Joint Research Project:
Barcelona Metropolitan Area's Policy Framework& Best Practices for Energy- Efficient Buildings
FINAL REPORT

Funded by the European Union

Joint Research Project: Building Energy Efficiency

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Abbreviation

AMB	Administration of the Metropolitan Area of Barcelona
BDCES	Building Design Criteria for Energy Saving
BECC	Building Energy Code Compliance
BEECS	Building Energy Efficiency Certification System
BEMS	Building Energy Management System
BIPV	Building-integrated Photovoltaics
BRP	Building Retrofit Project
CEE	Certificado de Eficiencia Energética
CMH	Metropolitan Housing Consortium
EIID	Energy Independence Innovation District
EIR	Energy independence rate
EPBD	The Energy Performance of Buildings Directive
EPC	Energy Performance Certificate
EU	European Unions
FSC	Forest Stewardship Council
G-SEED	Green Standard for Energy and Environmental Design
IDC	Internet Data Centers
IMPSOL	Instituto Metropolitano de Promoción de Suelo y Gestión Patrimonial, Metropolitan Institute of Land Development and Property Management
KAIA	Korea Agency for Infrastructure Technology Advancement
KEPCO	Korea Electric Power Corporation
LH	Korea Land & Housing Corporation
MEP	Mechanical, Electrical and Plumbing
MoLIT	Ministry of Land and Transport
MoTIE	Ministry of Trade, Industry and Energy
nZEB	nearly Zero-Energy Building
OSB	Oriented Strand Board
SDGs	Sustainable Development Goals
SMG	Seoul Metropolitan Government
UAB	Autonomous University of Barcelona
VPO	Viviendas de protección official
ZEB	Zero-Energy Building

ORGANIZATION

CITYNET

CityNet is the largest association of urban stakeholders committed to sustainable development in the Asia-Pacific region. Established in 1987 with the support of UN-ESCAP, UNDP, and UN-Habitat, the network of cities has grown to include 163 municipalities, NGOs, private companies and research centers. CityNet connects actors, exchange knowledge and build commitment to more sustainable and resilient cities. Through capacity building, city-to-city cooperation and tangible projects, we help our members respond to Climate Change, Disaster, the Sustainable Development Goals, and rising Infrastructure demands.

AREA METROPOLITANA DE BARCELONA

AMB is the public administration of the metropolitan area of Barcelona with specific powers in urban planning, public space, housing, sustainable mobility, waste and water management, international relations and strategic planning. AMB has more than 40 years of experience in institutional cooperation and provision of technical and financial support to its 36 municipalities, covering 636 km2 with 3.2 million inhabitants. Most of its municipalities belong to the EU Covenant of Mayors for Climate and Energy.

EU-KOREA CLIMATE ACTION PROJECT

EU-Korea Climate Action project is a three-year project funded by the EU which aims to connect the Korean and European actors, providing opportunities for collaboration to accelerate climate actions in Korea.[1] The priority themes of the project are as follows: energy-efficient building, low-carbon mobility, circular economy, business practices, and renewable energy.

This joint research project was funded under the topic of energy-efficient buildings, which is expected to contribute to Korea's low-carbon energy transition efforts, fostering political commitment and concrete climate action.[2]

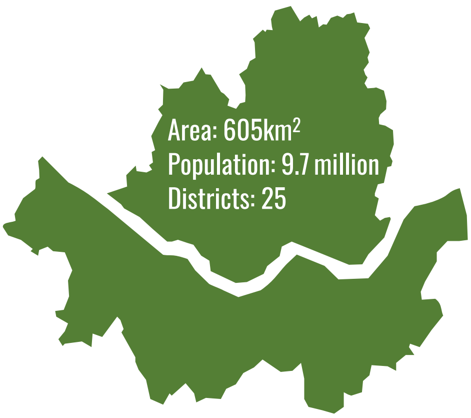
1) https://www.climateaction-korea.eu/about/
2) https://www.climateaction-korea.eu/?eoi_info=1

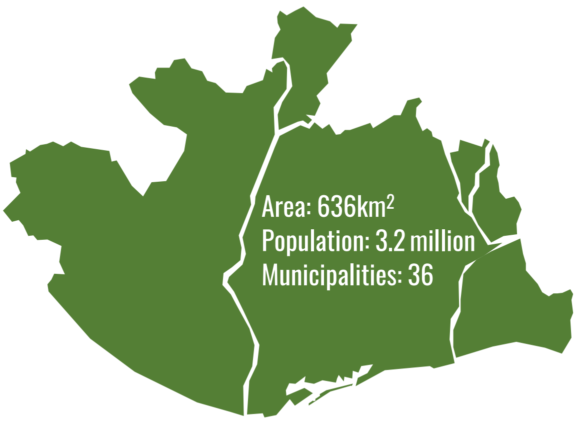
01 INTRODUCTION

FOCUS

The focus of the joint research project is the energy-efficient public buildings of the metropolitan area of Barcelona. The legal definition of the public building in the EU is a building occupied by a public authority and frequently visited by the public; that in Korea is a building, facilities and subsidiary facilities used by unspecified mass. Within the context of this report, the public building is defined as those owned, used and/or funded by public sources.
The target cities that the research aims to address are Korean member cities of CityNet, which includes Seoul, Incheon, Busan, Suwon, and Jeju. There are many similarities between the AMB and target cities—such as Seoul—in terms of their area, high building energy consumption, issues of aging buildings, and the use of solar and geothermal energy. Yet, the contextual differences between Spain and Korea have resulted in their varied approaches to address building energy efficiency.
Most of the legislation in both countries begin with their application to public buildings, which then expands out to private properties. Public buildings are accessible and usable by people from different socioeconomic sectors, meaning that improvements made to public buildings would set a visible low-carbon example for the entire community. The condition of the public buildings also reflect the political will of the government, as both AMB as well as target CityNet member cities in Korea are public bodies. The case studies address new and renovated public buildings in the metropolitan area of Barcelona of various usage with high energy efficiency.
This report and collaboration between CityNet and AMB was made possible due to Seoul Metropolitan Government (SMG) and AMB having held a continuous, effective and successful cooperation for the last 4 years. In 2017 and 2019 AMB was a guest institution at the 'Seoul Biennale of Architecture and Urbanism' to show the world both the city of Barcelona and its metropolitan surroundings through the urban planning experience, green infrastructure and projects in selected public spaces. AMB also showed how they engage with urban life at the exhibition hosting 50 cities and metropolises from all over the world. In 2018 SMG and the city of Barcelona have signed an agreement on strengthening their friendly relationship and for expanding cooperation in urban renewal and public transportation on the city level. In line with this effective cooperation between SMG and AMB, AMB has also started a fruitful cooperation with CityNet.

Figure 1. Outline of Seoul and the metropolitan area of Barcelona





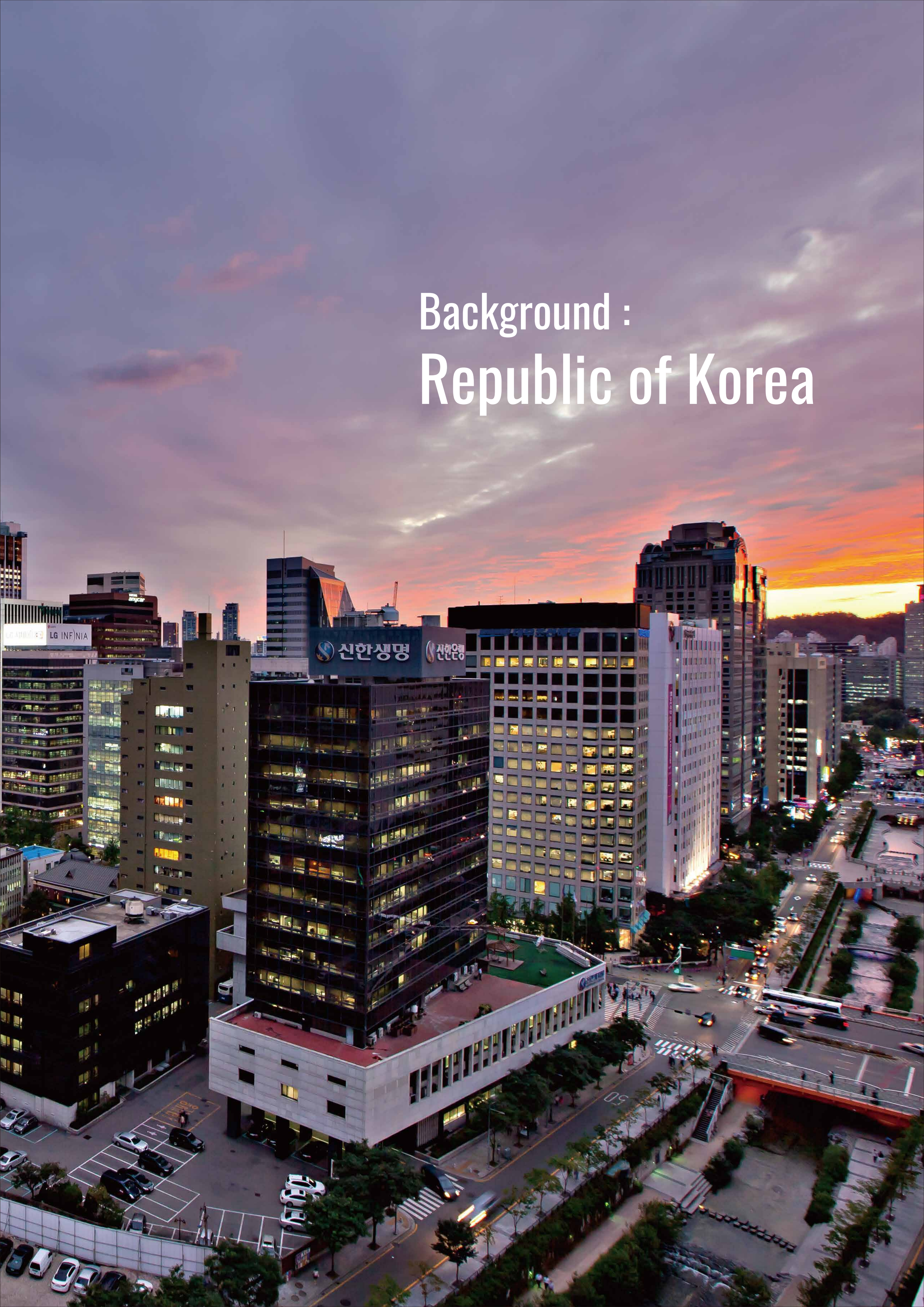
METHODOLOGY

The report consists of background research into current building energy efficiency practices of Korea and Spain from national down to metropolitan level, as well as documentation of various energy-efficient case studies in the metropolitan area of Barcelona via study visit. The background research puts emphasis on the definition and certification of zero-energy buildings (shortened to ZEB or nZEB) whose definition differs according to country. The report aims to not only show the differences in policy frameworks between AMB and Seoul but also provide tangible examples of energy-efficient case studies in the metropolitan area of Barcelona.[3]

3) Most of the sources used in this report are drawn from the regional level (e.g. Catalonia) among three administrative levels: national (Spain), regional (e.g. Catalonia), and local (e.g. Barcelona City). Please refer to p. 22 for more information.


신한은행

Background :
Republic of Korea



02 BACKGROUND : Republic of Korea

NATIONAL PLANNING

-Focus on large-scale buildings/ districts

-Public buildings/ new buildings prioritized

-Incentives and loans

-Emphasis on renewable source of energy

-Emphasis on smart technology

History of Building Energy Efficiency

The Republic of Korea has recognized the importance of building energy efficiency from early on. Korea has two representative national energy policies: the Building Energy Code Compliance (BECC) and the Building Energy Efficiency Certification System (BEECS). BECC is a regulation to specify minimum requirements for building energy performance, targeting buildings with gross areas over 500㎡.[4] It is essentially a plan about how the building can conserve its energy, and the building permit is only issued upon the approval of the BECC.

BEECS was enacted in 2001 which evaluates and certifies buildings to provide customers information on building energy use. Although it was initially developed for multifamily residential buildings, it was expanded and recalibrated in 2013 to include non-residential buildings.

1. Formation of the Presidential Committee on Green Growth

President Myung-bak Lee's administration (2008-2013) had a particular focus on green growth. As a result, the Presidential Committee on Green Growth was formed in 2009 to overlook green growth policies. Following the Committee formation, lots of sustainability criteria related to buildings were revised and strengthened. As an example, Building Design Criteria for Energy Saving (BDCES) was strengthened by thicker wall insulation, and it was made mandatory for all new and existing residential buildings with a total floor area of more than 500㎡.
Moreover, the Standards and Performance of Eco-friendly Houses were revised so that certain energy-efficient features like fluorescent lamps became obligatory.[7] This was mandated for residential housing complexes with more than 20 households.

Figure 2. Previous criteria for the BEECS .[5]

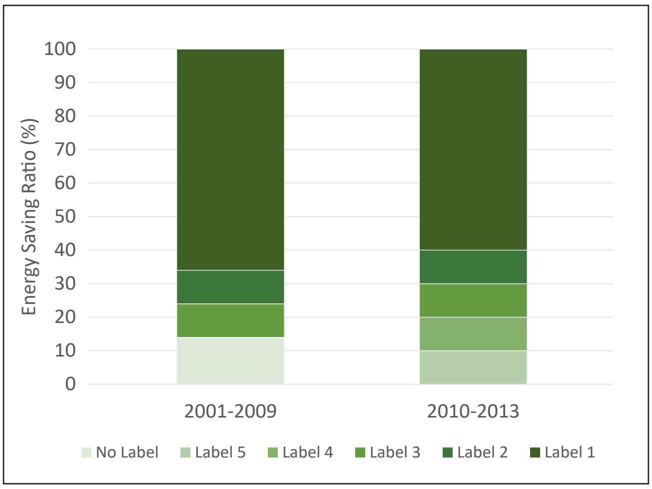


Figure 3. Comparison of Passive House criteria and Korean BDCES criteria (2017) .[6]

Components	BDCES 2017 in Korea
Building envelope	
Wall Insulation	U≤0.17 (0.26) WM²K
Roof Insulation	U≤0.15 (0.15) WM²K
Floor Insulation	U≤0.15 (0.18) WM²K
Window	U≤0.10 (0.50) WM²K
Door	U≤0.14 (0.50) WM²K
System	
Efficient heating system	Boiler efficiency: 87%
Air change rate	0.5h¹

4) http://www.eria.org/RPR_FY2015_No.5_Annex_2.pdf
5) Adapted from Figure 7, 'Analysis of a Building Energy Efficiency Certification System in Korea,' P. Duk Joon et al., 2015. https://www.mdpi.com/2071-1050/7/12/15804/htm.
6) Adapted from Table 2-3, p. 45, Xu, W., & Zhang, S. (2018). Apec Nearly (Net) Zero-energy building Roadmap. APEC Secretariat
7) http://www.kemco.or.kr/nd_file/kemco_eng/KoreaEnergyStandards&Labeling.pdf

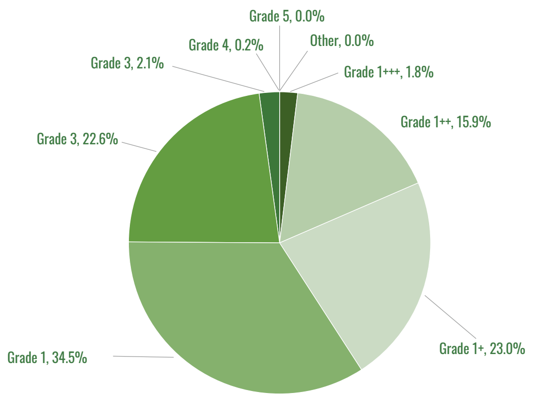
2. Enactment of the Green Building Construction Support Act

Due to the report of the Presidential Committee on Green Growth, the national Green Building Construction Support Act was enacted in 2013 spearheaded by the Ministry of Land and Transport (MoLIT)'s. This resulted in the first ever National Master Plan on Green Building (2014-2018).[8] BEECS was recalibrated in the same year to expand the scope of mandate to all new and existing public buildings. G-SEED (green standard for energy and environmental design) was also revised in 2013 to include all public buildings with a total floor area of over 3,000㎡, a significant improvement from the original 10,000㎡.[9]

Figure 4. Grading Chart for Building Energy Efficiency Rating Certification System (BEECS).[10]

Grade	Residential Building	Non-residential Building
	Annual primary [renewable] energy requirement per unit area (kWh/m^2 year)	Annual primary [renewable] energy requirement per unit area (kWh/m^2 year)
1+++	$x < 60$	$x < 80$
1++	$60 \le x < 90$	$80 \le x < 140$
1+	$90 \le x < 120$	$140 \le x < 200$
1	$120 \le x < 150$	$200 \le x < 260$
2	$150 \le x < 190$	$260 \le x < 320$
3	$190 \le x < 230$	$320 \le x < 380$
4	$230 \le x < 270$	$380 \le x < 450$
5	$270 \le x < 320$	$450 \le x < 520$
6	$320 \le x < 370$	$520 \le x < 610$
7	$370 \le x < 420$	$610 \le x < 700$

Figure 5. Pie Chart of BEECS Certification Status by Grade as of February 2020 .[11]



3. Zero-energy building Certification and Mandate

The Green Building Construction Support Act was revised to implement the Zero-energy building (ZEB) Certification System, which began in January 2017 for new and existing buildings of all purposes. Although it was optional for both the public and private sectors, obtaining certification was mandatory for the construction of certain public buildings and research facilities with total floor area of more than 3,000㎡.

On June 21, 2019, the government has announced that the ZEB certification will be mandated for new buildings in several stages:

1) Public buildings with a total floor area of 1,000㎡ and above in 2020,
2) Public/ Private buildings with a total floor area of 1,000㎡ in 2025,
3) All buildings with a total floor area of 500㎡ and above by 2030.[12]

The idea is to put the public sector on lead to expand the ZEB market, eventually leading to mass production of ZEB that will lower the unit price.[13] This is one of the strongest national mandates regarding building energy efficiency implemented in Korea so far.

8) https://unfccc.int/sites/default/files/2nd_biennial_update_report_republic_of_korea_eng.pdf
9) https://www.gbc.re.kr/app/info/outline.do
10) Contents cited from "Building Energy Efficiency Rating Certification System," by Korea Energy Agency. http://www.kemco.or.kr.
11) Contents cited from "Total Certification Status by Grade," by Korea Energy Agency, http://beec.kemco.or.kr/.
12) http://www.startuptoday.kr/news/articleView.html?idxno=10700
13) http://www.seoul.go.kr/main/index.jsp

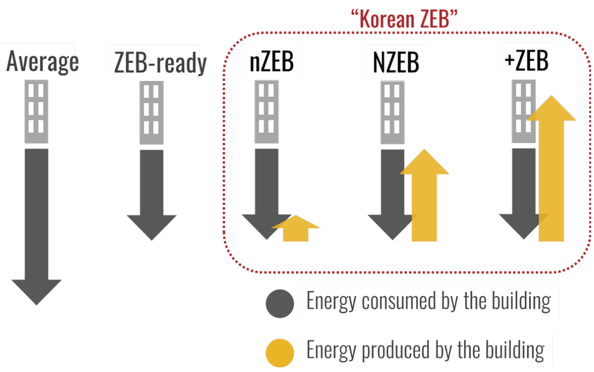
Note: G-SEED

G-SEED stands for Green Standard for Energy and Environmental Design, which is used to certify green buildings that contributed to energy conservation and pollution reduction throughout its life cycle. It originally began as an eco-friendly building certification in 2002 targeting apartment buildings but was thoroughly revised in 2013 upon the Green Building Construction Support Act. Now G-SEED is mandated for all public buildings with a total floor area greater than 3,000㎡.

Zero-Energy Buildings

Zero-Energy Buildings (ZEB) is a concept that has been discussed since the 1970s when people began to consider the downsides of fossil fuel dependency.

Figure 6. Definition of Zero-energy buildings.[14]



There are four widely discussed divisions of zero-energy buildings. The first one is the "ZEB-ready" building, which has reduced its energy demand through improving features such as the lighting but is yet to produce its own energy on-site. Next, there is "nearly-ZEB" or nZEB building, which has lower energy demand and also produces its own energy through renewable means. "Net ZEB" or NZEB is a building that is able to produce as much energy as it consumes, whose net energy consumption would be equal to zero. Lastly, there is "plus-ZEB" or +ZEB, which produces more energy than it can consume. The surplus energy is either used within the building or sold back to the grid for a profit.

ZEB is defined in Korea as "a building which minimizes the total energy consumption through the usage of insulation features such as façade insulation and exterior windows, and the usage of renewable energy such as solar power". This definition of ZEB in Korea is inclusive of nZEB, NZEB and +ZEB, although most of the said ZEB buildings in Korea are nZEB. ZEB is supported by two national ministries in Korea: Ministry of Land, Infrastructure and Transport (MoLIT), and Ministry of Trade, Industry and Energy (MoTIE). MoLIT concentrates on improving passive elements of ZEB such as façade insulation, whereas MoTIE focuses on improving active elements such as equipment efficiency and renewable energy supply.

In 2017, Korea's Green Building Construction Support Act (2013) was amended to introduce the ZEB certification system. In order to be ZEB-certified, the building has to meet three requirements:

1) Building energy efficiency codes (BEECS) of level 1++ or above
2) Building Energy Management System (BEMS) installation
3) Energy independence rate (EIR) above 20%.

Given that the first two requirements are met, the building will receive Grade 1 Certification if its energy consumption equals energy produced. If the difference between energy consumed and energy produced—building's energy independence rate—is between 20% and 40%, the lowest Grade 5 Certification would be given.[15] However, the status of most of the buildings that are certified in Korea up until now remains at Grade 5 Certification or Preliminary Certification.[16] The building can apply for ZEB Preliminary Certification during its design stage, and apply for an Actual Certification after the building is constructed.

14) Adapted from the book 'Zero energy green remodeling,' by K. Hakgun et al., 2019, p. 29.
15) http://www.seoul.go.kr/main/index.jsp
16) http://www.electimes.com/article.php?aid=1566460339184931002

Figure 7. ZEB Certification criteria in Korea [17]

ZEB Grades	Energy independence rate (EIR)	Maximum % easing of building standard*
Grade 1	Over 100%	15%
Grade 2	80~100%	14%
Grade 3	60~ 80%	13%
Grade 4	40~ 60%	12%
Grade 5	20~ 40%	11%

**Energy consumption for cooking and electrical outlets are excluded during EIR calculation as they are irrelevant to the energy efficient architecture.*

**Building Standard: Floor area ratio- under 100/115, Maximum building height - under 100/115.*

Except for the easing of building standards, the current incentives that apply to zero-energy buildings (ZEBs) such as tax deduction rate (maximum 6% of income or corporate tax deduction for energy-saving facility investment cost) are considered relatively weak. This discourages the existing buildings from being ZEB- certified: only one existing private building in Korea, renovated by an environmental architectural firm, was granted a ZEB Grade 5 Certification. It is also difficult to measure the effectiveness of the incentives: for example, the tax deduction occurs only through the installation of energy-efficient facilities, not by tracking the actual performance of the building and its facilities.

The number of ZEB-certified buildings is expected to rise upon the mandate which begins in 2020 for all public buildings with the total floor area greater than 1,000m2. This would solve pre-existing issues such as the lack of willingness from public institutions to participate voluntarily, and lack of interest from the construction sector. However, in order to ensure efficient promotion and diffusion of ZEB, the mandate has to be supported further through means such as bringing together scattered information sources related to ZEB and addressing the lack of ZEB experts by education and training. [18]

Other national funding sources

Green Home Project

Korea Land & Housing Corporation (LH) is a government -owned corporation in charge of the development and management of land and housing. Since 2010, LH's Green Home Project targeted LH-built permanent lease and 50-year lease housings that have been occupied for over 15 years. The building energy efficiency of these buildings is improved by LH's financial support to replace the existing windows, lightings, hallway and balcony chassis and other aged facilities. [19]

Green Remodeling

MoLIT and LH's joint initiative for Green Remodeling of Public Buildings began in 2013. The funding is provided for the diagnosis of the existing building condition and for construction costs. In 2019, the initiative had 850 million won of funding to renovate existing public buildings owned or managed by the central administrative agency or local government. Only 21 projects will be chosen for 2019, and the effectiveness of the project will be guaranteed via 3-year monitoring of energy consumption of the chosen projects. Green Remodeling of private buildings also became possible since 2014, which provides a 3-4% interest rate for the loan. [20]

17) Contents cited from "Zero-energy building Certification," by Korea Energy Agency. http://www.kemco.or.kr.
18) https://zeb.energy.or.kr/supportZero/%EC%A0%9C%EB%A1%9C%EC%97%90%EB%84%88%EC%A7%80%EB%B9%8C%EB%94%A9%20%EC%9C%B5%ED%95%A9%EC%96%BC%EB%9D%BC%EC%9D%B4%EC%96%B8%EC%8A%A4%201%EC%B0%A8%EB%85%84%EB%8F%84%20%EB%B3%B4%EA%B3%A0%EC%84%9C.pdf
19) https://welfaresystem.kr/%EB%85%B8%ED%9B%84-%EA%B3%B5%EA%B3%B5%EC%9E%84%EB%8C%80%EC%A3%BC%ED%83%9D-%EC%8B%9C%EC%84%A4-%EA%B0%9C%EC%84%A0-%EA%B7%B8%EB%A6%B0%ED%99%88-%EC%A7%80%EC%9B%90%EB%8C%80%EC%83%81-%EB%82%B4%EC%9A%A9/
20) Kim, Hakgun et al. (2019). Zero energy green remodeling. Seoul: Housing and Culture Inc.

Research & Development Project

MoLIT's national R&D project began in 2013 and was managed by the Korea Agency for Infrastructure Technology Advancement (KAIA). Nowon EZ House was the first grant-receiving project that focused on energy-efficient building practice.

Zero-energy Demonstration Complex project

LH has initiated the Zero-energy Demonstration Complex project which involves the development of three high-rise multifamily residential complexes in Namyangju, Gwacheon and Incheon city (Gumdan). The three complexes are expected to supply 2,389 residential units. Moreover, these large-scale development aims to resolve the limitations of on-site renewable energy generation by implementing partial off-site power generation such as photovoltaic public bus stops, streetlights, and road sound barriers.[21)]

Focus: Seoul, Republic of Korea

As the capital city of Korea where 81% of the total population lives in urban areas, Seoul naturally requires a high amount of energy.[22)] In Seoul, 83% of the electricity consumed is used to power its buildings: the same amount of electricity makes up 56.8% of Seoul's total energy consumption (electricity, oil, gas, etc.).[23)] Within Seoul, there are 333 buildings that are classified as High Energy Consumption Building including universities, Internet Data Centers (IDC), and hospitals.[24)] In 2017, one-third of these buildings' energy consumption has increased from that of the previous year.

To address the issue of high energy consumption by buildings, Seoul Metropolitan Government came up with the Building Retrofit Project (BRP) loan support scheme in 2008. Introduced to materialize the building energy rationalization project agreed at C40, BRP has initially targeted the public buildings only. Now, it is expanded to finance both the private and public sectors to reduce greenhouse gas by finding and modifying the causes of the building's high energy. As an example, Dongdaemun Migliore Mall has achieved an energy saving of 73% through 900 million won (500 million-loan support) in 2008 mainly through LED installations.[25)] In 2014, SMG collected data from 100 buildings retrofitted from 2012 to 2013 which showed an average energy reduction of 10% in residential housing and 6.5% in non-residential building.[26)] At the same time, BRP has experienced a lack of interest due to the economic downturn and the different interests between the building owner and leaseholder. Moreover, building energy consumption diagnosis done through BRP funding did not automatically lead to actual improvement and renovation of existing facilities. Interest rate loans (1.45%) and the loan limits are still considered to be too low to lift the barrier to entry.

Another effort to enhance energy efficiency in buildings is the Energy Independence Innovation District (EIID), one of Seoul's 'Energy Independence Village 2.0' projects. It is an attempt to promote cooperation between autonomous districts, Seoul Metropolitan Government, residents, and private enterprises to strengthen energy demand management and identify profitable businesses through energy savings.[27)] Although the EIID focuses more on energy independence rather than building energy efficiency, it does analyze the building energy uses of the selected autonomous districts for possible energy saving. Seodaemun-gu is set to receive the investment worth 1.25 billion won, and such EIIDs are planned to be expanded until 2022 through an additional 3 billion won investment to four autonomous districts.

21) https://www.ctis.re.kr/ko/downloadBbsFile.do?atchmnflNo=3720
22) https://data.worldbank.org/indicator/SP.URB.TOTL.IN.ZS?most_recent_value_desc=true
23) http://www.seoul.go.kr/main/index.jsp
24) http://www.aurum.re.kr/Research/PostView.aspx?mm=1&ss=1&pid=14243&gid=0&cpage=1#.Xe4JfOgzaUk
25) http://susa.or.kr/sites/default/files/resources/%ED%99%98%EA%B2%BD_8_Building%20Retrofit%20Program.pdf
26) http://www.kankyo.metro.tokyo.jp/en/int/c40/c40_pse_r.files/UEII_Chapter3.5_Seoul.pdf
27) https://www.yna.co.kr/view/AKR20190726154200004?input=1195m

Case Studies : Republic of Korea

Seoul- Seoul Energy Dream Center (ZEB Grade 3 Certification)

Seoul Energy Dream Center was completed in 2012 by Seoul Metropolitan Government. It is described as a "declarative building of Seoul as an energy-independent city.[28]" Its main use is an educational center to showcase green, renewable technology. The building utilizes known passive energy-saving features such as thick facade insulation, triple-glazed glass, motorized window blind for insolation control, and atrium to maximize natural sunlight. However, there are other unique features such as the building's pinwheel-inspired design and faux-marble facade, which help to reflect 60% of direct sunlight.
The building produces its own energy through solar panels (864 modules with a photovoltaic capacity of 272kW). Geothermal energy (112kW: 37 50m-deep boreholes) also provides radiant heating and cooling using the consistency of the ground temperature.[29]

Figure 8. Seoul Energy Dream Center

Seoul- Nowon Energy Zero (EZ)

Nowon EZ House was built for the vulnerable group as it serves as a 121-unit public lease housing. It was part of MoLIT's R&D project initiated in 2013, with the building completed in 2018. EZ House was awarded BEECS Grade of 1+++: although it is yet to obtain ZEB Certification, the building is considered as one of the first representative ZEBs in Korea. Its main renewable features include photovoltaic panels (409kW) and geothermal heat pump, and other active and passive energy-saving elements such as airtight design, external window blinds, triple- glazed glasses, and heat recovery ventilation system. EZ house has achieved a 61% reduction in annual energy demand compared to those of average Korean housing and is capable of achieving net energy consumption of zero. If the energy output of the EZ House exceeds the energy consumption, the remaining energy would be used for outlets and cooking for EZ House residents or sold to Korea Electric Power Corporation (KEPCO).

Figure 9. View of the Nowon EZ House complex [30]

Incheon-Gumdan AA10-2BL

Gumdan AA10-2BL is a high-rise public apartment complex being built by Kunwon Architects, Planners, and Engineers, which is part of Korea Land and Housing Corporation (LH)'s Zero-energy Demonstration Complex project. It is the first long-term lease public housing complex that received the ZEB certification (preliminary) in Korea. With a total floor area of 88,005m2, it is expected to serve 1,188 households.[31] AA10-2BL aims to achieve energy efficiency in a high-rise building, which is made more difficult by its high operational energy to evenly transport and distribute resources on each floor. Upon completion, it is expected to conserve 71% of the energy cost compared to those of 10-year old average public housing complexes. Some of the complexes' energy-saving strategy would be reinforcing insulation, reducing air leakage, and utilizing solar energy. Moreover, new insulating material for building walls and windows is planned to be developed.

Figure 10. Incheon Gumdan AA10-2BL

28) http://www.seouledc.or.kr/content/index.sgk?dname=center
29) http://www.seouledc.or.kr/bbs/board.php?bo_table=1010&represent=4
30) EU-Korea Climate Action. https://www.climateaction-korea.eu. (Image use approved by Nowon Environmental Foundation)
31) https://www.kunwon.com/board/perform.read.php?BBS_GUBUN=1&SC_LP=LATE&SC_YEAR=&SC_SUPPLY=&SC_LOCAL=&SC_word=&page=1&BBS_IDX=548

Busan

Followed by those of Seoul (59.6%), Busan's buildings are responsible for the second-highest percentage (37.4%) of the city's total energy consumption.[32] Busan is suffering from aging building infrastructure and the resulting energy inefficiency. In 2018, over 50% of the buildings in Busan were built 30 years or more ago, the highest percentage of aging building stocks in Korean cities.[33]
According to Busan Green Building Construction Plan (2017),[34] Busan has been planning to:

1) Establish green building design standards of existing buildings, and
2) Initiate Busan Green Remodeling Support Project for buildings that were approved for use more than 15 years ago.

Busan attempts to address the downsides of national strategies which often target public buildings only, and control the tendency to use glass façade in the design which increases the cost of air conditioning.
Busan also initiated the Cool Roof project in 2016 to prevent heat wave damage and urban heat island effect. Although the project is as simple as painting the rooftop with reflective white paint, it proved to be particularly beneficial to electricity savings for vulnerable groups, such as the disabled and senior citizens. In 2019, the Busan government has devoted 120 million won (100,000 dollars) for the provision of cool roofs.[35]

Jeju

Jeju Special Self-governing Province is well-known for its "Carbon Free Initiative by 2030". By 2030, Jeju Island plans to go carbon-free via substituting fossil fuel with renewable energy sources and electric cars. Nevertheless, addressing building energy efficiency is not one of Jeju Province's main goals yet.
However, Jeju City is beginning to acknowledge the importance of ZEBs. Currently, the only ZEB-certified building in Jeju is the "Eco-Town" youth hostel located next to the Camelia Hill Ramsar site. It is a public training center built by the Jeju City Hall which is to be used for training students about the environmental consciousness by utilizing the Camelia Hill Ramsar site which is designated as the wetland of international importance.

In December 2019, Jeju City Hall, Ministry of Land Infrastructure and Transport, Korea Appraisal Board have signed an MOU aiming to diffuse ZEB construction in Jeju City, particularly for the private detached housings. In line with the MOU, Jeju City will initiate the "Zero-energy House Support Project" starting in 2020, which supports the cost of renewable energy installation in private detached housings.[36]

Suwon

Suwon is a densely populated city with high energy dependence of 87.3%.[37] As a result, Suwon focuses on developing sustainable energy supply via renewable sources, specifically solar energy. Suwon is yet to have any ZEB-certified buildings but is attempting to recognize energy-efficient buildings that do not generate on-site renewable energy. In 2019, Suwon Research Institute has conducted a study on the Improvement of Building Energy Efficiency and Energy Governance Operation. This study mentions the introduction of the Total Energy Consumption System: unlike the ZEB Certification System, this system could show energy efficiency improvement in buildings where the renewable energy source is not applicable (ZEB-ready buildings).

Figure 11. Jeju Eco-Town youth hostel

32) https://www.busan.go.kr/nbtnews/835103?curPage=85&srchBeginDt=&srchEndDt=&srchKey=&srchText=
33) http://www.eais.go.kr/eais/
34) Minyong Park et al. (2017). Busan Green Building Construction Plan. Busan, Republic of Korea: Busan Metropolitan City.
35) http://www.newsis.com/view/?id=NISX20190307_0000580716&cID=10899&pID=10800
36) https://www.kharn.kr/mobile/article.html?no=11577
37) Eunha Kang (2019). Study on the Improvement of Building Energy Efficiency and Energy Governance Operation. Suwon, Republic of Korea: Suwon Research Institute.

Other notable case studies

Asan City Central Library (ZEB Grade 5 Certification)

Asan city government has a strong political will to construct public ZEB-certified buildings. Completed in 2018, Asan city central library has a total floor area of 9,037m2. It is the first library in Korea to be ZEB- certified, and is currently being benchmarked by other Korean cities such as Seoul. The total budget of 28.3 billion won (23.8 million dollarss) was spent on this project.[38]

Chungyeon Building (ZEB Grade 5 Certification)

Chungyeon Building is the headquarters of the Chungyeon Sustainable Architecture Design Group located in Seoul. It was the first renovated building, and also the first privately-owned building to be ZEB-certified in Korea. Chungyeon Building was partially funded by the national Green Remodeling Project through loan interest rate support.[39] The existing building was reinforced with roof and facade insulation, and triple-glazed, airtight windows for a tight building envelope. In addition, active systems such as air-to-air heat recuperator, motorized external blinds, and BEMS were installed. Chungyeon building also produces its energy by photovoltaic panels on the rooftop as well as BIPV (building-integrated photovoltaics) on the facade. LED lightings, and water-conserving faucets and toilets are utilized throughout the building. Upon the renovation, it has achieved a total energy reduction of 68% as well as a G-SEED Grade 1 Certification.

Figure 12. Asan City Central Library

Figure 13. Chungyeon Building

Summary

Overall, most of the case studies are from Seoul followed by Incheon. The main focus of Busan, Suwon, and Jeju is on the generation and usage of renewable energy. They have recently established plans for improving building energy efficiency, but not many projects are being implemented compared to Seoul.

Such focus on energy source in Korea is not without its reason: Korea's energy dependence rate, (meaning how much energy is imported as compared to domestically generated), is at 81.4% while that of Spain remains at lower 73.3%.[40] Spain used to be at the same level of energy dependency as today's Korea 10 years ago: however, its energy dependency was lowered by active usage of solar and geothermal energy in buildings.

Moreover, raising the percentage of renewable energy sources in total energy consumed by up to 20% by 2030 is the target of the current Moon Jae-In administration in Korea. However, only about 5% of Korea's energy production is from renewable sources [41] as compared to 42.8% in Spain.[42] This could mean that less attention could be given to improving the total energy demand in Korea, as long as the source of the energy is 'clean' and the building is capable of producing as much energy as it spends.

38) https://www.asan.go.kr/main/cms/?no=76&pds_no=2018072616191149664&m_mode=view&tb_nm=real_name_push
39) Kim, Hakgun et al. (2019). Zero energy green remodeling. Seoul: Housing and Culture Inc
40) https://ec.europa.eu/eurostat/tgm/table.do?tab=table&init=1&language=en&pcode=t2020_rd320&plugin=1
41) http://kosis.kr/statHtml/statHtml.do?orgId=337&tblId=DT_337N_A001
42) https://www.ree.es/sites/default/files/downloadable/the_spanish_electricity_system_2014_0.pdf

Background : Spain

03 BACKGROUND : Spain

NATIONAL PLANNING

In Spain, buildings are responsible for 31% of energy consumption, and roughly 66% of the building energy consumed is used for heating, cooling, and ventilation.[43] Spain is also suffering from the issue of aging buildings: however, deep renovation of existing buildings has the potential to cut 36% of building energy consumption by 2030.[44] The country's high baseline water stress also leads them to incorporate water conservation measures in the buildings.

Definition of nZEB

The Energy Performance of Buildings Directive (EPBD) or Directive 2002/91/ EC is the legislation which applies to the European Union that encourages energy performance improvement in buildings. It was recast in 2010 (Directive 2010/31/EU), which required all new public buildings in the EU to meet the nZEB standard as of December 31, 2018. Moreover, the recast EPBD requires all new buildings to be nZEB starting from December 31, 2020. EPBD generally defines nZEB as a building with very high energy performance, with renewable energy production either on-site or in the vicinity. However, all EU Directives including EPBD require each country to come up with its own implementation measures. This means that Spain would have a different definition of nZEB that its buildings would have to follow.

The legal definition of Spain's nZEB is based on the existing Technical Building Code (CTE 2013), which was created to reduce energy demands and energy consumption in buildings. The newest CTE (CTE 2018) is expected to include a new indicator of "global non-renewable primary energy use". It will still include pre-existing indicators such as the building envelope (maximum thermal transmittance, air infiltration requirement, solar protection) and domestic hot water production. However, the approval of the Spanish national nearly zero-energy buildings (nZEB) definition in the legislation is pending since the CTE 2018 has not yet been published .[46]

Figure 14. Spanish nZEB criteria based on CTE 2018 (pending) [45]

Services Included	Energy needs (building level)	Non-renewable Primary Energy	Total Primary Energy (renew + non renew)	Minimum renewable energy contribution
Heating	NO-but minimum prescriptions for transmittance, air tightness, solar control	YES-No limit	YES-No limit	NO
Cooling		YES-No limit	YES-No limit	NO
Domestic Hot Water	Standard calculation- number of liters per person at 60°C	YES-No limit	YES-No limit	YES, 50% annual energy needed
Global	NO	<32 kWh/($m^2 \cdot y$)	<64 kWh/($m^2 \cdot y$)	NO

43) https://www.interregeurope.eu/enerselves/news/news-article/2758/world-energy-efficiency-day-challenges-in-spain/
44) http://bpie.eu/focus-areas/renovating-the-eu-building-stock/
45) https://ec.europa.eu/energy/en/content/nzeb-24
46) Contents cited from Table 5, p.22,"Definition of indicators and assessment methods for cost effective nZEB and Energy+ Buildings," by AZEB. April 2019. https://azeb.eu.

One of the central elements of the EPBD is the Energy Performance Certificate (EPC), which is implemented differently according to each member state. Spain's EPC, also known as Certificado de Eficiencia Energética (CEE), certifies the energy efficiency of both residential and non-residential buildings. According to the Spanish royal decree of 235/2013, all property owners planning to sell or rent their property are required to have an EPC. EPC classifies the building energy consumption on the scale ranging from Grade A (most energy efficient) to G (least energy efficient), with the Grade A building spends up to 10 times less energy than the Grade G building. The grades are given based on the calculation of the building's energy consumption (kWh/m² year) and emissions (kgCO²/m² year) by examining features such as insulation, HVAC, boiler, and windows. Most of the buildings in Spain have the grade of E, F or G.[47] Unlike that of Korea's BEECS, the criteria for Spain's EPC grading scale is not clearly defined. As a result, renovation projects such as Renovem el Barris by Santa Coloma de Gramenet (discussed later in this report) may result in a high percentage improvement in energy consumption but no change in the letter grade. EPC is valid for 10 years unless major changes or renovations are carried out.

Note: European Union

The European Union is a strong supra-national entity which overlooks 27 European member states. It is said that around two-thirds of legislation in Europe come from the European Union. Legislations made by the European Union can take two forms: directives and regulations. Directives require each country to come up with national implementation measures, while regulations need to be implemented in their entirety to all member states. Below is a Directive that is relevant to building energy efficiency.

Directive 2010/31/EU – recast EPBD [48]

Article 9- all public buildings have to be nearly zero-energy buildings by 2020, and all public buildings from 2018 (buildings where a total useful floor area over 500m2 is occupied by a public authority and frequently visited by the public. On 9 July 2015, this threshold of 500m2 shall be lowered to 250m².
Article 12- energy performance certificate should be issued when buildings are constructed, sold or rented out.

Directive as such supports bigger goals and targets set by the European Union. For example, the EU's '20-20-20' targets implemented through the 2009 climate and energy package and the 2012 Energy Efficiency Directive focus on:

1) 20 % reduction of the EU's GHG emissions compared to 1990;
2) 20 % share of renewable energy sources in the EU's gross final energy consumption;
3) 20 % saving of the EU's primary energy consumption compared to projections.[49]

In addition, three EU-recognized standardization organizations support the standardization activities of 34 European countries. Requirements such as filtration of outdoor air and installing a fan in all non-residential buildings (EN 16798 -3/4:2017) are established by one of these organizations called CEN, or European Committee for Standardization.

47) https://sgarq.com/en/energy-certification/
48) https://eur-lex.europa.eu/eli/dir/2010/31/oj
49) https://www.actu-environnement.com/media/pdf/news-23105-etude-eea-europe-climat-energie.pdf

Note: Land and Ownership Structure in Spain

Land expropriation is very common in Spain, meaning that privately-owned land could be used according to the local municipality's interest to build public infrastructure and social housing for the common good. The owners are compensated accordingly. As an example, the municipality can decide to build a public park on a privately-owned plot: as a compensation, the municipality can pay money to the plot owner for the building rights, or make the owner pay for the park but waive the plot's construction limits.

Over 75% of Spanish households own housing, with the highest percentage living in multifamily buildings whereby the ownership is different according to each flat. Most households with below 60% median equalized income own housing, and the opposite (income above 60% median equalized income) live in multifamily flats. The most common form of housing is owner-occupied housing, and the most common tenure is condominiums (comunidad de propietarios).

Since those who own housing have to maintain it with their own money, the amount of income per family per year affects the degree of building renovation and the resulting accessibility and energy efficiency issues. However, the range of household income varies greatly as any household with income less than 60,000 EUR per year can apply to tosocial housing.

Figure 15. Structure of AMB Government, 2019-2023

Focus: Àrea Metropolitana de Barcelona, Catalonia, Spain

Spain has three administrative levels: national (Spain), regional (e.g. Catalonia), and local (e.g. Barcelona City). The metropolitan area of Barcelona is one of the local governments in the region and it is the only metropolitan area with an institution in Spain. AMB is comparable to the Seoul Capital Area (Sudogwon) in Korea. It was created as a single administration in 2010. But the original CMB -Barcelona Metropolitan Corporation- was created back in 1974 2010 upon the Parliament of Catalonia passing the Law 31/2010 to create a new tier of governance. 52% of Catalan GDP and 10% of Spanish GDP comes from the metropolitan area of Barcelona.

AMB's budget comes mainly from municipal contributions and from service provisions: AMB has different investment plans that benefit all the municipalities, especially those with less population and those with greater socio-economic needs. The majority of the funding is directed to AMB's three priority areas: transport, environment, planning, and territory.

Other than energy-efficient buildings, AMB is attempting to enhance Climate Action by encouraging sustainable transport. Bicibox, which provides safe spaces to park the bikes and also rent out electric bikes, has been installed throughout the metropolitan area of Barcelona. AMB also cooperated with Barcelona City, four surrounding municipalities and the Government of Catalonia to establish a permanent "Low Emission Zone" around the ring road encircling Barcelona. The entry of the most polluting vehicles, or vehicles without an environmental label, would be restricted within the zone.

AMB Public Space Department

Based on a study visit presentation by Albert Gassull, Director, Public Space Department, AMB

AMB's Public Space Department builds and manages public spaces in the metropolitan area of Barcelona. The idea is to make all the public space open, free, fluid and flexible for the general public to utilize. There are five major types of public spaces defined by the Department.

1. Urban

Urban public space refers to either the historic city centers or recovered fractures.

1) Historic city centers are applicable to the European context: they are pedestrian-friendly and often irregular in terms of width, length, and pattern of the streets. However, due to the rise of automobiles in the 20th century, pedestrian spaces were being slowly diminished.
2) Recovered fractures stands for areas that contain main roads that were mostly built during the 19th and the 20th century, whereby the roads divided an existing area and acted as a barrier.

2. Open

Open public space stands for parks. The parks not only introduce greenery into urban neighborhoods but also establish social connections between the neighborhoods. The case of Solidaritat Park in the Espluges de Llobregat municipality shows how the two communities divided by a highway were reconnected through constructing a park on the elevated platform above the highway.

3. Covered

Covered public space is public buildings and facilities such as the library and football stadium. Most of the case studies on this report belong to this category, except the social housing. Some examples of the covered public space are El Molí Library in Molins del Rei municipality and Els Encants school in Barcelona city.

4. Coastal

Some of the seafronts were not as accessible to the public such as the Castelldefels seafront. Due to the orientation of the seafront housings facing away from the sea, the seafront area was not very accessible to the public. To resolve the issue, AMB constructed wood ways that directly connect the streets to the beach and a promenade across the sand, and planted vegetation to preserve the environment.

5. Fluvial

The metropolitan area of Barcelona is defined by two main rivers: Llobregat River and Besòs River. Although the river banks were considered as the most fertile land, urbanization, pollution, and flooding risk led many river banks to be abandoned. AMB aims to recover these abandoned spaces to be utilized by the nearby communities, such as the Sant Boi de Llobregat municipality's riverbank. The river bank's environmental recovery and enhanced accessibility were carried out by AMB through building footbridges, pedestrian paths, redirecting river's meandering course and re-vegetation of both lower stretches.

AMB Sustainability Protocol Implementation

Based on a study visit presentation by Ivan Capdevila, Director, Estudi Ramon Folch I Associats, S.L.

Through public tender, AMB has requested Estudi Ramon Folch I Associats, S.L., an energy efficiency engineering consultancy, to design a sustainability protocol suited to the context of the metropolitan area of Barcelona. The sustainability protocol named AMB2 is an integrative & holistic tool that utilizes 6 areas and 19 criteria which are all mandatory. It is made up of three elements: protocol, education and training, and implementation. AMB2's areas and criteria are as below:

1. Water

a. Drinking water consumption minimization

2. Site sustainability

a. Green infrastructure increase
b. Contribution to the urban biodiversity
c. Active management of rainwater
d. Provision of shade
e. Heat island reduction materials
f. Facilities for bicycles, scooters and unicycles
g. Infrastructure for electric vehicles

3. Energy

a. Energy demand and consumption minimization
b. Renewable energy generation for self-consumption

4. Comfort

a. Hygrothermal comfort- temperature and humidity
b. Light comfort
c. Avoiding materials with high VOC concentration
d. Avoiding toxic chemicals

5. Cross-sectional analysis and monitoring

a. Alternatives assessment & program optimization
b. Interdisciplinary monitoring committee
c. Maintenance plan

6. Materials

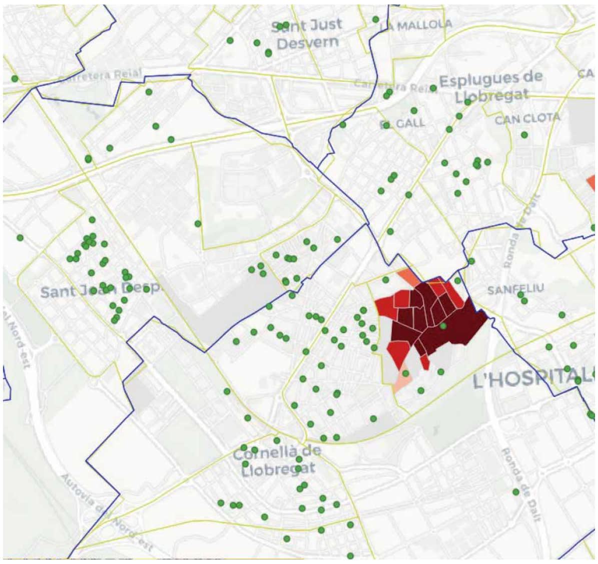
a. CO_2 footprint minimization
b. Eco-labels (types I and III) for building materials

AMB Sustainability Protocol Implementation

Based on a study visit presentation by Jordi Mas, Technical Area Coordinator, Metropolitan Housing Consortium

CMH is an associated public body, established by the Government of Catalonia and AMB. It provides housing services to the municipalities that are members of the AMB except for Barcelona City, where they have Barcelona Housing Consortium. CMH focuses on retrofitting of privately-owned residential buildings, mostly condominiums. Between 2014 and 2015, CMH initiated a campaign to renovate condominiums with a 25 million Euro grant. However, out of all the census sections (area with 1,000 voters and roughly 500 dwellings) which were targeted for renovation, only half of the lowest third of the section (with a disposable family income of less than 26,000 euro) applied for grant. The remaining two-thirds of the section with higher disposable family income actively applied for a grant. Moreover, out of the total amount of grants given, only 14.8% went to the census sections with the lowest disposable family income as highlighted in Figure 11. Therefore, CMH is trying to implement a successful past renovation project “Renovem els Barris” on a larger scale to redirect the grant funding back to the poorest area.

Figure 16. Map of the 2014-2015 CMH campaign renovation location: green marks the projects that have received the grant, and the poorest census sections are marked in red . [50]



50) Based on a study visit presentation by Jordi Mas, Technical Area Coordinator, Metropolitan Housing Consortium.

Santa Coloma de Gramenet is one of the municipalities within the metropolitan area of Barcelona. The City Council had an existing initiative for building renovation grants: however, they noticed that while grants for central areas were 100% awarded, only 60% of the fund available was spent on the poorest area.
In response, Santa Coloma de Gramenet City Council has launched an area-specific local campaign called “Renovem els Barris” in 2009. With a budget of 2.1 million Euros, the campaign’s aimed to renovate existing buildings for energy efficiency.
The selected neighborhood consisted of 32 buildings, 386 flats, and 360 owners, with most buildings built in the 1950/60s. 44.5% of the flat owners did not live in the area, and another 21.9% was owned by the bank. 83% of the flat owners were Spanish, but 71% of the renters were foreigners. Due to the multifamily nature of the buildings as well as the difference between the flat owners and renters, it was very difficult to undertake thorough building renovation.
According to Spanish law, the government can mandate the renovation of aging buildings which puts the financial burden upon the building owners. Santa Coloma de Gramenet hence defined the neighborhood as “Conservation and retrofitting zone” and mandated building renovation, but with various options for renovation payment:
1) Full payment by the owner
2) Full payment by CMH in return for the flat going on the public register for renovation charge (CMH recovers the renovation money when the flat is later sold to another owner)
3) Partial payment, whereby the owner pays a small sum of money every month over 5 years.

The main renovation involved improvements to the roof and electrical distribution systems, façade painting, and façade insulation (ETICS).[51] The additional 30% building retrofitting grant by the AMB also made the renovation more affordable. Most of the flat owners chose partial payment methods which were roughly 60 euros per month. As the result, the Energy Performance Certificate (EPC) grading of the buildings has improved from E-G to D-E for both the energy consumption (average 20.32% improvement) and emissions (average 34.68% improvement).

51) Residential Retrofits at district scale Business Models under Public Private Partnerships, InnoEnergy.

AMB's Case Studies

Between January 20th and 23rd, 2020, CityNet visited Àrea Metropolitana de Barcelona to document the best practices of the metropolitan area of Barcelona in the field of building energy efficiency. Throughout the four days, a total of 7 best practices were visited along with presentations about 2 additional projects which are at early stages of construction.

*Group photo from the Study Visit, AMB Headquarters

Figure 17. Map of the metropolitan area of Barcelona with marked study visit sites.

*AMB Headquarters

*Figure x. Map of the AMB with marked study visit sites

1. AMB Headquarters

Figure 18. AMB Headquarters, building A.

Municipality: Barcelona (Sants-Montjuïc)
Status: under construction (2018-)
Designed by: dataAE
Relevant study visit/presentation by: Claudi Aguiló Aran, Co-Founder, dataAE

Context

The AMB headquarters was newly built in 1973 by Mitjans-Borrell architecture studio. It is made up of five buildings, and building A and B are the targets of renovation. In 2018, an open competition for renovating the AMB Headquarters was won by dataAE architects. The proposed renovation aims to not only preserve the essential elements of the architecture of Francesc Mitjans but also to make minor modifications to improve its energy performance. As other existing projects of Francesc Mitjans have undergone huge transformations that make them almost unrecognizable, the exterior image of the AMB would remain intact. Only the 8F of building A was visited during the study visit.

Objectives

The objectives of the renovation are to:

1. Resolve the existing deficiencies,
2. Act as the reference model for the nearly zero-energy building,
3. Act as the reference model for research space.

Although special attention was paid to preserve the unique façade that defines the style of the original architect, the energy use of the whole building and its user behavior were considered for the renovation plan. Therefore, the core structure, façade's vertical slat element, and base of the building were kept almost intact.

Actions and Implementations

Figure 19-21. Renovated section of the AMB Headquarters.

The renovation will be carried out in a few different phases. The 8th floor has been renovated and is partially being used, which would be followed by the ground floor, basement and façade renovation.

1. Energy

It is hard to lower the cooling cost as well as lighting in an office building. Therefore, the focus was mainly on the minimization of heating energy.

As the temperature difference between the outside and the building interior is big, window screens to effectively control insolation would be installed. In certain places where ventilation and shadowing are problematic due to interior curtains, large fixed windows with screens and small opaque window openings are installed to remove the need for curtains.

Different climates within the building were analyzed to provide maximum comfort. The meeting rooms were classified as on-off areas, where the energy usage could be turned off when it is not being used. Therefore, these areas would be enclosed so as to concentrate the impact of mechanical climatization into the required space. However, intermediate spaces such as break rooms and cafeteria where users spend less time would not require heating and cooling, reducing the total area that requires mechanical heating and cooling.

To address the building overheating of the office buildings during the working hours, automated windows would open during the night for the natural ventilation to cool the building. Radiant cooling and heating ceilings are also installed, which removes the need for maintenance of vents and filters for conventional forced-air heating. They are an efficient way to climatize less insulated buildings such as the AMB Headquarters with a glass façade.

Figure 22-23. Translucent window and ceiling fan.

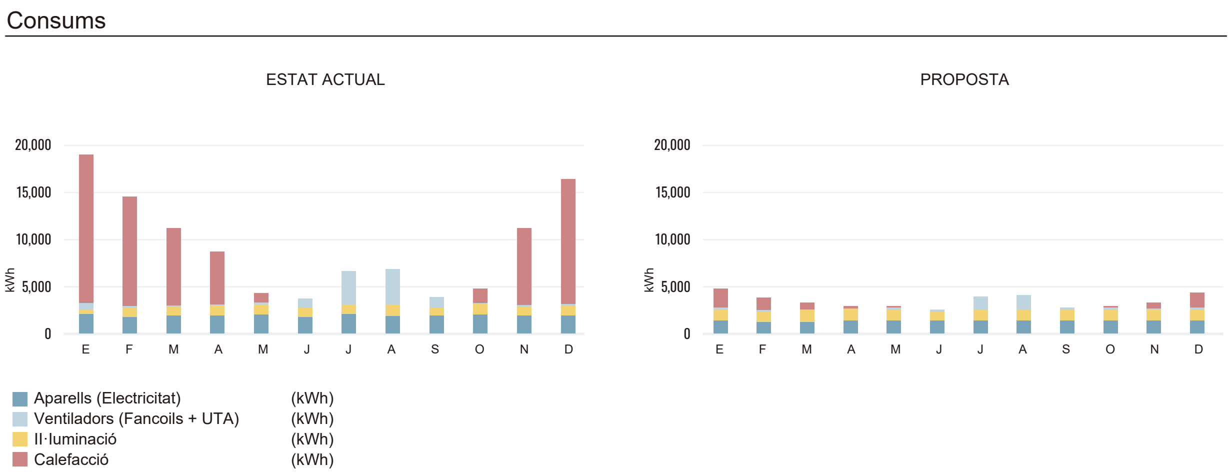


Figure 24. Energy demand of AMB Headquarters before and after the renovation. Image provided by AMB.

2. Water

As Spain is the 28th most water-stressed country in the world, water conservation and reuse plays an important role in building.[52] Therefore, all the black and yellow water flow from the building would be filtered through the vegetation in the outdoor garden. The solar panel would be installed to the building which could be used to produce hot water.

3. Materials and CO_2

The interior façade of the building is wood (including maple and pine wood) reinforced with a fireproof coating and insulation layer. This can not only hide the electrical system but also promote the biophilic atmosphere within the building. For places where wood could not be implemented such as the staircase, traditional materials such as lime mortar were used. The slats on the façade are made out of recycled aluminum with protective coatings which makes it resistant to rust.

Figure 25 Close-up of façade slats.

4. Façade

As the AMB Headquarters' slat façade is representative of modern Catalan architecture, preservation of the exterior image was important. However, some slats were taken out for more effective insolation control depending on the direction of the façade. Similarly, more insulation was used on the north façade where not much sunlight is received compared to the south façade which is well-lit. On the ground level, the transparent glass would be used to promote continuity between the building interior and exterior. Through such asymmetrical design solutions, passive energy efficiency design was achieved.

52) https://www.wri.org/blog/2019/08/17-countries-home-one-quarter-world-population-face-extremely-high-water-stress

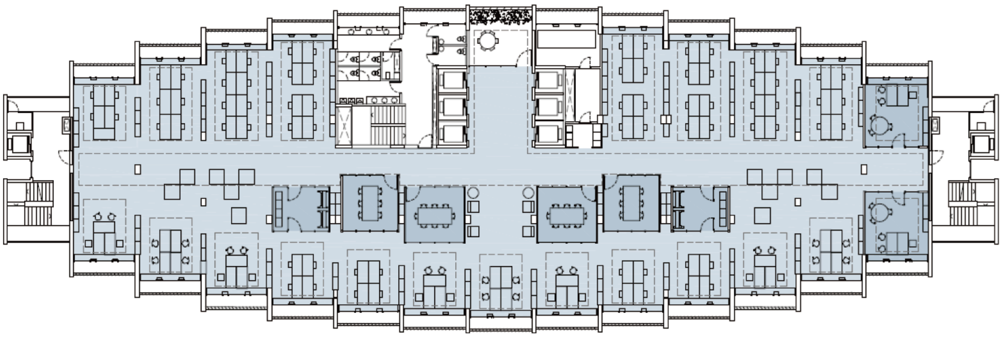


Figure 26. Proposed layout of AMB Headquarters Building A, 4th floor. Image provided by AMB.

5. Layout

For effective transversal natural lighting and ventilation, the current layout of closed office spaces at the perimeter of the building would be changed to open spaces with transparent or translucent walls. For example, some of the closed meeting rooms at the perimeter would become a break room with vegetation without heating, which benefits the building with a greenhouse effect. Important offices (administrative use), meeting rooms and printing rooms (productive use) would remain enclosed, but they would be strategically placed in the middle or at the end corner of the building so as to not interfere with the cross-ventilation and lighting.

The renovated headquarters buildings are expected to use up to four times less energy compared to before, and also would be able to generate renewable energy on-site through photovoltaic system. The water use of the buildings is expected to be reduced by 85%.

▪ Note: IMPSOL

Within the AMB, an organization called IMPSOL (*Instituto Metropolitano de Promoción de Suelo y Gestión Patrimonial*, Metropolitan Institute of Land Development and Property Management) acts as a public enterprise which builds social housing for rent and sale. IMPSOL does so by building new housings or renovating existing buildings. IMPSOL is almost financially self-sufficient and does not receive funding from the government. Since the economic crisis of 2007-8, IMPSOL began to borrow money from the bank and return it by selling (roughly 50%) or renting (roughly 50%) the social housing units that they have built.

<Stages of IMPSOL projects>

1. Land negotiation- Buying private land, or negotiate from the municipalities through expropriation
2. Financing from the bank
3. IMPSOL & City Council Agreement
4. Architectural competition
5. Housing lottery- commercialization
6. Construction
7. Completion & sale
8. After-sale

Social housing, or VPO (Viviendas de protección official), was stigmatized in Spain in the 1970-80s which was normalized since the economic crisis. The range of people who qualify for social housing not only includes low but also middle-high income class: it is said that a maximum of 80% of the total Spanish households qualify for social housing.[53] The social housing is distributed through a lottery system, and there are set percentages of housing that are reserved for vulnerable groups such as the disabled, single mom, and youth.

The aims of the IMPSOL are as following:

1. Energy Efficiency
   The housing would utilize healthy materials with low ecological footprints and aim to be an efficient nearly zero-energy building (nZEB).
2. Flexibility & Adaptability
   The layout of the housings would be flexible to accommodate changes in household structure and use, but already be adaptable for multiple functions without requiring space modifications.
3. Inclusive homes
   The housings would take into consideration gender equality through equitable division of space by use, and special needs such as the handicapped and senior citizens.
4. Financial self-sufficiency
   The housings aim to prevent energy poverty and guarantee comfort for the resident who cannot afford high heating or cooling costs.

Figure 27 shows that between the years 2018-2021, IMPSOL is set to supply 1,218 housing units in 11 municipalities, with a total cost of roughly 170 million euros (180 million dollars). Considering that Korea's Nowon EZ House cost roughly 49.3 billion won (42 million dollars) to supply 121 housing units, IMPSOL's housing cost – which is a mix of renovated and new buildings- is less than half the price per unit than that of Korea.

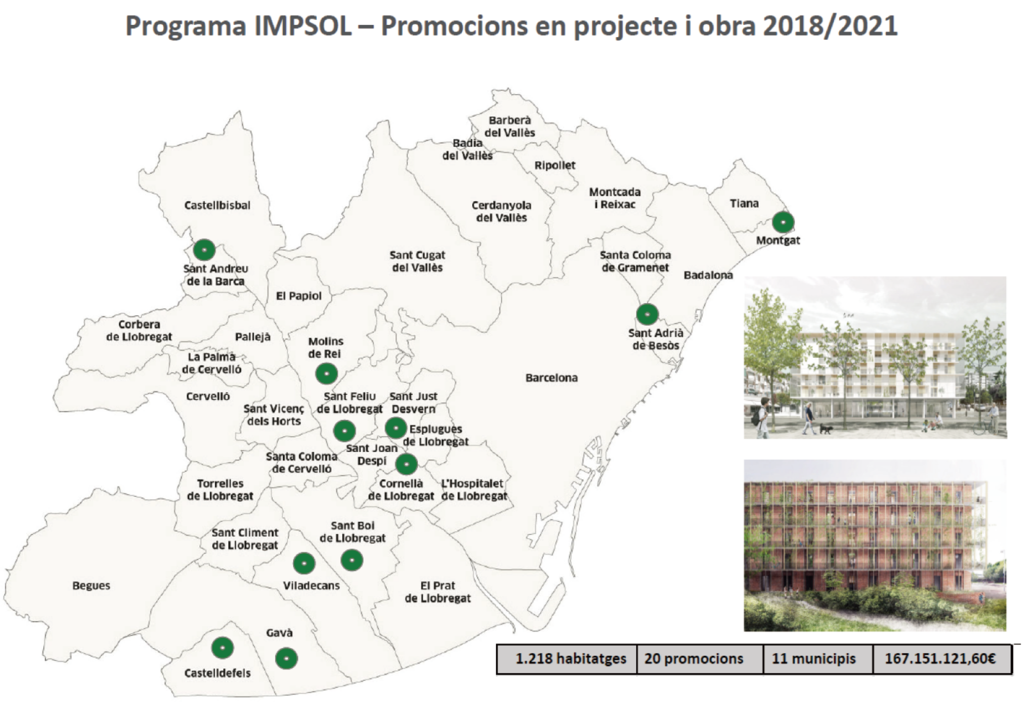
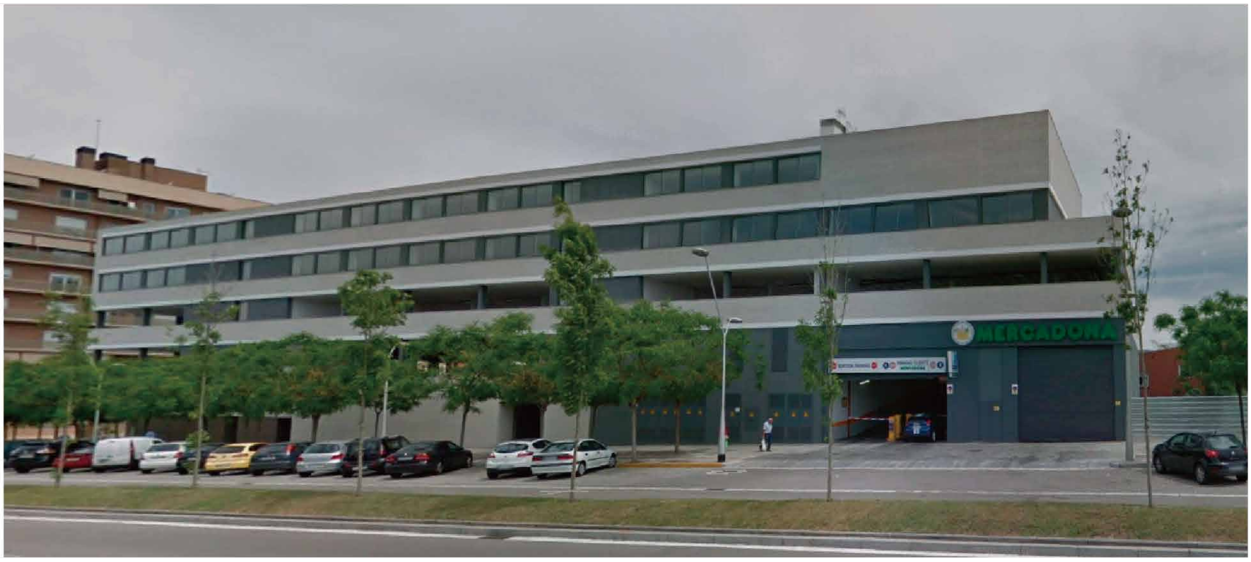


Figure 27. Map of IMPSOL projects that would be implemented during 2018-2021. Image Image provided by IMPSOL.

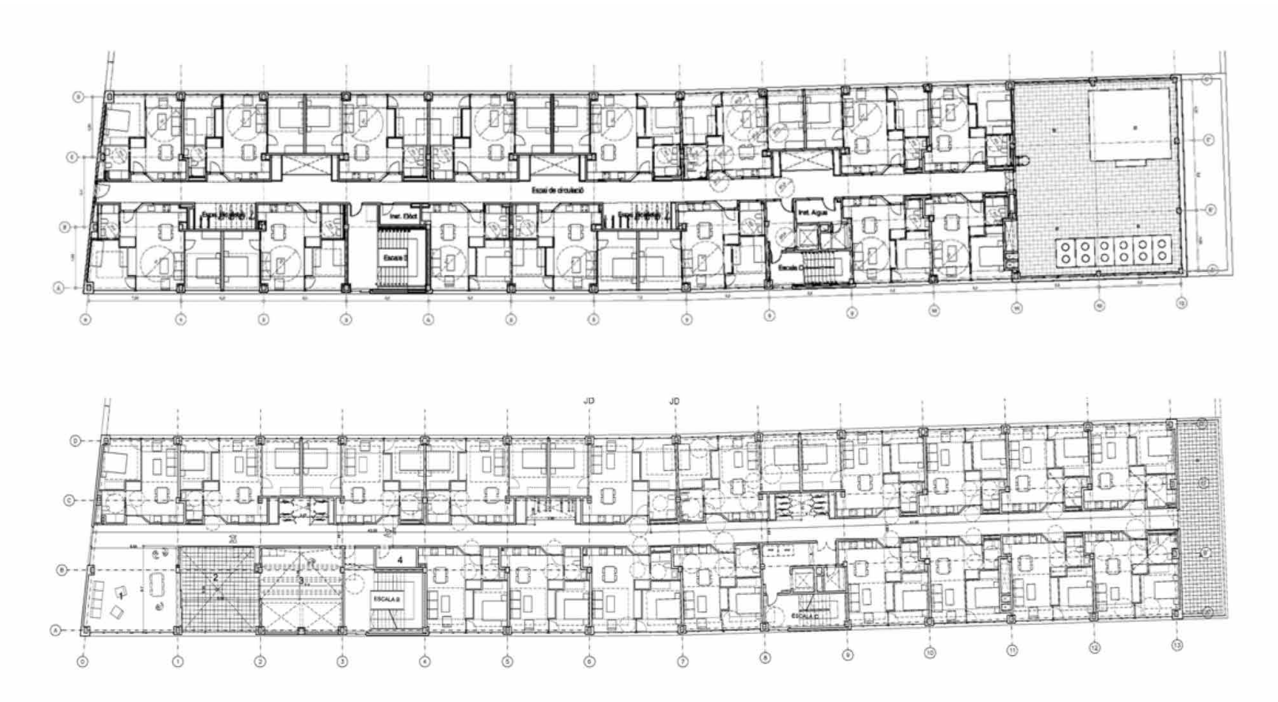
53) Scanlon, K., Whitehead, C. M. E., & Arrigoitia Melissa Fernández. (2014). Social housing in Europe, 232.

2. Social Housing Units-Carrer El Pla



▲ Figure 28. Exterior of Carrer El Pla [54].

▼ Figure 29. Layout of the third and fourth floors, Carrer el Pla. Image provided by IMPSOL.



Municipality: Sant Feliu de Llobregat

Status: under construction

Designed by: Mariona Benedito, Martí Sanz (MIM-A)

Total surface area: 1,340m²

Relevant study visit/presentation by: Josep Maria Borrell, Head of Construction Department, AMB/IMPSOL

54) “3a Planta Carrer El Pla”, AMB. http://www.amb.cat/.

Context

Social housing is an indispensable part of cities, providing affordable residences for those who are most in need. Carrer El Pla is an existing mixed-use building, with a supermarket on the ground level, parking space on the first and second floor, and vacant office space on the third and fourth floors. Currently, 35 social housing units are being built in the top two floors in two phases: the third floor which is already acquired, then the fourth floor which is still being negotiated by the municipality.[55] The report focuses on the third floor which contains 19 units.

Objectives

The objective was to renovate the top two floors of a mixed-use building to establish residential areas with communal spaces, and to ensure horizontal communication of the building for passive lighting and ventilation.

Actions and Implementations

The important fixed element of the Carrer El Pla is its horizontal volume. To enable effective natural light penetration and cross-ventilation by a chimney effect, 3-4 vertical openings between the third floor and the rooftop are being made. Mechanized skylight windows would be installed on the roof to enable vertical ventilation. Moreover, weather -sensitive, mechanized windows were installed on either end of the floor for horizontal ventilation. These would create microclimate at the corridors and the vertical openings, providing indirect ventilation to each unit.

Each floor contains communal space for bikes and laundry, as well as a multipurpose room. The rest of the floor is composed of either 1 or 2-bedroom residential units. LED lightings were installed throughout the building. For intermediate space like a multipurpose room, more weather resistant flooring was used to differentiate it from the residential unit. A single water count that measures the water consumption of each unit was installed on each floor to increase efficiency. Heating and cooling are provided to each unit by a high-efficiency hydrothermal pump. Awnings for solar protection were installed for every outside-facing windows.

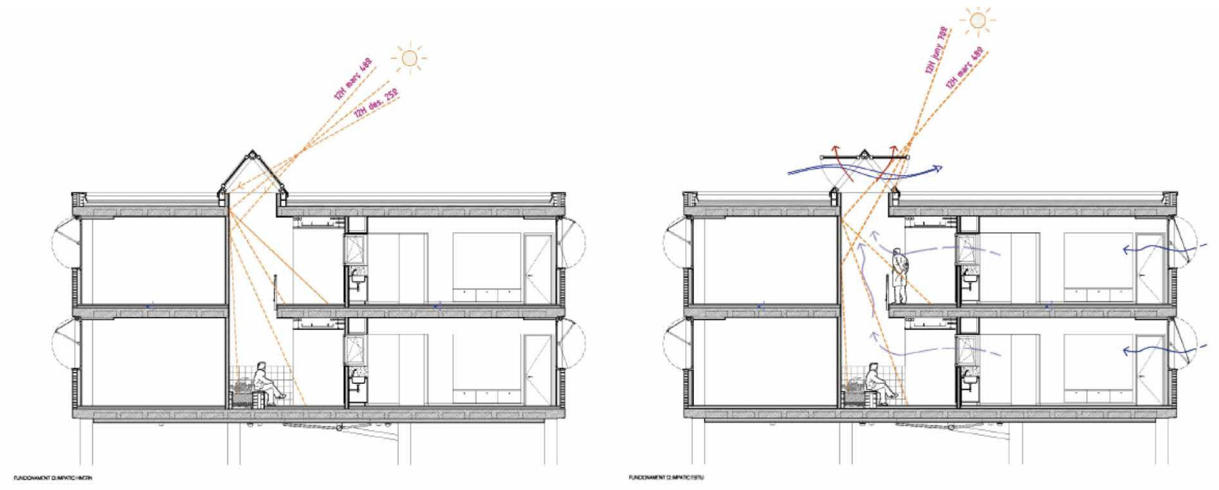
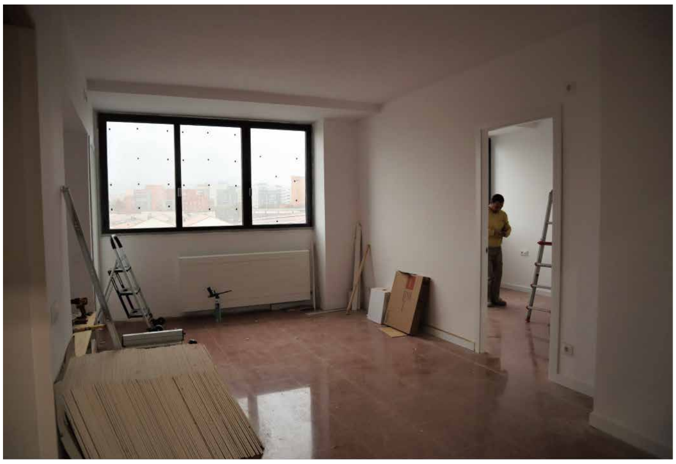


Figure 30. Profile of the Carrer El Pla showing vertical openings for ventilation. Image provided by AMB.

55) http://www.mim-a.com/projectes/habitatges/18-hpo-st-feliu-ll-a/

Figure 31-32. Interior of the third floor.



Domestically sourced CLT wood (such as pinewood) was used for walls and doors, creating a sense of comfort. 12-inch insulations were added to the walls and floors for effective building envelope, but the existing building structure including the façade was kept intact. Moreover, the building utilized air-to-air heat recuperator, which recovers the outgoing air's heat and transfers it to the incoming air to minimize the interior heat loss. According to the projection, the energy balance of the residential area (third and fourth floor) is expected to be nearly zero

Figure 33-34. Awning and water count in Carrer el Pla.

3. Social Housing Units-H2O Salo Central

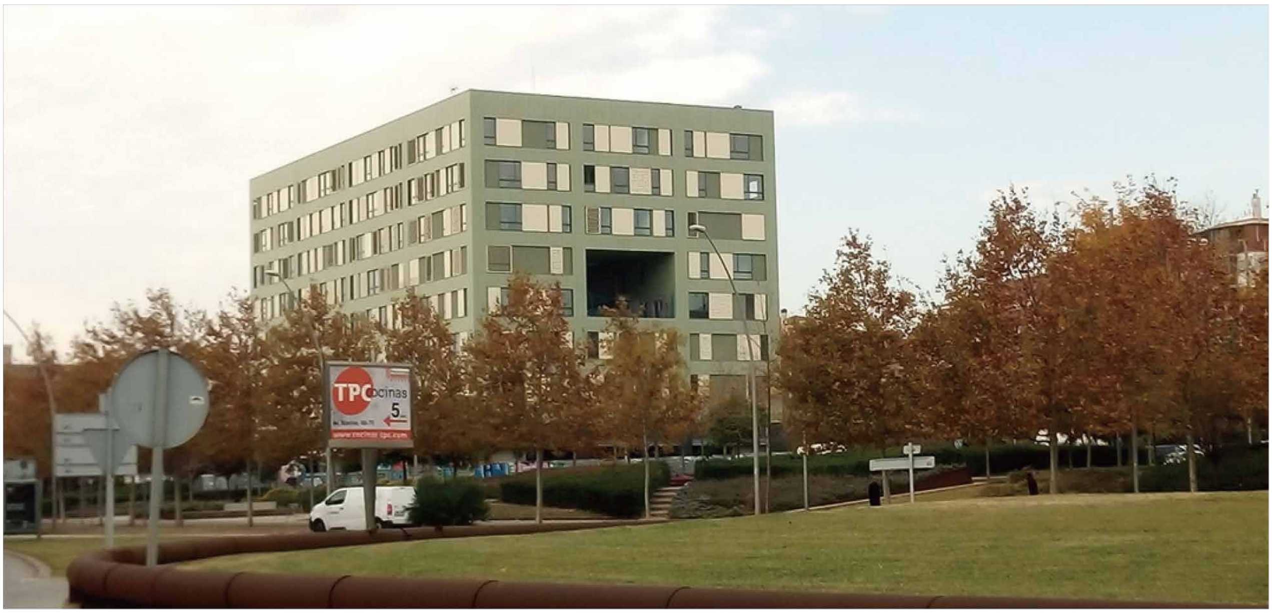


Figure 35. Exterior of H2O Salo Central.[56)]

Municipality: Sant Boi de Llobregat

Status: completed, awaiting occupancy (2018-2020)

Designed by: Mariona Benedito, Martí Sanz (MIM-A), Juan Herreros (Estudio Hermanos)

Total surface area: 9,000m²

Energy certification: B (energy consumption, 30 kWh/m² year), A (emissions, 5 kgCO_2/m² year)[57)]

Other certification: n/a

Relevant study visit/presentation by: Josep Maria Borrell, Head of Construction Department, AMB/IMPSOL

Context

H_2O Saló Central is a social housing built next to another IMPSOL project, a pedestrian thoroughfare and the meeting area with large pergola (2009-2012). It is designed as a multifamily building with 79 units (partially for rent, partially for sale), 2 commercial premises on the ground level, and 118 parking spaces. Another IMPSOL social housing is being built in the vicinity under different architect with similar shape but completely different design.

Objectives

The objective was to provide social housing with access to natural ventilation and lighting to every unit.

Figure 36-37. Interior courtyard.

56) "H_2O Salo Central", AMB. http://www.amb.cat.

57) https://cercadorhabitatges.amb.cat/Arxius/Documents/Promocio/152/9bbc7185-7c45-4aca-bc8e-d99f2eba4df0.pdf

Actions and Implementations

H_2O Saló Central has a unique design whereby the building has two systems of stairs that never cross each other, distinguished by green and pink colors. Despite the physical division of building into two vertical communities, these zigzag circulation systems allow interaction between people on different floors. The elevator opens on both sides, giving horizontal access between the vertical communities. The whole building, not just the staircases, utilizes both green and pink colors: green exterior façade, colored tiles on the ground floor that mimic traditional Catalan roofing, and even the pink-colored grout between the tiles in each residence.

The design strategy was to reduce the vertical core for circulation down to a minimum, leaving more space for the residential and common areas. There are two open courtyards on the third floor which any residents can utilize as a playground or gathering space. Each residential unit has a view of the inner courtyard and the outdoor, and all the courtyards and circulation systems (staircases) have a view of the outdoor. Certain units on the 7th floor have private indoor courtyards.
The building is not fully enclosed as the façade has openings on the side and top to allow effective cross-ventilation.

H_2O Saló Central is mostly made up of three-bedroom residential units that cost 174,668 euros to purchase.[58] The building's heating and cooling system uses a high-efficiency hydrothermal pump, which is identical to that of the Carrer El Pla. Solar panels are installed on the rooftop, mainly used to provide hot water to the building.

Figure 38 Layout of the third floor. Image provided by IMPSOL.

Figure 39-40. Residential unit in H2O Salo Central

58) http://www.amb.cat/es/web/habitatge/impsol/cercador/-/habitatge/ufYg9gOTMSO6/detall/152

4. Social Housing Units-PISA Cornellà

Figure 41-42. PISA Cornella under construction. Images provided by IMPSOL.

Total floor area: 12,753m²

Energy certification: A

Relevant study visit/presentation by: Josep Maria Borrell, Head of Construction Department, AMB/IMPSOL

Context

The neighborhood of PISA Cornellà has many aging buildings that were built in the 1960-70s. The site of PISA Cornellà was formerly occupied by a cinema called Cine Pisa which opened its doors in 1965. However, Cine Pisa was torn down to give space for a social housing consisting of 85 units, 58 parking spaces, 13 storage rooms and 1 commercial premise on the ground floor. [59]

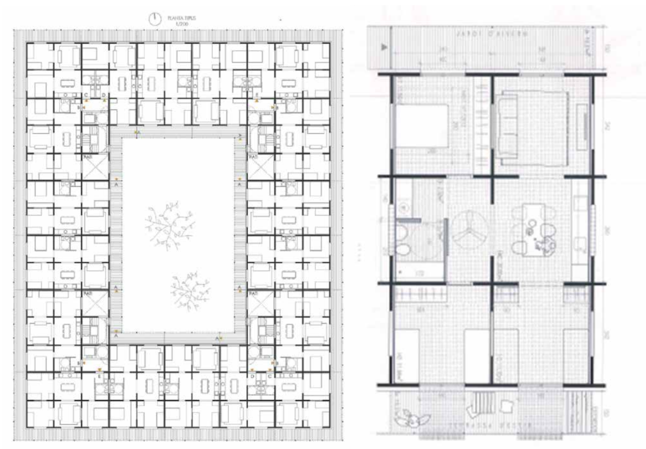


Figure 43-44. Layout of PISA Cornella and individual unit. Images provided by IMPSOL.

Objectives

PISA Cornellà attempted to integrate the perspective of equality – particularly pertaining to gender –, by dividing all flats into six equal-sized units with balcony views of the indoor patio and the outdoor. Moreover, the building is required to obtain an EPC Grade of B or higher according to the agreement between the Cornellà de Llobregat City Council and the Government of Catalonia.[60]

The building also aims to minimize carbon emissions, utilize ecological material with appropriate hygrothermal behavior and odor-absorbing properties, construct a lighter structure, and reduce the time taken for construction.

59) http://www.amb.cat/es/web/habitatge/impsol/cercador/-/habitatge/ufYg9gOTMSO6/detall/153#
60) http://www.cornella.cat/es/NotaDePremsa308.asp

Actions and Implementations

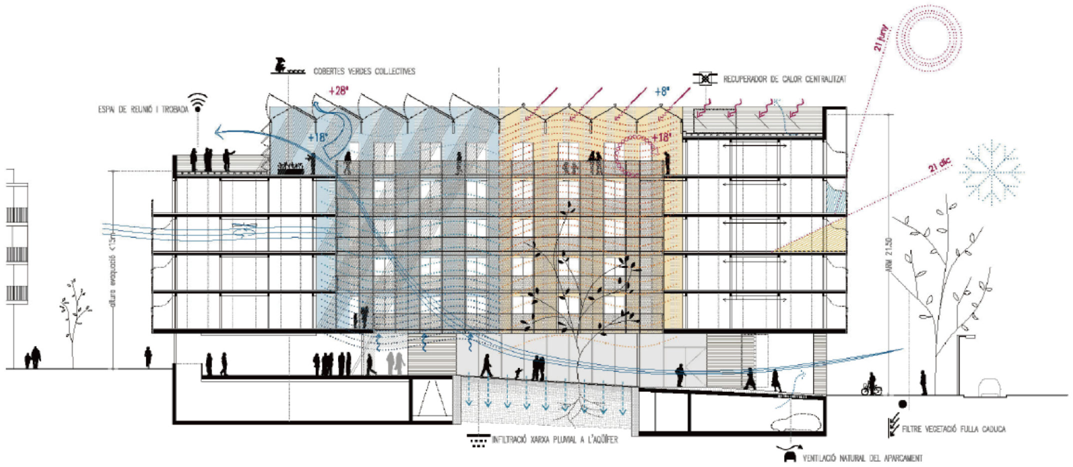


Figure 43-44. Proposed façade, and the diagram for building's cross-ventilation and insolation. Images provided by IMPSOL.

PISA Cornellà has a flat roof with a communal indoor patio. These features make use of passive solar energy to minimize building energy demands, primarily heating. The flats are organized around the indoor patio, accessible to the public from the ground level by two entrances. Every flat is divided into 6 equal-sized square units that are flexible in use, with the views of the indoor patio and outdoor through balconies. Such layout is loosely based on the idea of Le Corbusier's Le Petit Cabanon (1926) and Margarete Schütte-Lihotzky's Frankfurt Kitchen (1952). The balconies act as intermediary spaces that buffer against outdoor temperature and drafts.

The vegetation at the indoor patio, which doubles as a rainwater collector, improves the microclimate by providing oxygen and balancing the air humidity. Pre-heated air through the translucent skylight is naturally circulated and ventilated through the atrium's chimney effect. The building is made up of concrete up to the first floor for structural integrity, but the rest of the building is mostly made out of wood. The top floor is going to be used as a communal gardening space.

5. ICTA Research Center

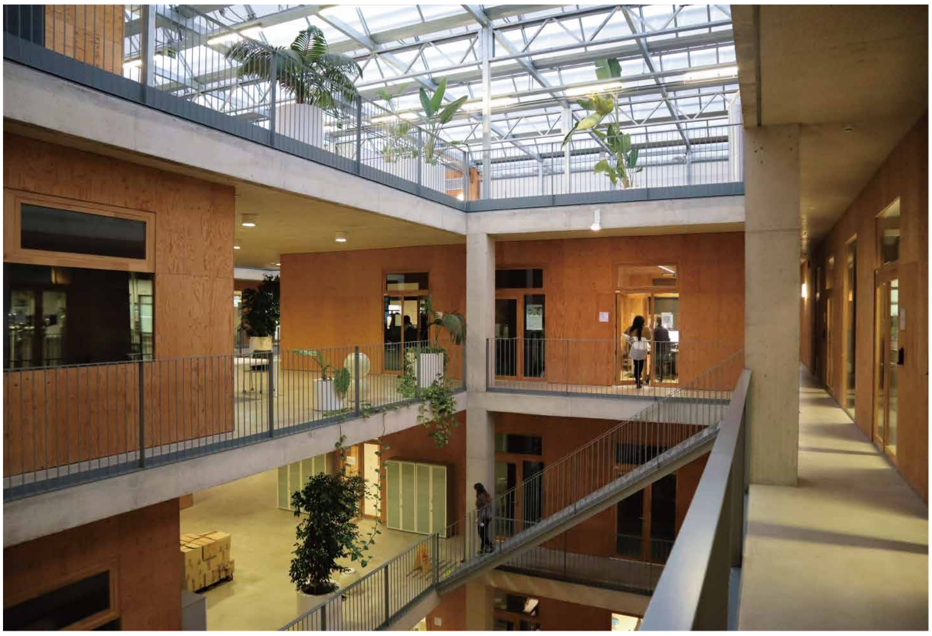


Figure 45. Interior of the ICTA Research Center.

Municipality: Cerdanyola del Vallès

Status: completed, occupied

Designed by: dataAE, H Arquitectes

Total floor area: 9,400m²

Energy certification: A

Other certification: LEED Gold (73 points), FAD Opinion Award for Architecture (2015)

Relevant study visit/presentation by: Claudi Aguiló Aran, Co-Founder, dataAE; Luca Volpi, Environmental consultant, Societat Orgànica

Context

ICTA Research Center is a facility within the Autonomous University of Barcelona (UAB). It is devoted to the study of environmental sciences and paleontology and hosts 200 students and faculty researchers. The construction of the research center was partially funded by European funds for regional development projects (2007-2013 FEDER program of Catalonia) and the Spanish Ministry of Economy and Competitiveness. The building is said to cost roughly 1,000 euros per square meter.

Objectives

The objective was to design the building so that it would efficiently seal the building during the winter and dissipate heat during summer.

Figure 46. Layout of the ICTA Research center. Image provided by IMPSOL.

Actions and Implementations

Figure 47-48. Interior of the ICTA Research Center.

The structure of the building is cast concrete, reinforced by post-tensioning the concrete with steel cables. The concrete structure is wrapped by a low-cost bioclimatic skin consisting of automated shutters. The shutters are made up of transparent, corrugated polycarbonate which regulates the temperature of the research center like a greenhouse.[61] Therefore, the building façade is enclosed and compact during the winter, but it could be adjusted to have multiple openings during summer for heat dissipation. Due to its unique building structure, it took a year to develop appropriate BEMS for the research center.

The energy demand was reduced significantly by designing 53% of the building interior to be a bioclimatic space, which doesn't require mechanical climatization to feel thermal comfort. Fans are also installed in the building which increases user's thermal comfort without changing the overall temperature. The majority of the interior structure consisted of CLT wood, but the floor is a concrete slab that acts as a thermal mass. The slab is kept at a constant temperature by geothermal pipes that utilize the thermal inertia of the soil. It is lightened by holes that contain the building's technical systems such as radiant heating and cooling system. There are multiple atriums created by a division of the building with wooden volumes containing fire escapes, mechanical systems, and toilets. Due to the skylight, atriums, and transparency of the offices, the hallway does not require much artificial lighting.

As the top floor provides effective ventilation, all the research offices with heavy equipment are placed there. The rooftop above the top floor consists of motorized skylights and acoustic membranes that absorb noise instead of the ceiling. The rooftop also has a greenhouse: the CO_2-rich air which aids plant growth is pumped out here through mechanical ventilation to be removed. The mechanical ventilation is only activated when motorized windows are closed according to indoor temperature or air quality (CO_2).

Artificial wetland was formed outside the research center with excavated soil: it has vegetation that filters the building's grey and yellow water to be reused. Rainwater collector is also in place, but the supply is not as significant due to the dry climate.

ICTA research center does not produce its own energy, but renewable energy production is planned to be addressed on a university campus level. Due to the increased cost required for commissioning and maintenance, the building settled for LEED Gold instead of LEED Platinum.

61) https://www.dezeen.com/2015/05/26/1102-h-arquitectes-icta-icp-building-research-centre-spain-universitat-autonoma-de-barcelona-polycarbonate-shutters/

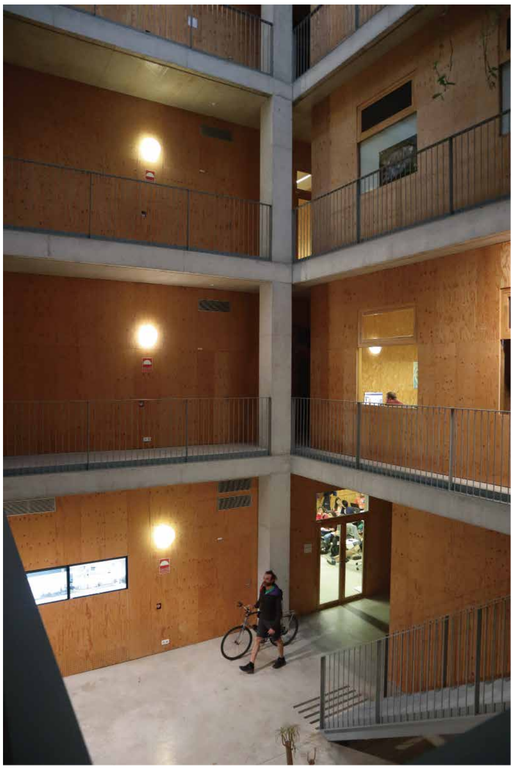


Figure 49-50. Interior lighting and polycarbonate shutters.

6. Fontsana-Fatjo Library

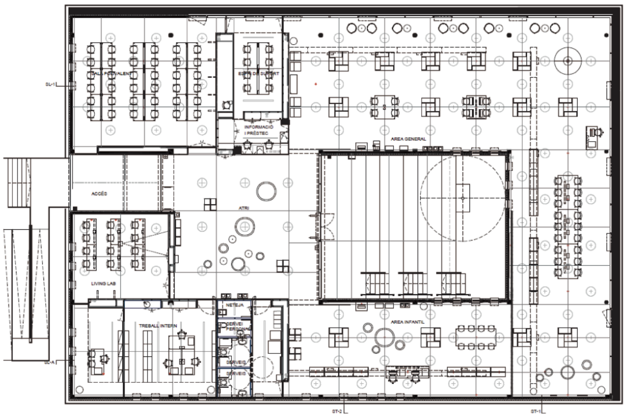


Figure 51-52. Front façade, and layout of the library. Images provided by AMB.

Municipality: Cornellà de Llobregat

Status: nearing completion (2013-Present]

Designed by: Luisa Solsona, Noemi Martinez.

Total floor area: 1,000m²

Relevant study visit/presentation by:

Luisa Solsona, Architect, Public Space Department, AMB.

Noemi Martinez, Head of projects and urban design section, Public Space Department, AMB.

Context

Public Libraries in the province of Barcelona are managed by the Diputació de Barcelona, a local administration with competencies in the province of Barcelona, and they serve an important role in the community as the free source of accessible information and the public area to work and study. Despite the emergence of electronic books and carry-on devices, public libraries still serve as the gateway for the lower socioeconomic group to gain opportunities for education and employment.

Fontsana-Fatjo Library was built for a neighborhood population of roughly 5,000. Although the neighborhood did not need another library, Fontsana-Fatjo Library's main feature – a reading room that is accessible by the public 24/7 – made it an exception. The library is located next to a park (Parc del canal de la Infanta) managed by AMB which cancels out some noise from the adjacent street.

Objectives

The objective was to build an energy-efficient library within the land plot's height and floor area restriction, taking into account the municipality Mayor's request to have a 24-hour multipurpose room that is accessible at all times by the general public and outdoor space.

The energy consumption/production and water consumption of the library need to be monitored, and the relevant data sent to the Barcelona Energy Agency.

Actions and Implementations

Fontsana-Fatjo Library was faced with various building restrictions of the specific land plot: maximum of 70% occupancy of 1,300m2 plot by the building, maximum building height of 7.5 meters from the street level, building orientation according to the plot shape, and a buried wastewater pipe. The building site's soil was poor, so many thin concrete rods were required to establish a strong building foundation. Concrete slabs that double as an effective thermal mass were used for the floor, but they were made lighter by putting hollow pipes in the slabs to house the electrical wires. The concrete slabs also contain radiant heating and cooling pipes connected to the geothermal system, which keeps the water inside the pipes at a constant temperature.

Figure 53-54. Library lobby and interior without artificial lighting.

Due to the change in the municipality's request, the building has changed in nature from the reading room to the current library with less bioclimatic area. It is hard to effectively predict the use in a library compared to that of a residential building or research center with set users and defined purpose. Therefore, an HVAC system is installed and zoned so that in the event that an area is inactive, the air conditioning system in that area can be disconnected. On the other hand, bioclimatic strategies (like cross ventilation) are active when weather conditions allow it. When conditions are not favorable, a mechanical HVAC system is available. The HVAC system is highly efficient due to its geothermal heat pump, which gives heat and cold through a heating and cooling underfloor system. It also important to highlight that the mechanical ventilation system has a variable air flow, capable of reducing the ventilation flow depending on the occupation. The aim is to educate the user so that the range of comfort temperatures can be expanded, thus also reducing energy consumption.

The building is well-insulated through its asymmetric façades. The northeast and southwest-facing façades face out towards the street, so they were designed with brick covered with a thick layer of exterior isolation along with small windows. The remaining two façades that face the park are made out of big glass with high thermal performance and an additional geometric metal layer. The metal layer provides the library users with visuals of the park but simultaneously blocks the strong sunlight. Also, it creates a sense of privacy for library users, as its design prevents people from outside to observe the inside. The unique pattern of the metal façade defines the library as a public building, differentiating it from other residential buildings that are similar in size. The library remains well-ventilated through the combination of manually and mechanically-operated windows.

Figure 55-56. Outdoor atrium and back façade connected to the park.

One main decision of the architect was to create an atrium in the middle of the building. This was to create an outdoor space for the public and to allow for better natural lighting and ventilation into the building. The deciduous tree was placed in the middle of the atrium to provide natural shade during summer. The walls of the atrium are painted white so that images could be projected onto them for outdoor events. Most of the building materials including wood have minimum protective coatings to maintain their original texture and color.

The construction of the Fontsana-Fatjo Library began before the EU Directive (Dec 31st, 2018) that requires all new public buildings in the EU to be nZEB. However, the architects and the city council were self-motivated to make it into an nZEB, even by involving an environmental consultant which is not a legal requirement.
The behavior of the building would be monitored post-construction: the BEMS has to be tuned according to how the building behaves in real life. Moreover, the users and workers of the library would be trained about the design of the building to maximize its efficiency throughout different seasons.

7. Turo de la Peira Sports Hall

Figure 57.
Interior of the Turo de la Peira Sports Hall.

Municipality: Barcelona (Nou Barris)

Status: completed, occupied

Designed by: Anna Noguera, Jose Javier Fernandez Ponce

Area: 4,430m² (building) + 3,200m² (plaza)

Energy certification: A

Other certification: LEED Platinum (85 points), "Premis Ciutat de Barcelona Award" (Category: architecture-urbanism), Mapei Awards for sustainable architecture (2019)

Relevant study visit/presentation by: Jose Javier Fernandez Ponce, Architect, COAC (Architects' Association of Catalonia)

Context

In Catalonia, the Physical Activity, Sports and Health Plan aims to build capacity for health and sports professionals through the identification, design and resource creation for physical activity at the local level.[62] Turo de la Peira Sports Hall is located in El Turo de la Peira, one of the neighborhoods with the lowest income. Previously, there was a concrete sports courtyard and a swimming pool from the 1970s which were surrounded by a concrete wall. However, they did not meet the regulation standards and were set to be replaced by a new facility. Upon the architectural competition held by the Barcelona City Council, the plot was made greener through the formation of a public garden and the new sports center.

Objectives

The idea behind the construction was to benefit the general public by liberating and greening the existing swimming pool and concrete courtyard. The building also considered the needs of the sports facility by the nearby schools (E.g. Escola Calderón de la Barca) as well as the local sports club.

62) https://ec.europa.eu/assets/eac/sport/library/factsheets/spain-factsheet_en.pdf

Actions and Implementations

Figure 58-59. Lower ground with a swimming pool, and a wooden staircase leading up to the sports courtyard.

First, the outdoor public garden was made available by combining the swimming pool and the sports courtyard into one compact building. The garden is sloped to absorb the height difference of 7.4m between the elderly housing and the upper street level. The underground water collection system is embedded into the lower section of the slope, which helps to filter and collect rainwater to be reused in the building.

The building has two main entrances, one at the lower ground level and one at the upper street level, for better accessibility. The building is partially embedded into the soil, which not only absorbs the height difference but also gives the building better thermal inertia. The structure of the building is mainly CLT as it reduces the weight of the structure and has a sustainable life cycle with a low CO_2 footprint. Despite being a breathable material, CLT is treated for risks such as humidity and fungal growth. The building does not use many nails or screws to hold the structure together as the CLT components were pre-designed to fit with one another. The building took 2 years to complete, but assembling the wooden frame took only a month. Building materials are exposed to minimum treatment to reduce furnishing costs and to enhance the building's biophilic atmosphere. At times, the walls have HPL finish due to its durability and waterproof nature.

Figure 60-61. Sports courtyard.

The ground level's main component is the heated swimming pool. The swimming pool is 400m² wide (which is bigger than the standard 300m²) due to an additional swimming lane for the children. Swimming pool is the building element that uses up the most building energy. However, it benefits from the soil's thermal inertia and an efficient MEP (mechanical, electrical and plumbing) system with high COP (coefficient of performance). Part of the swimming pool is made transparent through the use of glass, which is reinforced with translucent acoustic membranes for sound absorption.

The upper level is a sports courtyard which is 800m² in size. It is directly ventilated through the skylight connected to light, heat, and CO_2 sensors, which opens up depending on the occupancy and weather. There is no HVAC on the upper level, as the passive design of the building provides enough thermal comfort for physical activities. There is an external ramp (Figure 61) that connects the upper-level sports courtyard to the street level, mainly for the accessibility of the children from the adjacent school.

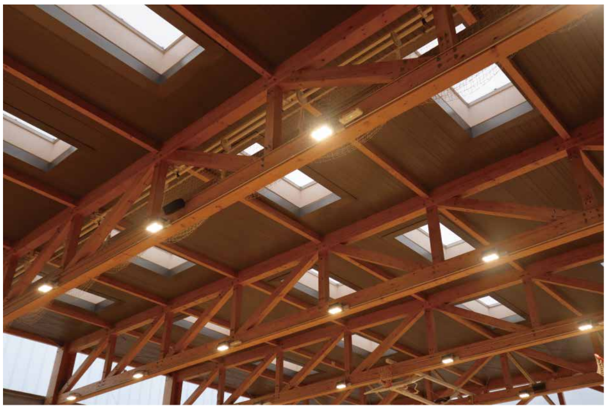


Figure 62-63. Motorized skylight and rooftop photovoltaic panels.

The rooftop is covered with 600m² of photovoltaic panels (300 panels), which is used to heat the pool and produce hot water. It has the capacity to supply 90% of the building energy, and produces 97.4 kilowatts of electricity per year. The swimming pool and sports courtyard, as well as other administrative spaces, are lit by LED lighting.

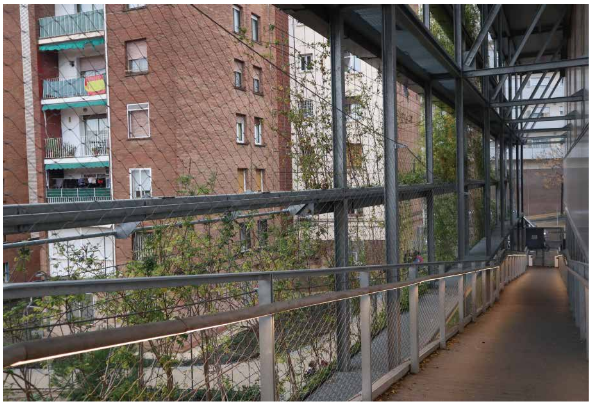


Figure 64. Curtain wall and exterior ramp.

The building is mostly wrapped with a highly durable polycarbonate façade, which creates pockets of air for building insulation and filters the natural light due to its translucent nature. The south-facing façade has an additional layer of curtain wall made up of hydroponic plants. It controls sunlight depending on the season and is watered by the building's rainwater reuse system.

8. Sant Andreu Market

Figure 65-66. Proposed market design. Image Image provided by AMB.

Status: pending remodeling works

Designed by: Balnca Noguera, Architect, Public Space Department, AMB

Area: 1,669m2 (sales area: 882m²)

Relevant study visit/presentation by: Blanca Noguera, Architect, Public Space Department, AMB

Context

A market is a place where the exchange of goods and services occur, which was historically used to define outdoor vendors and stalls. However, due to sanitary, seasonal and regulatory reasons, the markets have been transforming into covered markets or market hall, whereby the vendors sell foods and other goods in a covered area. Markets are now also serving an additional purpose of community hub whereby people from the neighborhood could gather and interact with one another while purchasing fresh produce and household goods.

Figure 67. Market building (yellow) before renovation. Image provided by AMB.

The original Sant Andreu covered market was built in 1914.[63] It consists of two sections: the first section is a freestanding building that sells fruits and vegetables, and the second section is a covered passageway that sells meat and poultry. Most of the current vendors are descendants of the original market vendors, and they are currently relocated to another area to continue their business while the market construction occurs. The characteristic of the original market building was its metallic trusses, cast-iron pillars, and zinc roofing which the new market building attempts to preserve.

Objectives

1) Construction of new freestanding building for the fruits and vegetable stalls
2) Incorporating transparency to establish continuity between the outdoor and indoor space: better integration with surroundings
3) Visibility of the market building by design, as markets could become the emblem of the city, such as the La Boqueria market in Barcelona city
4) Design of the new façade, which is a transition from the former opaque façade

63) https://meet.barcelona.cat/en/discover-barcelona/districts/sant-andreu/sant-andreu-market

Although the construction of the market began before the AMB2 sustainability criteria are implemented, it aims to meet the criteria to maximize sustainability.

Actions and Implementations

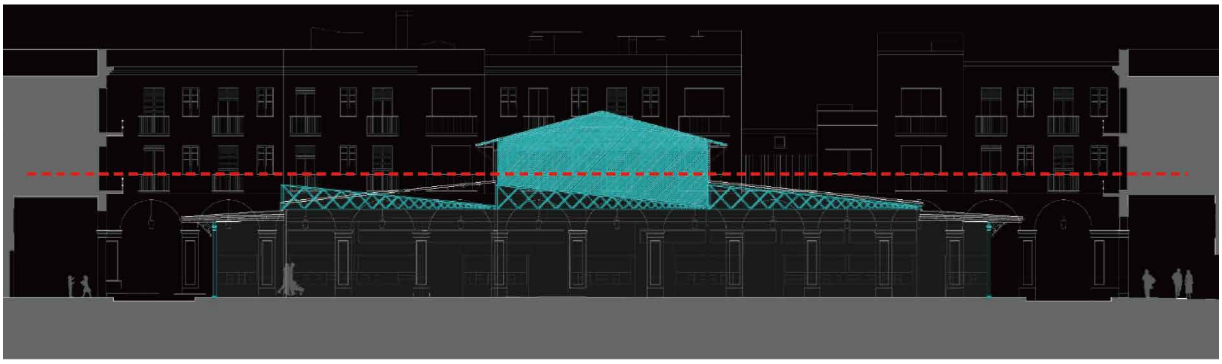


Figure 68. Proposed market building design, with eliminated middle section volume colored in blue. Image Image provided by AMB.

Layout

The main change is the reconstruction of the freestanding market building. The original market building was torn down, as it had low heritage value and did not meet the requirement for load and fire resistance. However, elements of the original building such as cast-iron pillars and metallic trusses were preserved and are being incorporated into the market building with reinforcement.

The originally elevated middle section of the building would be reduced in volume, but the building would still maintain the original strong vertical rhythm by glass and steel façade. The steel frame would also conceal the building's technical systems. 7 different pedestrian entrances that connect the building to the existing path and streets would be made. Identical pavement would be used for both indoors and outdoors to promote continuity of space. Transparency of the building façade would be ensured by using high-performance glasses to recreate the feeling of public plaza. The stall layout is flexible so that vendors can pay per square meter depending on their spatial needs and financial condition. The technical facilities, waste disposal and refrigeration chamber would be located underground. The existing covered passageway would be mostly maintained and refurbished, and the additional floor would be added on the top for administrative use.

Materials

The architect attempted to reduce the use of materials that produce hazardous byproducts such as concrete and steel while maintaining the building's high durability. The basement of the market building would be concrete which provides a strong foundation, but the basement height was reduced to use less concrete. Wooden blocks containing recycled aggregates and timber slabs would be used as a concrete substitute to reduce the overall structural weight. The amount of cladding and steel used would also be minimal.

Water

As the market consists of many different users including vendors, water consumption is more difficult to regulate compared to other buildings. Moreover, the water used in the market has to be maintained at high quality for hygiene. Therefore, the main way to reduce water consumption would be to install high-efficiency equipment that saves water. Additionally, the rainwater collection and reuse system would be installed for brown water.

Energy

Analysis of similar buildings showed that 84% of the annual building energy consumption would result from cooking, cooling, and heating appliances. The remaining 13% and 3% are each energy demand for lighting and climatization. To minimize the energy demand, efficient machinery ensuring effective cross-ventilation and partial climatization of the building would be implemented. One main feature is the heat recovery in industrial refrigeration, whereby the surplus energy from refrigeration is recovered and used to heat up the water supplied throughout the market. Some other examples would be LED lighting and motorized skylight windows for effective ventilation.

Additionally, climatization for thermal comfort would be used only in the ground level with high passenger use. However, as most people would be dressed the same way inside the market as outdoors, the climatization would be kept to its minimum. The transparent facade which could increase the indoor temperature by letting in natural light would be supplemented with wooden window blinds. Last, renewable energy would be supplied through the photovoltaic glass skylight placed in the main building, and 35 photovoltaic panels on top of the passageway.

9. Sant Just Desvern Waste Classification Center

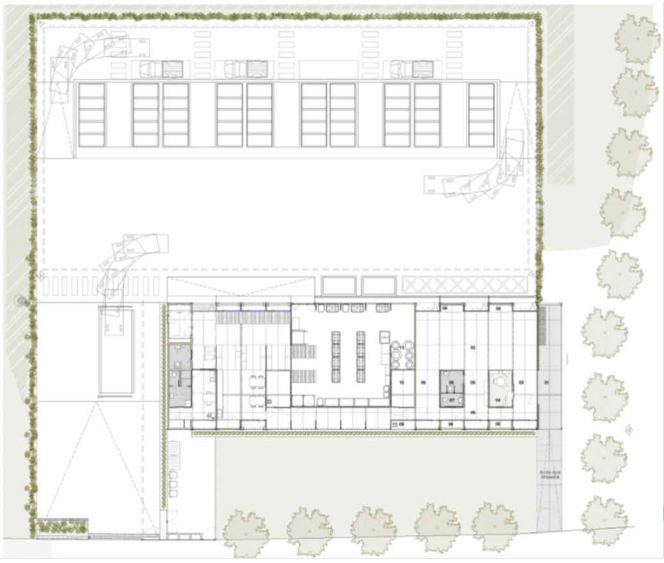


Figure 69. Layout of the waste classification center. Image Image provided by AMB.

Municipality: Sant Just Desvern

Status: (under construction)

Designed by: Roger Mendez, Architect, Public Space Department, AMB

Relevant study visit/presentation by: Roger Mendez, Architect, Public Space Department, AMB

Context

22% of the AMB's budget is allocated to waste management of its 36 municipalities. The waste is collected by each municipality, and AMB takes them to the waste management facilities. In the middle, the wastes pass through a classification center which separates wastes into different types. Sant Just Desvern waste classification center is located along a green corridor (Riera de Sant Just) close to the Serra de Collserola Natural Park, but also within an industrial neighborhood with new developments. It aims to serve multiple purposes: as a waste classification center, secondhand store, and environmental education classroom.

Objectives

1) To incorporate efficiency and environmental parameters
   The center attempts to be integrated within the context of the green corridor and Natural Park. It also received a special request from the municipality to design the building entrance by the green corridor that serves as a local meeting point. Moreover, the center aims to serve multiple purposes that are relevant to the theme of waste recycling and the environment.
2) To build a low impact and low energy building
   From the materials to the design, the center reflects an embedded value: that waste can become a usable commodity. Hence, not only the energy efficiency of the building but also the energy efficiency throughout the building material's life cycle were addressed through the building design.

Actions and Implementations

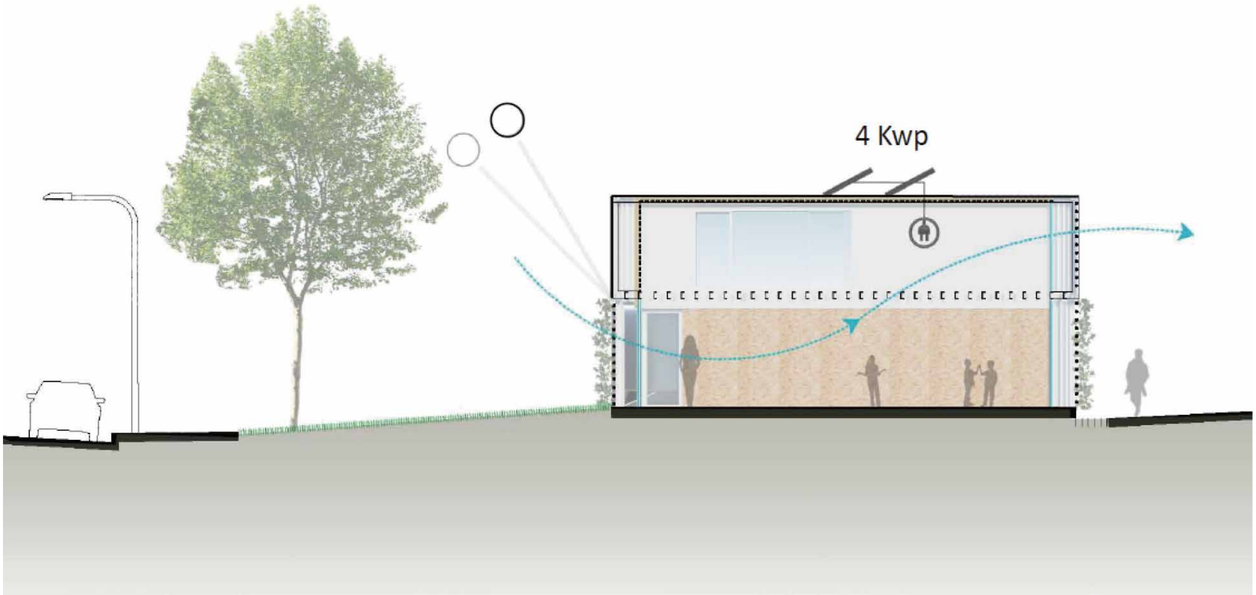


Figure 70. Profile of the center with indication of cross-ventilation and renewable energy production. Image provided by AMB.

Sant Just Desvern waste classification center is receiving environmental consultation from Societat Orgànica. The center would incorporate a large amount of recycled materials, starting with using old shipping containers as its structure. The shipping containers are affordable, durable, and can be converted into a building within a short time. Ecological materials such as recycled cork and cotton would be used to reinforce the floor and roof insulation. OSB (oriented strand board), a compressed wood board, would be used as wall cladding. Both cork and OSB have Forest Stewardship Council (FSC) certification meaning that they are low-impact, recycled building materials. For outdoor road pavements, recycled gravel for heavy-load vehicles and recycled asphalt for light vehicles were used.

The building has to address potential problems of overheating due to its westward orientation. Therefore, a transparent glass façade was put on the ground-level but with effective insolation control. Deciduous plant walls would be used as an additional layer, which lets in more sunlight during winter and blocks the sun during summer. This would be coupled with retractable window screens and added vertical elements perpendicular to the window for shading. Fans would be installed to provide thermal comfort and to minimize the use of the HVAC system.

Resource-efficient facilities such as faucets and toilets are planned to be used for water conservation. Draining pipe is installed underground to collect the used water to be treated and be returned to the aquifer, making up for the impermeability of the site. The treated water would be used to irrigate vegetation surrounding the waste classification center. The building sections that are used as an environmental classroom and a secondhand store have additional containers stacked up for the chimney effect to dissipate the indoor heat, as regular occupancy by people is expected. PV panels (4kWp) would be installed on the rooftop to allow on-site energy production.

Overall Impacts and Expectations

AMB's case studies span across a variety of use that the general public actively utilizes daily, including office building, research center, library, sports center, market, and waste classification center. Therefore, most of the case studies can be described as urban interventions whereby the new/renovated buildings were put inside the existing neighborhood. That is why case studies like Turo de la Peira sports center have to focus not just on building energy efficiency, but also on ways to achieve social assimilation.

Various energy-saving strategies were implemented via high public sector motivation although there were no legal mandates to do so. One of the most important impacts that the case studies provided, or are expected to provide, is an improvement of the neighborhood living quality. This is done by means such as the provision of public utilities built out of non-toxic and natural materials, and conversion of aging buildings to energy-efficient residences. AMB's case studies are expected to benefit the general public, particularly the most vulnerable socioeconomic group, buildings serve as visible energy-efficient examples to the community as well as the private buildings.

Overall Replicability and Scalibility

All buildings are designed to suit their immediate environment, but they have many energy-efficient features and techniques that are replicable and scalable.

1. Cross-ventilation

Horizontal ventilation can be easily achieved through windows and corridors. For vertical ventilation, either atrium like that of the PISA Cornellà or smaller vertical caps of Carrer el Pla could be included. Sometimes, the building has been designed to have openings on the side for ventilation, which includes H_2O Saló Central and ICTA Research Center.

2. Material

The building material could have minimal finish for water/-fireproofing to reduce the cost, and to create a biophilic atmosphere in the case of ecological materials like wood and cork. In the case of Sant Just Desvern waste classification center and AMB Headquarters, recycled materials with low carbon footprint were used for both the building energy efficiency and sustainable building material life cycle. Although concrete which has a high carbon footprint is often required for building foundation, its amount is reduced just enough to act as an effective thermal mass and structural support.

3. Layout

Building features are strategically placed considering their energy uses. For example, the greenhouse at ICTA Research Center is placed on the top floor as the air with high CO_2 concentration – which aids the plant growth – is pumped upwards for skylight ventilation. The equipment-heavy research facilities are also placed right below the top floor for effective ventilation of the heat. Turo de la Peira has a swimming pool on the ground level to benefit from soil's thermal inertia. Both pool and sports courtyard were put on top of one another for optimal surface area to volume ratio which minimizes heat gain and loss.

Facades are made asymmetric depending on the local environment. AMB Headquarter's slats were either maintained or partially removed depending on building orientation and the corresponding insolation, and Fontsana-Fatjo library was covered by either brick wall or glass depending on whether the immediate surrounding is road or park.

4. Renovation

When possible, AMB's case studies renovate existing buildings instead of constructing a new one, as can be seen by Carrer el Pla and Sant Andreu Market's covered passageway. Of course, some building that does not meet the load and fire hazard requirements like Sant Andreu's freestanding market building and Cine Pisa (PISA Cornellà) had to be torn down. However, the architects made sure to include elements such as metallic trusses that are reminiscent of the previous building's use.

5. Vegetation

Most of the buildings had atrium or terraces that accommodate vegetation and bring in natural light. Vegetation was also used to control insolation in the form of green curtain façade (Sant Just Desvern waste classification center and Turo de la Peira sports hall) and strategically planted trees around the building perimeter or at the atrium (AMB Headquarters): even a single tree at the Fontsana-Fatjo Library's atrium serves its purpose. When there was enough space, ground-level gardens were constructed to filter the wastewater from the building (AMB Headquarters, ICTA Research Center).

6. Renewable energy and energy conservation

Most of the buildings had photovoltaic panels installed on the rooftop for hot water production and photovoltaic glasses in special cases. Although the geothermal system does not produce energy, it helps to maintain a constant temperature of 15 degrees Celsius. Concrete slabs on the floor were often connected to the geothermal system as they are effective thermal masses. Another way in which the energy was conserved was through air-to-air heat recuperator used in Carrer El Pla, which transfers the outgoing air's heat to cooler incoming air.

Analysis and Conclusion

Analysis

Policy

1. Focus on renewable energy source

Korea is slowly putting more emphasis on controlling building energy efficiency. However, Korea is still more focused on utilizing renewable energy sources since they only make up only 2% of Korea's total primary energy consumption. Coupled with the fact that 81.4% of Korea's energy is imported, establishing a strong renewable energy supply to guarantee energy independence would outweigh reducing energy demand through ZEBs.[64)]

2. Inclusiveness

a. Existing buildings

Spain's legal definition of nZEB is pending, but existing aging building stocks are actively being renovated on a metropolitan and municipal level up to the expected nZEB standard. Korea has a legal definition of ZEB, which focuses on new buildings and does not actively address the existing buildings. There are no public agencies in Korea which focus on renovating existing buildings such as the CMH. The lack of renovation may become problematic, as more than 36% of the existing buildings in Korea are over 30 years old and would soon need to be revamped.[65)]

As per Figure 5, existing buildings in Korea that qualify as ZEB (BEECS level 1+++ and 1++) make up only 17.7% of the total buildings. Since the ZEB Certification mandate is only applicable to new buildings, there aren't any active means to improve the energy efficiency of the existing 82.3% of the buildings that do not meet the ZEB criteria. With only a few domestic case studies and vague guidelines (which are still under development by the Korean ZEB Alliance), how the ZEB Certification mandate would effectively decrease the future building energy demand without addressing the existing buildings remains questionable.

b. Small-scale buildings

Both Korea and Spain rank within the top 10 countries and regions for LEED Green Building. However, Korea has half the number of LEED-certified projects and double the amount of certified gross square meters compared to that of Spain.[66)] This implies that Korea is tackling building energy efficiency by a small number of large-scale projects. However, small buildings with a total floor area of less than 500㎡ account for nearly 86% of the total buildings in Korea (60 million houses).[67)]

Although there are a lot of apartment complexes that contain multiple small freestanding buildings, other small-scale buildings that are not part of the large planned complexes or districts are left out from becoming energy-efficient. EPBD has already reduced the threshold of energy-efficient public buildings to those over 250m2 in 2015. Although the current ZEB mandate only applies to bigger public buildings that can better absorb the increased construction cost, it should eventually be expanded to include small-scale buildings along with appropriate financial support. 50.6% of the lowest socioeconomic class in Korea live in small detached buildings, and they are the ones who need the low energy bills and greater thermal comfort that energy-efficient buildings provide the most.[68)]

3. Certification rather than maintenance

There were only 9 buildings in Korea that have received actual ZEB certifications as of November 2019: the rest remain at the preliminary certification, but they only amount to slightly over 60 buildings. Most of the buildings with preliminary and actual certification remain at the lowest ZEB Grade 5 Certification.

4. Long-term sustainability

There are three elements that were always resonant in AMB's case studies: biodiversity, materials cycle, and social sustainability. Instead of only looking at the total energy demand and on/off-site energy production of the building itself, AMB's case studies also pay attention to the overall building materials cycle, impact upon the local biodiversity and community. Moreover, AMB is attempting to institutionalize the above-mentioned aspects through AMB2 criteria. In Korean case studies, such a building would only be achievable if it has obtained both the ZEB and G-SEED certification.

5. Weak Initiative at city and municipal level

Other than Sudokwon cities such as Seoul and Incheon, the remaining Korean cities are not as motivated at a local level to supply energy-efficient building stock. Moreover, Korean local administrative districts don't have as much power as the Spanish municipalities as can be seen by the difference in land-use systems. Although short-term solutions are provided to the most vulnerable socio-economic groups such as Busan's cool roof campaign, they do not always address the fundamental issue of energy inefficiency.

6. Policy areas where Korea can learn from Spain

- Prioritize renovation areas on a metropolitan and municipal level up to the ZEB standard and include public and small-scale buildings.
- Build public agencies where focus is on renovating existing buildings and actively address necessary changes for the ZEB criteria applicable to aging buildings such as the CMH.
- Include and achieve long-term sustainability (materials cycle, impact upon the local biodiversity, and social sustainability).
- Extend local government power to fundamentally deal with energy-efficient buildings.

64) https://data.worldbank.org/indicator/EG.IMP.CONS.ZS?locations=KR
65) http://stat.molit.go.kr/portal/cate/statMetaView.do?hRsId=19&hFormId=&hDivEng=&month_yn=

Technology

It is said that Korean zero-energy architecture technology is only 78% compared to those of developed countries. As a result, the Korean notion of ZEB tends to put heavy emphasis on high-performance technology and material. The common fallacy is that the resulting projects end up being an unaffordable high-technology show house rather than a replicable ZEB precedent.

The Korean ZEB Certification mandates the installation of BEMS, a computerized system that connects all the sources of building energy consumption such as HVAC and lighting onto a single platform and monitors/ controls them in real-time. However, BEMS comes together with high installation costs, a lack of trained domestic experts, and resulting difficulty in maintenance within the Korean context. Moreover, there is a lack of data on impact analysis and the exact energy savings that have occurred through BEMS in Korea. Overall, focus on high-tech methods could increase the ZEB construction cost by more than 160% compared to normal buildings in Korea as compared to 105 - 110% in Europe.

The Commission Recommendation (EU) 2016/1318 on guidelines for the nZEB also recommends that the technological cost be lowered by December 31, 2020, with the underlying implication that existing technologies are enough to meet the current goal of turning all new buildings into nZEB by 2020. If there isn't an urgent need to improve the building technology, the focus should rather be on lowering the technological cost for the general public to use.

Cost

ZEBs already have high investment costs and long payback period which limits their diffusion. However, Korea focuses on high-cost materials with high performance which further increases the cost. It is said that ZEB construction in Korea costs 30% more on average compared to normal building construction.[69] Simultaneously, Korea has a lower energy bill compared to developed countries, which makes the payback period through energy cost savings longer. The average household electricity price indicator for Korea is 0.11 while that of Spain is 0.23 (dollars/kWh).[70]

The Korean government does provide incentives to counteract the cost of construction, such as easing the building standards, providing subsidies, and increasing the limit of housing loans. However, the uncertainties associated with the ZEB Certification's return on investment is high. Building owners who want zero-energy construction need to submit ZEB applications before the building is complete to receive and apply building incentives. However, if the building fails to obtain the actual ZEB certification after the construction is complete, the building owner must bear the entire cost. More effort is needed to improve the effectiveness of incentives as the additional costs and risks of zero energy construction are still perceived as high.

66) https://gbci.org/us-green-building-council-announces-top-10-countries-and-regions-leed-green-building
67) http://stat.molit.go.kr/portal/cate/statMetaView.do?hRsId=19&hFormId=&hDivEng=&month_yn=
68) http://kosis.kr/statHtml/statHtml.do?orgId=116&tblId=DT_MLTM_5727
69) https://www.climateaction-korea.eu/actions/energy-zero-ez-easy-housing/?lang=ko
70) https://www.globalpetrolprices.com/electricity_prices/

Conclusion

Through research and study visit conducted to complete this report, not only similarities but the fundamental differences in Korea and Spain such as climate, disaster risk, population density, and homeownership rate became more apparent.

Korea lacks supra-national entities such as the European Union which imposes Directives and Regulations that all its member states have to follow and adapt. Korea is inclined to develop high-rise buildings that can withstand temperature and humidity fluctuations caused by temperate climate. The buildings are often made out of reinforced concrete to protect it against the risk of flooding, typhoon, and earthquake. Due to the worsening air pollution, less natural ventilation and more mechanical air filtration are being used. During summer and winter, Korean public buildings tend to use a high amount of HVAC to provide maximum thermal comfort for the general public.

Spain's energy-efficient buildings, as can be seen from AMB's case studies, are lower in height and are often made out of CLT wood. Due to its Mediterranean climate and cleaner air, buildings benefit from natural ventilation and lighting, although strong insolation often has to be blocked by shading. As Spain is a more water-stressed country than Korea, all the buildings have water-saving facilities in place including rainwater reuse systems and wastewater filtration through vegetation. Unlike those of Korea, Spain's public buildings are designed to provide minimal thermal comfort to its users by minimizing the use of mechanical heating, cooling, and ventilation.

However, the differences do not mean that the solutions that AMB's case studies provide cannot be scaled and replicated to suit the Korean context. For example, CLT wood structures could be highly wind and flood-resistant: they are already being used on skyscrapers around the world. The French government is already planning to enact a law that will mandate all new public buildings to be built from at least 50% timber or other natural materials from 2022.[71)]

To promote the energy-efficient buildings in Korea, the current rules and regulations should be widened from targeting public buildings to including all buildings of different area, age, and uses. Particular attention should be paid to the inclusion of elements that guarantee the building's long-term sustainability and material conservation. It is important to look into the entire building's life cycle: although the final building itself may consume minimal energy, a large amount of energy can still be required to produce the building materials.[72)] Mandating partial use of recycled/ ecological building materials with a low carbon footprint, or improving the current ZEB certification with G-SEED certification criteria, would be some possible ways to improve the overall energy efficiency of Korean buildings.

The renovation of existing buildings is another important topic: retrofitting is often cheaper than constructing a new building, and can still be as energy-efficient by installing active energy-saving equipment. Renovation is more difficult in Korea, as there isn't a strong legal base that forces the property owners to keep their building up to the latest energy-efficiency standard. Moreover, as the property owners and renters are different people in most cases, the property owners do not see the need nor benefits of retrofitting even if the renters think otherwise. Either more effective retrofitting incentives or stricter legal mandate for the aging property owners should be implemented to encourage the proliferation of renovated buildings.

Another lesson was to focus on passive energy-saving means from the building's design stage. Coupled with a notion that ZEBs require complicated technology, Korea's focus on the generation of renewable energy could potentially justify high-technology buildings with slightly reduced building energy demand, as long as the building can produce the energy to counteract the demand. However, traditional buildings such as the Korean Hanok show that there was a time in the past without any technology, where the orientation, design, and material of the building alone had to be as energy-efficient as possible for comfort. Although newly-developed materials and technology does reduce building energy demands, the fundamental passive building elements such as airtightness and insulation have to be considered from the beginning for maximum building energy efficiency.

To end, AMB's case studies showed a strong local public leadership which the Korean local authorities could take away. Even before the recast EPBD required all new public buildings to be nZEB, the architects and engineers of AMB were self-motivated to build energy-efficient public buildings by hiring environmental consultants. Sant Andreu Market began its construction before the AMB2 sustainability criteria were implemented, but it had been later adjusted to fulfill the criteria.

There are many energy-efficient buildings in both Korea and Spain with exemplar use of passive and active technologies, designs and materials. The real challenge is finding ways to make energy-efficient buildings more prevalent, cheaper and accessible to the general public.
As stated on the AMB's Climate Action Plan 2030, "the energy agents of the future must preferably act based on public authority but at a local level."[73)] Public administration has to first lead the way for change, with the final aim of designing the buildings for the people.

71) https://archinect.com/news/article/150183480/france-requires-new-public-buildings-to-contain-at-least-50-wood
72) http://www.ecomedia.co.kr/news/newsview.php?ncode=1065577173381410
73) https://issuu.com/ambcomunicacio/docs/pla__adaptacio_canvi_clima_2030_eng

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