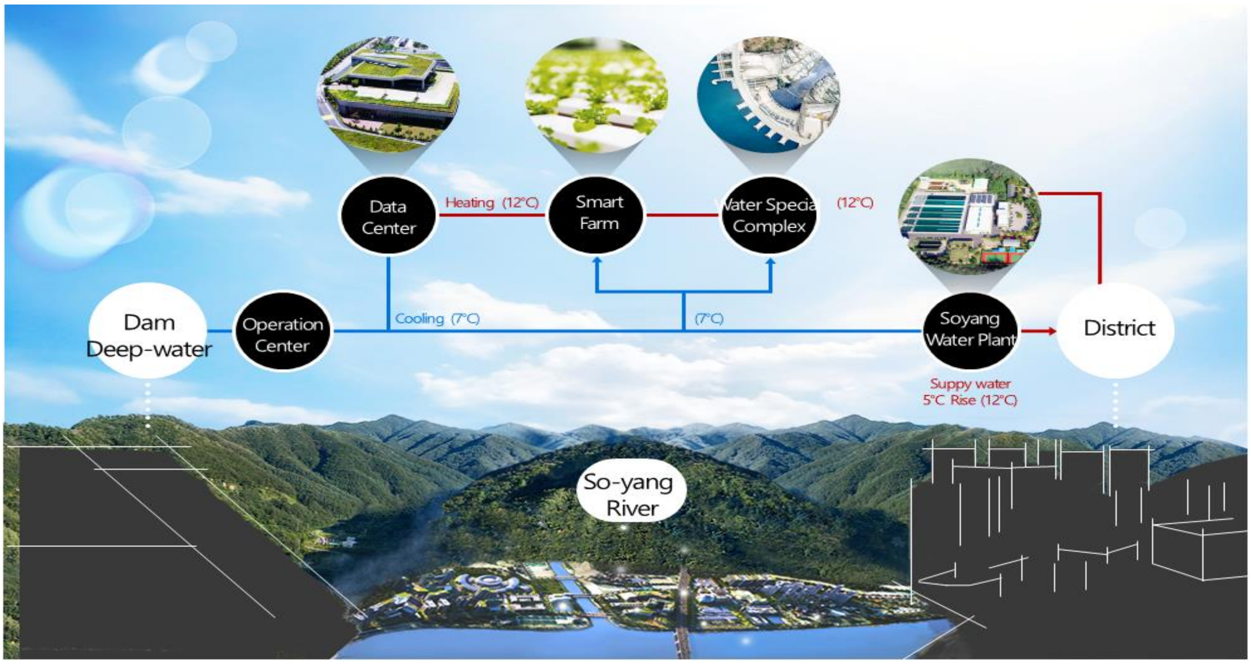
**Figure 2.** Korea's final energy consumption's Trend




Firstly, the establishment of a hydrothermal energy circulation district involves the construction of a hydrothermal energy system utilizing existing pipelines that connect the dam, water intake facilities, and water purification plants. This strategy is designed with ease of development and cost-effectiveness in mind.

Additionally, the strategy for the development of regional industry-specific districts aims to promote regional industrial competitiveness and foster related industries by industrializing local resources through the supply of cost-effective hydrothermal energy to specialized companies within the region as shown in Figure 1. As a supplementary benefit, it can generate job opportunities through regional cooperation and promote the creation of environmentally friendly energy development platforms within the riverfront parks.

**Figure 3.** Gangwon Province Hydrothermal Complex Cluster Project's Overview




### *3.2.1 Business Model Facilities*

The dam deep-water hydrothermal energy business model is a strategy based on the establishment of districts using the hydrothermal energy from existing dam deep-water conduits. This approach involves the introduction of facilities such as eco-friendly data centers, smart farms, and region-specific industries.

**Table 4**. Dam Business Model Facilities

| Complex List | Introduction Facilities | Remarks |
|---|---|---|
| Eco-friendly data center clusters | Industrial | Internet Data Center (IDC)/Cloud Data Center (CDC) |
| | Research | Research and Development Center (R&D Center) |
| | Support | nowledge Industry Centers, Public Support Facilities, Welfare Facilities |
| | Infrastructure | Hydrothermal energy integrated management centers, Substations, Parking lots, Parks, Roads |

| | | |
|---|---|---|
| Smart Farm Advanced Agricultural Complex | Agricultural | Nursery specialty complexes, Smart farm facilities, Agricultural complexes |
| | Educational | Smart Farm Pilot |
| | Infrastructure | Cold storage facilities, Parking lots |
| Regional Specialized Industrial Complex | Industrial | Regional specialized industrial complexes, IT bio, High-tech logistics facilities |
| | Support | Regional Specialized Industry Promotion Facilities, Demonstration Facilities |
| | Infrastructure | Sewage treatment plants, Parking lots, Roads, Parks |
| Support Complex | Commercial | Retail facilities, Neighborhood facilities |
| | Residential | Residential complexes, Eco-friendly residential complexes |
| | Support | Community facilities (village cafes, meeting halls, healthcare functions, etc.) |
| | Infrastructure | Waterfront parks, Children's parks, Parking lots |

### *3.2.2 Performance Indicators*

To further refine the strategy, it is essential to closely monitor general and policy trends related to key business facilities. Therefore, in the context of this business model research, it is crucial to continuously review the domestic market trends of data centers, which are the primary consumers.

According news from Korea Data Center Energy Efficiency Association (2023), the number of commercial data centers has been steadily increasing, with 21 in 2010, 26 in 2016, 32 in 2020, and a projected 40 by 2023. Currently, there are over 34 new projects for commercial data centers in progress or planned, with an estimated investment volume of approximately 1.4 trillion KRW. In terms of power supply, it is predicted that the market will see a significant increase in power usage, from 544MW in 2023 to 1,850MW by 2027, almost tripling the power consumption. Given this substantial surge in power usage, there is growing consideration of eco-friendly energy usage policies to ensure the sustainability of data centers.

Another critical demand source, smart farming facilities, according to Ministry of Science and ICT

(2021), is evolving from Agriculture Ver 4.0(early 2010s) to Ver 5.0(current), integrating robotics and AI-based autonomous decision-making systems. Similarly, industries such as IT, biotechnology, and advanced manufacturing are actively adopting AI. As a result, data centers become essential facilities, and their sustainability should be considered as a performance indicator in the planning of the hydrothermal cluster development.

**Table 5**. Dam Business Plan Metrics

| Introduction Facilities | Examples of business plan metrics |
|---|---|
| Data Center | Domestic general and policy trends |
| Smart farm, IT bio, Advanced logistics | Domestic general and policy trends<br>However, support and infrastructure: 00% of the facility area |
| R&D | 00% of industrial land |
| Public Buildings | 00 million m3 |
| Community Centers | 00 million m3 |
| Specialized industrial | Engage local governments and residents |
| Infrastructure | Parks and green spaces 00%, Parking lots 0.0%, Roads 00% |
| Residential | Single-family properties 00%, Multi-family properties 00% |
| Schools | Within 00km of school, with a residential property size of 00 million ㎥ or more |
| Commercial | Within 0% of total |

### *3.2.3 Development Types by Scale*

The scale of demand sources plays a crucial role in determining the practical potential capacity of dam deep-seated hydrothermal energy. Therefore, it is essential to establish criteria for demand source scales and develop business plans according to different scales. In this study, we broadly categorized demand source scales into small, medium, and large.

For small-scale projects, the focus is on establishing clusters primarily centered around data center sites and infrastructure. These clusters are typically located near rural areas, towns, or villages, and the scale involves demand sources with integrated functions of less than 300,000㎥, which includes data centers.

In contrast, medium and large-scale projects are on a much grander scale, with a particular focus on the Gangwon Province Hydrothermal Complex Cluster Project. These clusters combine three or more functions, such as data centers, smart farming, IT-biotech, advanced logistics, water industry specialized facilities, and residential areas. These projects are typically located near urban areas and are categorized into medium-scale (30~50 million ㎥) and large-scale (50~100 million ㎥).

**Table 6.** Dam Business Scale

| Scale | Data Center | Smart farm,<br>IT bio,<br>Ad logistics | R&D | Eco-<br>friendly<br>Residential | Public<br>Utilities | Parks,<br>Green<br>spaces |
|---|---|---|---|---|---|---|
| Small | 25% | 15~20% | 15~20% | - | 20% | 20% |
| Medium,<br>Large | 15% | 10% | 10% | 20~30% | 20% | 15% |

### *3.3 Model Concept*

Given the abundance of available hydrothermal energy and the favorable infrastructure, workforce, and especially the surplus power supply in nearby areas such as Daejeon, Sejong Special Autonomous City, and Cheongju City in Chungcheongbuk-do, the model selects the Daechung Dam as a representative model for the data center cluster concept within the large-scale hydrothermal energy project. The following provides a basic conceptual guide for the large-scale hydrothermal business model.

#### *3.3.1 Basic Concept*

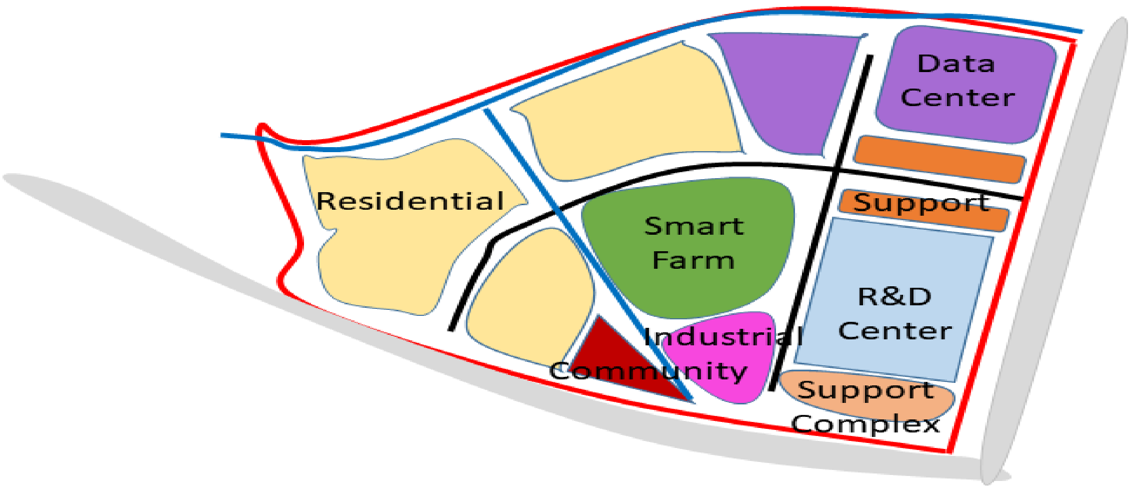
To efficiently utilize hydrothermal energy, the project will place data centers at the connection point to the project site. These data centers will be integrated with industrial facilities and smart farming facilities and infrastructures, creating a symbiotic effect and efficient land use.

**Table 7.** Dam Business Model

| Lists | Gangwon-do Hydrothermal Cluster | Business models |
|---|---|---|
| Total Area | 815,964㎡ | 666,000㎡ |
| Data center | 156,241㎡(32.3%) | 200,000㎡ |
| Available Hydrothermal Energy (RT) | 16,500RT | 21,960RT |
| Smart farms, Industrial facilities, etc. | 98,292㎡(62.9% of Data center) | 126,000㎡ |

The spatial structure of the project model includes the arrangement of industrial spaces that are linked to a hydrothermal energy circulation system connecting the Daechung Dam, data centers, water-related industries, and smart farms like Figure 1. Residential functions are concentrated in the western part, taking into account existing infrastructures and an efficient energy circulation system. Transportation is facilitated by regional arterial roads connecting Cheongju and Daejeon city centers and a main entrance road connecting to the project site through the Shimokbu River Road. A hydrothermal energy circulation network plan is established, starting from the northern hydrothermal supply pipeline that provides deep cold water from the Daechung Dam and connects it to data centers, knowledge industry centers, smart farms, and industrial facilities. Additionally, park and green spaces planning takes into consideration the continuous waterfront and green space network, including the northern Oecheon River and the waterways crossing within the project site.

**Figure 4.** District Unit Plan for Hydrothermal Energy Circulation Network



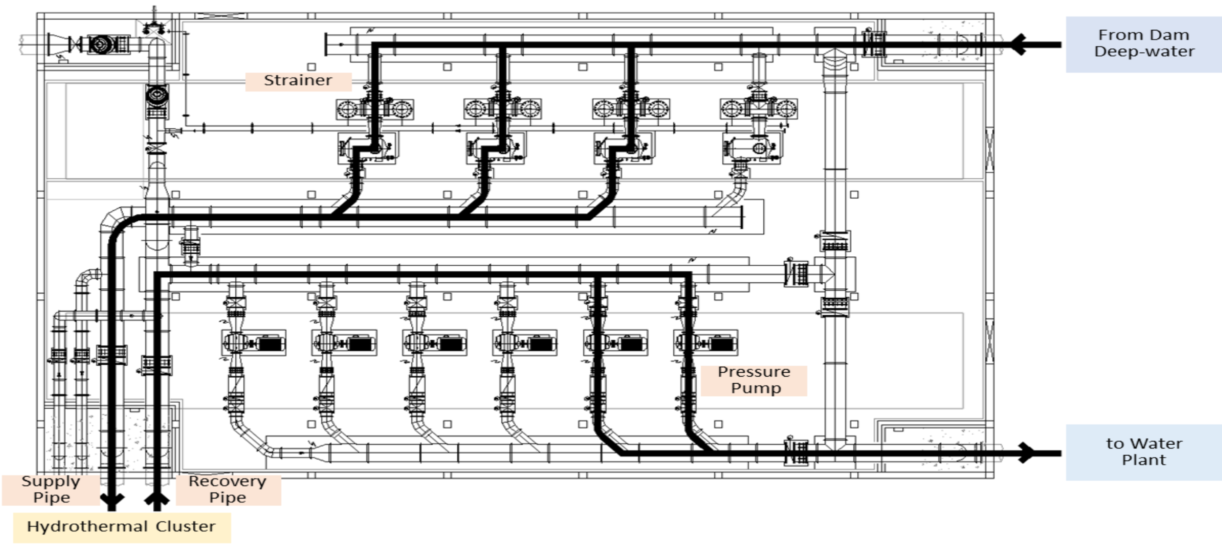

### *3.3.2 Hydrothermal System*

This business model establishes an operation center for deep dam water to supply heat energy to each industrial demand facility in order to realize the hydrothermal energy circulation network plan described above. The operation center serves to supply cooling and heating heat to the hydrothermal cluster through a hydrothermal supply pipe by a constant heat source of deep dam water for four seasons and then to the water purification plant through a hydrothermal recovery pipe.

The basic facility design consists of strainers, water supply pipes, water recovery pipes, and pressure pumps. It is a simple operating sequence that usually receives deep water from a dam in highland, supplies it to a hydrothemal cluster, and supplies water to a water purification plant through pressure pumps. Here, the pressure pump can be appropriately added and supplemented according to the pressure in the supply pipe.

An important part to be considered in this system is the strainer. If foreign substances, large and small from the raw water in dam, are pressurized in the pipe and the pump, it may cause the whole system failure and accident. Therefore, it is essential to plan for proper strainer capacity and continuous maintenance.

**Figure 5.** Basic System for Hydrothermal Energy Line




### *3.3.3 Effectiveness analysis*

The effect analysis on the model can be quantified such as Table 8.

**Table 8.** Outlined Effects of Dam Business Model

| Division | Gangwon Hydrothermal Cluster (Soyanggang Dam) | Model (Daecheong Dam) | Remarks |
|---|---|---|---|
| ① Data Center Power | 220 MW | 198 MW | |
| ② Data Center Server Heat Generation1) | 24,400 RT | 21,960 RT1) | |
| ③ Available Hydrothermal Energy | 16,500 RT | 21,960 RT | |
| ④ Supply Rate | 68% | 100 % | ③ ÷ ② × 100 |
| ⑤ Outside Air Cooling Power Usage (MWh/year) | □ 14,568.52 | □ 13,111.67 | Referencing Hydrothermal Values in Gangwon Hydrothermal Cluster |
| ⑥ Annual hydrothermal System Power Usage (MWh/year) | 8,902.90 | 8,628.83 | Application of Hydrothermal System |
| Hydrothermal(MWh/yr) | □ 4,240.97 | 4,066.692) | Hydrothermal Operation Only (Accounting for Days Below the Reference Temperature) |
| other(MWh/yr) | 4,661.93 | 4,562.143) | Non-hydrothermal Operation (Accounting for Days Above the Reference Temperature) |
| ⑦ Power Usage Reduction | 5,665.62 MWh/yr | 4,482.84 MWh/yr | ⑤ - ⑥ |

| ⑧ Carbon Reduction Effects | 2,708.73 tCO2eq/yr | 2,143.25 tCO2eq/yr | |
|---|---|---|---|

1) Data Center Power × Server Utilization Rate (60%) × Average Server Heat Emission (65%) = Converted to 85.8MW in RT

2) □ ÷ Standard Hydrothermal Supply Rate (68%) × Taechung Dam Hydrothermal Supply Rate (100%) × Days Below Reference Temperature Ratio (238 days out of 365 days)

3) □ × Taechung Dam Hydrothermal Supply Rate (100%) × Days Above Reference Temperature Ratio {(365 days - 238 days)/365 days}

※ Taechung Dam Days Below 16℃: 238 days

※ Applying National Greenhouse Gas Emission Absorption Coefficient : 0.4781 tCO2eq/MWh

※ For Taechung Dam, it is assumed that the data center's capacity is utilizing 100% of the available Hydrothermal supply capacity.

### *3.4 Model Evaluation*

Before evaluating the dam deep-water hydrothermal energy business model, it is essential to investigate the characteristics of hydrothermal energy in each dam, the characteristics of potential locations for the complex, and other relevant factors. This research will help ensure that the selection process is fair and rational when conducting feasibility and preliminary feasibility studies for each dam.

In the ongoing Gangwon Province Hydrothermal Complex Cluster Project, the model is primarily focused on establishing data centers at its core and developing smart farms, big data specialized zones, residential areas, etc. Considering this basic model, the hydrothermal cluster is defined as a site that primarily revolves around a data center and may include specialized industries and residential areas in the respective dam regions. Therefore, when evaluating the model, it is essential to establish evaluation criteria based on the hydrothermal energy utilization characteristics specific to each dam, development indicators for industrial zones centered around data centers, and other factors.

#### *3.4.1 Evaluation Criteria*

In the evaluation of this model, critical factors can be categorized into several areas reflecting the characteristics of suppliers and consumers, site-related factors, planning-related factors, and disaster safety-related factors.

Starting with hydrothermal energy utilization, the focus should be on evaluating the safety and economic aspects of hydrothermal supply concerning the supplier's business's basic survey. Detailed factors to be considered include:

- *Hydrothermal Supply Safety: Water intake method, hydrothermal energy available, water temperature of the hydrothermal source (annual average, days below the reference temperature), environmental impact of the discharge water.*

- *Hydrothermal Supply Economic Viability: Construction cost (considering new water intake or the distance to the water intake point).*

Next are site-related factors. The primary focus should be on the evaluation of natural conditions and regulatory factors, taking into account consumer needs, infrastructure within the site, and the availability of specialized workforce. The detailed factors include:

- *Natural Conditions: Topography, slope.*

- *Public Regulatory Factors: National environmental assessment rating, the development-inhibited ratio of ecological nature, forest class grade, and other public regulatory inclusion rates.*

- *Infrastructure: Connectivity to communication networks, availability of electricity supply, excess electricity supply, accessibility to major transportation routes, accessibility to development sites, and the presence of universities and research institutions.*

- *Availability of Specialized Workforce: Population size and the number of universities and research institutions in the area.*

Planning-related factors consider external factors related to the site. The appropriateness of the plan, ease of land acquisition, local government's willingness and community acceptance will be assessed. Detailed factors include:

- *Plan Appropriateness: Ratio of planning management areas, land ownership rate in areas scheduled for urbanization, availability of expansion sites, compliance with higher-level plans (urban basic plan, regional development plan, etc.).*

- *Land Acquisition Convenience: Including the presence of obstacles and government-owned land.*

- *Local Government Willingness and Community Acceptance: The degree to which the opinions of relevant authorities have been considered and whether the opinions of local residents have been incorporated.*

Finally, disaster safety-related factors consider potential risks beyond site-related and planning-related aspects.

- *Disaster Risk: The ratio of disaster risk areas, seismic zone and regional coefficients, landslide risk area classification, flood frequency, etc.*

This evaluation framework takes into account a wide range of factors that contribute to a comprehensive assessment of the hydrothermal cluster model.

### *3.4.2 Evaluation Method*

The dam deep water hydrothermal energy business model is a national long-term project that requires a feasibility study concerning project scale and costs. Therefore, as a measurement theory to handle quantitative and qualitative criteria in the decision-making process is essential, the Analytic Hierarchy Process (Saatry&vargas, 2001) is suitable.

To implement the hierarchical weight analysis, a five-step process is followed:

*Step 1: Decompose the given decision problem into a hierarchical structure.*

*Step 2: Conduct pairwise comparisons among elements at the same level.*

*Step 3: Use the eigenvalue method to estimate the relative importance or weights of elements.*

*Step 4: Verify consistency by evaluating the Consistency Ratio (C.R.), comparing the Consistency Index (C.I.) with the Random Index (R.I.) to ensure that C.R. is below 0.1.*

*Step 5: Aggregate the relative weights of evaluation criteria calculated at each level.*

For the assessment of this business model, structured research will be conducted using the AHP method. The survey targets individuals with expertise in hydrothermal energy and those with expertise in complex development. The evaluation of the model's weights will be based on criteria like Table 9.

**Table 9.** Evaluation of the model's weights for Dam Business

| H1 (Factors) | H2 (Large category) | H3 (Medium category) | H4 (Small category) | Score |
|---|---|---|---|---|
| Energy utilization (0.329) | Hydrothermal Supply Safety (0.750) | •Water Intake Method(0.083) | | 2.044 |
| | | •Hydrothermal Utilization Capacity(0.327) | | 8.072 |
| | | •Temperature of Hydrothermal Source(0.327) | •Annual Average Temperature of Hydrothermal Source(0.503) | 4.057 |
| | | | •Number of Days Below Standard Temperature(0.497) | 4.007 |
| | | •Environmental Impact Due to Changes in Discharge Water Temperature(0.264) | | 6.510 |
| | Hydrothermal Supply Economic Viability (0.250) | •Construction Costs(0.642) | •Necessity of New Water Intake Facilities(0.282) | 1.488 |
| | | | •Distance to Water Intake Point(0.718) | 3.794 |
| | | •Operating Costs(0.358) | •Water Rates(0.282) | 0.831 |
| | | | •Electricity Rates(0.718) | 2.118 |
| Site (0.252) | Natural Conditions (0.146) | •Terrain (Elevation Height)(0.460) | | 1.696 |
| | | •Slope (Slope Ratio)(0.540) | | 1.991 |
| | Public Regulatory Factors (0.255) | •National Land Environmental Impact Assessment Grade(0.228) | | 1.466 |
| | | •Percentage of Ecologically Restricted Development(0.362) | | 2.332 |
| | | •Land Class Rating(0.289) | | 1.858 |
| | | •Inclusion of Other Public Regulations(0.121) | | 0.781 |

| | | | |
|---|---|---|---|
| | Infrastructure (0.368) | •Telecommunication Connectivity(0.171) | 1.584 |
| | | •Power Supply Connectivity(0.221) | 2.051 |
| | | •Power Supply Redundancy(0.292) | 2.709 |
| | | •Regional Transportation Connectivity(0.138) | 1.282 |
| | | •Accessibility to Developed Areas(0.179) | 1.658 |
| | Availability of Specialized Workforce (0.231) | •Population Size(0.367) | 2.132 |
| | | •Number of Universities and Research Institutions(0.633) | 3.683 |
| Planning (0.187) | Plan Appropriateness (0.277) | •Percentage of Planned Management Areas(0.136) | 0.704 |
| | | •Land Holding Rate with Scheduled Urbanization(0.204) | 1.057 |
| | | •Feasibility of Acquiring Nearby Expansion Sites(0.233) | 1.205 |
| | | •Compliance with Upper-Level Plans(0.427) | 2.207 |
| | Land Acquisition Convenience (0.335) | •Geological Obstacles(0.600) | 3.754 |
| | | •Percentage of National Public Lands Included(0.400) | 2.503 |
| | Local Government Willingness and Community Acceptance (0.388) | •Degree of Consideration of Input from Relevant Agencies(0.283) | 2.050 |
| | | •Consideration of Local Resident Opinions(0.717) | 5.186 |
| Disaster safety (0.232) | Disaster Risk (1.000) | •Percentage of Disaster-Prone Areas Included(0.204) | 4.740 |
| | | •Earthquake Zones and Regional Coefficients(0.171) | 3.958 |
| | | •Landslide Risk Map Ratings(0.270) | 6.255 |
| | | •Flood Frequency(0.355) | 8.237 |
| Total | | | 100 |

## 4. Descriptive Analysis_River Water Hydrothermal Energy Model Study

### *4.1 Estimation of Potential Capacity*

The energy potential of river water is also defined based on the method of utilizing water heat using heat pumps as in the dam model, and the potential was calculated for major water intakes in the Han River, Geumgang/Yeongsan River/Sumjin River(hereinafter referred to as Geumyeongsum), and Nakdong River systems.

Target: Water intakes in the Han River, Geumyeongsum River, and Nakdong River systems (34 locations)

Heat Calculation Formula: $Q = mC\Delta T$

### *4.1.1 Theoretical Potential Calculation*

To calculate the theoretical potential of river water, the water discharge of 34 intakes in each regions as shown in Figure 1. was investigated, and the annual theoretical potential was calculated for the last five years ('18~'22) in the same way as the theoretical potential of dams.

According to the Water Supply Yearbook (Korea Water Resource Corporation, 2022), it can be seen that the theoretical potential of river water has been stable over the last five years (2018-2022), with almost no significant difference, compared to the theoretical potential of hydrothermal energy based on dam discharge, which varies significantly with precipitation. This means that the hydrothermal energy in the withdrawn source water can be stably supplied throughout the year, and it has a good potential as a hydrothermal source.

**Table 10.** Theoretical Potential Capacity of River Water in 34 Intakes River

| River | Theoretical Potential Calculation | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | ‘18 MW (RT) | ‘19 MW (RT) | ‘20 MW (RT) | ‘21 MW (RT) | ‘22 MW (RT) | Ave MW (RT) | Min MW (RT) | Max MW (RT) |
| Han | 1,244 (353,719) | 1,255 (356,818) | 1,269 (360,929) | 1,317 (374,390) | 1,333 (379,118) | 1,284 (364,995) | 1,244 (353,719) | 1,333 (379,118) |
| Geumyeongsum | 865 (245,936) | 892 (253,718) | 886 (251,969) | 931 (264,770) | 946 (268,974) | 904 (257,074) | 865 (245,936) | 946 (268,974) |
| Nakdong | 564 (160,535) | 581 (165,244) | 568 (161,366) | 587 (166,916) | 599 (170,257) | 580 (164,864) | 565 (160,535) | 599 (170,257) |
| Total | 2,673 (760,190) | 2,728 (775,780) | 2,723 (774,264) | 2,835 (806,076) | 2,878 (818,348) | 2,768 (786,932) | 2673 (760,190) | 2,878 (818,348) |

* Han River : Gyeonggi Northwest Region, Gyeonggi Northeast Region, Paldang Region, Gyeonggi Southwest Region, Gyeonggi Southeast Region, Hwaseong Region, Hwaseong Wonju Region, Gangwon South Region, Chungju Region

* Geumyeongsum : Asan Region, Cheonan Region, Chungju Region, Chungnam Central Region, Boryeong Region, Geumsan Region, Seosan Region, Jeonju Region, Buan Region, Jeong-eup Region, Donghwa Region,

Jeonnam northern Region, Jeonnam Central Region, Yeosu Region, Jeonnam Southwest Region

* Nakdong River : Gumi Region, Pohang Region, Goryeong Region, Unmun Region, Ulsan Region, Miryang Region, Changwon Region, Gyeongnam West Region, Geoje Region

### *4.1.2 Practical Potential Capacity*

Unlike dams, river water has a more technical approach to actual potential. In the case of dam models, if the theoretical potential is sufficient, the demand at the source is the actual potential. However, in the case of river water, a more technical approach is needed to calculate the actual potential in the transmission pipeline(Bulk water) to meet the demand for hydrothermal energy in a city or neighborhood.

The technical approach reflected in this study for river water is the Coefficient of Performance (COP) of the heat pump. The temperature of the raw water varies depending on the location of the water intake, which in turn affects the average COP of the heat pump. In order to accurately take into account the impact of this raw water temperature, a very extensive calculation is required, taking into account raw water temperature data from all over the country and all climatic data that affects the COP of the heat pump. This is a very difficult task, but it is possible to find out the approximate actual potential by using the hydronthermal portential power generation data previously surveyed at the city, country and district level by Korea Water Resource Corporation (2021)

One additional consideration is the minimum temperature of the water source in winter. Heat pumps perform better at higher water temperatures when the water source is used for winter heating and lower water temperatures when the water source is used for summer cooling because the heat pump consumes less power. However, if the lowest temperature of the water source is 5℃ or lower, the efficiency of the heat pump deteriorates rapidly, and there are concerns about freezing accidents of the heat exchanger, so measures against low water temperature in winter are necessary. As a countermeasure, the design temperature difference for water heating is increasingly applied to 3℃ instead of 5℃. Therefore, the calculation of the actual potential is based on (=0.6, 3℃/5℃) for winter low water temperature. This was applied to the five-year (2018-2022) average value of the theoretical potential described above to calculate the actual potential of river water hydrothermal energy.

**Table 11.** Practical Potential Capacity of River Water in 34 Intakes River

| Category | Duration (days) | COP | Caloric equation |
|---|---|---|---|
| Cooling | May to October (184 days) | 4.3 | COP/(COP+1)*Theoretical Potential |
| Heating | November to April (181 days) | 3.6 | COP/(COP-1)*theoretical potential *$\Delta T'$ |

| River | Practical Potential Capacity | | | Practical /theoretical (%) |
|---|---|---|---|---|
| | Cooling MW (RT) | Heating MW (RT) | Total MW (RT) | |
| Han | 525 (149,281) | 529 (150,367) | 1,054 (299,648) | |
| Geumyeongsum | 370 (105,142) | 372 (105,907) | 742 (211,048) | |
| Nakdong | 237 (67,428) | 239 (67,919) | 476 (135,347) | |
| Sum | | | 2272 (646,043) | 82.1 |

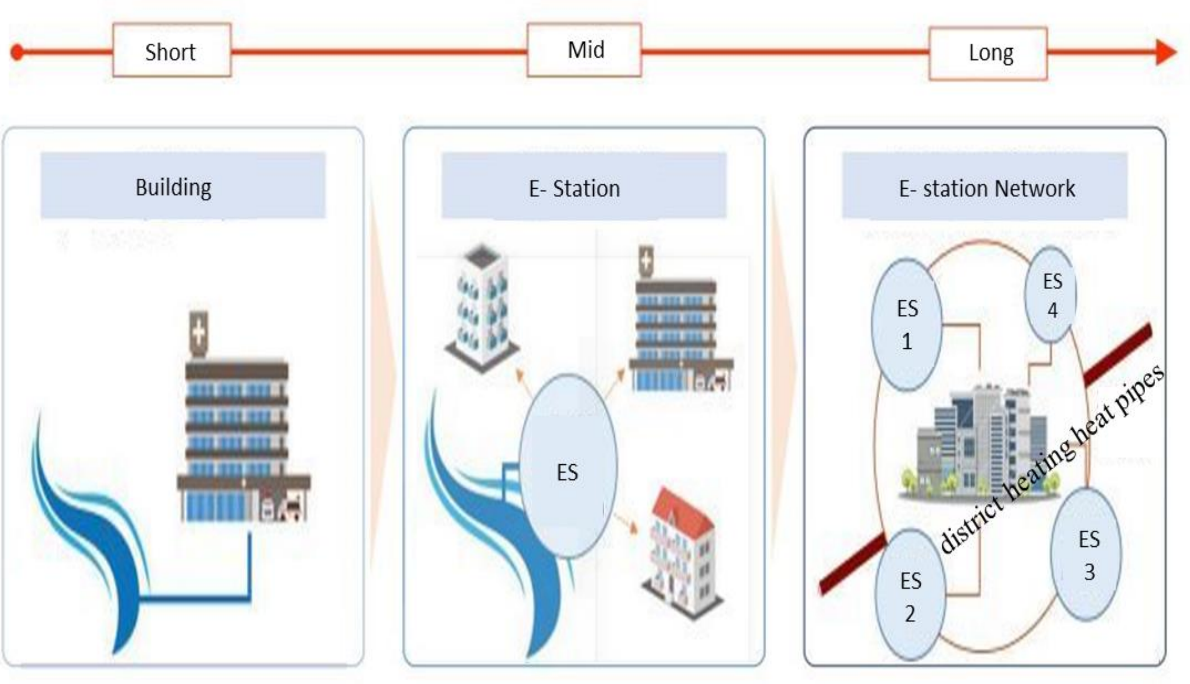
### *4.2 Model Strategy*

Looking at the characteristics of domestic energy consumption, it is necessary to diversify the mix of cooling and heating energy, as there is a large seasonal load depending on climate conditions, and there is a distinct consumption of heating energy in winter and cooling energy in summer. In addition, it is necessary to establish a short-term, medium-term, and long-term strategy to expand hydrothermal energy in urban centers.

The short-term strategy is to recover heat energy by installing heat pumps centered on individual building unit demand sources adjacent to water heat sources. These can be energy-inefficient buildings, apartment complexes, fire stations, large hospitals, and major public institutions. The medium-term strategy is to supply hydrothermal energy to multiple demand sources. By building a thermal energy station, which is a low-carbon thermal energy supply base based on a large-scale hydrothermal source, the thermal energy produced can be supplied to nearby demand sources. In addition, as a long-term strategy, a large-scale hydrothermal energy supply system connected to district heating pipes is built to expand hydrothermal energy in the city. This is a method of producing and supplying hydrothermal energy using district heating heat pipes, which allows the thermal energy produced by multiple thermal energy stations to be utilized in any place where district heating pipes are installed. (JO & YOON, 2020)

This study is a river water source hydrothermal business model aimed at 2nd Lotte World Hydrothermal Project, which is a business model using raw water hydrothermal sources in the metropolitan area, and can be categorized as a short-term strategy based on the above strategies. This can be attributed to the activation of hydrothermal energy in South Korea, which is in its infancy.

**Figure 6.** Short·Mid·Long-term Strategy for River Water Hydrothermal Energy Model




### *4.2.1 Business Model Eligible Facilities*

The river water source business model utilizes the thermal energy of the wide area water supply pipeline and applies it to the demand of large building facilities.

**Table 12.** River Model's Important Factor

| Facility Type | Gross Floor Area | Raw Water Line Distance | Existing system |
|---|---|---|---|
| Accommodation, sales facilities, medical facilities, neighborhood public facilities, education and research facilities, business facilities, and recreational facilities. | 10,000 or more | Within 300 meters | Thermal storage, absorption |

The most important factor for the commercialization of this business model is the willingness of consumers to use hydrothermal energy and the acceptability of the technology. For example, even if the technology to use hydrothermal energy is established, it will be difficult to expand the spread of the technology if the demanders are reluctant to adopt the technology due to lack of understanding of the technology or lack of reliability. Therefore, it is important to identify the willingness to adopt hydrothermal energy in the strategy of the business model, but it is difficult to evaluate quantitatively because it differs dramatically depending on the situation of the demanders, such as privately owned buildings or corporate-owned buildings, and the willingness to adopt depends on the relationship with building owner, building facility manager, tenant.

However, we can categorize the establishment of a business location in terms of supply sources into three stages as follows. First, tier 1 sites are those where remodeling or facility changes are expected in the near future and business can be promoted immediately or within 5 years, and are relatively accessible for future pilot projects, joint development projects, etc. Tier 2 sites are those that are expected to be able to utilize hydrothermal energy within 10 years, as long as the technology is reliable. Finally, Stage 3 is the area where there are no plans to utilize hydrothermal energy within the next 10 years, but it can be introduced from a long-term perspective.

### *4.2.2 Planning Indicators*

If the dam deep-water hydrothermal energy model utilizes macro planning indicators of national infrastructure and complex development, the river hydrothermal business model needs to be approached from a micro perspective, characterizing the demand destinations in more detail. Each and every one of the myriad of large demand sources within a city or urban neighborhood should be targeted, and the evaluation of the targets should be derived from the indicators of the plan. From this point of view, quantitative planning indicators are needed to create a list in order of the highest probability of project implementation, even within the target facilities that are categorized by stage.

**Table 13.** River Model's Planning Indicator

| Planning indicator | Details | |
|---|---|---|
| Pipeline Separation | Pipeline separation distance (within 300 meters) | 50 meter increments |
| Time to replace equipment | Possibility of equipment replacement | 5-year increments |
| Building size | Gross floor area | 5,000 m2 increments |
| Building use | Public, lodging, retail, medical, other facilities | Energy consumption in relation to area |
| Construction conditions (obstructions, etc.) | Existence of obstructions and construction conditions | Scale and number of disruptions |
| Economics of implementation | Simple payback period | Divided into 5-year increments |
| Intention to adopt hydrothermal system | Interviews, business meetings, etc. | Intention to adopt |

### *4.3 Model Design*

The business model design should aim to design a practical system after evaluating the project target facilities and planning indicators. Unlike the dam deep-water hydrothermal energy business model, the river water business model will be promoted in the form of a business proposal from the supply side to the demand side. Therefore, the model design is also implemented from the micro perspective mentioned in the previous section.

### *4.3.1 Key Points of Business Concept*

The basic concept of the business model can vary a lot depending on the characteristics of the customer. Therefore, the analysis of the target facility is the most important aspect of the basic concept.

The target facility analysis first examines the geographical conditions of the target building and evaluates the distance to the raw water pipeline and the floor area of the building for hydrothermal energy supply. In general, the shorter the separation distance from the pipeline, the lower the initial cost and the less heat losses or backlash. In addition, the building's floor area is an indirect indicator of the building's heating and cooling load, and the larger the heating and cooling load of the target building, the smaller the relative share of the pipeline construction cost and the greater the overall energy savings. Therefore, the shorter the pipeline distance and the larger the building's floor area, the more feasible it is to utilize the hydrothermal energy. The pipe separation distance is measured by referring to the regional water supply network map and the underground water pipeline map of Korea Water Resources Corporation, K-water. Based on previous studies and preliminary analyses, buildings within 300 meters of the pipeline were selected, as buildings with a separation distance of more than 300 meters are considered to be significantly less economical. On the other hand, buildings with a gross floor area of 10,000㎡ or more were first selected for the business model by referring to housing information map sites and each building's homepage.

Next, this study reviewed the applicability of the project in the field, considering the actual implementation, such as the situation of obstacles around the building and the status of building facilities. Obstructions such as underground burials, water and sewerage pipes, and gas pipes are important factors in the construction of hydrothermal energy utilization pipelines, which can lead to difficulties in the construction itself or increased construction costs due to the construction of bypass pipes. On the other hand, the age of the building's equipment replacement and the year of construction are also investigated, which are important factors when considering the introduction of a hydrothermal energy system.

The last step is to evaluate the economic feasibility of introducing hydrothermal energy in buildings with excellent geographical conditions by analyzing the simple payback period. The economic feasibility is evaluated by simultaneously considering initial investment costs such as pipeline construction costs and water source heat pump costs, and operating costs considering the performance of water source heat pumps.

After completing the above step-by-step analysis, list the projects using the summary form of the main points of the target facilities below Table 14. This is for the purpose of comparing and evaluating the target facilities, and the characteristics of various demand sources can be materialized into a business model. The project costs and payback periods in the table below will be discussed in Section 4.4 Project Evaluation.

**Table 14.** Hydrothermal Energy Business Model Highlights Summary Form

| | | | | | |
|---|---|---|---|---|---|
| Building title | | | Number of cases | | |
| Building Status | □ Operating<br>□ Under construction<br>□ Designing<br>□ Planning | | Building Completion Date (Estimated year of completion) | | |
| Building Purpose | | Gross floor area | | Building Scale | Above ground:<br>Underground : |
| Contact person and contacts | | | HVAC<br>When to build and replacement cycles | | |
| Heating and Cooling Method/Capacity (Actual) | | | Operating patterns and hours of operation | | |
| Annual heat load Usage | | | Nearby buildings Status | | |
| Hydrothermal Supply Model | | | Comparative Heat Sources<br>Supply Model (Estimated) | | |
| Hydrothermal Pipeline Information | | | Main Pipes Information | | |
| Total Project Costs | | Pipeline Construction | | Equipment | |

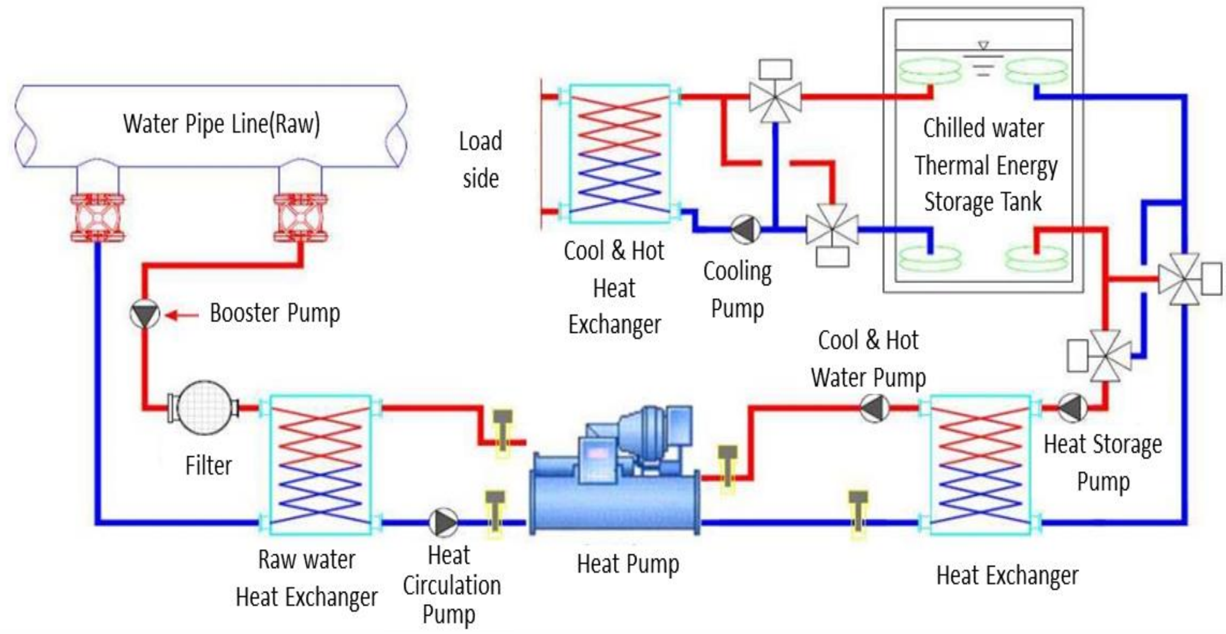
| | | | | | |
|---|---|---|---|---|---|
| | | Costs | | Construction Costs | |
| Comparative Heat Source<br>Total Project Costs | | Operation and Maintenance Costs (Hydrothermal) | | Operating and management expenses (Comparative Heat Source) | |
| Total business expenses<br>Difference | | Annualized Benefits | | Investment cost<br>Payback period | |
| Location map and pipeline status, Underground | Location Map | | Pipeline Status (WIS) | | |
| | Underground | | | | |
| Anomalies and review comments | | | | | |

### *4.3.2 Hydrothermal Systems*

The system of the river water business model should prioritize the review of laws and regulations. According to Ministry of Land, Infrastructure, and Transport (2021), a contraction heat system, ice storage heat system, and gas-fired absorption water heater should be applied as a large-scale centralized cooling system.

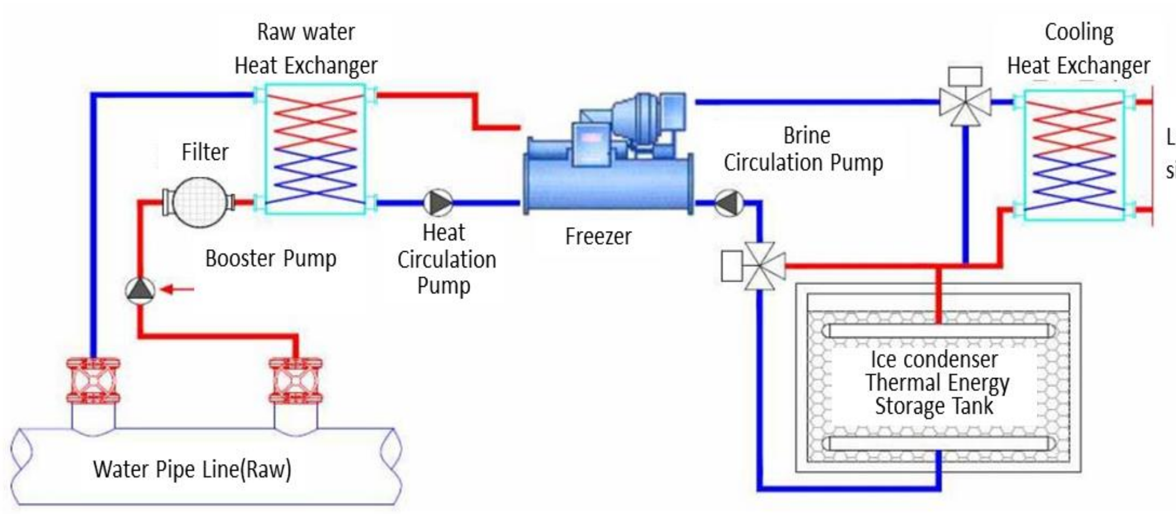
- *Contraction heat pump system : Cooling and heating system applied to large buildings such as the 2nd Lotte World Hydrothermal Project*

**Figure 7.** Contraction Heat Pump System



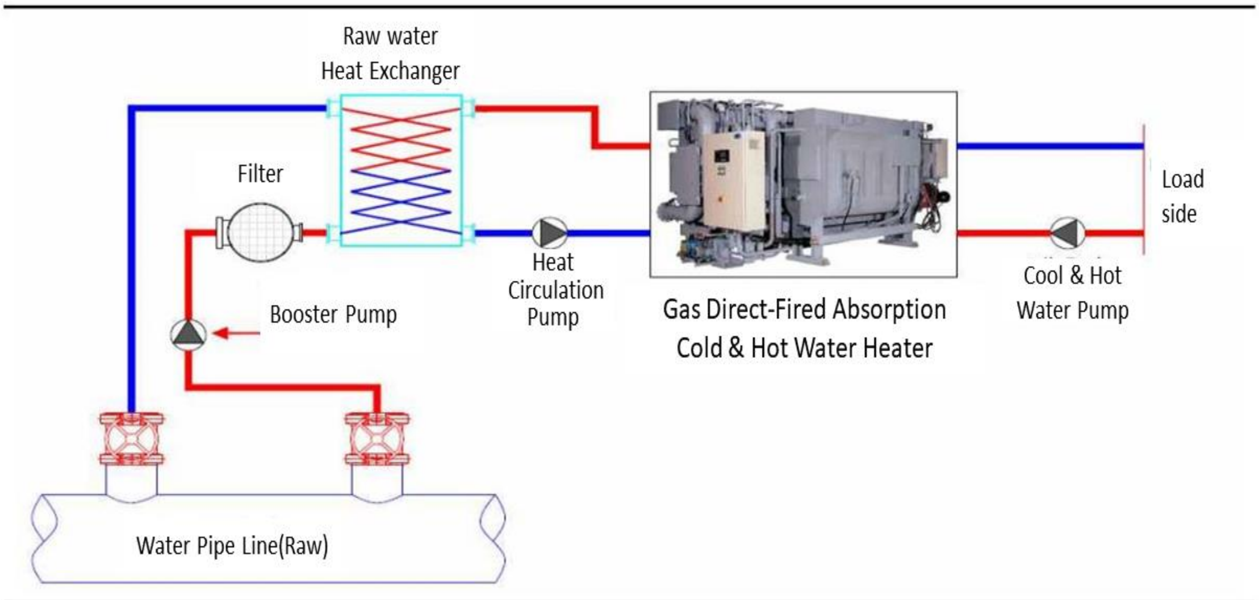

*- Ice condenser storage heat pump system: Cooling system applied to large buildings such as department stores*

**Figure 8.** Ice Condenser Storage Heat Pump System



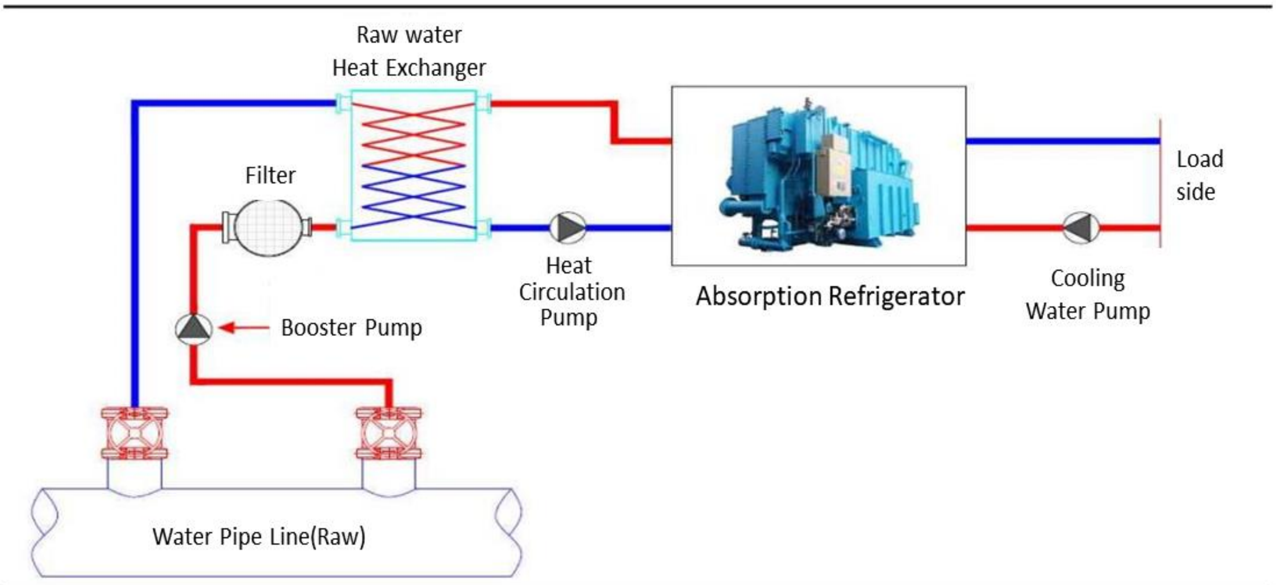

*- Gas direct-fired absorption water cold and hot water heater system: Cooling and heating systems using gas as an energy source*

**Figure 9.** Gas Direct-Fired Absorption Cold & Hot Water Heater System




- *Absorption refrigerator system: Cooling system using low-temperature water, medium-temperature water, and steam as energy sources*

**Figure 10.** Absorption Refrigerator System




### *4.4 Model Evaluation*

As mentioned above, the most important factor in the model strategy and business plan is the characteristics of the project site. This requires a thorough survey of the project site and an evaluation of the project economics. However, the information that can be obtained from the target facility is very limited, such as the gross floor area of the building and the separation distance of the pipeline. Therefore, the business model evaluation should be able to make a rough economic evaluation based on this limited information.

### *4.4.1 Economic evaluation method*

In order to evaluate the economic feasibility of introducing a heat pump system utilizing hydrothermal energy, it is necessary to consider both the initial cost required for introduction and the operating cost after introduction. Therefore, the economic evaluation tool calculates the outdoor piping construction cost and system installation cost based on the unit heating and cooling load of the building, and evaluates the economic feasibility of the model through the simple payback period.

The following is the order of the economic evaluation method. First, collect the information of the target building and determine the heating and cooling area based on the building's gross floor area, use, etc. Based on the derived heating and cooling area and building use, the annual heating and cooling load of the building is schematically calculated, and the capacity of the heating and cooling system is determined to respond to the building load. Based on the determined system capacity, the initial investment cost of the facility is calculated, and the operating cost is calculated by considering the system operating efficiency and power consumption cost. Finally, using the calculated initial cost and operating cost, the simple payback period is analyzed to derive the initial investment cost recovery period, which is the economic evaluation criteria.

*① Determine Return On Investment (George & Franklin, 1996) analysis method: Present value method*

*② Initial investment cost calculation: building use and scale calculation, plumbing cost calculation, facility system installation cost calculation*

*③ Annual operating cost calculation: heat pump efficiency determination, comparison group determination, management cost determination*

*④ Determine initial investment cost recovery period*

### *4.4.2 Investment cost and operating cost calculation criteria*

In order to calculate the initial investment cost for the economic evaluation of the model, it is necessary to prepare the calculation criteria for the unit heating and cooling load, system capacity and cost, and the system operating cost is based on the heating and cooling energy requirement, COP of the heating and cooling equipment, energy rate, and the reflection of the facility maintenance cost.

First of all, the unit heating and cooling load is essential for the economic calculation of the water source heat pump system and is the most important item for the accuracy of the investment cost calculated later. However, it is difficult to calculate the exact heating and cooling load based on the size and use of the building before the demand is determined. Therefore, it is necessary to calculate the unit heating and cooling load for each building type before the project is implemented, and calculate the actual heating and cooling load once the demand is determined and feedback it to the economic evaluation. The approximate heating and cooling load can be calculated based on Seoul Energy Corporation. (2017)

The next step is to calculate the system capacity and cost. The system capacity utilizes the unit cooling load calculated earlier. The capacity of the heating and cooling system is considered based on the building load with a load factor of 85%. The load factor is the ratio of the heated and cooled area to the gross floor area of the building. Therefore, the water source heat pump system capacity is selected according to the cooling and heating system capacity. Here, COP which is the efficiency of the system, should be reflected, and the hydrothermal heat pump COP at this time is calculated by requesting a test to the Korea Refrigeration& Air-conditioning Assessment Center. With the selected capacity, the initial investment cost is determined by calculating the construction cost through the 'standard market unit price for construction work', 'Korean price information', and 'standard itemization'.

Finally, the approximate operating cost is calculated. The maximum annual cooling and heating energy consumption can be calculated by reviewing the daily and monthly operating hours and the number of months of cooling and heating operation using the table 15 by Seoul Energy Corporation. (2017). The energy rate is calculated by calculating the approximate operating cost by calculating the appropriate facility maintenance cost in consideration of facility repair and replacement, and utilizing the energy rate table of the Korea Electric Power Corporation and the Korea Gas Corporation.

**Table 15.** Unit Heat Load Table

| Building Uses | Unit Heating Load (W/m²) | | Unit Cooling Load (W/m²) | Daily Operating Hours | Monthly Operating Hours |
|---|---|---|---|---|---|
| | A | B | | | |
| Neighborhood Living Facilities | 100 | 127.9 | 179.1 | 10 | 21 |
| Neighborhood Public Facilities | 103.5 | 127.9 | 132.6 | 10 | 21 |
| Religious Facilities | 133.7 | 157 | 122.1 | 10 | 30 |
| Senior Facilities | 100 | 122.1 | 122.1 | 10 | 21 |
| Medical Facilities | 122.1 | 145.3 | 132.6 | 24 | 30 |
| Educational and research facilities | 103.5 | 133.7 | 122.1 | 10 | 21 |
| Business Facilities | 100 | 133.7 | 132.6 | 10 | 21 |
| Lodging | 103.5 | 127.9 | 150 | 24 | 30 |
| Sales Facilities | 114 | 139.5 | 179.1 | 12 | 28 |
| Recreation | 127.9 | 139.5 | 164 | 10 | 30 |
| Viewing and assembly facilities | 133.7 | 157 | 164 | 10 | 21 |
| Exhibition facilities | 133.7 | 157 | 179.1 | 10 | 30 |
| Other | Consult with Consumers | | | | |
| A | If radiators, convectors, and fan coil units (FCUs) are your primary heat source | | | | |
| B | If air handlers (AHUs) are the primary heat source | | | | |

## 5. Conclusion

### *5.1 Summary and future research*

The business models for dam deep-water and river water hydrothermal energy, which are important projects to promote hydrothermal energy in South Korea, differ in scale.

In the case of dam deep-water, a strategy can be established on a national scale, targeting energy-intensive clusters such as data centers, which have recently increased in demand. In the process of establishing this strategy, it is necessary to consider the actual potential amount and important indicators of the business to see if the business can actually supply the demand. Therefore, we have calculated the actual potential of the project by referring to the Gangwon-do hydrothermal cluster project and listed the important indicators of the project as a national strategic project. We have also presented a hierarchical weighting analysis to evaluate the important indicators.

However, the calculation of the actual potential here should be accurately calculated in the implementation design after the project is conceived. This study used the dam discharge water data to utilize the hydrothermal energy of the dam deep-water, but it is difficult to collect and analyze the vast data of 20 dams and discharge water lines at the project planning stage, so it is judged that the actual potential amount should be confirmed after the project plan.

River water is suitable as a renewable energy source for heating and cooling large buildings in cities. Over 51% of the final energy we use is heat energy, especially for cooling and heating in cities. With this in mind, we conceived a strategy for the river water heat business, which is currently under development. However, the initial investment cost is higher than other renewable energies, so it should be evaluated in terms of Return On Investment (George & Franklin, 1996).

COP, an indicator of cooling and heating efficiency, should be continuously updated in consideration of environmental factors and technological advances at the business site, and an accurate Return On Investment (George & Franklin, 1996) should be calculated or a review should be made to improve the return, similar to the dam deep-water project. This should use a diversified evaluation technique different from simple evaluation of investment returns, such as technology for legislating policies for mandatory thermal energy such as Renewable Heat Obligation and Renewable Heat Incentive, accumulation of operational data, and in-depth analysis of overseas cases.

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